THE RIPARIAN AND AQUATIC BIRD COMMUNITIES ALONG THE COLORADO RIVER FROM GLEN CANYON DAM TO LAKE MEAD, 1996-2000

FINAL REPORT
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EXECUTIVE SUMMARY - This report presents data and analyses of a 5-year effort to develop a monitoring program and collect baseline data on the aquatic and riparian avifauna of the Colorado River from Glen Canyon Dam to upper Lake Mead. We established point count stations in 62 patches of riparian vegetation, and collected data on detection rates from 1700 point counts and 546 area searches within patches three times a year, based on one trip in each of April, May and June. During the winter months two trips were launched in January and February between 1998 and 2000 to survey aquatic avifauna and riparian terrestrial avifauna in the same patches. In all 332 area searches were conducted in patches on winter trips. Riparian vegetation patches were sampled using the total vegetation volume (TVV) method, with data collected from 62 patches. Terrestrial winter and breeding riparian birds and TVV data were subjected to power tests to determine if sufficient power was available to detect trends.

The winter terrestrial bird community was diverse, with 75 species recorded. The most commonly encountered winter terrestrial bird along the river corridor was the ruby-crowned kinglet, followed in abundance by white-crowned sparrow, dark-eyed junco, and song sparrow. First winter records in the study area were documented for 17 species, and four additional species were recorded as new to the region, yellow-bellied sapsucker, Hutton's vireo, prairie warbler, and streak-backed oriole. Winter diversity peaked in the lower portions of the study area, particularly below RK330, with Spencer's Canyon on upper Lake Mead the most diverse single patch sampled. Double sampling of patches suggested that high turn-over in species detections could occur in the same patch between days. Time of day appeared to not affect detection rates.

Floating surveys on the Colorado River counted 22,927 individuals of 42 aquatic species on six trips. Most commonly encountered were lesser scaup, common goldeneye, American coot, bufflehead, ring-necked duck, gadwall and mallard. Bird abundance was strongly correlated with river location, a proxy variable for primary productivity. Turbidity gradients vary exponentially downstream from the dam and bird abundance was highly correlated with turbidity. Over 70% of all detections occurred between Glen Canyon Dam and RK18. In addition to turbidity, all groups showed correlations with river width, with more birds recorded in wider reaches. Significant between-month and between year differences were found for many species.

Point counts and area surveys detected 32 species that either breed or potentially breed in the study area. Most commonly encountered were Lucy's warbler, Bell's vireo, Bewick's wren, house finch, black-chinned hummingbird, ash-throated flycatcher, yellow-breasted chat and blue-gray gnatcatcher. Lucy's warblers accounted for between 26% and 36% of all detections. Species-specific significant differences were found between months and between years for many species. One species, blue-gray gnatcatcher, appears to be showing a long-term decline in the study area. We found that fixed-radius point counts were preferable to area searches in contrasts of the two methods, due in part to fewer uncontrolled factors in the former.

TVV data were analyzed by plant species and compared with bird variables. Strong and in many cases significant correlations were found between many riparian breeding and wintering species and selected plant variables. Patch location was found to be a good predictor of many bird variables, and significant differences were found in different reaches along the river corridor for many plant and bird variables. Based on MRPP and Mantel's test, significant positive relationships were found between distance matrices of all three data sets, winter terrestrial birds, breeding riparian birds, and vegetation. This suggests that vegetation composition and structure affects both bird communities in similar ways. All patches were over-sampled for TVV based on distance metric accumulation curves.

Retrospective power analyses were conducted on breeding riparian bird (point counts), winter terrestrial bird (area searches), and vegetation (TVV) data sets. Power was adequate to detect trends in TVV as small as 5% over time-frames of 5-10 years. Sufficient power to detect larger trend rates existed for only a few bird species over a time frame of 10 years, including eight breeding birds and four wintering bird species. Hence most species within the study area are not abundant enough to be monitored by the logistically intensive 1996-2000 program.

Distance estimation was conducted in 2000 from Lee's Ferry to Diamond Creek. Overall, only three species were sufficiently abundant to meet model assumptions, Lucy's warbler, Bell's vireo, and Bewick's wren. The 1996 design violated many assumptions of distance sampling, and any future monitoring program will need to be established with care to avoid these problems.

Data on nest searches, draft conceptual models, and comparisons with riparian and wintering bird communities elsewhere on the Colorado River both downstream and upstream are also provided. Finally, recommendations are made for future avifaunal monitoring by Grand Canyon Monitoring and Research Center and the Adaptive Monitoring Program.

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All chapters except for X and XI, and the conclusions and recommendations, were written by J.R. Spence. Chapters X (Distance Estimation) and XI (Nest Searches) were written by Jennifer Holmes.

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PART A: INTRODUCTION, SETTING AND GOALS

CHAPTER I. INTRODUCTION

In 1995, the Record of Decision (ROD) on the revised operations of Glen Canyon Dam was signed. Among other things, the ROD established a long-term science program to monitor the effects of dam operations on biological, cultural and physical resources along the Colorado River from the dam to the head of Lake Mead, a distance of 409 km. This monitoring program was established to provide the necessary data to adaptively manage dam operations in order to minimize impacts to selected resources (NRC 1999). Various monitoring programs had been established as part of the environmental impact studies since 1982, under management of the Glen Canyon Environmental Studies Program (GCES; NRC 1987, 1996). These monitoring and baseline data, including studies on the avifauna, were used to develop the alternatives for the environmental impact statement (EIS). In 1996 the Grand Canyon Monitoring and Research Center (GCMRC) was established to oversee scientific monitoring of the resources as laid out in the ROD and the long-term monitoring and research strategic plan (GCMRC 1997). The avifauna, principally riparian breeding birds and the endangered southwestern willow flycatcher, have been an integral part of past and on-going monitoring studies along the river corridor.

Avian communities along the Colorado River below Glen Canyon Dam have changed substantially since completion of the dam (Carothers and Brown 1991). Pre-dam vegetation along the river consisted of a thin riparian strip controlled primarily by spring flooding. Following completion of the dam, the largest tracts of riparian vegetation (in Glen Canyon) were destroyed, while an extensive "new high water zone" (NHWZ) community developed downstream of the dam through the Grand Canyon. In addition, extensive stands of riparian habitat have become established on silt terraces on the lower portion of Grand Canyon draining into Lake Mead. These habitat changes have caused changes in the canyon bird community (Brown et al. 1987; Carothers and Brown 1991), and may continue to do so in response to current and future dam operations.

Birds are a conspicuous component of the lacustrine and riparian ecosystems along the Colorado River and on Lake Powell and Lake Mead (Rosenberg et al. 1990; Carothers and Brown 1991; Spence 1998, unpublished). Birds are considered good indicators of change in ecosystems, as they can respond quickly to subtle changes in habitat. Such changes could be in response to climatic variation, invasion of the ecosystem by a new exotic species, recreational-based disturbances, changes in prey-base, management practices, or some combination of these factors. Due to the strong tendency of passerine birds to exhibit pronounced habitat selection (Hilden 1965, Cody 1985), they are an excellent group of organisms for monitoring habitat effects in a dynamic system such as the Colorado River (Perrins et al. 1991). Two of the major forcing variables controlling the riparian system are quantity and timing of dam releases, so it is likely that most breeding birds (other than those two or three species that nest right at the water's edge) are responding to changes in vegetation rather than the fluctuating flows per se. By monitoring avian populations, changes in other components of the riparian ecosystem may be detected, and management practices can be developed to remedy any problem areas.

For these reasons, it may be important to include monitoring of the avian community in an ecosystem level long-term monitoring program. However, because of variation in avian population abundance, and factors influencing populations on their wintering grounds and during migration, local trends may not always reflect local conditions of breeding habitat, amd are also difficult to detect with only a few years of data. Long-term studies are required to statistically analyze and relate changes in avian populations to specific management activities (Ralph et al 1981, Bibby et al 1992). Along the Colorado River corridor, 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. Short-term data sets of only a few years duration are usually inadequate to determine long-term trends that are often masked by year to year variability (Perrins et al. 1991; Bibby et al. 1992; Spence 1997). Also, possible long-term declines in some neotropical migrants cannot be easily detected until many years of data have been collected (Verner 1985; Ralph et al. 1993).

This report presents the results of five years of avifauna studies along the Colorado River between Glen Canyon Dam and upper Lake Mead. The principal emphasis of the program was to develop a baseline data set and standardized methodology to monitor birds in riparian vegetation, and to monitor the endangered southwestern willow flycatcher. The second goal has been completed and reported on elsewhere (Tibbitts and Johnson 1998, 1999; Johnson and Abieta 2000). The first two years, 1996-1997, were conducted with a grant from Glen Canyon Environmental Studies (summarized in Petterson and Spence 1997; Spence et al. 1998). In 1998, funding was obtained from the Grand Canyon Monitoring and Research Center to continue the earlier studies and to expand their scope and integrate them with habitat characterization and Glen Canyon NRA projects (Spence and Tibbitts 1997; Spence et al. 1999). These two programs owe much to the earlier USGS project that conducted preliminary monitoring feasibility studies on the river corridor from 1993-1995 (Sogge et al. 1998). This final report includes all program elements except southwestern willow flycatcher monitoring, which is summarized in Tibbitts and Johnson (1998, 1999) and Johnson and Abieta (2000).

The report is organized into four sections, 15 chapters, and supporting appendices. Section A includes the introduction, background and general literature review, goals, and study area description. Section B documents the results of the program, with chapters on breeding bird monitoring, winter terrestrial bird surveys, winter aquatic bird surveys, nest searches, habitat characterization, power analyses, and comparisons with previous programs. Section C includes overall recommendations for future long-term monitoring and suggests management goals for the avifauna of the river corridor. Section D includes references, winter and breeding season annotated checklists, appendices of supporting data, protocols, and study site locations.

CHAPTER II. GENERAL BACKGROUND AND REVIEW

The pre-dam environment from Lees Ferry downstream through the Grand Canyon has been described elsewhere (e.g., Turner and Karpiscak 1980; Carothers and Brown 1991), and is detailed in Section IV below. Prior to the completion of Glen Canyon Dam, no systematic surveys of birds along the river corridor were done. Early bird surveys in the region mention birds along the river at points such as Lee’s Ferry and Phantom Ranch, but not along the river corridor itself. Accounts of birds in the greater Grand Canyon region include those of Rasmussen (1941) for the Kaibab Plateau; Woodbury and Russell (1945) for the Navajo Nation; Behle et al. (1958) for the Kanab area; and Woodburry (1958), Behle and Higgins (1959), Behle (1960), LaRue et al. (2001a), and Spence and Bobowski (2003) for Glen Canyon. Rosenberg et al. (1990) summarize the avifauna of the lower Colorado River corridor below Lake Mead. Brown et al. (1984, 1987) summarizes previous bird studies of the Grand Canyon region. LaRue et al. (2001b) documents recent additions to the regional avifauna.

IV.A. Avifauna

The first surveys of breeding birds along the Colorado River were by Carothers and Sharber (1976). They summarized previous information and collected preliminary data on numbers by counting birds seen or heard as they floated the river. Breeding bird studies have been conducted along the river corridor from Glen Canyon Dam to Lake Mead since the initiation of the Glen Canyon Environmental Studies program in 1982 (Brown 1987, 1989; Brown and Trossett 1989; Spence and Pinnock 1993; Grahame and Pinnock 1994a, 1995a; Sogge et al. 1998; Hualapai Tribe and SWCA 1995; Petterson and Spence 1997; Spence 1997). Extensive data on species composition, abundance, and breeding and nesting habitat have been collected over the 13-year period between 1982-1995. A variety of methods have been used, including point counts (Ralph et al. 1993; Grahame and Pinnock 1995a), floating surveys (Carothers and Sharber 1976; Sogge et al. 1998), spot mapping and mist netting (Verner 1985, Sogge et al. 1998), and total count (area) surveys (Brown 1989, Sogge et al. 1998). This work has produced a valuable data set on the composition, biology, and dynamics of the breeding avifauna of the river corridor. After a thorough review of these previous studies, a baseline monitoring program was established in 1996. This program used permanently located fixed-radius point total count stations and total survey searches distributed in patches along the length of the river corridor (from RK -25 above Lee's Ferry to RK 426; Petterson and Spence 1997; Spence 1997).

Species-specific studies have been conducted along the river corridor on bald eagle (Brown et al. 1989; Brown and Stevens 1992, 1993, 1997; Spence et al. 2002), southwestern willow flycatcher (Brown 1988; Sogge et al. 1997), Bell's vireo (Brown et al. 1983), black-chinned hummingbird (Brown 1992), and brown-headed cowbird (Brown 1994). Bald eagles are relatively common in Marble Canyon between ca. RK 10-RK 100 in winter months, and in past years have concentrated near Nankoweap Creek (RK 84) during times when introduced rainbow trout spawn. Distributional data suggest that eagles are sensitive to recreational disturbances, as they are significantly rarer in areas where human visitation rates are high (Brown and Stevens 1997; Spence et al. 2002). Bell's vireo has shown a significant range expansion from the Lake Mead and lower canyon portions of the study area since the 1960's, coinciding with the building of Glen Canyon Dam and development of the new high water zone vegetation. During the 1980's the species started to appear above the Little Colorado River, with documented breeding at RK 69 (Brown et al. 1983). Since about 1993, individuals have been seen almost every year in the Glen Canyon reach and on lower Lake Powell (this report; Spence 1997; LaRue et al. 20001a). However, there has not been any documented breeding in the Glen Canyon reach, and the species remains extremely rare above the Little Colorado River. The nesting biology of black-chinned hummingbird in the river corridor was studied by Brown (1992). The species nests almost exclusively in tamarisk in the new high water zone vegetation, generally in larger patches of vegetation with a well developed canopy cover. Nesting commences in March, with a peak in May. Brown-headed cowbirds are relatively common in the study area during the breeding season. Brown (1994) documented parasitism rates of 7.0% to 60.0% on native terrestrial riparian breeders, including southwestern willow flycatcher, blue-gray gnatcatcher, Bell's vireo, Lucy's warbler, yellow warbler, common yellowthroat, yellow-breasted chat, and blue grosbeak. Additional nesting and parasitism rate data are presented in chapter nine.

Felley and Sogge (1997) compared a variety of census techniques for terrestrial birds on the Colorado River corridor. They showed that area surveys and point counts gave similar results. Point counts were recommended as they provide more strict control of survey effort and reduce observer variability (cf. Petterson and Spence 1997; Spence et al. 1998).

Relatively little is known about wintering and migrant terrestrial avifauna on the river corridor (Sogge et al. 1998). Spence (1996a) found that numbers of terrestrial bird species and individuals declined significantly after the controlled flood of 1996 in selected NHWZ patches above Lee's Ferry. A considerable amount of anecdotal information on the bird composition along the river corridor, particularly during migration, has accumulated (Brown et al. 1984, 1987). Sogge et al. (1998) conducted the first comprehensive survey data on the composition of the winter terrestrial avifauna.

More information is available on waterfowl and other aquatic species composition and dynamics. Glen Canyon NRA has been conducting monthly waterfowl surveys since 1992 in the Glen Canyon reach (Pinnock and Spence 1993; Grahame and Pinnock 1994b, 1995b; Spence 1996b, unpublished data). Stevens et al. (1997) reported results of surveys of water birds along the Colorado River through Grand Canyon. Waterfowl numbers are greatest in the stretch above Lee's Ferry, with high turnover and high species diversity. The large number of birds is a direct consequence of the high productivity in the cold clear waters released from the dam. Numbers of waterfowl steadily increased from 1992 to 1997, with peak winter numbers doubling between 1992 and 1997 (Grahame and Pinnock 1995b; Spence, unpublished data). In January and February as many as 3600 birds of 20 species can occur in the 15 mile stretch from the dam to Lee's Ferry. Significant species include Barrow's goldeneye, greater scaup, long-tailed duck, and white-winged scoter. The controlled flood of 1996 appears to have had little effect on the waterfowl assemblage between the dam and Lee's Ferry. This may have been a consequence of the timing of the flood (March-April), which is when waterfowl migration has peaked and is in decline (Spence 1996b). Numbers were not significantly different in the 1996-97 compared to 1995-96 (Spence, unpublished data). Stevens et al. (1997) examined the relationship between reach variables such as width and turbidity and the composition and abundance of water birds below Lee's Ferry. They documented the presence of 58 species between 1973-1994. Winter bird abundance was greatest in the upper reaches of the canyon, above the Little Colorado River, and decreased rapidly downstream from the confluence.

IV.B. Vegetation

A great deal of data is available for the Colorado River corridor on vegetation composition, structure and dynamics and potential impacts of dam operations and flooding (Stevens et al. 1995; Kearsley and Ayers 1999). Studies on the relationship between riparian habitat and bird communities include Brown (1989), Sogge et al. (1998), and Hualapai Tribe and SWCA (1995). Important correlates with bird species richness and abundance include canopy cover, size and shape of riparian patches, and canopy volume and structure. The Hualapai Tribe and SWCA (1995) have been monitoring habitat for several years, using the technique of Mills et al. (1991), where a pole marked in 0.1-meter increments is held horizontally in the vegetation. All vegetation contacts within 10 cm of the pole are recorded, up to 1 per 0.1 meter and 10 per meter segment.

The new high water zone riparian vegetation along the Colorado River developed relatively rapidly following closure of Glen Canyon Dam (Pucherelli 1986). The floods of 1983-1985 reduced the extent of the NHWZ by 39%, with recovery back to pre-1983 levels by the early 1990's. Anderson and Ruffner (1987) studied the dynamics of the old high water zone vegetation. They indicated that there was little evidence of long-term decline in the zone, but that seedling establishment had either ceased or was extremely rare. Salzer et al. (1996) examined tree-ring widths of the OHWZ species *Celtis reticulata* in the Grand Canyon and in Cataract Canyon through Canyonlands National Park. No differences in ring width were detected that could be directly related to the change in flows along the river in 1963, although ring width correlations with flow rates, temperature and precipitation changed significantly after 1963 in trees from the Grand Canyon downstream of the dam.

Stevens et al. (1995) studied the development of marsh vegetation along the Colorado River through Grand Canyon. Marshes developed after the completion of Glen Canyon Dam in response to fluctuating flows. Although relatively limited in extent, marshes support the majority of the wintering populations of some species such as marsh wren, as well as the breeding season population of common yellowthroat along the river corridor.

Kearsley and Ayers (1999) studied the impacts of the 1996 controlled flood on species composition, vegetation structure, and seed bank dynamics at nine long-term study sites along the Colorado River between RK 69 and RK 336. Slight reductions in vegetation cover occurred, but there were no significant differences in patch and vegetation type extent before and after the flood. Most effects of the flood were concentrated in the herbaceous layer, with extensive scouring and burial occurring in some patches. Soil seed banks lost up to 45% of their germinable seed following the flood.

CHAPTER III. PROGRAM GOALS

Because the initial avifauna work of 1996-1997 under GCES had different goals than the program initiated in 1998, the goals of the two programs have been combined below into more general categories. There were eight principal goals of these combined programs.

1. Conduct baseline monitoring studies on the riparian breeding birds along the river corridor;

2. Develop a monitoring protocol for breeding birds that combines objective methods with repeatable results that can be efficiently implemented under the difficult logistical constraints of the river corridor;

3. Determine the statistical power of the monitoring program to detect change;

4. Develop a habitat monitoring program that links avifauna dynamics with habitat dynamics resulting from potential effects of dam operations;

5. Conduct baseline surveys of wintering aquatic and terrestrial birds along the river corridor;

6. Compare the principal results of the breeding bird program with earlier work conducted along the river corridor;

7. Develop specific monitoring criteria (threshold values) that can be directed towards adaptive management goals of the long-term science program;

8. Make long-term recommendations of the feasibility of bird monitoring in detecting ecosystem-wide changes along the river corridor as a result of dam operations.

CHAPTER IV. STUDY AREA DESCRIPTION

The Colorado River flows from south and west from Glen Canyon Dam 409 km to Separation Canyon on upper Lake Mead. The elevation of the river at the dam is 955 meters and where it reaches upper Lake Mead ca. 365 meters, for a total drop of 590 meters. Only two climate stations occur near the river in the study area, at Lee's Ferry and at Phantom Ranch. Climate data are summarized for these two stations in Table IV-1 (Spence 2001). The climate of both stations is arid-temperate, with high mean annual temperatures and low precipitation. Trends over the last few decades include significant increases (1.5 ^{o}C) in January and February minimum temperatures, and 15-20% increases in precipitation. Mean annual temperatures have not changed significantly at either station. Mean maximum temperature has not changed in the last 50 years at Lee's Ferry, but a significant increase in maximum temperature of 2 ^{o}C has occurred at Phantom Ranch. Particularly significant are the relatively warm and mild conditions in January and February at both stations since 1995. For example, the mean minimum temperature at Phantom Ranch for 1998-2000 was 4.4^{o}, 3.4^{o}, and 4.1^{o} respectively, all well above the long-term mean of 2.7^{o}.

Stevens et al. (1997) noted that turbidity in the river increases downstream from Glen Canyon Dam to upper Lake Mead. Mean secchi depth declines from ca. 5.4 meters in the Glen Canyon reach to ca. 0.3-0.6 meters in the lower reaches. During the February 1998 trip water samples were collected every 5 miles (8 km) from the middle of the channel. Samples were analyzed in the lab with a turbidity meter. Mean turbidity (NTU’s) was calculated for each reach. Figure IV-1 shows the results. Turbidity was consistent with results reported elsewhere, with a gradual increase from 1.0 in Glen Canyon to 65.0 in upper Lake Mead. The relationship between reach and turbidity downstream is highly significant (r^2=0.86, p<0.0001). The slight rise in reaches 2 and 3 may be the result of a minor storm event that moved through the area on the evening of February 17, with some rain occurring.

The geology of the region has been well described elsewhere (Beus and Morales 1990). Probably the most important geological factors relevant to the study of bird communities along the river corridor are the kinds of bedrock geology present and the presence of major side canyons (Turner and Karpiscak 1980; Stevens et al. 1995). The principal canyons along the Colorado River include Glen Canyon, Marble Canyon, and the Grand Canyon. Each of these in turn is classified into various geomorphological "reaches" (Table IV-2) developed by Schmidt and Graf (1990). Reaches where the bedrock consists of Precambrian schist and granite are relatively narrow and tend not to support much riparian vegetation except at the mouths of tributaries. Reaches where sandstones and shales predominate tend to be wider, and riparian vegetation is often well established along river margins. Where major tributaries enter the river, additional sediment loads occur and in particular return channel-eddy complexes form that trap finer sediments such as sand. Vegetation on these complexes includes much of the largest and better developed riparian patches in the study area, and also support the post-dam marshes (Stevens et al. 1995).

The vegetation of the Colorado River corridor is complex and extremely dynamic, changing in response to climate, flooding, the invasion of new exotic species, and long-term successional patterns. Spring flooding originally controlled the abundance and distribution of riparian vegetation, with a distinct "trim-line" at about the 100,000-125,000 cfs level. Above this line an extensive "old high water zone" (OHWZ) community occurred, consisting of a variety of species, of which the most important were apache plume (*Fallugia paradoxa*), net-leaf hackberry (*Celtis reticulata*), mesquite (*Prosopis glandulosa*), and catclaw (*Acacia greggii*). Below this line sparse vegetation consisting of coyote willow (*Salix exigua*), tamarisk (*Tamarix chinensis*), and rushes and grasses occurred. This lower zone was flooded and scoured most years. Following completion of the dam, spring flooding ceased. The area below ca. 50,000 cfs rapidly filled in with riparian species, with tamarisk being the most abundant. This new vegetation, termed the new high water zone (NHWZ), greatly increased in abundance between 1963-1983 (Pucherelli 1986). Areas of marsh developed in return channel-eddy complexes (Cluer 1995), covering ca. 1% of the river corridor NHWZ by 1991 (Stevens et al. 1995). The floods and subsequent high flows of 1983-1985 produced considerable scour of the NHWZ, with an estimated reduction of ca. 39% (Pucherelli 1986). Following the floods, the NHWZ gradually recovered. In 1991 interim flows were established that caused further changes, primarily by stabilization of marshes and colonization of the lower portion of the NHWZ between 33,000-25,000 cfs. The 1996 controlled flood through the river corridor was designed to scour tamarisk vegetation in the lower portions of the NHWZ. However, this flood had only short-term impacts on the vegetation, with rapid recovery (Kearsley and Ayers 1999; Stevens et al. 2001).

Both the NHWZ and OHWZ are variable in composition along the Colorado River, with a major change in the latter occurring at RK 64. Below, these different portions of the riparian vegetation and associated upland vegetation are characterized for different sections of the river corridor. The understory herbaceous vegetation of the OHWZ is not discussed, but consists primarily of upland desert species and exotics such as *Bromus* species.

A. UPLAND (-24.6K-0.0K): the upland vegetation on high terraces in the Glen Canyon reach differs from upland vegetation below Lee's Ferry is several significant ways. Perhaps most important, extensive high terraces support dense stands of four-wing saltbush (*Atriplex cansecens*) and the vegetation is floristically most similar to the Colorado Plateau.

B. UPLAND (0.0K-ca. 150K): for large stretches below Lee's Ferry there is little upland vegetation because of the proximity of cliffs to the river. Below ca. RK 64 fairly extensive upland vegetation reappears, with floristic affinities primarily to the Mojave-Sonoran deserts. Catclaw (*Acacia greggii*) starts to occur on slopes and cliffs, and species like brittlebush (*Encelia farinosa*) and barrel cactus (*Ferrocactus acanthoides*) appear. Four-wing saltbush remains common, although not in the dense stands that characterize the Glen Canyon reach.

C. UPLAND (ca. 150K and below): the upland gradually becomes more desert-like, and strongly Mojavean-Sonoran in composition. Species that appear downstream from Phantom Ranch along the river corridor include bursage (*Ambrosia dumosa*), creosote bush (*Larrea divaricata*), ocotillo (*Foquieria splendens*), beargrass (*Nolina* cf. *microcarpa*), graythorn (*Ziziphus obtusifolia*), large species of beavertail cactus (*Opuntia* species), and cholla's (*Cylindropuntia* species).

D. OHWZ (-24.6K-0.0K): The OHWZ in Glen Canyon is a remnant of the riparian vegetation that occurred throughout Glen Canyon prior to the filling of Lake Powell. Principal species include apache plume (*Fallugia paradoxa*), netleaf hackberry (*Celtis reticulata*), western redbud (*Cercis occidentalis*), live oak (*Quercus turbinella*), and New Mexico olive (*Forestiera pubsecens*). The last two species do not occur below Lee's Ferry in river corridor riparian vegetation.

E. OHWZ (0.0K-64K): similar to the previous zone, but generally sparsely developed, without the presence of live oak and New Mexico olive.

F. OHWZ (64K-205K): Both catclaw (*Acacia greggii*) and mesquite (*Prosopis glandulosa*) appear at RK 64, and dominate the OHWZ throughout the remainder of the river corridor. Below ca. RK 97 apache plume disappears, while below RK 205 water broom (*Baccharis sarathroides*) appears in on the river corridor and becomes an important component of the lower portions of the OHWZ.

G. OHWZ (205K-260K): below RK 205 the OHWZ becomes dense and well developed, and water broom becomes an important component.

H. OHWZ (below 260K): below RK 260 mistletoe (*Phoradendron californicum*) appears as a parasite on catclaw and mesquite. This species is significant as it provides fruit for certain species in the winter, principally western bluebird, phainopepla, and Townsend's solitaire.

I. NHWZ scrub (-24.6K-260K): the NHWZ scrub is fairly uniform through much of the river corridor, with tamarisk (*Tamarix chinensis*), coyote willow (*Salix exigua*), arrowweed (*Tessaria sericea*), and seepwillow (*Baccharis emoryi*) the dominant woody species. There is some linear differentiation in this zone with distance from the river. Higher stands (>35,000 cfs) consist primarily of dense tamarisk with exotic brome species (*Bromus diandrus*, *B. rubens*, and *B. tectorum*) in the understory. Above this a transition zone usually occurs that has been called the middle riparian zone, in which scattered species from the OHWZ as well as tamarisk occur with an understory of desert species. In the lower portions of the zone a mixture of tamarisk, willow and seepwillow occurs, with an often dense understory of scouring rush (*Equisetum*), rushes (*Juncus* species), western goldenrod (*Euthamia occidentalis*), spiny aster (*Chloracantha spinosa*), and grasses and forbs.

J. NHWZ scrub (below 260K): the principal difference in the NHWZ below RK 260 is the occurrence of water broom.

K. NHWZ marshes (throughout the river corridor): these marshes and their development and dynamics have been described by Stevens et al. (1995). They develop in association debris flows and return-channel eddy complexes below the 25,000 cfs level. Standing water occurs in marshes up to the level of stage that discharegs from the dam reach. Common species include rushes (*Juncus* species), aquatic sedge (*Carex aquatilis*), bulrush (*Scirpus* species), cattail (*Typha domingensis*), and reedgrass (*Phragmites australis*). These marshes provide important habitat for marsh specialists, such as common yellowthroat in the breeding season and marsh wren in the winter and during migration.

L. Springs (scattered throughout the river corridor): spring vegetation is generally rare in the riparian vegetation along the Colorado River, occurring primarily at higher elevations above the river corridor. Significant exceptions occur at RK -14L (Horseshore Bend spring), RK 51R (Vasey's Paradise), RK 237R seep, and RK 289L (Lava Falls springs). Extensive marshland occurs at the Lava Falls springs, dominated by *Cladium californicum*. A small but unusual patch of marshland is associated with Horseshoe Bend spring, with the presence of two Arizona-rare species, rice cutgrass (*Leersia oryzoides*) and American bugleweed (*Lycopus americanus*). These are the only known locations for these species from the Colorado River between Glen Canyon Dam and Lake Mead. The seep at RK 237L is primarily a hanging garden, with a seepy rock face dominated by the Colorado River endemic *Flaveria macdougalii*. Small patches of woodland vegetation with distinctive composition occur at both Vasey's Paradise and Horseshoe Bend.

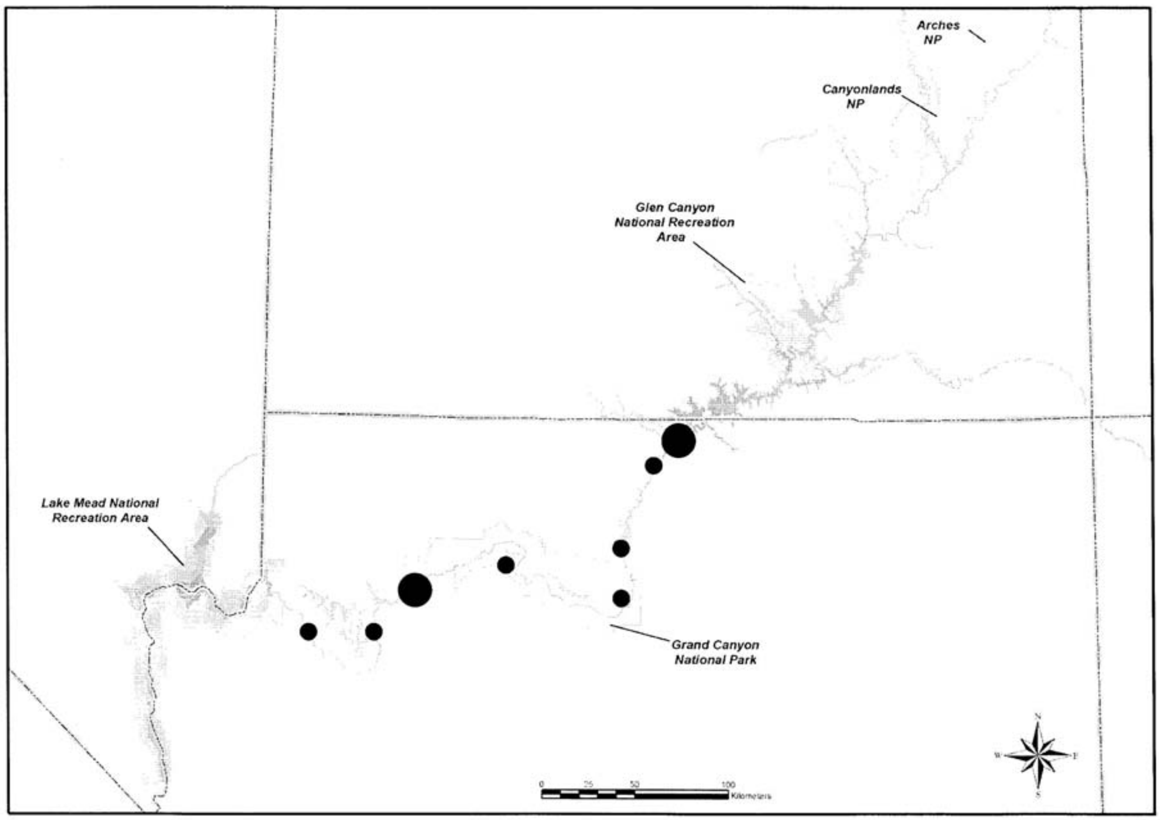
Table IV-1. Climate summaries for Lee's Ferry and Phantom Ranch. Data from the Western Regional Climate Center, Desert Research Institute, Reno, Nevada (www.wrcc.dri.edu/summary).

	Lee's Ferry	**Phantom Ranch**
Elevation (meters)	978	784
Duration of Record	1916-2000	1966-2000
Mean Annual Precipitation (mm)	153	247
Mean Annual Temperature (^{o}C)	16.9	20.4
Mean Annual Maximum (^{o}C)	24.7	27.6
Mean Annual Minimum (^{o}C)	9.2	13.6
Mean July Maximum (^{o}C)	39.5	41.0
Mean January Minimum (^{o}C)	-3.1	2.7
Potential Evapotranspiration (mm)	993	1161

Table IV-2. The geomorphological reaches in the study area from Glen Canyon Dam to upper Lake Mead, based on Schmidt and Graf (1990). By convention, river mile 0 starts at Lee's Ferry, so miles above Lee's Ferry to the base of Glen Canyon Dam are negative. Study patches are summarized for each reach, and consist of patches of riparian vegetation that have been surveyed at least once between 1996-2000 for either breeding or wintering birds.

Reach Name	**River Miles**	**River Kilometers**	**Number of Study Patches**
1. Glen Canyon	-15.0-0.6	-24.6-1.0	15
2. Permian Gorge	0.6-10.8	1.0-17.7	9
3. Supai Gorge	10.8-22.1	17.7-36.2	0
4. Redwall Gorge	22.1-39.3	36.2-64.4	1
5. Marble Canyon	39.3-60.1	64.4-98.6	19
6. Furnace Flats	60.1-76.0	98.6-124.5	5
7. Upper Granite Gorge	76.0-115.6	124.5-189.5	3
8. The Isles	115.6-123.2	189.5-201.9	1
9. Middle Granite Gorge	123.2-137.4	201.9-225.3	2
10. Muav Gorge	137.4-157.0	225.3-257.4	0
11. Lower Canyon	157.0-209.9	257.4-344.1	24
12. Lower Granite Gorge	209.9-235.6	344.1-386.2	3
13. Upper Lake Mead	235.6-273.8	386.2-448.9	6

Figure IV-1. The study area in northern Arizona along the Colorado River from Glen Canyon Dam to Lake Mead. Circles represent areas where patches of riparian vegetation were surveyed during the course of the study. The large circles represent stretches with 10 or more sampled patches, while the smaller circles represent stretches with <10 sampled patches. All individual patch locations can be found in Appendix A.



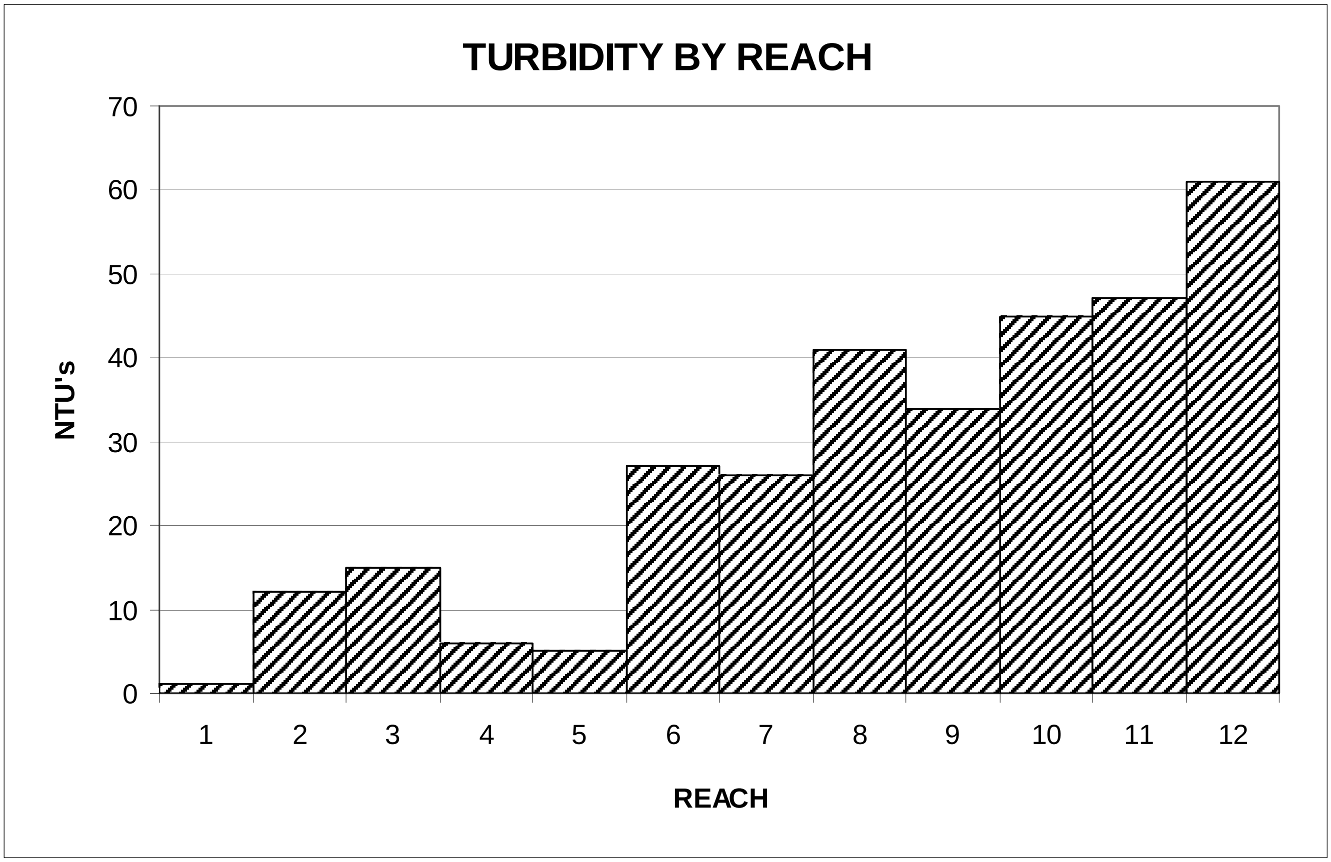


Figure IV-2. Mean turbidity in NTU's by Graf-Schmidt reach from Glen Canyon Dam to Lake Mead between Feb 17-26, 1998.

PART B: RESULTS

CHAPTER V. WINTER TERRESTRIAL AVIFAUNA

V.A. Introduction

This chapter presents preliminary survey data on the winter terrestrial bird community in the riparian zone of the Colorado River from Glen Canyon Dam to upper Lake Mead. Brown et al. (1984, 1987) had summarized the available records on winter birds in the study area, but the only previous systematic work is that of Sogge et al. (1998), who conducted surveys in January of 1994 and February of 1995. They reported on the abundance and distribution of 35 terrestrial species encountered on these surveys. Bird nomenclature follows the AOU 7th edition and supplements.

V.B. Methods

Six trips were conducted in January and February of 1998, 1999 and 2000. Each trip lasted 12 days, starting at Lee's Ferry and ending at Pearce Ferry on Lake Mead. A single 22' motor snout was used for the trip. This boat provided the necessary stability for surveying water birds along the river corridor, and the speed to sample as many patches of riparian vegetation as possible. During the two months, patches were also surveyed in the Glen Canyon reach using an NPS motor boat.

Distinct patches of riparian vegetation were surveyed for terrestrial birds on each trip between the hours of ca. 0700 and 1700 each day. The method used was a timed area search survey, based on the recommendations of Sogge et al. (1998). Two observers were used on each survey. Cloud cover, wind speed, and temperature were recorded, and each bird heard or seen while traversing the patch was noted. The general habitat location of each individual was recorded where possible.

On the 1998 surveys, two surveys of each patch were conducted sequentially. The order of the survey, first or second, was recorded. During the surveys, a test of attracting birds by pishing was conducted. One surveyor stopped, pished quietly for a few seconds, then moved approximately 30 meters and repeated the procedure until the patch was completed. A Kruskal-Wallis ANOVA was performed on the data to test for differences between pishing, non-pishing, and first and second surveys.

Regression analysis was used to examine the relationship between timed surveys, start time and number of species and individuals. Differences between months within years and between years for total individuals and species richness per surveyed patch were analyzed with ANOVA. Differences in presence or absence of the most common species among patches between years were tested by the χ^2 test using Fisher's exact probability. For individuals and species per patch, the two-way interaction between month and year was tested using an unbalanced two-way ANOVA without replication (repeated measures design). Exact F statistics were calculated and compared with the approximate F statistics using the method of Bingham and Feinberg (1982).

For changes in species composition and abundance between months and years, the nonparametric multiple response permutation procedure (MRPP) was used to test for differences. Euclidean distance was used as the measure of matrix dissimilarity. Only those patches that were surveyed on each trip (six in all) were used, resulting in a matrix of 20 patches by 56 species. Patches were grouped by year, month, and year by month. Details and applications of this method can be found in Zimmerman et al. (1985) and McCune and Mefford (1995). Comparisons in species composition at different times on the same trip were made to determine how repeatable the results were. For sites where the survey crew camped, afternoon surveys were compared with morning surveys on the next day at seven riparian patches. Sorenson's coefficient of similarity was calculated between each contrast.

For each year, abundance was determined for the 15 most common species. The distribution of total number of birds detected in each reach of the river corridor for the most common species was also graphed. These summaries can be found in Appendix C. Throughout, the number of individuals and the number of detections mean the same thing, i.e., the number of individuals detected either visually or aurally during a survey.

V.C. Results

332 winter area search surveys were conducted during the study in 82 patches of riparian vegetation (Appendix A, Figure V-1). Another 50 secondary surveys were conducted in 1998 to test for differences between sequential surveys within a patch on the same day. The data from these secondary surveys was not included in the analyses.

Seventy five species were detected on the 332 surveys, excluding primarily aquatic species. More species were detected in 1999 (57) compared with 1998 (51 species) or 2000 (47 species). The most commonly detected species can be found in Table V-1. For 1998 and 2000, white-crowned sparrow was the most common species, followed by dark-eyed junco and ruby-crowned kinglet. In 1999, white-crowned sparrow was only the seventh most commonly detected species, while ruby-crowned kinglet was the most common species. The rankings of all species changed from year to year. Over the three years, ruby-crowned kinglet was the most consistent species in abundance, and was also the most widely distributed species (number of patches detected in) in the study area. Many unusual and rare species were found during the three years. Four species are reported as new to the region, yellow-bellied sapsucker, Hutton's vireo, prairie warbler, and streak-backed oriole. First winter records for 17 species in the study area are reported: red-shouldered hawk, common poorwill, Anna's hummingbird, Hammond's flycatcher, gray flycatcher, dusky flycatcher, tree swallow, northern rough-winged swallow, house wren, northern mockingbird, sage thrasher, orange-crowned warbler, common yellowthroat, Brewer's sparrow, black-throated sparrow, swamp sparrow, and red crossbill. Details on the significance of these records can be found in LaRue et al. (2001b) and are summarized in Appendix B.

Mean individuals detected per patch survey varied from 17.03 in 2000 to 20.85 in 1998. Species detected per patch survey varied from 4.77 in 2000 to 5.52 in 1999. There were no significant differences in individuals and species detected per survey among years. The two-way interaction was also non-significant (Table V-3). For 1998 and 1999, there were no significant differences for mean individuals and species per survey between January and February. However, a significant difference between months in 2000 was found ($F=4.7$, $p=0.032$), with significantly more individuals detected in February (Table V-3).

The number of patches each species was detected in changed significantly between years for seven species (Table V-4). Ruby-crowned kinglet was found at significantly fewer patches in 1998 compared with 1999. Dark-eyed junco was found at many more patches in 1999 compared with 2000, and at fewer patches in 1998 compared with 2000. Song sparrow was detected at more patches in 2000 compared with 1999. Yellow-rumped warbler was found at more patches in 1998 than in 1999. Lincoln's sparrow was found at more patches in 1998 compared with both 1999 and 2000. Say's phoebe was found at fewer patches in 1998 than in 2000. Finally, a rare but widely distributed species, red-naped sapsucker, was detected at more patches in 1998 than in 1999 or 2000. In general, these changes in distribution within the study area are reflected in the changes in abundance for species between years (Table V-1).

In all three years, the majority of individuals detected were in new high water zone vegetation (Table V-2). For both 1998 and 2000, more individuals were detected in upland vegetation compared with old high water zone vegetation. However, in 1999 almost as many individuals were detected in old high water zone vegetation compared with new high water zone vegetation. Reasons for this are unknown, although climate records indicate that the winter of 1998-1999 was unusually dry, with only 36% of long-term mean precipitation recorded from December through February. Relatively few birds were detected in air during the winter surveys. Summaries of detection rates among habitats for the most common species can be found in Appendix C.

The relationship between length of survey time per patch and the total number of individuals and species detected for each year is shown in Table V-5. The slopes of the regression lines are positive and highly significant for all three years for both species and individuals. For start time, the slopes of the regression lines are negative and significant for both species and individuals except for 1999, where number of individuals detected was not significantly related to start time. These results show that more species and individuals were detected as survey length increased. This would be expected as length of time surveyed is positively correlated with amount of habitat searched. For start time, generally more species and individuals were detected on earlier surveys in the day, although the relationships are much weaker than for survey length. These four relationships are graphed in Figures V-2 to V-5.

To determine if species composition and abundance changed between years and months within years, multiple response permutation procedure tests were run. Results are given in Table V-6. Composition and abundance in 1998 was significantly different than 1999 and 2000 ($p=0.045$). No differences existed for the two months or for the six month by year groups. These results indicate that 1998 was significantly different in species composition and abundance compared with the other two years for the 20 sampled patches of riparian vegetation.

Species composition at patches showed relatively large differences between surveys (Table V-7). Sorenson's coefficient varied between a low of 25% to a high of 61%. On average about 50% of the species found in one survey were found in the second survey. These differences may be attributable to time (morning vs. afternoon) as there were significantly more species on morning surveys in patches compared with afternoon surveys for the six patches (Wilcoxon signed-rank test, two-tailed, $p=0.036$). The data from 1998 where two surveys were conducted sequentially in patches could be used to test repeatability of the survey method. However, since birds often flee or hide from surveyors, this may confound differences in species detection rates. The second survey detected significantly fewer species than the first survey (see below). Because of the nature of the study area, with surveys conducted sequentially downstream, and lacking the ability to move upstream in many areas of the river corridor due to rapids, patches could generally not be surveyed at the same time on consecutive days. Hence, testing the repeatability of the survey method was not feasible.

Kruskal-Wallis ANOVA was performed with the 1998 abundance data using two variables, order of survey (first or second), and pishing (yes or no). Significantly more species and individuals were detected by the first survey team than the second survey team (species: $\rho=0.023$; individuals: $\rho=0.018$). Pishing attracted more individuals than non-pishing, but the difference was only weakly significant ($\rho=0.086$). Much of the increased detections were due to ruby-crowned kinglet, which is a species that is strongly attracted to pishing sounds. There was no difference in number of species attracted by non-pishing and pishing ($\rho=0.919$). There were also no significant interactions between survey order and pishing or non-pishing.

Relationships between the winter avifauna community and habitat characteristics of the patches can be found in Chapter X, while tests of the power of the program to monitor changes in abundance for the more common species can be found in Chapter XI.

V.D. Summary

The winter survey results presented in this study represent the largest systematic data set of winter terrestrial birds in the riparian and adjacent upland vegetation along the Colorado River in the study area. The remarkable number of new records, both new to the region and new to the study area in winter, indicates how relatively little is known about the winter avifauna in the region.

The most common wintering terrestrial species were migrants from elsewhere, including dark-eyed junco, ruby-crowned kinglet, and white-crowned sparrows. Common resident species included Bewick's wren, canyon wren, house finch, Say's phoebe, and song sparrow. However, for residents it is not known if the wintering birds are from the same population as the breeders. Sogge et al. (1998) reported that at least some of the Bewick's wrens in the study area during the breeding season appear to remain year-round.

There is high variability in composition from year to year, suggesting that additional surveys in future years will detect additional rare species. This variability is supported by the MRPP analyses, showing that there were significant differences in species composition between years. This is primarily due to the substantial number of different rare species found in 1998 and 1999, as well as changes in the abundance of some of the more commonly detected species. Interestingly, there was less variability between trips within years except for 2000, when many more birds were counted in February compared with January.

Year to year variability in the winter avifauna of the river corridor could result from numerous factors. Most important are conditions on breeding grounds the previous breeding season, migration and weather patterns, and conditions on the winter grounds in the study area. Some species are closely tied to the availability of mistletoe fruit, including phainopepla, wetsern bluebird, and Townsend's solitaire, and their abundance during the winter may be a reflection of the abundance of this important resource. The reasons why other birds, including both granivorous species and insectivorous species, vary in abundance from year to year is likely to be much harder to determine. No attempt has been made in this study to examine distribution and abundance relationships by resource or foraging guilds, although it would be interesting and might suggest some of the reasons for the high variability in the data.

Another factor that may affect survey results is within-corridor movements. Sogge et al. (1998) report on site fidelity and inter-patch movements for some breeding species, but they do not report on winter species' movements. Some species flock in winter, especially bushtit, and it is likely that these flocks wander from patch to patch during the winter. However, other than bushtit flocks, very little evidence of mixed-species flocks was found during the course of the study. This may have been in part because the observers were generally not able to identify flocking groups while also walking through dense riparian vegetation and attempting to identify and record birds. However, it would be an interesting study to see if flocking does occur along the river corridor, and what such flocks might be composed of. A common nucleus flock species elsewhere in the western U.S., the mountain chickadee, was relatively rare in the study area during the three years.

The majority of the birds detected occurred in new high water zone vegetation, especially in 1998 when 63% of all birds were found in this habitat. However, in 1999 the distribution of birds between the new and old high water zone was more similar at 40% and 38% respectively. The uplands are significant for some species that are generally uncommon in the riparian vegetation, in particular canyon wren, rock wren, and white-crowned sparrow. There are likely to be complex interactions occurring for some species in their distributions in different reaches of the river corridor, within patches with different amounts and types of vegetation, and perhaps with time of day. One example of the interaction between distribution and abundance is shown by white-crowned sparrow, which occurs primarily in Glen Canyon (reach 1; Appendix C), and is generally found associated with extensive stands of four-wing saltbush (*Atriplex canescens*) adjacent to large patches of new high water zone vegetation. This combination of factors is rare elsewhere in the study area.

It proved difficult during the study to examine the repeatability of the area search survey method. Although this is probably the best method to use when time and funds and limited for winter surveys, tests are still needed on the efficacy of the method as a monitoring tool. The preliminary results suggest that both time of day and length of survey will affect the results. In general, more species and individuals were detected in the morning compared with later times of the day. Comparing results within the same patch could not be done as there was no way to control for time of day. Other factors that may affect the results include weather conditions and experience of the observer. Chapter XI includes preliminary analyses of the power of the survey data to detect change for selected species.

Table V-1. *The most common winter terrestrial species along the Colorado River riparian corridor for 1998-2000, based on number of detections. Each data set is based on two trips, one each in January and February. Those species with at least 1% of the total number of birds detected in any one year are listed.*

	1998		**1999**		**2000**	
Species	**Rank**	**Number**	**Rank**	**Number**	**Rank**	**Number**
White-crowned Sparrow	1	470	7	140	1	385
Ruby-crowned Kinglet	2	351	1	351	3	183
Dark-eyed Junco	3	287	2	259	10	47
Song Sparrow	4	119	6	145	4	112
Bushtit	5	116	3	180	2	380
Western Bluebird	6	115	5	168	9	52
Bewick's Wren	7	109	8	124	6	76
Pinyon Jay	8	101	11	58	15	15
House Finch	9	94	4	168	11	40
Red-winged Blackbird	10	72	-	-	-	1
Canyon Wren	11	55	9	102	8	50
Yellow-rumped Warbler	12	53	10	68	5	83
Lincoln's Sparrow	13	40	14	21	16	13
Rock Wren	14	38	12	46	14	15
Say's Phoebe	15	35	13	33	12	29
Marsh Wren	16	34	15	31	13	22
Phainopepla	-	8	12	33	17	12
Horned Lark	-	-	-	-	7	50
Patches Surveyed		**103**		**128**		**101**
Total Bird Abundance	**-**	**1939**	**-**	**2150**	**-**	**1656**
Total Species	**-**	**51**	**-**	**57**	**-**	**47**

Table V-2. Summary statistics for mean individuals and species detected per patch in the study area between 1998-2000. The standard error (SE of the mean) is also shown for means in parentheses. The total number of individuals detected in each of four primary habitats is also listed.

	1998	**1999**	**2000**
Individuals/Patch	20.85 (3.14)	17.34 (1.71)	17.03 (2.13)
Individuals in NHWZ	1215	866	948
Individuals in OHWZ	287	819	302
Individuals in Upland	374	328	429
Individuals in Air	12	78	13
Species/Patch	5.31 (0.39)	5.52 (0.32)	4.77 (0.32)

Table V-3. Differences in mean number of individuals and species detected per patch for winter terrestrial birds detected in 1998-2000 are tested between months within years, between years, and their two-way interaction using ANOVA. The two-way ANOVA was an unbalanced design, with exact F-test values given. Results significant at the 0.05 level are bolded.

Contrast	**Method**	**Exact F-Test**	**Significance**
Individuals/patch			
1998 January X February	One-way AOV	0.001	0.970
1999 January X February	One-way AOV	0.024	0.876
2000 January X February	**One-way AOV**	**4.707**	**0.032**
Year	One-way AOV	0.860	0.427
Month	One-way AOV	0.860	0.354
Month X Year	Two-way AOV (unbalanced)[1]	1.350	0.426
Species/Patch			
1998 January X February	One-way AOV	0.125	0.724
1999 January X February	One-way AOV	0.128	0.721
2000 January X February	One-way AOV	0.750	0.388
Year	One-way AOV	1.470	0.230
Month	One-way AOV	0.470	0.494
Month X Year	Two-way AOV (unbalanced)[2]	1.510	0.398

[1]Approximate F=1.72, p=0.179
[2]Approximate F=0.35, p=0.709

Table V-4. Changes in the distributions of the most common winter terrestrial species detected among all patches surveyed each year are tested using Fisher's exact test derived from a χ^2 analysis. Significant changes ($p<0.10$) in distribution between years is indicated in bold, with the change (more or fewer patches) shown in superscript.

Species	**1998→1999**	**1999→2000**	**1998→2000**
White-crowned Sparrow	0.621	0.157	0.355
Ruby-crowned Kinglet	**0.044**$^{98<99}$	0.699	0.161
Dark-eyed Junco	0.361	**0.006**$^{99>00}$	**0.094**$^{00>98}$
Song Sparrow	0.462	**0.059**$^{00<99}$	0.341
Bushtit	0.784	0.322	0.188
Western Bluebird	0.605	0.281	0.767
Bewick's Wren	1.000	0.453	0.430
Pinyon Jay	1.000	0.618	1.000
House Finch	0.329	0.131	0.778
Canyon Wren	0.174	0.256	1.000
Yellow-rumped Warbler	**0.079**$^{98>99}$	0.429	0.454
Lincoln's Sparrow	**0.084**$^{98>99}$	0.774	**0.037**$^{00<<98}$
Rock Wren	1.000	0.487	0.631
Say's Phoebe	0.249	0.497	**0.094**$^{00>98}$
Marsh Wren	1.000	1.000	1.000
Phainopepla	0.162	0.162	1.000
Orange-crowned Warbler	0.726	0.329	0.753
Red-naped Sapsucker	**0.002**$^{98>>99}$	0.660	**0.018**$^{00<<98}$

Table V-5. Least-squares regressions of the linear relationships between number of species and number of individuals detected per patch against length of survey (minutes) and start time for the winter terrestrial species in 1998-2000. The adjusted coefficient of variation is listed.

	1998			1999			2000		
	F	**p**	$\mathbf{r^2}$	**F**	**p**	$\mathbf{r^2}$	**F**	**p**	$\mathbf{r^2}$
Survey Length									
Species	65.2	<<0.001	0.434	4.7	<<0.001	0.283	70.7	<<0.001	0.435
Individuals	10.2	0.002	0.107	26.5	<<0.001	0.183	31.8	<<0.001	0.261
Start Time									
Species	1.9	0.167	0.020	5.0	0.027	0.039	6.9	0.010	0.065
Individuals	0.1	0.759	0.001	1.4	0.238	0.011	7.0	0.009	0.067

Table V-6. The results of multiple response permutation procedure (MRPP) tests of species composition and abundance among patches between years, months within years, and months by years for the winter terrestrial avifauna between 1998-2000. The number of groups per contrast, along with both observed and expected δ's and significance values are given. The 1998 data set is significantly different from 1999 and 2000, while the latter two are not different from each other.

Contrast	**Number of Groups**	**Observed δ**	**Expected δ**	**P**
Years	3	13.591727	13.685926	0.045[1]
Months	2	13.688433	13.685926	0.431
Months X Years	6	13.608159	13.685926	0.152

[1](A)1998>(B)1999=(B)2000

Table V-7. Comparisons in species composition of the same patch on consecutive days on the same trip for winter terrestrial birds. The number of species in each survey, the number of species common to both surveys, and Sorenson's coefficient of similarity are shown. The number in parentheses is the total number of individuals detected on the survey. Patch 209.0L was surveyed on consecutive days in two years.

Patch	**Species in Survey 1**	**Species in Survey 2**	**Species in common**	**Sorenson's Coefficient**
50.0R	4 (22)	5 (10)	2	44%
53.0R	4 (7)	10 (27)	4	57%
168.8R	1 (3)	7 (8)	1	25%
196.0R	4 (25)	11 (56)	4	53%
209.0L	12 (62)	13 (36)	7	56%
209.0L	9 (27)	14 (55)	7	61%
246.0L	8 (52)	8 (42)	4	50%

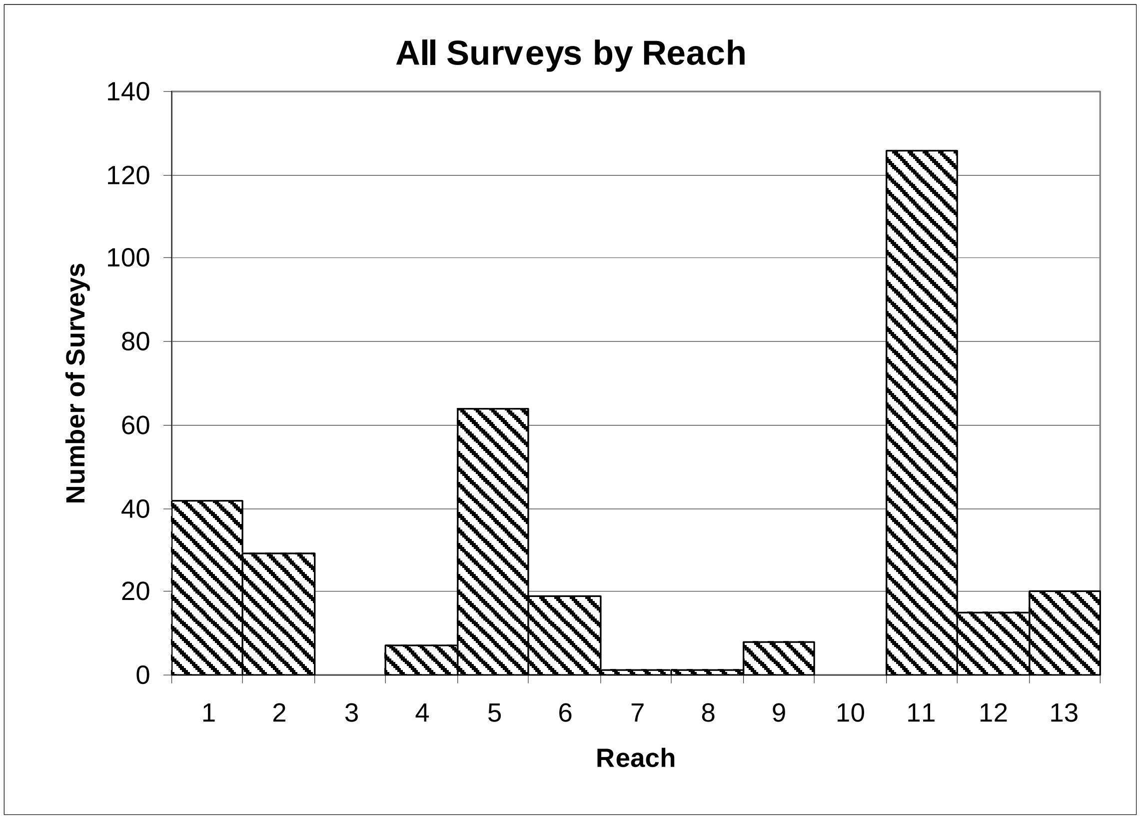


Figure V-1. Number of winter terrestrial bird surveys conducted by reach for 1998-2000.

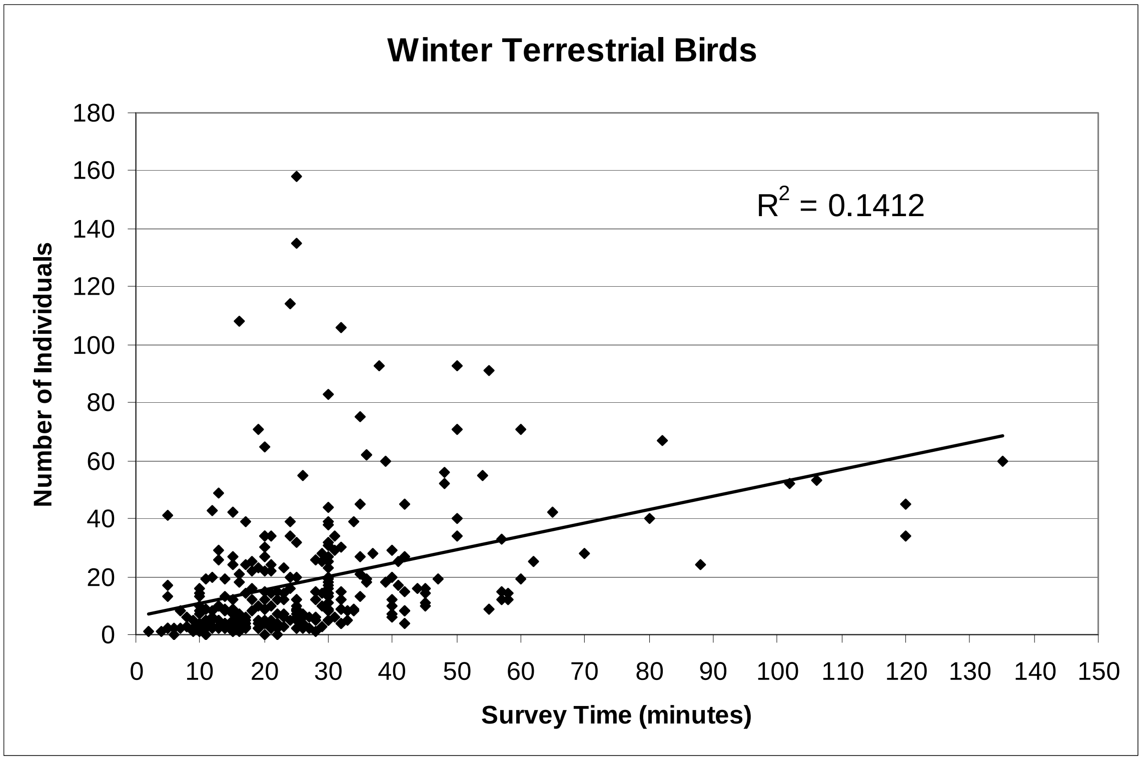


Figure V-2. The relationship between survey length (in minutes) and number of individuals of winter terrestrial birds detected per patch for the years 1998-2000, along with the least-squares fitted line.

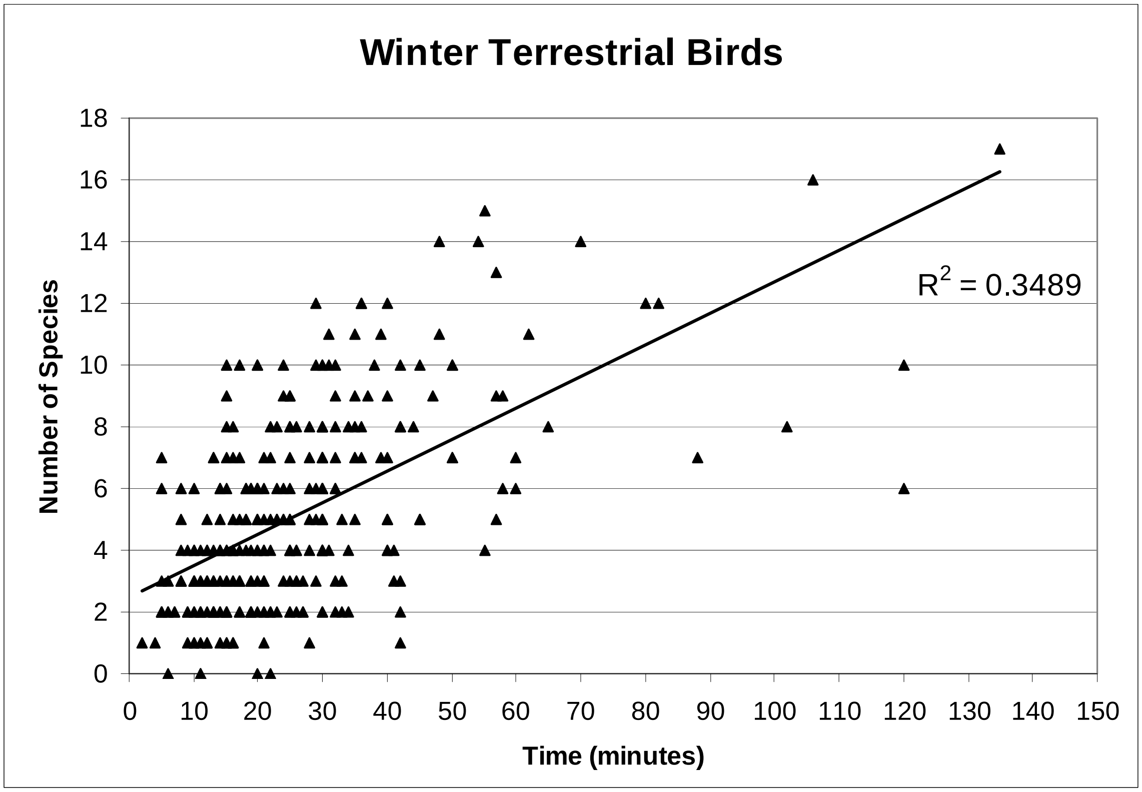


Figure V-3. The relationship between survey length (in minutes) and number of species of winter terrestrial birds detected per patch for the years 1998-2000, along with the least-squares fitted line.

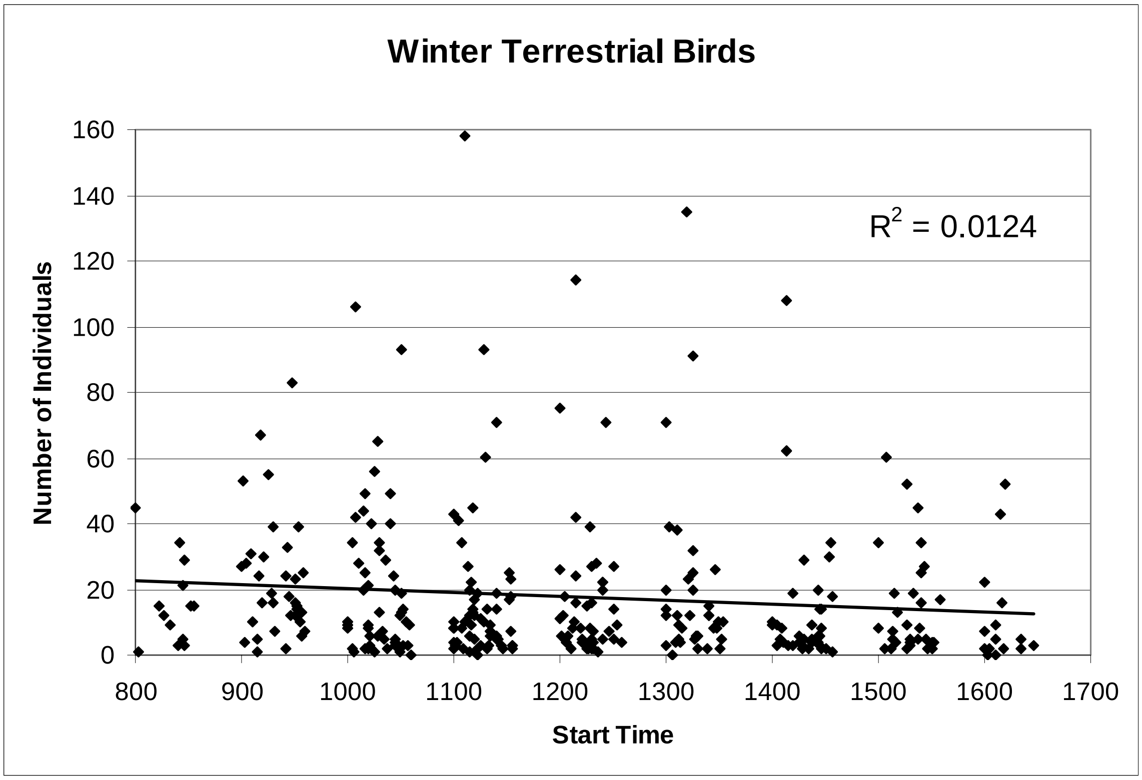


Figure V-4. The relationship between survey start time (24 hour clock) and number of individuals of winter terrestrial birds detected per patch for the years 1998-2000, along with the least-squares fitted line.

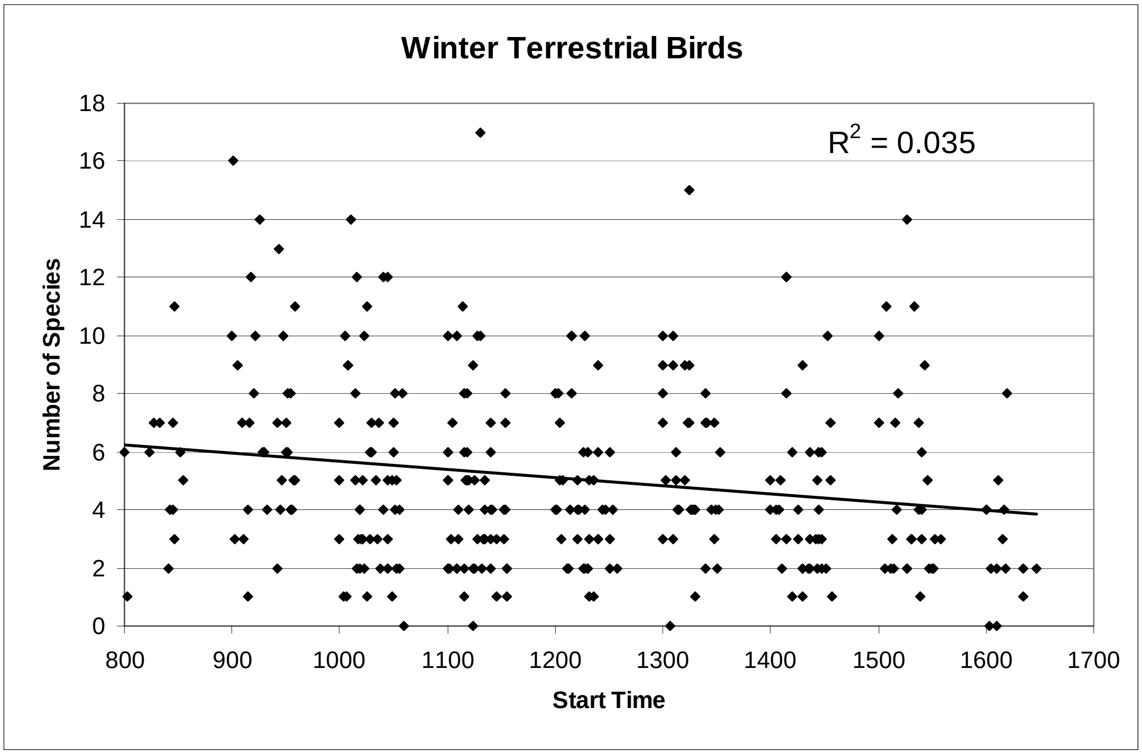


Figure V-5. The relationship between survey start time (24 hour clock) and number of species of winter terrestrial birds detected per patch for the years 1998-2000, along with the least-squares fitted line.

CHAPTER VI. WINTER AQUATIC BIRDS

VI.A. Introduction

This chapter details the results of six winter trips from Glen Canyon Dam to Lake Mead to survey for aquatic bird species. Aquatic species are those in the families Gaviidae, Podicipedidae, Phalacrocoracidae, Ardeidae, Anatidae, Rallidae, and Scolopacidae. American dipper and belted kingfisher were also included in the analyses. Brown et al. (1984, 1987) has summarized previous records of aquatic species found along the river corridor in the study area. Stevens et al. (1997) reported on previous aquatic species distribution and abundance, and Sogge et al. (1998) presented the results of two winter surveys, one in January of 1994 and one in February of 1995. Bird nomenclature follows the AOU 7^{th} edition and supplements.

VI.B. Methods

Six trips were conducted in January and February of 1998, 1999 and 2000. Each trip lasted 12 days, starting at Lee's Ferry and ending at Pearce Ferry on Lake Mead. A single 22' motor snout was used for the trip. This boat proved the necessary stability for surveying water birds along the river corridor, and the speed to sample as many patches of riparian vegetation as possible. Birds were counted as they flew upriver past the boat. If a group of birds flew downstream, they were not counted unless they were a distinctive group that was not observed on the rest of the trip. The location along the river corridor (RK) was noted for each identified individual. Just prior to the launch from Lee's Ferry, the Glen Canyon stretch was surveyed for aquatic species using an NPS motor boat. The February 2000 trip could not be done due to boat and logistical problems. For purposes of graphic display and regression, number of birds in this stretch for February 2000 is estimated from the mean of the previous two February surveys.

Data were summarized by reach and by 5-kilometer segments from the base of Glen Canyon Dam to Separation Canyon (RK 390), and upper Lake Mead (Separation Canyon to Pearce Ferry) for all species, dabblers, and divers. Differences in species composition between years and between trips within years were analyzed for two data sets. One data set comprised all survey data by 5-km segment from Glen Canyon Dam to the mouth of the Little Colorado River (RK 100) for 1998 and 1999 (there were very few birds reported below this location). The second data set comprised all survey data by 5-km segment from just below Lee's Ferry (starting with reach 2) to the mouth of the Little Colorado River for all three years. These data sets were analyzed by the nonparametric multi-response permutation procedure (MRPP) using Euclidean distance as the measure of matrix dissimilarity. Details and applications of this method can be found in Zimmerman et al. (1985) and McCune and Mefford (1995).

Regressions were computed between each trip survey data set and reach water surface area (km^2), mean reach width (m^2), and turbidity in NTU's (data from Stevens et al. (1997) and this report). The approach taken by Stevens et al. (1997) in their analysis of previous aquatic bird data is adopted in this study. Stepwise linear regression analysis was used to determine the model that best explained the variance in the bird data. Variables were considered independent and entered into a backwards selection analysis. Data were first standardized by dividing the number of birds detected by the length of each reach in km. Preliminary inspection of the data revealed that abundance per reach declined exponentially rather than linearly. The resulting standardized values were then transformed by the expression $\log_{10}$ [standardized value +1]. All coefficients of determination (r^2 values) reported are the adjusted values. Throughout, the number of individuals and the number of detections mean the same thing, i.e., the number of individuals detected either visually or aurally during a survey.

VI.C. Results

During the three years of surveys, a total of 22,927 individuals of 42 aquatic species were detected from boat surveys in the study area. Two species, least bittern and trumpeter swan, are reported new to the region, and Barrow's goldeneye is reported new to Grand Canyon National Park. First winter records of nine species are reported for the river corridor between Glen Canyon Dam and Lake Mead: horned grebe, greater scaup, white-winged scoter, long-tailed duck, hooded merganser, red-breasted merganser, Virginia rail, sora, and common moorhen. Details on the significance of these records can be found in LaRue et al. (2001b) and are summarized in Appendix B.

The most commonly detected species for each of the three years are listed in Table VI-1. Lesser scaup was the most common species in 1998, but was ranked only fifth in 1999 and third in 2000. American coot was consistently the second most common species, while common goldeneye, which was ranked third in 1998, was far and away the most common species in 1999 and 2000. The number of species seen each year varied from 30 in 1998, 35 in 1999, to 31 in 2000. Number of individuals varied from 9099 in1999, 7097 in 2000, to 6731 in 1998. It is likely that the numbers for 2000 would have been much higher if the February Glen Canyon survey had been done, as this stretch consistently supports 1500-2500 birds in the winter (Spence, unpublished data). For example, a survey on 3 March 2000 in the Glen Canyon reach found 2,500 birds. Summaries of the abundance by reach for the most common species can be found in Appendix D.

The relationship between reach designation and standardized abundance for all years combined is shown in Figure VI-1. All three groups (total aquatics, dabblers and divers) drop in numbers from reach 1 through reach 12 exponentially. All three curves show highly significant relationships with reach designation (see below). Total abundance, dabbler abundance, and diver abundance are listed for each reach on each trip in Table VI-2. Most birds occurred in reaches 1 and 2, comprising 71% of all detections during the three years. Smaller numbers occurred down to reach 6 at the beginning of the first Granite Gorge. Birds were virtually absent from reach 7 through reach 10, then a few were detected in reach 11 (Lower Canyon). Few birds were found in reach 12, then numbers began to increase in reach 13 (Lake Mead).

Regressions were computed between total abundance, dabbler abundance, and diver abundance and four physical variables for the three years using values standardized by reach length and then [$\log_{10} + 1$] transformed. The four physical variables were reach designation (1-12), reach mean area, reach mean width, and reach mean NTU's (based on the February 1998 trip). Reach 13 (Lake Mead) was not included in the analyses. Results are found in Table VI-3. For all regressions, reach was the single most strongly correlated variable with bird abundance. Width was consistently the second most strongly correlated variable, except for diver abundance in 2000, where only reach was. Overall, a combination of reach designation and mean reach width provided the best explanatory models for bird abundance.

To test if reach designation is correlated with turbidity (cf. Stevens et al. 1997), a regression analysis was performed with turbidity as the dependent variable. The results indicated that turbidity was highly significantly correlated with reach (r^2=0.863, F=70.3, p<0.0001). The regressions between reach and width and area as the dependent variables were weaker (width r^2=0.210, F=3.93, p=0.0757; area r^2=0.045, F=0.53, p=0.485). Reach designation was removed from the analysis, and regressions were re-computed with the remaining three variables. The results are shown in Table VI-4. For most groupings, the combination of turbidity in NTU's and reach mean width provided the best model. However, for total abundance in 1998, reach area and width was the best model. For dabblers in 2000, the best model included only reach width, while for divers in 2000 the best model included only turbidity. As can be seen from the associated T-statistics and significance, reach width was a more important variable for dabblers, while turbidity was more important for divers in 1999 and 2000. Reach area in 1998 best explained total abundance, and turbidity in 1999 and 2000 best explained total abundance. Overall, the results indicate that aquatic species as a whole are controlled by factors related to turbidity and reach mean width. For dabblers, the most important single variable was reach mean width, while for divers the single most important variable was turbidity.

The results of the multiple response permutation procedure analyses are listed in Table VI-5. For the complete data from 1998 and 1999 (Glen Canyon Dam to Little Colorado River) there was a significant difference in species composition and abundance between years. No differences occurred in dissimilarity matrices for months or trips. For the three years of data from reach 2 to the Little Colorado River, both years and trips showed significant differences. The differences are the result of three distinct groupings, January 1998 (group one), combined February 1998 and January 1999 (group two), and February 1999 (group three). All three were different from one another in species composition and abundance.

VI-D. Summary

Aquatic bird communities on the Colorado River show considerable fluctuations in species composition and abundance between years (Tables VI-1 and VI-5). Generally, differences between trips within years were smaller than between years. The resources available to waterfowl in the study area are relatively stable given similar flows, with primary productivity greatest near the dam, and with a rapid drop downstream as the river becomes more turbid. Hence it is likely that the year-to-year fluctuations seen are due to factors outside the region. These factors are likely to include conditions on breeding grounds to the north as well as fall and early winter weather and associated migratory patterns.

In general diving species outnumber dabbling species in the study are by a factor of two. This is probably due to the extent of different types of habitat available to the two guilds. The upper stretches of the river tend to be relatively clear and support an abundance of introduced rainbow trout, providing excellent habitat for divers. The only areas with extensive shallower low-turbidity water where dabbling species can forage are the wider reaches, primarily reaches 1, 5 and to a lesser extent 6. The regression results indicated that reach width was significantly positively correlated with dabbler abundance, although turbidity was also significant as well (Tables V-3 and V-4). Hence dabblers are concentrated in wider reaches above the Little Colorado River, while divers are found in all reaches where the turbidity remains below ca. 10 NTU's (ca. secchi depth of $\geq$1.0 m; Stevens et al. 1997).

The avifauna community on Lake Mead is strikingly different from the upper stretches of the river corridor. Because of the high turbidity in this portion of Lake Mead, the diving species that characterize the river corridor are absent. Instead, the composition is similar to that of Lake Powell, with an abundance of *Aechmophorus* grebes and American coot (cf. Spence 1998; Spence and Bobowski 2003).

Coots are the most common species for the first 40-50 km of the lake below Separation Canyon. The grebes only become common near Pearce Ferry where the lake begins to clear.

There are strong similarities in aquatic bird communities reported from this study and from Stevens et al. (1997). They reported 41 aquatic species in winter from Lee's Ferry to Diamond Creek between 1973 and 1994. Species reported by them that were not found in this study include tundra swan, snow goose, wood duck, killdeer, solitary sandpiper, Wilson's phalarope, ring-billed gull, and California gull. Species new to the river corridor in winter from the current study include pacific loon, horned grebe, greater scaup, Barrow'' goldeneye, red-breasted merganser, and Virginia rail. An additional four species are new to the study area from Lake Mead: Clark's grebe, least bittern, common moorhen, and sora. Common winter species in both studies include great blue heron, Canada goose, gadwall, American wigeon, lesser scaup, common goldeneye, and common merganser.

Chapter XI examines the problems associated with monitoring aquatic birds in the study area. Because of the high variability in abundance for many species, power is relatively low. In order to detect changes in the winter aquatic avifauna longer-term data sets are necessary.

Table VI-1. Summary of the winter aquatic bird surveys on the Colorado River from 1998-2000. The 18 most common species are ranked in order of number of detections.

	1998		**1999**		**2000**	
Species	**Rank**	**Abundance**	**Rank**	**Abundance**	**Rank**	**Abundance**
Lesser Scaup	1	1057	5	528	3	784
American Coot	2	974	2	927	2	1398
Common Goldeneye	3	929	1	3745	1	2209
Bufflehead	4	775	7	498	7	336
Gadwall	5	759	6	507	4	604
Ring-necked Duck	6	620	8	324	9	159
Mallard	7	416	3	856	6	425
American Wigeon	8	379	4	552	5	460
Common Merganser	9	221	9	282	8	201
Green-winged Teal	10	155	10	242	12	87
Barrow's Goldeneye	11	100	11	93	16	14
Redhead	12	83	14	44	11	98
Canada Goose	13	79	12	82	10	117
Great Blue Heron	14	48	13	71	13	63
Greater Scaup	15	42	17	16	14	38
D-C Comorant	16	27	15	42	17	16
Cinnamon Teal	17	5	16	26	-	0
American Dipper	18	6	18	15	15	22
All Other Species		**56**		**249**		**66**
Total Species	**30**		**35**		**31**	
Total Abundance		**6731**		**9099**		**7097**

Table VI-2. Number of detections by reach for winter aquatic birds along the Colorado in 1998-2000 on six trips. The totals for each reach and percent of total by reach are also listed.

Year	**1998**		**1999**		**2000**			
Reach	**Trip 1**	**Trip 2**	**Trip 3**	**Trip 4**	**Trip 5**	**Trip 6**	**Totals**	**% of Total[1]**
1	1613	2435	1627	2581	1528	-	9784	48%
2	573	707	760	1149	1459	1603	6251	23%
3	103	99	270	481	264	262	1479	6%
4	72	39	77	99	139	95	521	2%
5	200	271	339	275	369	228	1682	7%
6	89	96	232	206	161	71	855	4%
7	7	15	36	23	21	21	123	<1%
8	0	0	0	1	3	0	4	<1%
9	1	5	13	11	6	0	36	<1%
10	4	0	13	20	2	7	46	<1%
11	11	7	96	38	64	10	226	1%
12	11	3	24	32	19	24	113	<1%
13	151	219	411	285	427	314	1807	7%
Totals	2835	3896	3898	5201	4462	2635	22927	

[1]Percent of totals are based on the first five complete trips from Glen Canyon Dam to Lake Mead

Table VI-3. Stepwise regressions of total detections, dabbler detections and diver detections of winter aquatic species along the Colorado River from 1998-2000. The best model, Student's T, r^2 and probability are listed for each analysis. Four variables were introduced using a backward stepwise model, reach designation, mean reach area, mean reach width, and mean turbidity (NTU's) per reach.

Analysis by Year	**Best Model**	**Student's T**	**r^2**	**p**
1998				
Totals	Reach + Width	$-4.61_{reach} + 2.37_{width}$	0.824	$0.0013_{reach} + 0.0421_{width}$
Dabblers	Reach + Width	$-4.64_{reach} + 4.06_{width}$	0.878	$0.0012_{reach} + 0.0028_{width}$
Divers	Reach + Width	$-6.07_{reach} + 4.04_{width}$	0.909	$0.0002_{reach} + 0.0029_{width}$
1999				
Totals	Reach + Width	$-4.46_{reach} + 2.42_{width}$	0.819	$0.0016_{reach} + 0.0385_{width}$
Dabblers	Reach + Width	$-3.57_{reach} + 2.81_{width}$	0.791	$0.0060_{reach} + 0.0204_{width}$
Divers	Reach + Width	$-6.40_{reach} + 2.33_{width}$	0.855	$0.0004_{reach} + 0.0445_{width}$
2000				
Totals	Reach + Width	$-5.17_{reach} + 2.35_{width}$	0.847	$0.0006_{reach} + 0.0434_{width}$
Dabblers	Reach + Width	$-2.63_{reach} + 3.92_{width}$	0.801	$0.0275_{reach} + 0.0035_{width}$
Divers	Reach	-7.17_{reach}	0.821	$<0.0001_{reach}$

Table VI-4. Stepwise regressions of total detections, dabbler detections and diver detections of winter aquatic species along the Colorado River from 1998-2000 and the combined totals. The best model, Student's T, r^2 and probability are listed for each analysis. Three variables were introduced using a backward stepwise model, mean reach area, mean reach width, and mean turbidity (NTU's) per reach.

Analysis by Year	**Best Model**	**Student's T**	r^2	**p**
1998				
Totals	Area + Width	$-2.89_{area} + 5.13_{width}$	0.694	$0.0178_{area} + 0.0006_{width}$
Dabblers	NTU + Width	$-3.03_{NTU} + 3.77_{width}$	0.794	$0.0143_{NTU} + 0.0044_{width}$
Divers	NTU + Width	$-3.41_{NTU} + 3.42_{width}$	0.796	$0.0077_{NTU} + 0.0076_{width}$
1999				
Totals	NTU + Width	$-2.85_{NTU} + 2.46_{width}$	0.695	$0.0190_{NTU} + 0.0363_{width}$
Dabblers	NTU + Width	$-2.56_{NTU} + 2.90_{width}$	0.708	$0.0305_{NTU} + 0.0176_{width}$
Divers	NTU + Width	$-3.00_{NTU} + 2.26_{width}$	0.692	$0.0151_{NTU} + 0.0498_{width}$
2000				
Totals	NTU + Width	$-3.11_{NTU} + 2.33_{width}$	0.707	$0.0125_{NTU} + 0.0449_{width}$
Dabblers	Width	4.98_{width}	0.684	0.0006_{width}
Divers	NTU	-4.23_{NTU}	0.606	0.0017_{NTU}
All 3 Years				
Totals	NTU + Width	$-3.13_{NTU} + 2.39_{width}$	0.714	$0.0120_{NTU} + 0.0409_{width}$
Dabblers	NTU + Width	$-2.73_{NTU} + 3.35_{width}$	0.753	$0.0233_{NTU} + 0.0085_{width}$
Divers	NTU + Width	$-3.63_{NTU} + 2.56_{width}$	0.761	$0.0055_{NTU} + 0.0309_{width}$

Table VI-5. Results of multiple response permutation procedure (MRPP) tests for two data sets, species composition and detections by 5-km segment from Lee's Ferry to the Little Colorado River for 1998-2000, and species composition and abundance by 5-km segment from Glen Canyon Dam to the Little Colorado River for 1998 and 1999. The number of groups per contrast, along with both observed and expected δ's and significance values are given. January 1998 is significantly different from all 3 other months, while February 1998 and January 1999 are not significantly different, and February 1999 is significantly different with all three other months.

Contrast	**Number of Groups**	**Observed δ**	**Expected δ**	**P**
1998-2000 (Lees Ferry-Lake Mead)				
Years	3	72.535646	73.497768	0.0379[1]
Months	2	73.598819	73.497768	0.5081
Months X Years	6	73.240208	73.497768	0.3045
1998-1999 (Glen Canyon Dam-Lake Mead)				
Years	2	110.69750	114.26284	0.0013
Months	2	114.76440	114.26284	0.8977
Months X Years	4	111.68181	114.26284	0.0264[2]

[1]all 3 years significantly different

[2](A)January 1998>(B)February 1998=(B)January 1999>(C)February 1999

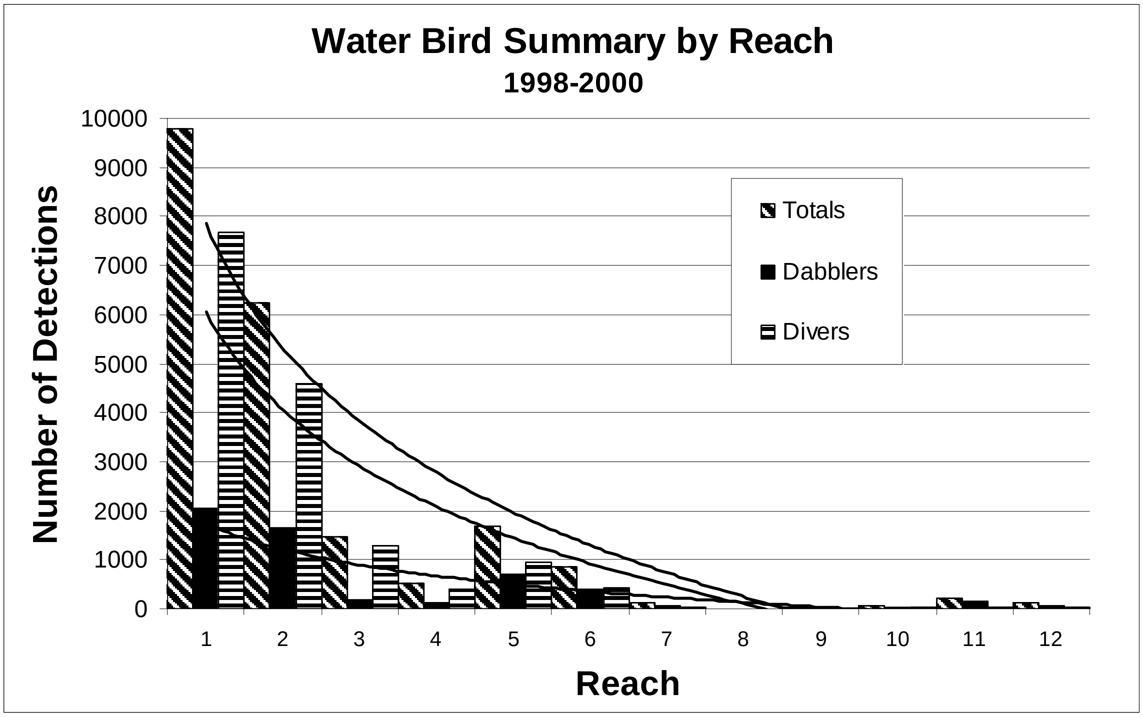


Figure VI-1. Plot of the relationship between abundance and reach designation (excluding upper Lake Mead-reach 13) over 1998-2000 for total aquatic birds, dabblers, and divers. The logarithmic regression line is fitted to each of the three curves.

CHAPTER VII. BREEDING BIRDS

VII-A. Introduction

This chapter summarizes the principal results of the breeding bird program using three data sets, 1992-1999 Glen Canyon (NPS), 1995-2000 Grand Canyon (USGS-NPS), and 1996-2000 Glen Canyon and Grand Canyon (NPS). Data on point counts, area surveys, and summaries for the more common breeding species are presented. Power tests are found in Chapter XI.

Prior to our study, only Sogge et al. (1998) had conducted point count surveys in the study area. Other work has used variations of timed area surveys (e.g., "modified Emlen transects", Brown 1987, 1989; Hualapai Nation and SWCA 1995). However, these surveys are inherently more variable than point counts in the dense scrub typically found along the Colorado River (Felley and Sogge 1997; Petterson and Spence 1997). Another concern about previous work is the relatively small sample sizes, with from six to ten patches surveyed by this method. It was decided at the outset to use point counts as the primary sampling method, and to use timed area surveys as a secondary method and for basic comparisons with previous data. The following analyses concentrate primarily on the point count data collected in the years 1996 through 2000. Bird nomenclature follows the AOU 7th edition and supplements.

VII-B. Methods

A breeding bird trip was launched from Lee's Ferry downstream on or near the dates of April 1, May 1 and June 1 on each year. Trips averaged 16 days each. Each trip included two primary bird surveyors, one for point counts and the second for area surveys, as well as boat operators and botanists. The primary boat used was a 22-foot motor snout. During the hotter months (May and June) a zodiac sport-boat was used to transport the bird crew rapidly between patches. After the end of each trip, patches in the Glen Canyon reach were sampled using an NPS motorboat.

The breeding bird program selected a subset of riparian vegetation patches in 1996. The choice of which patches to survey was based primarily on patch size and logistics considerations. Given a 16-day trip and work that needed to be completed by 0830-0900, the patches selected necessarily occurred in groups at and downstream of each night's camp. Based on the results of Sogge et al. (1998), larger patches were selected over smaller ones in order to maximize number of species and individuals detected. Initially, a 10-minute point count length was considered, but five minutes was adopted because of the relatively large number of count stations and patches that needed to be visited each morning.

Within each patch from one to ten point count stations were positioned at least 250 meters apart. At each station a single surveyor moved to the station and recorded all birds heard or seen for five minutes. Birds that left the circle as the surveyor approached were counted. Birds were recorded as either within or outside a fixed 50-meter radius circle around the center, depending on where they were first detected. Because of the generally narrower riparian zone in Glen Canyon, point counts used a fixed radius of 25 meters rather than 50 meters between 1992-1995. In 1996, a 50-meter fixed radius was adopted to integrate results throughout the river corridor (Spence 1997). Unbounded point count data includes all birds detected at a station. Aerial species (swallows, swifts) were recorded as well. Other data recorded included temperature, cloud cover and wind speed, disturbances, singing or not, and bird sex and behavior. Throughout, the number of individuals and the number of detections mean the same thing, i.e., the number of individuals detected either visually or aurally during a survey.

For area surveys, a second surveyor entered the patch ca. 15-20 minutes after the point count surveyor had begun, and walked throughout the patch recording birds seen, sex, behavior and habitat. Each area survey was timed, and generally lasted from five minutes in small patches up to an hour or more in large patches.

Included in this study are point count data for 1992-2000, as well as area survey data for 1996-1998. Glen Canyon NRA monitored point counts in the Glen Canyon reach between 1992 and 1999, while Grand Canyon data is available from 1996-2000 (this program) as well as a limited data set from 1995 from Sogge et al. (1998). For rough comparisons with the complete 1996-1999 data set, the 1995 data from Sogge et al. (1998) were combined with the Glen Canyon data from that year. Data are reported in several forms. To compare patch differences statistically, point count data were summed within a patch for those with more than one point count station. Unless otherwise specified, analyses were based on the unbounded point count data rather than data from within the 50-meter radius. Mean number of birds and species detected per point count or patch was calculated, based on three trips per year. Although data on singing birds (primarily males) was collected, it was not analyzed in this report. Data were analyzed by linear regression and analysis of variance (ANOVA). For comparisons between years among patches, a repeated measures ANOVA was used to assess trends. For multiple comparisons of means, Tukey's method was used.

VII-C. Results

Species-specific data on distribution within the study area, detection rates over years and months, and breeding status can be found in Appendix F.

VII-C.1. Breeding Riparian Species of the Study Area

We adopted the decision rules used by Sogge et al. (1998) to determine the breeding status of non-aerialist species in the riparian zone of the Colorado River. They provided species-specific rules to determine breeding vs. migratory status. In addition to those species they examined, an additional nine species were added during the five years of the study. Decision rules for these species, bushtit, black phoebe, black-headed grosbeak, great-tailed grackle, hooded oriole, indigo bunting, lazuli bunting and red-winged blackbird, can be found in the annotated breeding bird species list (Appendix F). This list includes 32 species, two of which, bank swallow and southwestern willow flycatcher, are not discussed. The bank swallow was extremely rare (LaRue et al. 2001b), while the flycatcher was dealt with elsewhere. Of the 32 species, breeding records (primarily nests) exist for 24 species, with the remaining eight are considered possible breeders, e.g., suitable habitat occurs and the species probably breeds but there are no records, or apparently suitable habitat is available but there are no breeding records. The four categories of breeding status are: summer breeder (March-July), resident (permanent resident) breeder, possible summer breeder, and possible resident (permanent resident) breeder. Data on aerialist species, including white-throated swift, cliff swallow, northern rough-winged swallow, and violet-green swallow were not analyzed in this study because of the inherent difficulties in obtaining reliable counts for these species, although detections are reported in the data files. Other species that breed primarily in the adjacent uplands, including raptors, canyon and rock wrens, Say's phoebe, ladder-backed woodpecker, common raven, and black-throated and rufous-crowned sparrows, were not included in the analyses although detections are included in the databases. Data on all species is included in the Excel databases for each year.

VII-C.2. Contrasts between Area Surveys and Point Counts

Felley and Sogge (1997) and Petterson and Spence (1997) had previously contrasted detection rates between area surveys and point counts. In general, correspondence was fairly close in their studies, and for many species the two methods appear to be comparable. However, as patch size and number of birds increased, the results of the two methods become less similar (cf. Spence et al. 1998). Figure VII-1 portrays the relationship for total detections of the 15 most common species contrasted between paired unbounded point counts (summed within patches) and area surveys in 56 patches. For small numbers of birds, the correspondence is fairly good, but it becomes weaker as the number of birds detected by either method increases.

Paired unbounded point count sums and area survey sums were contrasted for the 20 most common species detected in 1997 and 1998. The results are summarized in Table VII-1. Contrasts for paired surveys for those species that had enough detections to be plotted for 1996 (data from Petterson and Spence 1997), 1997 and 1998, are shown in Figures VII-2 to VII-4. If the species fell below the fitted regression line, it indicates that more birds were detected by point counts, while if the species fell above the line, more individuals were detected by area surveys. The position of Lucy's warbler is not indicated because of the much larger detection rates compared with the remaining species. For this species, area and point count results were generally comparable for 1996 and 1998, while many more birds were detected by point counts than area surveys for 1997. There are relatively few consistent detection patterns among species. Blue-gray gnatcatcher had consistently higher numbers detected on area surveys for all three years. For 1996 and 1998, song sparrow numbers were also higher on area surveys compared with point counts. During 1998, when yellow warblers were fairly common, area surveys also recorded higher numbers. On the other hand, yellow-breasted chat was more commonly recorded on point counts for all years. One species, Bell’s vireo, showed fairly close correspondence between methods for all years. Many species showed inconsistent patterns, in particular house finch. Correlation coefficients were relatively high between methods for the selected species over the three years, with r^2=0.89 for 1996, r^2=0.95 for 1997, and r^2=0.92 for 1998.

VII-C.3. 1995-2000 Grand Canyon Point Counts

Only eight patches surveyed during the program were also surveyed in 1995 using 50-m point counts by the USGS group (Sogge et al. 1998). These patches were 1.0R, 1.6R, 46.7R, 197.6L, 198.0R, 198.2L, 204.1R and 204.5R. Patch 74.4L was also surveyed during both programs, but not consistently during the years 1996 to 2000. Because of the small sample size, differences between years and trips were not analyzed, although means for species and individuals can be found in Figures VII-6 and VII-7. Overall, these patches supported more birds and more species than the mean for larger samples of patches within the study area. Summary point count data for selected riparian species in these eight patches can be found in Appendix F.

VII-C.4. Complete Surveys from 1996-1999

From 1996 to 2000 15 trips were conducted to survey breeding birds between Glen Canyon Dam and upper Lake Mead. On these trips 1,700 point counts were completed in 76 patches. Of this total, 116 were conducted in patches of riparian vegetation on upper Lake Mead in 1996 and 1997. By 1998 the rising levels of Lake Mead had drowned most of the riparian vegetation below ca. RK 400. No surveys were done in the Glen Canyon reach in 2000. The summed distribution by reach of all point counts between 1996 and 2000 is shown in Figure VII-5. Most work was conducted in reaches 1, 2, 3, 5, 6 and 11 (88% of all point counts).

Between 1996 and 1999 surveys were conducted throughout the river corridor from Glen Canyon Dam to upper Lake Mead, although by 1998 surveys had to be abandoned below Diamond Creek because of Lake Mead water levels. During these four years 31 species that breed or potentially breed in the riparian zone along the Colorado River were detected, excluding aerialists. The only species from previous studies not detected during the breeding season was crissal thrasher. Table VII-2 lists these species and total detections based on unbounded point count data for each year. This table also includes data for 2000 from Lee's Ferry to Diamond Creek. Summary point count data for each species can be found in Appendix F.

Between 1996 and 1999 46 patches of riparian vegetation were consistently surveyed. There were no significant differences in number of birds detected per patch among years (Table VII-3, Figure VII-6). Mean number of birds detected per patch varied from 13.5 in 1996 to 17.9 in 1997. Mean number of species detected per patch varied from 4.7 in 1996 to 6.1 in 1997 and 1998, and was significantly different among years (Table VII-3; Figure VII-7). Significantly fewer species were detected in 1996 than in 1997-1999, while fewer species were detected in 1999 than in 1997 and 1998 (Table VII-3).

Four species showed significant differences in numbers detected per patch between years; black-chinned hummingbird, blue grosbeak, yellow warbler, and yellow-breasted chat (Table VII-4). None of these species showed a significant trend over the four years that would suggest a consistent decrease or increase over time. However, consistent non-significant trends occurred for three species. Blue-gray gnatcatcher showed a near-significant ($p=0.116$) decline between 1996 and 1999, while house finch and yellow warbler showed gradual increases since 1996. Numbers of black-chinned hummingbirds, blue grosbeaks, and yellow warblers detected were significantly lower in 1996 than in subsequent years, while blue grosbeaks were also less common in 1999 compared with 1997 and 1998 and yellow warblers were significantly more common in 1999 compared with 1996. Significantly more yellow-breasted chat's were detected in 1998 than in 1999.

Trip differences also occurred during the years 1996-1999 (Table VII-4; Figures VII-8 and VII-9). Significantly fewer species were detected on April trips compared with May and June trips. Significant differences also occurred between trips for ash-throated flycatcher, black-chinned hummingbird, blue grosbeak, blue-gray gnatcatcher, common yellowthroat, lesser goldfinch, yellow warbler and yellow-breasted chat. Significantly fewer ash-throated flycatchers, common yellowthroats, yellow warblers, and yellow-breasted chats were detected on April trips compared with May and June trips. Blue grosbeak was significantly more common in June than in April and May. Lesser Goldfinch was significantly more common early (April and May) compared with June. Black-chinned hummingbird showed a different pattern of being significantly more common in May compared with June, but with no differences between May and April and June and April.

VII-C.5. Grand Canyon Surveys from 1996-2000

Bird data from surveys in the Grand Canyon between 1996 and 2000, including only patches downstream of Lee's Ferry, were analyzed across 29 patches that were consistently sampled all years. Mean number of birds and species detected per patch survey are plotted in Figures VII-6 and VII-7.

There were no significant differences in number of birds and species detected between years (Table VII-5). Significant differences between years in detection rates occurred for five species; ash-throated flycatcher, black-chinned hummingbird, house finch, mourning dove, and yellow-breasted chat. Fewer house finches and yellow-breasted chats were detected in 1996 compared with subsequent years, while fewer house finches were detected in 1997 and 2000 compared with 1998 and 1999. More yellow-breasted chats were detected in 1999 compared with 1997, 1998 and 2000. For mourning dove, significantly fewer birds were detected in 2000 and significantly more were detected in 1999 compared with 1996, 1997 and 1998. Significantly fewer ash-throated flycatchers were detected in 1999 and 2000 compared with 1996-1997, while more were detected in 1998 than in other years. Black-chinned hummingbird showed more complex differences, with significantly fewer birds detected in 1996, and more in 1997.

There were no significant differences among trips for total individuals detected per patch survey (Table VII-6). Significant differences occurred for number of species detected per survey, as well as for ash-throated flycatcher, black-chinned hummingbird, blue grosbeak, common yellowthroat, lesser goldfinch, mourning dove, yellow warbler, and yellow-breasted chat. For most species, April had the fewest detections, followed by May, with the most in June. However, for black-chinned hummingbird, lesser goldfinch, and yellow warbler the reverse was true, with fewer detections in June.

VII-C.6. Glen Canyon Surveys from 1992-1999

The first five years of the Glen Canyon riparian bird monitoring program was summarized by Spence (1997). One conclusion of that study was that there was insufficient power to detect change in most breeding species, and that the Glen Canyon program should be combined with the Grand Canyon program. The number of point counts was increased from 20 in 1992 to 21 in 1993, and then to 25 in 1997. The number of patches was increased from 10 in 1992 to 11 in 1993, and then to 15 in 1997. Ten patches have been consistently surveyed at least three times per year since 1992. Mean number of birds and species per point count are graphed in Figures VII-6 and VII-7. Four species were most commonly detected in the Glen Canyon reach, blue grosbeak, brown-headed cowbird, Bullock's oriole, and mourning dove. The oriole was very rarely detected below Lee's Ferry, and then generally only in large patches on the upper Lake Mead reach in association with Fremont cottonwood stands (*Populus fremontii*). It's virtual restriction to the Glen Canyon reach along the river corridor remains unexplained. Summary mean detection rates for the Glen Canyon reach for selected species can be found in Appendix F.

VII-C.7. Qualitative Comparisons with 1984-1985 data

The Glen Canyon Environmental Studies Phase I funded preliminary riparian bird surveys at ten sites along the Colorado River riparian corridor (Brown 1987, 1989). These sites were either very close to or for the most part overlapped with patches –7.0L, 0.4R (combined as one "site"), 46.7R, 71.0L, 108.8R, 122.8L, 166.5L, 171.0R, 198.2R, 209.0L, and 220.0R. The method used was an area transect method, similar to the area total survey method used in 1996-1998. Total detection rates were not recorded, however. Rather, numbers were recorded in NHWZ and OHWZ habitats separately as pairs based on selected criteria, including the presence of singing or territorial males, pairs, etc. Data were then reported as pairs/40 hectares of available habitat. Hence the data cannot be compared with subsequent data quantitatively. However, the data can be compared qualitatively by ranking the abundance from the 1984-1986 data and comparing it with ranked detection rates from the 1996-1998 data. Data from 1984 and 1985, and 1997 and 1998, were used as a comparison. Table VII-7 ranks riparian species detected in 1984-1985, and 1997-1998 from those patches sampled in both studies (-7.0L, -0.4R, 46.7R, 71.0L, 122.8L, 171.0R, 198.2R, 209.0L). Four species from the 1984-1985 data were not included, American coot, western screech-owl, marsh wren, and house sparrow. Rank abundance for the 1984-1985 data was computed by adding up all values for each species within the OHWZ and NHWZ, and then dividing by the number of patches, then averaging the two values for the two habitats. The values for both data sets were then normalized by assigning the most abundant species a value of 100.

In all 26 riparian species were detected in 1984 and 1985, in addition to the four that were excluded from the analysis. With the exception of crissal thrasher, all of the species were also detected during the 1996-2000 program. However, black-headed grosbeak, bullock's oriole, phainopepla, and willow flycatcher were only detected by methods other than area searches. In general, results were fairly similar for the two surveys, although differences exist in ranking. Hummingbirds, particularly black-chinned, appear to have been relatively more common (or more easily detected) in 1984-1985. Another species that was commonly detected in the earlier surveys was blue-gray gnatcatcher. These species are relatively quiet and easily missed in dense riparian vegetation. The NHWZ in 1984 was just recovering from the 1983 floods and had been reduced by as much as 30-50% in total extent depending on locality. The more open canopy and lower cover of the vegetation in 1984-1985 may explain the higher detection rates for quiet or inconspicuous species. The alternative is that black-chinned hummingbird and blue-gray gnatcatcher may have declined since the earlier surveys. The complete absence of song sparrow from the 1984-1985 surveys is inexplicable. However, they may have recently expanded their range into the lower canyon with changes in habitat on the Lake Mead delta.

VII-C.8. Trends in selected species

Several species , mostly neotropical migrants, showed consistent trends during the study. Species showing apparent increases include Bullock's oriole and yellow warbler, while those showing consistent declines include blue-gray gnatcatcher and ash-throated flycatcher. Finally, the local resident lesser goldfinch has shown a strong decline in detections rates in the Grand Canyon since 1998. This latter species may be declining locally because of the drought that has occurred in the region since 1999.

Blue-gray gnatcatcher has shown a steady decline in both Glen Canyon and Grand Canyon. Detection rates in Glen Canyon have dropped from a mean of 0.4 per point count in the early 1990's to 0.05 by 1999, an 8-fold decline. Including all data, since 1995 detection rates in the study area have dropped about 30-50%. These declines are statistically significant using simple linear regression. Although ash-throated flycatcher detections appear to have declined in the study area, the trend is not significant using linear regression. Two species, Bullock's oriole in Glen Canyon, and yellow warbler throughout the study area, show statistically significant increases in detection rates using linear regression. Bullock's oriole, common only in the Glen Canyon stretch, has increased from about 0.08 detections per point count in the early 1990's to about 0.37 per point by 1999, a 4.6-fold increase. Yellow warbler has increased throughout the study area from about 0.07 detections per point count in the early 1990's to about 0.40 per point count by 2000, a 5.7-fold increase. Although more detailed analysis of these trends using a repeated measures design is not attempted in this study, there is sufficient power in the data to detect trends in blue-gray gnatcatcher, and if the values of power and α are relaxed, for yellow warbler as well. These is insufficient power to detect significant trends for Bullock's oriole with a two-tailed test. However, with a one-tailed test and $\alpha=0.10$, with other parameters held constant, there is sufficient power to detect an increase of 10% per year (power=0.900; Chapter XI).

VII-C.9. Reach Distributions

The distribution of point counts along the Colorado River in the study area was not random (Figure VII-5). Many reaches had few if any patches of riparian vegetation large enough to sample, including reaches 3, 4,7 9, and 10. The majority of the data was obtained from reaches 1, 2, 5, 6, 8, 11 and 12. The distribution of riparian species varied along the river corridor, with some showing significant restrictions among reaches. Species found throughout the river corridor in suitable habitat included ash-throated flycatcher, black-chinned hummingbird, blue-gray gnatcatcher, common yellowthroat, house finch, yellow warbler, and yellow-breasted chat. Three species, Bell's vireo, lesser goldfinch, and song sparrow, were distributed in most reaches but were much more common in the lower reaches. One species, Lucy's warbler, was found throughout the study area, but was much more common below Lee's Ferry. Bewick's wren was most common in the middle reaches of the study area. Finally, four species were most common in reach 1 in Glen Canyon; blue grosbeak, brown-headed cowbird, Bullock's oriole, and mourning dove. It is possible that blue grosbeak is more common in lower reaches of the study area than the data suggest, as it is a late breeder and survey work below Lee's Ferry was generally completed by June 15. The distribution of the rarer species also tended to follow this pattern. Brown-crested flycatcher, Costa's hummingbird, hooded oriole, phainopepla, and summer tanager were detected mostly below National Canyon (RK 272), while bustit was only detected in the breeding season in the upper reaches of the study area. Most of the remaining rare species were scattered in distributions throughout the study area, in an apparently random pattern. One species which seems to be increasing in distribution the study area is great-tailed grackle. Although originally confined mostly to Lee's Ferry and upper Lake Mead, this species was been detected on point counts, area surveys, and by causual observations in many reaches of the study area during the course of the study.

VII-D. Summary

This study has documented the presence of 32 species of terrestrial riparian species in the study area. All of these species have been previously documented in riparian vegetation within the study area (cf. Brown 1989; Sogge et al. 1998). Two species, northern rough-winged swallow and bushtit, although common at other times of the year, are newly documented breeding riparian species along the river corridor (LaRue et al. 2001b; NPS files). Over the course of the five years of surveys, an additional 85 terrestrial migrant and lingering winter resident and upland species were also detected at point counts or during area surveys.

Between 1996 and 2000, 1,700 point counts and 540 area searches were completed in the study area. This represents the largest available data set on riparian birds in the region. There remains a large amount of data in these surveys that has not been analyzed in this report. These include detections within the 50-meter radius, the principal habitats each bird was first detected in, detection rates of singing birds (males), behavioral and breeding notes, and detections of migrant and winter resident species. This study has concentrated analysis on the unbounded point counts as this represents the data most likely to be used for comparisons with other studies and to determine management goals and objectives.

As found in previous work, Lucy's warbler was the most common species along the Colorado River between Glen Canyon Dam and Lake Mead. Although number of detections of this species varied considerably from year to year, it accounted for between 26% and 36% of all detections during the course of the study. By comparison, the second most commonly detected species, house finch, accounted for between 9% and 14% of all detections. Between 1995 and 2000 there does not appear to have been any consistent trend in Lucy's warbler. However, the species appears to have become slightly more common in the Glen Canyon reach since 1992 (Appendix F). Other commonly detected species include house finch, Bell's vireo, Bewick's wren, black-chinned hummingbird, ash-throated flycatcher, and yellow-breasted chat. Many species were extremely rare in the study area, with the rarest 14 species only accounting for between 2-6% of all detections per year.

The ranking of species other than Lucy's warbler varied from year to year. For example, Bell's vireo was the second most common species in 1996, but then dropped to third in 1997 and 1998, fourth in 1999, and back to second in 2000. Three species showed especially large fluctuations between years. Black-chinned hummingbird was uncommon in 1996, following a severe winter drought, and became much more common in subsequent years. Mourning dove showed strong fluctuations between years, with high count years alternating with low count years. Several species that were most common in the Glen Canyon reach, including blue grosbeak, Bullock's oriole, and brown-headed cowbird, declined in 2000, primarily because the Glen Canyon reach was not surveyed that year. Finally, song sparrow declined in abundance after 1998, coinciding with the abandonment of surveys below Diamond Creek. This species is most common in the large riparian patches on upper Lake Mead.

Contrasts between point counts and area surveys (Table VII-1, Figures VII-1 to VII-4) showed that the two methods do not give similar results for many species. The pros and cons of the two methods have been dealt with elsewhere (for the study area by Felley and Sogge 1997; Petterson and Spence 1997; Spence et al. 1998). Area surveys are more likely to find rare and quiet species. For example, area surveys in the study consistently detected more blue-gray gnatcatchers than point counts. On the other hand, point counts have the advantage of being less variable in several ways. The two most important are constant time and a stationary observer. Area searches in the same patch on different occasions rarely record the same elapsed time, as observers move through the patch searching out birds. Unless a standardized path is taken every time, results may not be directly comparable between surveys and especially between observers. The second problem is that the observer is moving, and in the dense scrub of the Colorado River corridor this means a certain amount of noise is generated. While moving, the observer may miss a vocalization of a bird. Also, some shy species are less likely to vocalize if an observer is moving in their vicinity. One way to partly control for these problems is to cut a path through the patch of vegetation. If this path is consistently followed, some of the variability in the method can be removed. However, cutting paths through riparian vegetation in the Grand Canyon may be in conflict with NPS management and policy. Because of these considerations, the decision was made to use point counts as they are preferable for long-term monitoring purposes in the particular conditions encountered in the study area.

A combination of area searches and point counts is likely to produce a more complete list of the species inhabiting a patch of vegetation than either method alone. One way to monitor bird species is to compare the number of samples (patches) they occupy from year to year using both methods. If enough samples are available, this method can be used to track qualitative trends in species. Spence et al. (1998) applied this method to data from 1997 and 1998 surveys. A contingency table analysis with Fishers Exact Test was applied to presence/absence data of 16 species in 55 patches sampled consistently in 1997 and 1998. In general it is not recommended that this method be used for two reasons, the cost of sampling using both area searches and point counts, and the lack of detailed quantitative estimates of bird abundance. However, in certain circumstances, where funding was limited, area searches alone combined with association tests of presence/absence may provide some information on species trends.

The previous USGS program in the study area (Sogge et al. 1998) provided a solid basis for understanding the ecology and distribution of riparian breeding bird species along the Colorado River. In 1995, this program conducted point counts throughout the river corridor in selected patches of vegetation (Appendix A). However, only eight patches were sampled in 1995 that were also visited during 1996-2000. These eight patches probably do not represent a typical sample of the habitat and bird communities below Lee's Ferry. Numbers of individuals and species detected in these patches was consistently higher than for the entire data set (Figures VII-6 and VII-7). The small sample size also precludes any power analysis tests, or determination of any trends in selected species between 1995 and 2000.

Integration of the Glen Canyon and Grand Canyon programs in 1996 provided a larger sample size of riparian patches for conducting baseline sampling in the study area. Between 1996 and 1999, 76 patches were visited at least once, with 46 patches consistently sampled from near Glen Canyon Dam in reach 1 to Diamond Creek, and 29 were sampled every year below Lee's Ferry between 1996 and 2000. In addition, another 13 patches were sampled on at least three years during the same period. With the selection of additional patches, including those visited by the USGS program, a sufficient sample size of 60 or more patches could probably be surveyed every year. This would have the advantage of increasing power in the program to acceptable levels for most of the 16 most common riparian breeding species, except possibly brown-headed cowbird, Bullock's oriole, lesser goldfinch, and song sparrow (see Chapter XI). Song sparrow could be effectively monitored if riparian vegetation on upper Lake Mead was sampled as part of any future monitoring program.

Glen Canyon has a distinctly different bird community compared with the Grand Canyon and Marble Canyon. Several species are much more common above Lee's Ferry than below it, in particular blue grosbeak, Bullock's oriole, brown-headed cowbird, and mourning dove. Other species, including Bell's Vireo, lesser goldfinch, and song sparrow, are absent or very rare above Lee's Ferry. Although the presence of the cowbird may be explained in part by proximity to livestock grazing and horse corrals at nearby Page, the abundance of the remaining three species is not easily explained. There are significant differences in habitat between Glen Canyon and the rest of the study area, however (see Chapter X), and these differences may in part explain the differences in bird communities.

Because the 1984-1986 program and the current program recorded bird detections in different ways, the data are not easily compared. Further, the sample size (10 patches) is too small to provide a robust statistical analysis of the abundance of the avifauna throughout the study area in 1984-1986. There are some intriguing differences in the results of the two programs. Relative to other species, Lucy's warbler was much less common in the earlier study compared with the period 1995-2000, although it was still the most abundant species overall. On the other hand, black-chinned hummingbird and blue-gray gnatcatcher appear to have been more common in the mid 1980's compared with the 1990's. Since both species are quiet and easily overlooked, the differences may be explained by the more open and successional nature of the vegetation resulting from scour by the 1983 floods and subsequent 1984-1985 high flows. However, at least for the gnatcatcher, there may in fact be a long-term decline in populations in the canyon, as the species has been showing a consistent decline since the program was initiated in 1992 in Glen Canyon and since 1996 in the Grand Canyon. Interestingly, BBS data from North America reveal a highly significant decline of >3% per year in blue-gray gnatcatcher since 1995 (Pardieck and Sauer 2000). More monitoring of this species regionally may be warranted. Overall, the short-term nature of the data set reported in the current study (4-5 years) is insufficient to determine consistent trends in most other species in the study area (see also Chapter XI).

A major question that needs to be addressed more thoroughly is the relationship between true bird abundance and detection rates based on point count data. Elsewhere (Chapter VIII) distance data are evaluated based on sampling in 2000 in the Grand Canyon. Distance sampling is problematic in the dense riparian vegetation within the study area for several reasons. True distance to a vocal bird is extremely difficult to estimate in dense scrub, as it is complicated by foliage density, river noises, and the vocalization volume of the bird. Another problem is that different distance estimates can be obtained by different observers to the same bird, so there is a need for constant calibration if two or more surveyors are collecting data. Simple detection rates based on either unbounded point counts or constrained by 50 meters are subject to fewer problems. If a significant correlation could be established between estimates based on other methods, including distance methods, and detection rates this would obviate the need for distance estimation. However, because of the inherent variability in detection rates among species, it is unlikely that a simple positive correlation between bird abundance based on detection rates and distance estimates exists. Chapter VIII examines these questions in greater detail.

The data presented in this chapter represents baseline information on variability in breeding bird species detection rates in the study area. Five years of data may be adequate to capture much of the year-to-year variability, although this is an assumption that may be complicated by longer-term directional trends related to either successional patterns in the riparian vegetation along the river corridor, or changes in migratory and wintering habitats. The data are probably adequate to develop upper and lower limits in detection rates for many breeding species, and thus can be used to develop thresholds for long-term monitoring goals. This is examined further in Part C, Conclusions and Recommendations.

Table VII-1. Comparisons of the number of individuals detected for the 20 most commonly detected riparian breeding species by paired unbounded point counts and area surveys for 1997 and 1998. For 1997, only data from trips one and three were used, while for 1998 data from all three trips were used.

Species	**1997 Point Counts**	**1997 Area Surveys**	**1998 Point Counts**	**1998 Area Surveys**
Lucy's Warbler	611	522	651	674
House Finch	225	260	296	413
Bewick's Wren	157	121	213	204
Bell's Vireo	118	115	210	209
Black-chinned Hummingbird	90	73	144	92
Ash-throated Flycatcher	79	58	130	109
Yellow-breasted Chat	86	44	158	99
Blue-gray Gnatcatcher	45	120	82	127
Mourning Dove	75	67	27	50
Blue Grosbeak	66	34	44	32
Common Yellowthroat	31	23	71	59
Yellow Warbler	22	25	98	146
Bullock's Oriole	26	13	26	19
Lesser Goldfinch	23	32	52	43
Song Sparrow	31	53	54	70
Brown-headed Cowbird	25	33	34	39
Lazuli Bunting	3	0	19	21
Costa's Hummingbird	9	16	1	1
Summer Tanager	6	7	8	8
Brown-crested Flycatcher	8	7	4	3

Table VII-2. Total number of birds detected by species using unbounded point count data for the years 1996-2000.

Species	1996	1997	1998	1999	2000
Lucy's Warbler	729	1121	651	706	680
Bell's Vireo	317	286	210	126	125
House Finch	307	308	296	357	212
Bewick's Wren	285	301	213	304	221
Yellow-breasted Chat	214	209	158	77	55
Song Sparrow	195	179	54	38	38
Blue-gray Gnatcatcher	183	161	82	63	59
Ash-throated Flycatcher	154	147	130	96	112
Common Yellowthroat	92	101	77	55	50
Yellow Warbler	80	93	98	103	102
Brown-headed Cowbird	65	56	34	44	6
Lesser Goldfinch	44	61	52	34	34
Black-chinned Hummingbird	36	172	119	151	127
Mourning Dove	33	100	27	101	6
Blue Grosbeak	17	76	44	54	27
Bullock's Oriole	17	49	26	25	2
Brown-crested Flycatcher	15	10	4	6	0
Bushtit	14	9	18	38	24
Costa's Hummingbird	10	17	1	27	1
Great-tailed Grackle	8	9	3	2	4
Summer Tanager	4	16	8	15	15
Lazuli Bunting	3	18	19	1	0
Northern Mockingbird	3	5	0	4	4
Black Phoebe	0	11	3	6	4
Black-headed Grosbeak	0	4	6	0	0
Hooded Oriole	0	5	14	17	17
Indigo Bunting	0	4	0	0	0
Phainopepla	0	9	5	33	12
Red-winged Blackbird	0	22	0	0	0
Willow Flycatcher[1]	0	10	0	4	4
Totals	**2825**	**3569**	**2352**	**2487**	**1869**

[1]Includes migrants

Table VII-3. Summary ANOVA's by species and for total species and individuals per patch for the years 1996-1999. The data are from 46 patches from Glen Canyon Dam to Diamond Creek for the four years. A repeated measures ANOVA was computed for each species. Tukey's method was used to contrast years. Years that are connected or overlap by the underlines are not significantly different. The downward pointing arrow indicates which mean or group of means is significantly smaller.

Dependent Variable	**F-value**	**P**	**Contrast of Means**
Total individuals per patch	1.23	0.301	96 97 98 99
Species per patch	3.75	0.012	97 98 99 99 96↓
Ash-throated Flycatcher	2.14	0.095	96 97 98 99
Black-chinned Hummingbird	10.13	<0.001	97 99 98 96↓
Bell's Vireo[1]	1.06	0.371	96 97 98 99
Bewick's Wren	0.94	0.426	96 97 98 99
Blue Grosbeak	5.79	0.001	97 98 99 99 96↓
Blue-gray Gnatcatcher	1.99	0.116	96 97 98 99
Brown-headed Cowbird	0.13	0.936	96 97 98 99
Common Yellowthroat	0.85	0.473	96 97 98 99
House Finch	0.93	0.429	96 97 98 99
Lesser Goldfinch[1]	0.75	0.523	96 97 98 99
Lucy's Warbler	0.88	0.457	96 97 98 99
Mourning Dove	2.29	0.079	96 97 98 99
Song Sparrow[1]	0.36	0.787	96 97 98 99
Yellow Warbler	3.53	0.016	99 98 97 98 97 96↓
Yellow-breasted Chat	2.29	0.078	98 97 96 97 96 99↓

[1]Below Lee's Ferry only

Table VII-4. Summary ANOVA's by species and for total species and individuals per patch for three trips (one each in April, May and June) conducted per year for the years 1996-1999. The data are from 46 patches from Glen Canyon Dam to Diamond Creek for the four years. A repeated measures ANOVA was computed for each species. Tukey's method was used to contrast months. Months that are connected or overlap by the underlines are not significantly different. The downward pointing arrow indicates which mean or group of means is significantly smaller.

Dependent Variable	**F-value**	**P**	**Contrast of Means**
Total Individuals per patch	2.29	0.105	April May June
Species per patch	10.59	<0.001	April↓ May June
Ash-throated Flycatcher	7.57	0.001	April↓ May June
Black-chinned Hummingbird	5.94	0.004	May April↓ April June
Bell's Vireo[1]	2.32	0.101	April May June
Bewick's Wren	0.35	0.713	April May June
Blue Grosbeak	6.62	0.002	April May↓ June
Blue-gray Gnatcatcher	5.22	0.007	April June↓ June May
Brown-headed Cowbird	2.10	0.124	April May June
Common Yellowthroat	9.32	<0.001	April↓ May June
House Finch	0.06	0.934	April May June
Lesser Goldfinch[1]	4.29	0.016	April May June↓
Lucy's Warbler	1.10	0.336	April May June
Mourning Dove	0.95	0.392	April May June
Song Sparrow[1]	0.41	0.669	April May June
Yellow Warbler	17.71	<0.001	April↓ May June
Yellow-breasted Chat	9.59	<0.001	April↓ May June

[1]Below Lee's Ferry only

Table VII-5. Summary ANOVA's by species and for total species and individuals per patch for the years 1996-2000. The data are from 29 patches between Lee's Ferry and Diamond Creek for the five years. A repeated measures ANOVA was computed for each species. Tukey's method was used to contrast years. Years that are connected or overlap by the underlines are not significantly different. The downward pointing arrow indicates which mean or group of means is significantly smaller.

Dependent Variable	**F-value**	**P**	**Contrast of Means**
Total Individuals per patch	0.69	0.603	96 97 98 99 00
Species per patch	2.47	0.047	96 97 98 99 00
Ash-throated Flycatcher	12.60	<0.001	98 97 96 97 96 00 99↓
Black-chinned Hummingbird	6.22	<0.001	97 99 98 99 98 00↓ 00 96↓
Bell's Vireo	0.97	0.428	96 97 98 99 00
Bewick's Wren	0.56	0.695	96 97 98 99 00
Blue Grosbeak	0.94	0.446	96 97 98 99 00
Blue-gray Gnatcatcher	1.84	0.124	96 97 98 99 00
Brown-headed Cowbird	0.43	0.791	96 97 98 99 00
Common Yellowthroat	0.74	0.566	96 97 98 99 00
House Finch	2.97	0.022	99 98 97 00 97 00 96↓
Lesser Goldfinch	1.63	0.169	96 97 98 99 00
Lucy's Warbler	0.46	0.768	96 97 98 99 00
Mourning Dove	2.34	0.057	99 97 98 96 97 98 96 00↓
Song Sparrow	0.68	0.613	96 97 98 99 00
Yellow Warbler	1.34	0.257	96 97 98 99 00
Yellow-breasted Chat	2.83	0.027	99 98 00 97 98 00 97 96↓

Table VII-6. Summary ANOVA's by species and for total species and individuals per patch for three trips (one each in April, May and June) conducted per year for the years 1996-2000. The data are from 29 patches between Lee's Ferry and Diamond Creek for the five years. A repeated measures ANOVA was computed for each species. Tukey's method was used to contrast months. Months that are connected or overlap by the underlines are not significantly different. The downward pointing arrow indicates which mean or group of means is significantly smaller.

Dependent Variable	**F-value**	**p**	**Contrast of Means**
Total Individuals per patch	2.29	0.105	April May June
Species per patch	10.59	<0.001	April↓ May June
Ash-throated Flycatcher	12.60	<0.001	April↓ May June
Black-chinned Hummingbird	7.57	0.001	April May June↓
Bell's Vireo	1.02	0.366	April May June
Bewick's Wren	0.11	0.888	April May June
Blue Grosbeak	17.15	<0.001	April May↓ June
Blue-gray Gnatcatcher	2.74	0.068	April May June
Brown-headed Cowbird	1.17	0.316	April May June
Common Yellowthroat	10.58	<0.001	April↓ May June
House Finch	0.74	0.486	April May June
Lesser Goldfinch	4.27	0.018	April May May June↓
Lucy's Warbler	1.26	0.288	April May June
Mourning Dove	3.86	0.025	May June June April↓
Song Sparrow	0.24	0.787	April May June
Yellow Warbler	20.60	<0.001	April↓ May June↓
Yellow-breasted Chat	12.22	<0.001	April↓ May June

Table VII-7. Rank comparisons and abundance estimates (normalized to 100 based on the most common species, Lucy's warbler) for the riparian breeding species detected along the Colorado River during two study periods, 1984-1985, and 1997-1998. The data is based on area surveys.

Species	1984-1985 Rank	Species	1997-1998 Rank
Lucy's Warbler	100.0	Lucy's Warbler	100.0
Black-chinned Hummingbird	78.6	House Finch	27.5
Blue-gray Gnatcatcher	66.1	Bewick's Wren	26.9
Bell's Vireo	40.7	Bell's Vireo	25.5
Yellow Warbler	34.0	Yellow-breasted Chat	18.6
House Finch	31.4	Song Sparrow	16.0
Mourning Dove	30.5	Black-chinned Hummingbird	15.3
Yellow-breasted Chat	28.2	Blue-gray Gnatcatcher	14.4
Common Yellowthroat	29.2	Ash-throated Flycatcher	13.1
Brown-headed Cowbird	29.0	Common Yellowthroat	9.0
Bewick's Wren	26.3	Mourning Dove	8.9
Lesser Goldfinch	17.0	Yellow Warbler	8.3
Ash-throated Flycatcher	15.5	Blue Grosbeak	6.8
Costa's Hummingbird	8.0	Lesser Goldfinch	5.4
Great-tailed Grackle	6.4	Brown-headed Cowbird	5.0
Summer Tanager	6.3	Red-winged Blackbird	2.0
Hooded Oriole	5.6	Lazuli Bunting	1.6
Blue Grosbeak	4.8	Costa's Hummingbird	1.5
Lazuli Bunting	4.3	Summer Tanager	1.4
Willow Flycatcher	3.0	Brown-crested Flycatcher	0.9
Northern Mockingbird	1.7	Bushtit	0.8
Indigo Bunting	1.1	Great-tailed Grackle	0.7
Crissal Thrasher	0.8	Hooded Oriole	0.5
Bullock's Oriole	0.7	Northern Mockingbird	0.4
Black-headed Grosbeak	0.6	Black-headed Grosbeak	0.3
Phainopepla	0.5	Indigo Bunting	0.3

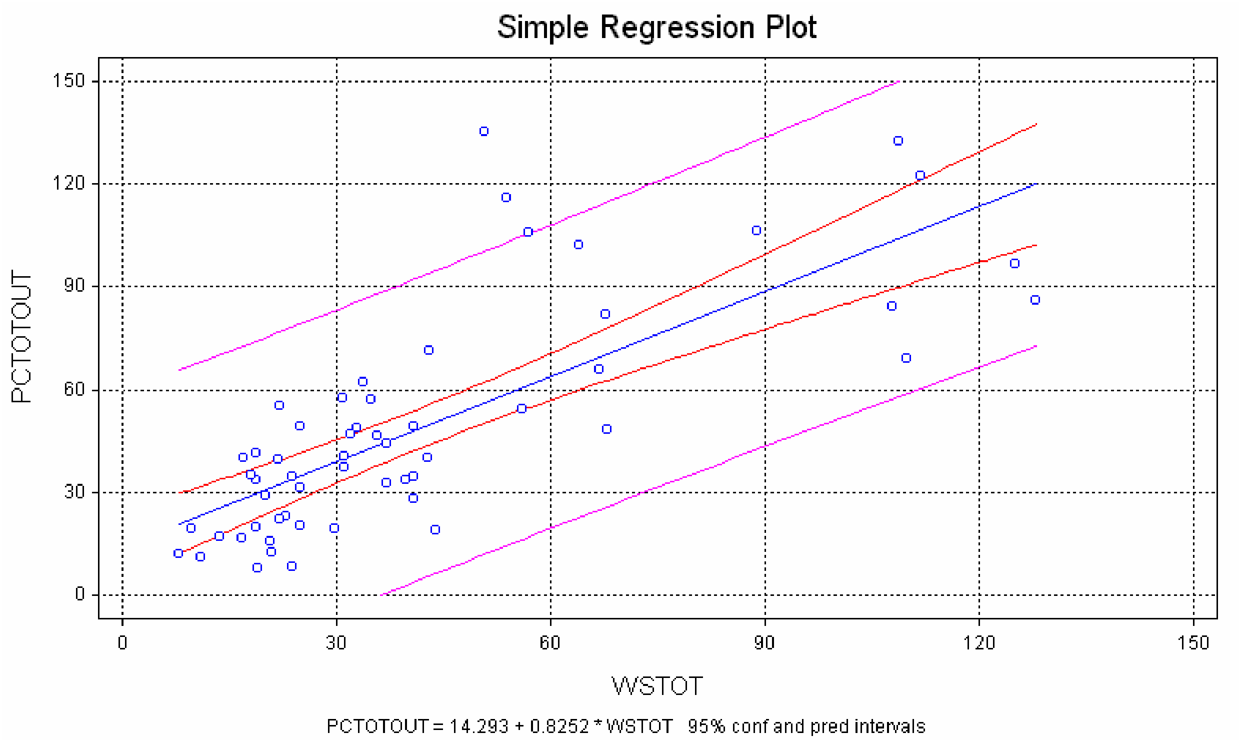


Figure VII-1. Paired 1997 area surveys and point counts (summed within patches) are contrasted for patches of riparian vegetation in the study area. The innermost line is the fitted least-squares line, the inner double lines represented the 95% confidence intervals, and the outer double lines represent the predicted values. PCTOTOUT is the total number of birds of the 15 most common riparian species detected in each patch on a survey by unbounded point counts, while WSTOT is the total number of birds detected by area surveys in a patch.

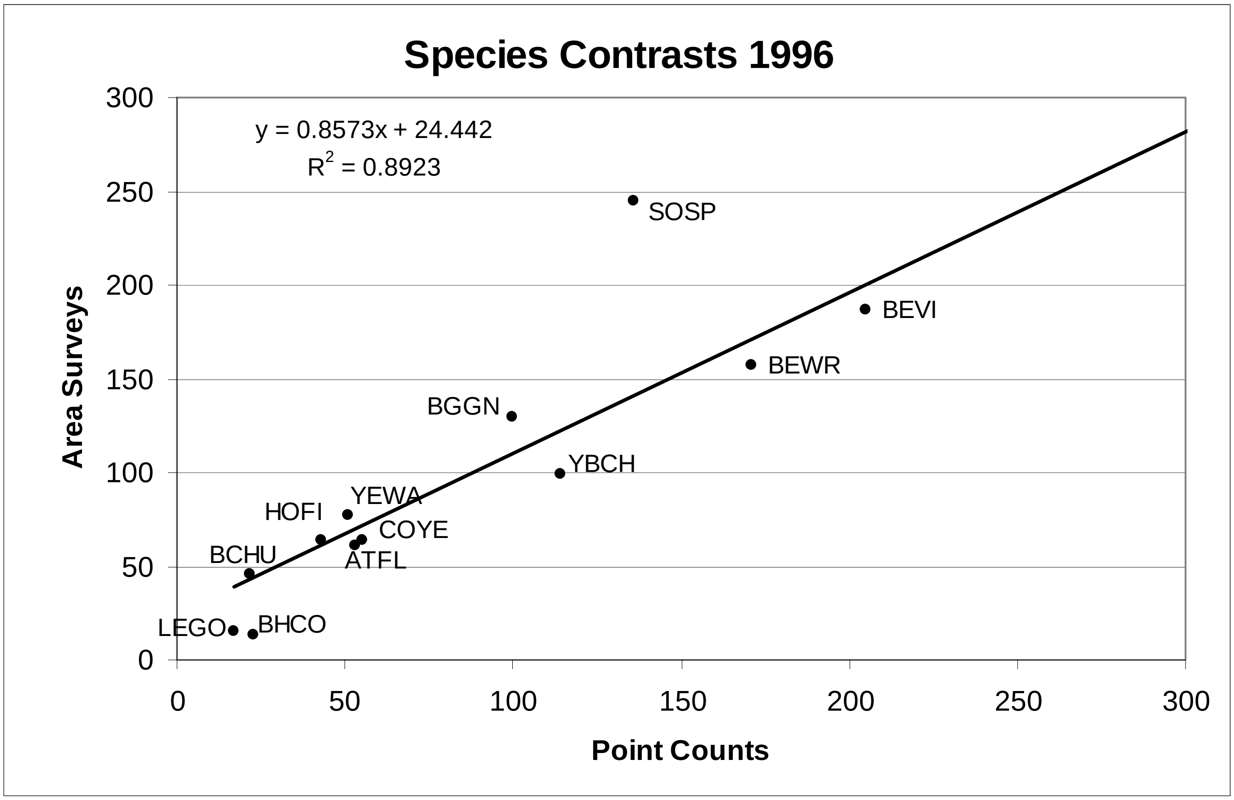


Figure VII-2. Paired area surveys and point counts (summed by patch) for the year 1996 are contrasted for 13 riparian breeding species along the Colorado River from Glen Canyon Dam to upper Lake Mead. The data point for Lucy's warbler is well to the right of the graph.

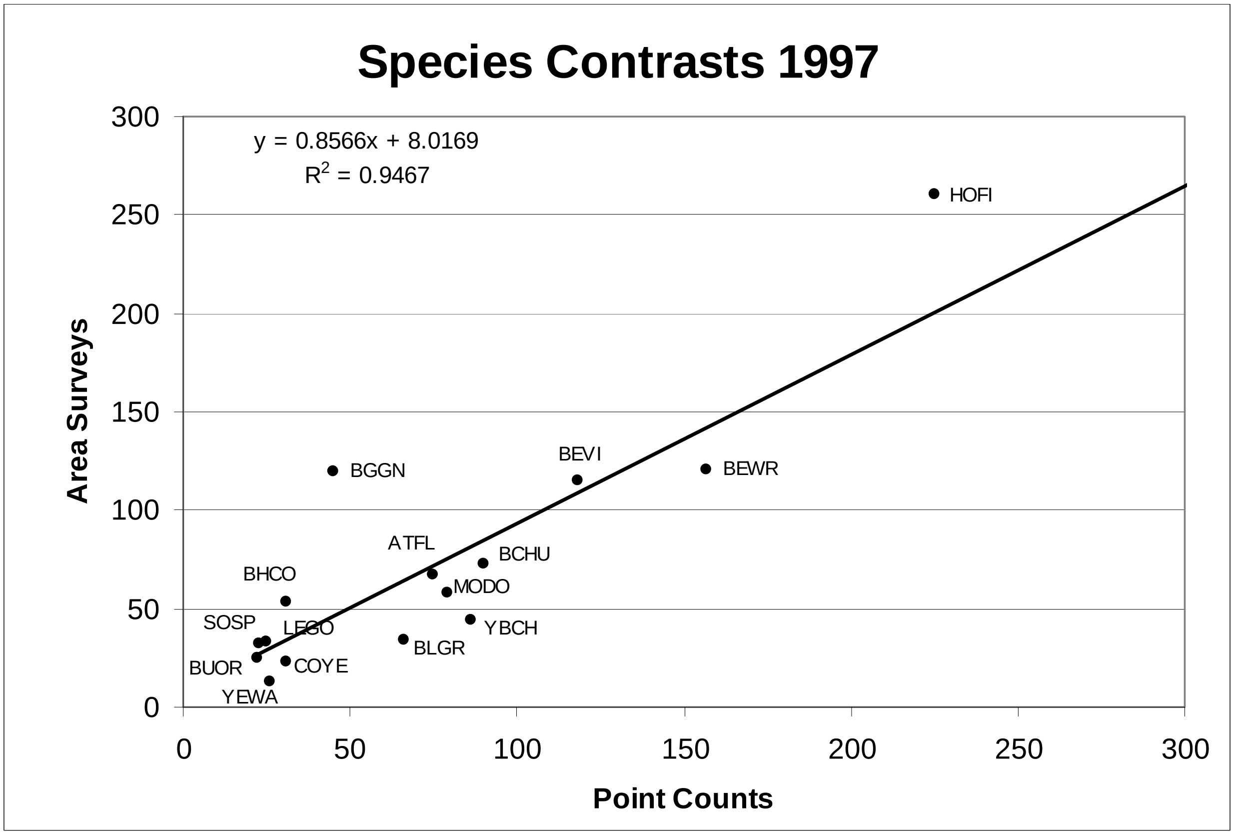


Figure VII-3. Paired area surveys and point counts (summed by patch) for the year 1997 are contrasted for 15 riparian breeding species along the Colorado River from Glen Canyon Dam to upper Lake Mead. The data point for Lucy's warbler is well to the right of the graph.

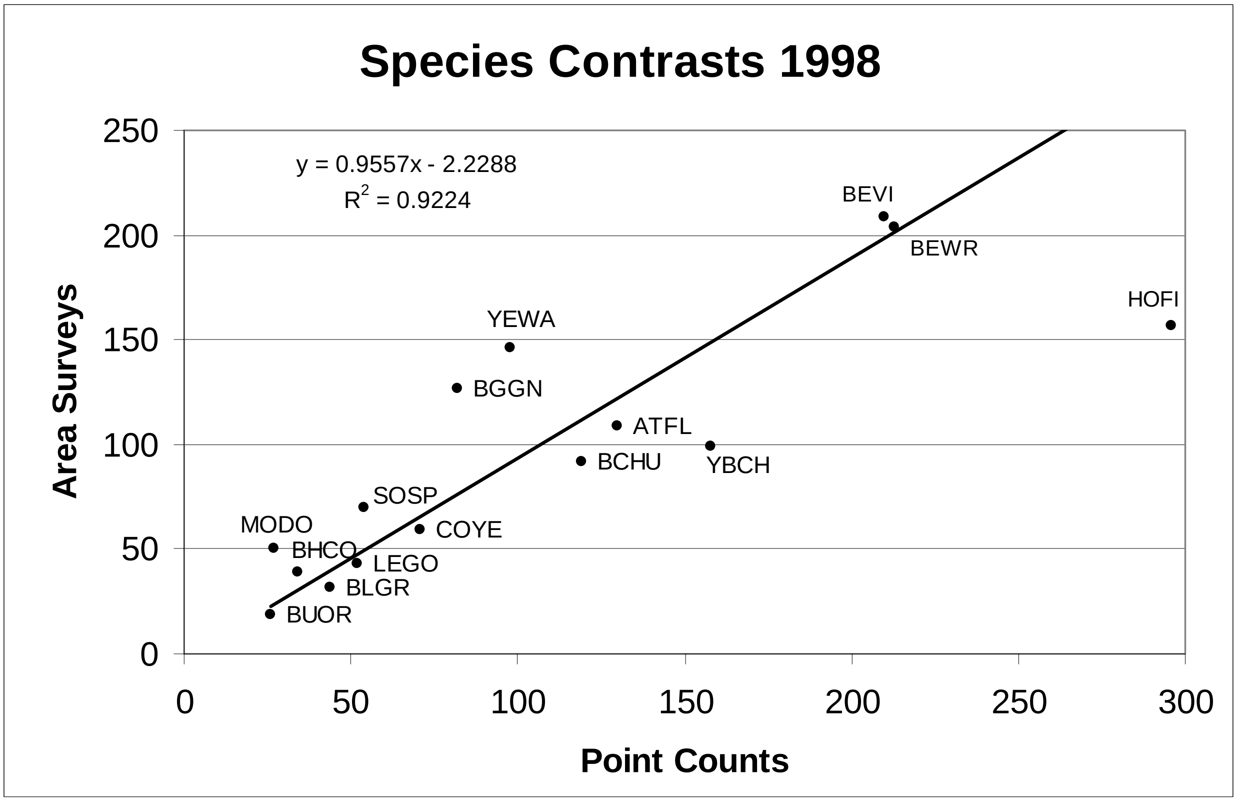


Figure VII-4. Paired area surveys and point counts (summed by patch) for the year 1998 are contrasted for 16 riparian breeding species along the Colorado River from Glen Canyon Dam to upper Lake Mead. The data point for Lucy's warbler is well to the right of the graph.

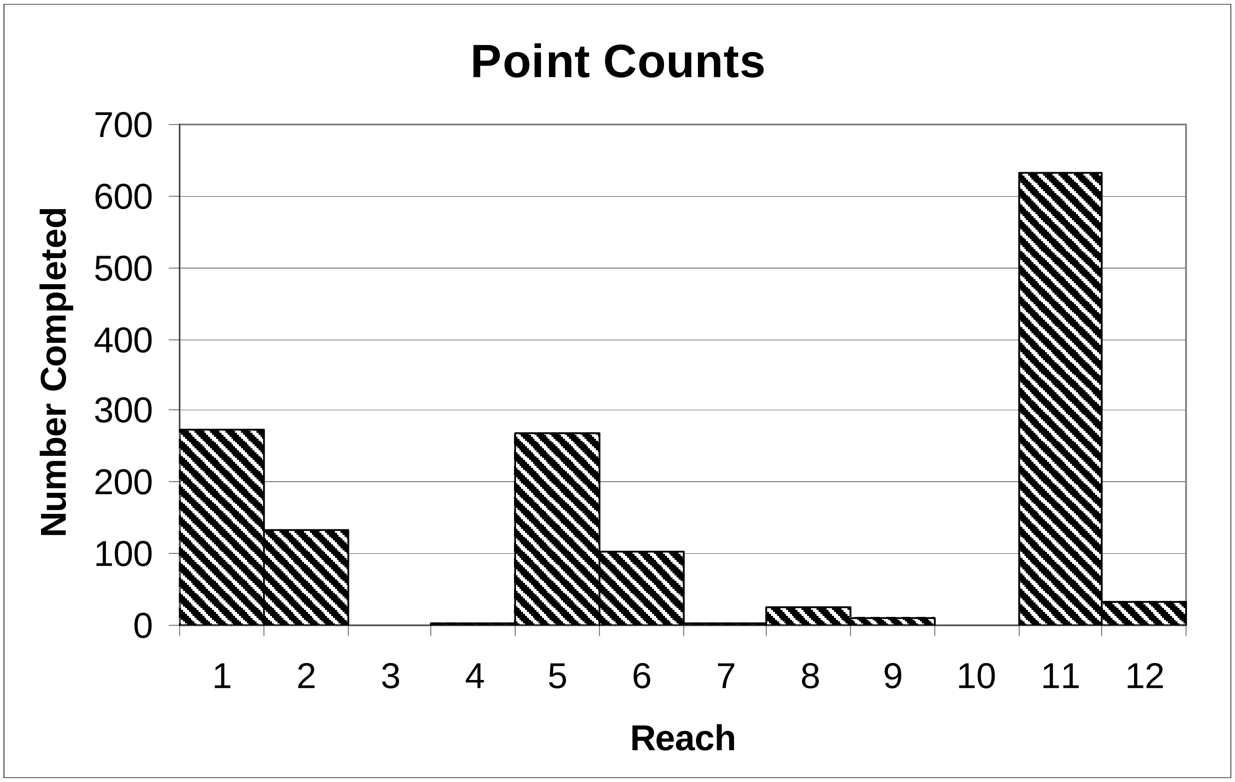


Figure VII-5. The distribution of point counts among reaches within the study area from Glen Canyon Dam to upper Lake Mead. The total number of point counts completed between 1996-2000 in each reach is depicted.

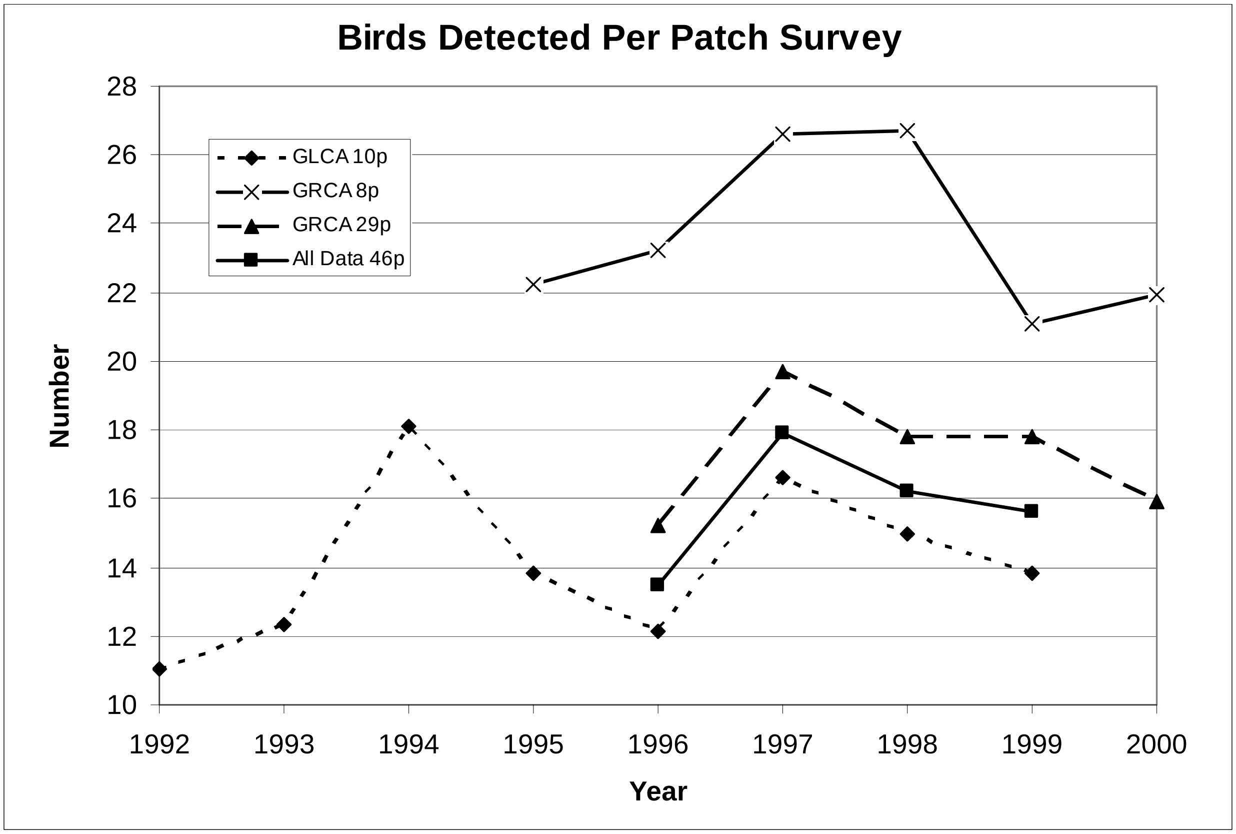


Figure VII-6. Mean number of birds detected per patch count between 1992 and 2000 for four data sets, Glen Canyon reach 1992-1999 (GLCA, 10 patches), Glen Canyon Dam to Lake Mead 1996-1999 (all data, 46 patches), Lees Ferry to Diamond Creek 1995-2000 (GRCA, 8 patches), and Lees Ferry to Diamond Creek 1996-2000 (GRCA 29 patches).

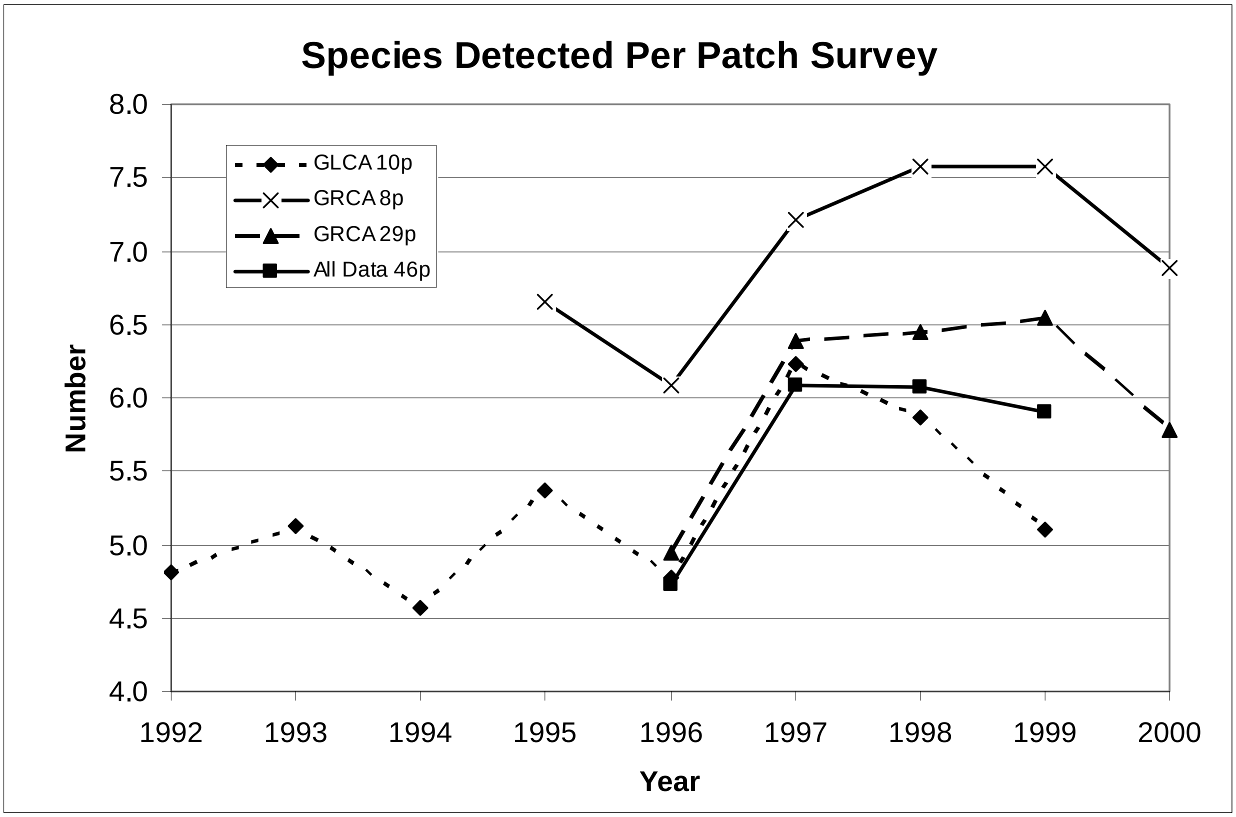


Figure VII-7. Mean number of species detected per patch between 1992 and 2000 four data sets, Glen Canyon reach 1992-1999 (GLCA, 10 patches), Glen Canyon Dam to Lake Mead 1996-1999 (all data, 46 patches), Lees Ferry to Diamond Creek 1995-2000 (GRCA, 8 patches), and Lees Ferry to Diamond Creek 1996-2000 (GRCA 29 patches).

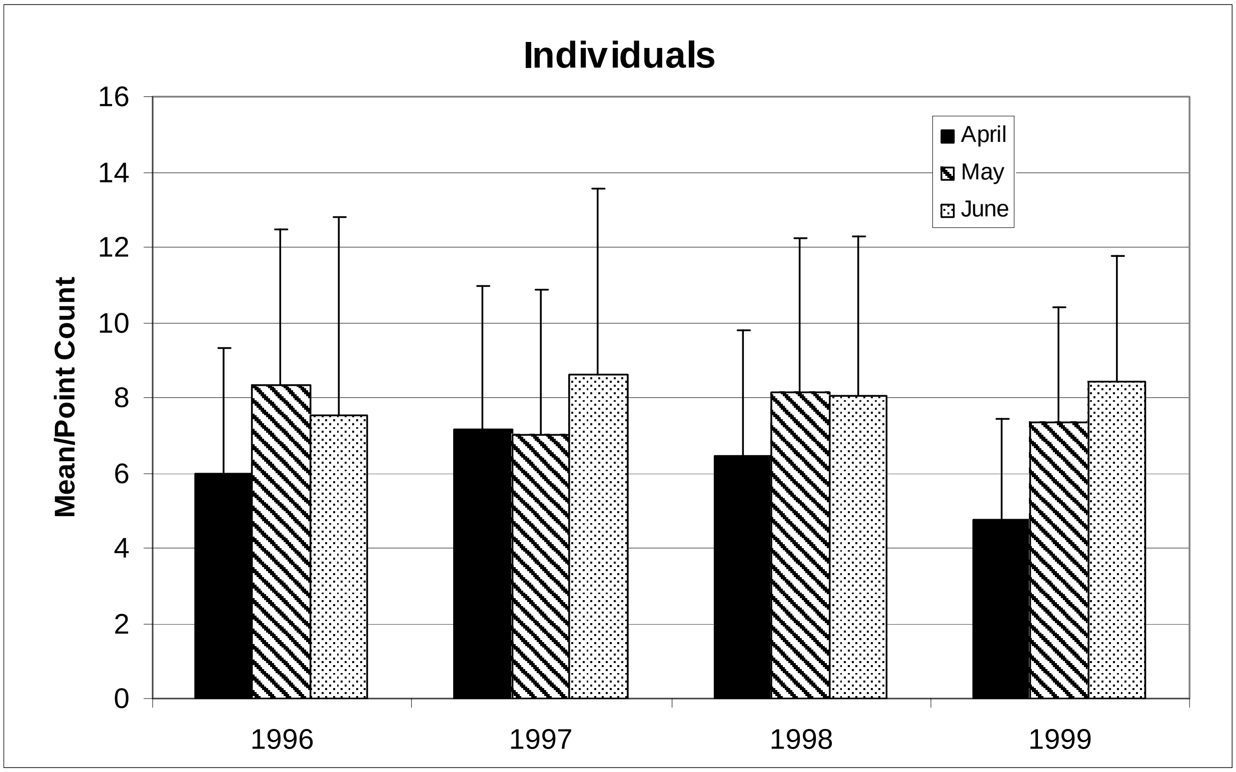


Figure VII-8. Mean number of individuals per point count detected on each of three months for the years 1996 to 1999 between Glen Canyon Dam and Lake Mead.

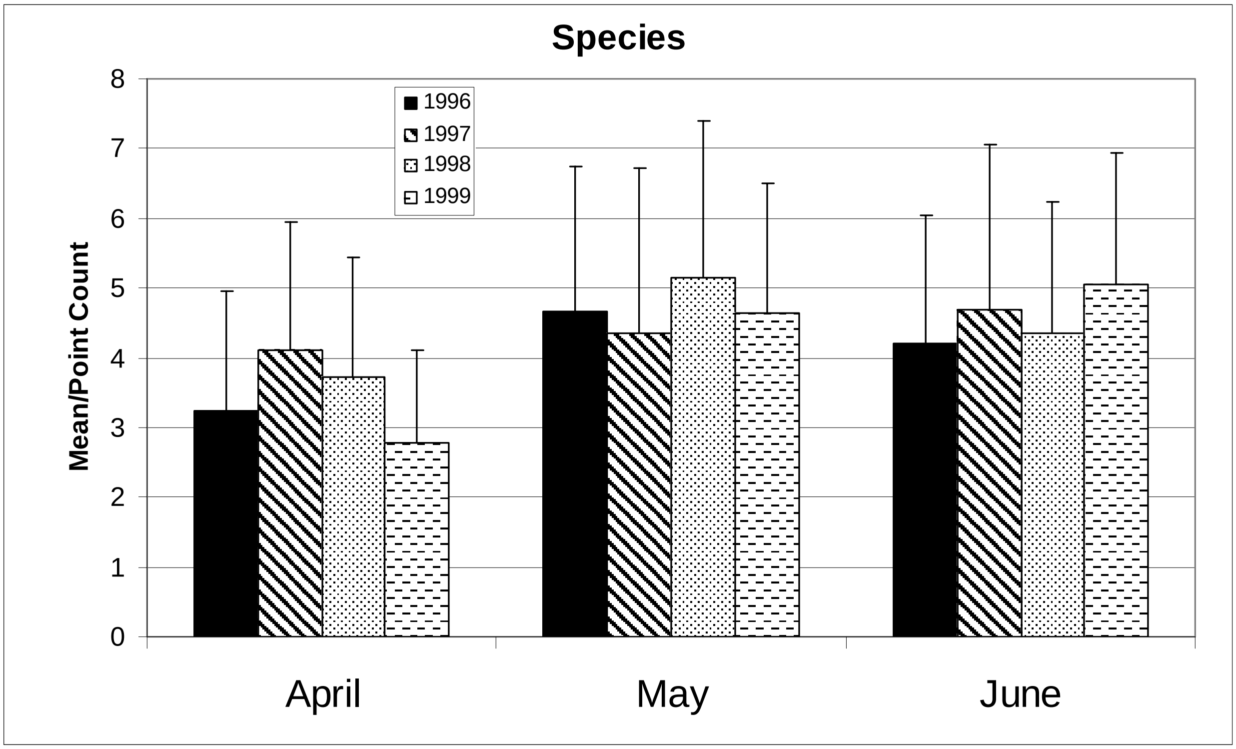


Figure VII-9. Mean number of species per point count detected on each of three months for the years 1996 to 1999 between Glen Canyon Dam and Lake Mead.

CHAPTER VIII. HABITAT ANALYSES AND RELATIONSHIPS WITH AVIFAUNA

VIII-A. Introduction

Because bird communities along the Colorado River are closely tied with riparian vegetation structure and extent (cf. Sogge et al. 1998), sampling of riparian vegetation in the breeding bird and winter bird patches was conducted. This chapter examines the broad relationships between winter and breeding bird communities and plant species composition and canopy volume data using a variety of statistical methods. A test of the statistical power of the habitat monitoring data can be found in Chapter IX.

VIII-B. Methods

The basic method used to sample vegetation structure and volume was the TVV method of Mills et al. (1991). A pole is planted on the ground and all contacts of live vegetation within 10 cm of the pole are recorded in 10 cm increments from ground level to seven meters. This provides a number of hits per meter up to 10 (one hit per decimeter). For the current program, one change was made to this method. The original method did not record the species that were contacting the pole. In this study we identified every species at each sampling point, thus allowing up to 10 hits per meter for each species. Because of this, the TVV reported in some cases will be higher than if only total live hits were recorded without identification to species. Samples were located within each patch in a stratified manner. First, aerial photographs were consulted to determine approximate percentages of the total area in each of three types of vegetation, new high water zone scrub and open areas, old high water zone, and marsh. Sampling intensity within each identified type was proportional to the extent of each type of vegetation. For example, if the approximate extent of the three types in a patch was 20% old high water zone, 70% new high water zone, and 10% marsh, total samples allocated were approximately 20%, 70% and 10% respectively. Within each type, samples were randomly placed using a five number coordinate system, indicating direction and number of paces to move between samples.

TVV data are reported as the mean values for each meter increment up to seven meters by patch, and mean total TVV for each species by patch. Many shrubby and herbaceous species were combined into groups, including perennial grasses, perennial forbs, annuals, marsh, and upland shrubs. The genera allocated to each of these groups are identified in Table VIII-1.

At each point count station vegetation was sampled by the relevé method. Each principal species identified within a 17.8 meter radius (0.1 hectare) circle centered around the point count station was recorded and assigned a dominance scale. The scale used was 1=rare (canopy cover <<1%), 2=occasional (canopy cover <1%), 3=uncommon (canopy cover of 1-10%), 4=common (canopy cover of 11-50%), 5=abundant (canopy cover of 51-95%), and 6=dominant (canopy cover >95%). Cover estimates were made visually by an experienced botanist.

Bird abundance was based on the mean detection rates in patches across all years, for the number of individuals and the number of species. Non-parametric Spearman's correlation coefficients were used to determine the strength of relationships between plant species TVV variables and bird abundance. Stepwise regressions were computed for subsets of plant variables and each bird species. All plant variables were entered simultaneously as independent variables. Two-way indicator species analysis (TWINSPAN) was conducted on four data sets comprising winter terrestrial birds (20 species X 45 patches), breeding birds (16 species X 45 patches), summary TVV plant species (20 species or groups X 45 patches), and relevés (59 species X 132 relevés). Detrended correspondence analysis (DCA) ordinations were computed for winter bird data, breeding bird data and TVV vegetation data. Rare species were down-weighted for DCA and TWINSPAN analyses. Bird species vectors were displayed on DCA ordinations of TVV vegetation. The correlations of bird and plant variables with the first three axes of DCA ordinations were computed using Kendall's τ. Bird and TVV vegetation data were grouped into three categories by patch distribution, Glen Canyon patches, Marble Canyon patches, and Grand Canyon patches. Patches were assigned to a group by river kilometer above or below Lee's Ferry (Glen Canyon –25 to 2.0; Marble Canyon 2.0 to 120.0; Grand Canyon 120.0 to 365.0). Multi-response permutation procedure (MRPP) analysis was used to test whether the three groups displayed significant differences in composition and structure. Bird data was also grouped by patch into two groups, patches with significant old high water zone vegetation, and patches lacking significant old high water zone vegetation. Multi-response permutation procedure (MRPP) analysis was used to test whether the two groups displayed significant differences in composition and structure. To test whether the three data sets winter birds, breeding birds, and TVV vegetation showed similar structure, Mantel's test was used to test the hypothesis that there were no similarities between distance (dissimilarity) matrices for the three data sets. A Monte Carlo randomization approach was used, with Sorenson's coefficient selected as the distance measure. To test whether the TVV sampling at the patch level was adequate to represent patch variability, species-area curves were computed for each patch. The species were the eight one-meter increments of the sampling pole. The method used a subsampling algorithm based on the number of samples taken for each patch. Mean structural dissimilarity was then computed as samples were added to the analysis. Mean dissimilarity was calculated using the quantitative Sorenson's index. The number of samples needed to reduce inter-sample variability to <5% difference was then determined. Regressions and correlations were computed using the SX program (Analytical Software 1998), and multivariate DCA, Mantel's Tests, MRPP, TWINSPAN, and species-area curves were computed using the PC-ORD package (McCune and Mefford 1995, 1997). Summary TVV data and relevé data can be found in Appendix G.

VIII-C. Results

TVV summary data can be found in Appendix G. Excel files summarizing TVV data for each patch, as well as the relevé data, can be found on the CD (Appendix M).

<u>VIII-C.1. Relevé Vegetation Classification</u>

The TWINSPAN analysis of 132 relevés associated with point count stations produced two alliances and 12 floristic associations (Table VIII-2). The two alliances were *Tamarix chinensis* and *Prosopis glandulosa*. Associations for the tamarisk alliances were based primarily on the presence of a variety of shrubs, forbs and annuals (primarily *Bromus* sp.). The two mesquite associations were defined by the presence of wetland species (tamarisk, *Baccharis* and *Tessaria*) or upland shrubs. These two alliances represent only a small fraction of the alliances found in the riparian zone along the Colorado River in the study area. Most point count stations were positioned either within dense tamarisk vegetation, or along the NHWZ-OHWZ boundary. Near-river associations that were not sampled by the relevé analysis included a variety of *Salix exigua*, *Equisetum*, *Baccharis*, *Phragmites* and marsh habitats as well as beaches dominated by *Tessaria* and annuals. A previous analysis of riparian alliances revealed 17 in the study area. These are the *Acacia greggii*, *Baccharis salicifolia*, *B. sarathroides*, *Carex aquatilis*, *Chloracantha spinosa*, *Equisetum xferrisii*, *Isocoma acradenius*, *Juncus articulatus*, *J. balticus, Phragmites australis*, *Prosopis glandulosa*, *Salix exigua*, *S. gooddingii*, *Tamarix chinensis*, and *Typha domingensis* alliances, as well as two additional mixed alliances based on *Salix exigua* (SAEX-*Tamarix chinensis*, SAEX-*Baccharis emoryi*) (Spence and Kearsley, unpublished data).

VIII-C.2. TVV Sample Size Determinations

The results of the sample size analysis indicate that all patches were sampled adequately to reduce inter-sample dissimilarity to <5%. Over-sampling varied from 0% to 191% (see Appendix G). The relationship between samples taken and samples needed to reduce dissimilarity to <5% is graphed in Figure VIII-1. As patch size and number of samples increased, the number of samples needed declined according to the power equation:

$$\text{Samples needed} = 24.3\text{Ln}(\text{samples taken}) - 56.5\ (r^2=0.922).$$

The fitted curve for this equation is displayed in Figure VIII-1. Reasons for the decline in samples needed with increasing patch size is not known, but may be related to the kinds of micro-patches and their spatial replication and distribution within patches.

VIII-C.3. Relationships between Bird Species and Vegetation

Spearman's correlations were computed between TVV data and both breeding and winter species abundance by patch (45 patches). The vegetation variables most strongly correlated with bird species were retained for regression analysis. Results of stepwise multiple regressions between vegetation variables and individual bird species are listed in Tables VIII-3 and VIII-4. Only models that were significant at the α=0.05 level are listed. One important variable not analyzed in this study was patch area. Sogge et al. (1998) found that patch area and volume of woody species were the best predictors of bird species abundance and richness. Area alone accounted for about 65% of the variation in their data. In this study, it was assumed that area remains one of the most important habitat variables. The relationships between species abundance and other variables were examined to elucidate predictive models for individual species. Future analysis of habitat data, area and bird species will be completed when patch areas are available based on other ongoing river projects.

Breeding birds showed numerous strong relationships with TVV vegetation data. Only ash-throated flycatcher could not be correlated with the volume of any particular plant species in the study area. The warbler species common yellowthroat, yellow-breasted chat, and yellow warbler showed relatively weak relationships with habitat variables. For common yellowthroat, abundance was weakly positively related to the volume of *Phragmites australis*. Yellow-breasted chat showed very weak positive correlations with the presence of *Phoradendron californicum* in patches, while yellow warbler showed a weak negative association with the volume of tamarisk. Particularly strong relationships occurred between TVV data and Bell's vireo, brown-headed cowbird, house finch, Lucy's warbler and mourning dove. Both total individuals and species richness per patch were strongly correlated with the same variables, total volume of annuals, *Phragmites australis*, and *Phoradendron californicum*.

Winter terrestrial bird species in general showed much weaker relationships to habitat data compared with breeding birds (Table VIII-4). Two exceptions to this were northern flicker and song sparrow.

Flicker abundance was strongly correlated with total volume of *Celtis reticulata*, *Forestiera neomexicana* and perennial forbs. Song sparrows showed strong positive relationships with total volume of marsh vegetation and perennial forbs. Three species, phainopepla, pinyon jay and ruby-crowned kinglet, were not significantly related to any habitat variables measured. Number of individuals (all species combined) per patch was moderately positively correlated with volume of perennial forbs and negatively correlated with volume of upland shrub species. Species richness of winter bird communities was moderately positively correlated with volume of perennial forbs and *Phoradendron californicum*, and negatively correlated with volume of upland shrubs and *Equisetum xferrisii* in patches.

Plant species mean TVV was regressed against river kilometer to determine if geographic location was related to habitat data. Multiple stepwise regression showed significant relationships between TVV data and river kilometer. Species volume that was negatively correlated with patch location (river kilometer) included *Baccharis emoryi*, marsh species, perennial forbs, *Salix exigua* and *Tamarix chinensis*. The best model included the three shrubs *B. emoryi*, *S. exigua* and *T. chinensis*. Species showing positive correlations with patch location included *Acacia greggii*, *Baccharis sarathroides*, *Equisetum xferrisii*, perennial grasses, *Phoradendron californicum*, *Prosopis glandulosa*, and upland shrub species. The best model combined all of these except the *Equisetum* and perennial grasses. This model was overall the best model resulting from the multiple stepwise regression for all TVV vegetation variables. Many plant species first appear along the river corridor in a sequence related to river kilometer position. For example *Acacia* and *Prosopis* appear at about RK 64, while *Baccharis sarathroides* first appears at RK 205 (Tuner and Karpiscak 1980; Phillips et al. 1987). Hence river location of a patch, as related through the plant species present, appears to be correlated with the distributions and abundance of many bird species. River position is thus a proxy variable that can be used to explain the presence and abundance of these species. Plant species and groups that were not correlated with river kilometer included annual species, *Baccharis salicifolia*, *Celtis reticulata, Fallugia paradoxa*, *Forestiera neomexicana*, *Phragmites australis*, *Salix gooddingii*, and *Tessaria sericea*. Some of these species, in particular the *Fallugia*, *Forestiera* and *Salix*, were very rarely encountered in patches, although they are restricted to patches above the Little Colorado River, Lee's Ferry, or at Cardenas Marsh respectively. The *Baccharis*, *Celtis*, *Phragmites*, and *Tessaria*, on the other hand, are widespread throughout the river corridor.

VIII-C.4. DCA Ordinations of Bird and Vegetation Data

The composition and distribution of the vegetation data for 45 patches was analyzed using DCA. The bird species abundance data was overlaid on the ordinations to show relationships between birds and vegetation in patches. Figure VIII-2 and VIII-3 graph the first and second and first and third axes respectively. Very little of the variance was explained on the third DCA axis compared with the first two. Glen Canyon and Grand Canyon patches are at opposite ends of the first DCA axis, with Marble Canyon patches intermediate. On the second axis Cardenas Marsh (MC14), with its stand of *Salix gooddingii*, is shown as an outlier. Vegetation volume species strongly positively correlated with the first axis included *Tamarix chinensis*, marsh species and perennial forb species. Species strongly negatively correlated with the first axis include *Acacia greggii*, *Baccharis sarathroides*, *Prosopis glandulosa*, and upland shrubs. Bird species that were most common in Glen Canyon patches and strongly correlated with the first axis included brown-headed cowbird, blue grosbeak, Bullock's oriole, house finch and mourning dove. Bird species most strongly correlated with the negative end of the first axis included black-chinned hummigbird, Bell's vireo, lesser goldfinch and Lucy's warbler. Bewick's wren was the only species strongly correlated with the second axis. A variety of vegetation species showed strong relationships with the second axis, including *Salix goodingii* and *Phragmites australis* on the positive end, and *Acacia greggii*, *Equisetum xferrisii*, perennial grass species and upland shrubs on the negative end.

The composition and distribution of 20 winter terrestrial bird species among 45 patches was analyzed using DCA. The bird species abundance data was overlaid on the ordinations to show relationships between birds and vegetation in patches. Figure VIII-4 and VIII-5 graph the first and second and first and third axes respectively. Very little of the variance was explained on the third DCA axis compared with the first two. On the second axis Cardenas Marsh (MC14), with its stand of *Salix gooddingii*, is shown as an outlier. Glen Canyon and Grand Canyon patches are at opposite ends of the first DCA axis, with Marble Canyon patches intermediate. Species that were most common in Glen Canyon patches and strongly correlated with the first axis include bushtit, canyon wren, dark-eyed junco, song sparrow, and white-crowned sparrow. Bird species most strongly correlated with the negative end of the first axis included pinyon jay, rock wren, and Say's phoebe. Bewick's wren, bushtit and Say's phoebe were the most strongly correlated species on the second axis.

VIII-C.5. TWINSPAN Classifications of Bird and Vegetation Data

Bird and vegetation TVV data and patches were classified into groups using TWINSPAN. The 45 patches were classified by each of the three data sets, with the first two branches and four groups listed in Table VIII-8. Although there were numerous differences in patch assignment, many were classified into the same groups by the three different data sets. In particular, many Glen Canyon patches appeared as a distinct group using all data sets. Other principal groups included Marble Canyon and lower Grand Canyon patches. A small set of anomalous patches was classified with all three data sets. These corresponded to Group 3 using vegetation data, Group 1 using winter terrestrial birds, and Group 3 using breeding birds.

The species were also classified into groups by the TWINSPAN analysis. Again, the first two branches and four groups are presented in Table VIII-9. Vegetation groups included *Acacia greggii*, *Baccharis salicifolia*, *B. sarathroides*, *Phoradendron californicum*, *Prosopis glandulosa*, *Salix gooddingii*, and upland shrubs in Group 1, *Equisetum xferrisii*, perenial grass, and *Tessaria sericea* in Group 2, *Tamarix chinensis* and annual species in Group 3, and *Baccharis emoryi*, *Celtis reticulata*, *Fallugia paradoxa*, *Forestiera neomexicana*, marsh species, perennial forbs, *Phragmites australis* and *Salix exigua* in Group 4.

The winter terrestrial bird groups included phainopepla, pinyon jay and western bluebird in Group 1, orange-crowned warbler, rock wren and Say's phoebe in Group 2, Bewick's wren, Lincoln's sparrow, northern flicker, ruby-crowned kinglet, red-naped sapsucker, song sparrow, spotted towhee and white-crowned sparrow in Group 3, and bushtit, canyon wren, dark-eyed junco, house finch, marsh wren and yellow-rumped warbler in Group 4.

The breeding species groups included Bell's vireo, lesser goldfinch, and song sparrow in Group 1, black-chinned hummingbird, blue-gray gnatcatcher, common yellowthroat, Lucy's warbler, yellow-breasted chat and yellow warbler in Group 2, ash-throated flycatcher, Bewick's wren and house finch in Group 3, and brown-headed cowbird, blue grosbeak, Bullock's oriole and mourning dove in Group 4.

VIII-C.6. MRPP Tests of Bird and Vegetation Groupings

In order to test various geographic and vegetation groupings of the vegetation and bird data, multiple response permutation procedures (MRPP) were computed for two different groups of patches using three data sets, vegetation, winter terrestrial birds, and breeding birds. The first grouping comprised Glen Canyon, Marble Canyon and Grand Canyon sites. For all three data sets, this grouping showed significant differences (Table VIII-10). The second test compared bird data for two groups of patches, those with significant OHWZ vegetation, and thosed composed primarily of NHWZ vegetation. Again, the groupings showed highly significant differences for both breeding and wintering birds. Hence, strongly significant differences in vegetation structure and composition, and bird distribution and abundance, exist within the study area.

VIII-C.7. Mantel's Test of the Similarity between Bird and Vegetation Data

In order to determine how similar the distance matrices for vegetation, winter terrestrial birds, and breeding birds were from the same sample of 45 riparian vegetation patches, Mantel's test was computed between the three pair-wise comparisons. In all three contrasts, the observed Z value was significantly higher than the expected Z value, indicating significant positive correlations in the distance matrices. The correlation between breeding bird and vegetation data was particularly strong. Hence all three data sets show similar structure in differences in composition and abundance or vegetation volume between patches.

VIII-D. Summary

The MRPP, DCA and TWINSPAN analyses revealed significant structure in the breeding and wintering avifauna along the Colorado River in the study area, with strong differences in composition and abundance associated with patch location along the river. This bird community structure was also significantly correlated with habitat structure. Surprisingly, the distance matrices for all three data sets showed similar (positive) structure (Table VIII-11). Hence winter bird and breeding bird community composition and abundance appear to be responding in similar ways to riparian habitat. Patch vegetation was grouped primarily by river location, which in turn was strongly correlated with most vegetation TVV variables. Three basic groups were revealed, patches in the upper part of the study area with high TVV values for tamarisk, patches in Marble Canyon which intermediate in TVV structure with upstream as well as downstream patches, and patches in the lower canyon characterized by high TVV values of mesquite, catclaw, and upland shrubs.

The total number of birds and species per patch were significantly correlated with several habitat variables. The best predictive model for breeding birds was the same for both abundance and richness, and included the presence of annuals, *Phragmites australis*, and *Phoradendron californicum*. For winter birds, the best predictive model of abundance was a combination of the presence of perennial forbs and upland shrubs. For winter bird species richness, the best model included perennial forbs, *P. californicum*, *Equisetum xferrisii*, and upland shrubs. However, because for some species there were significant differences between years (primarily between 1996 and later years), these relationships should be viewed as approximate and need to be fine-tuned to account for the heterogeneity in some of the data sets (see Chapter VII; Tables VII-3 and VII-5). Differences between months also existed for many species, and an alternative approach to data analysis would have been to select the month with the largest values for each species, then average this across those years for which there were no significant differences.

Sogge et al. (1998) determined that patch area, larger woody species volume (especially of tamarisk), and river location were the best predictors of breeding bird abundance and richness. This may also be the case for winter birds, although tests examining habitat area have not been performed. The results of the current study are very similar to the previous work, despite the data being derived from different patches. For all species as well as total richness and individuals, predictive models can be developed using the following generalized equation:

Bird variable = extent of habitat (area) + plant variables + patch location

Because most TVV variables were strongly correlated with river kilometer location of patches, something found also by Sogge et al. (1998), a geographic (patch location) variable is included as a fixed factor. Future tests using these variables and their interaction terms (2-way, 3-way and 4-way) will be useful in fine-tuning the relationships between bird communities and the riparian habitat in the study area. Also, dividing total area of each patch into its NHWZ and OHWZ components would prove useful, as it is likely that certain bird species have ecological preferences in nesting and foraging in one or the other type.

For many contrasts between particular bird species and habitat, there are no immediate biological explanations for the relationships. This may be because many vegetation TVV variables were strongly inter-correlated, and the stepwise models tended to pick the single best variable or group regardless of that variables potential biological significance to bird ecology. For example, the strong relationship between the presence of annuals, primarily *Bromus* species, and overall species richness and abundance in the breeding bird community is inexplicable on the surface. The bird community is not likely to be responding to the presence of annuals. However, annuals are strongly correlated with the density of tamarisk, which is probably an important factor in habitat selection by some bird species (e.g., Hunter et al. 1987, 1988; Sogge et al. 1998). Results of the DCA ordinations and TWINSPAN suggested some of these relationships (Tables VIII-8 and VIII-9). Tamarisk and annuals were grouped together by the TWINSPAN using vegetation TVV data, and were positively associated with a suite of breeding bird species including ash-throated flycatcher, Bewick's wren and house finch. For breeding bird species richness, the best predictive model included the TVV for annual species, *Phragmites australis*, and *Phoradendron californicum*. This is probably in part due to the appearance of habitat specialists such as common yellowthroat and phainopepla where the two plant species occur.

Although there were potential problems associated with year and month differences in the data for several species, some intriguing relationships were revealed between some bird species and habitat variables that may warrant closer inspection. For example, both Bell's vireo and blue-gray gnatcatcher abundance could be predicted by the TVV values of *Phoradendron californicum* and *Prosopis glandulosa*. For yellow-breasted chat, the presence of the mistletoe was also positively correlated with abundance. Chats, unlike other warblers, are known to include fruit in their diets (Eckerle and Thompson 2001). Several winter bird species, such as rock wren, Say's phoebe, and western bluebird were also closely associated with mistletoe. The presence of northern flickers in winter was most strongly related to the presence of hackberry (*Celtis reticulata*) as well as desert olive (*Forestiera neomexicana*). Another interesting observation is that there were differences in habitat association for some resident species between breeding months and winter months. Several species, including Bewick's wren, house finch, and song sparrows, appear to be associated with different aspects of patch structure or plant species in the two seasons.

Table VIII-1. Shrubby and herbaceous genera assigned to groups in the TVV analysis of riparian vegetation patches along the Colorado River.

Group	**Examples**
ANNUALS	*Bromus, Bouteloua, Conyza, Datura, Dicoria, Salsola, Sonchus*
PFORBS	*Alhagi, Chloracantha, Gnaphalium, Lepidium, Oenothera, Stanleya*
PGRASSES	*Andropogon, Aristida, Cynodon, Elymus, Muhlenbergia, Sporobolus, Stipa*
MARSH	*Carex, Eleocharis, Euthamia, Juncus, Scirpus, Typha*
UPLANDS	*Atriplex, Chrysothamnus, Encelia, Ephedra, Gutierrezia, Isocoma, Larrea, Lycium, Opuntia, Yucca, Zizyphus*

Table VIII-2. Classification of the riparian vegetation in 0.1 hectare plots associated with each point count station along the Colorado River. The classification was produced using TWINSPAN of 59 species and 132 relevés.

Group	**Alliance**	***Floristic Associations***
I	Prosopis glandulosa	Ia: *Acacia greggii-Baccharis sarathroides/Bromus rubens* Ib: *Tessaria sericea-Tamarix chinensis/Bromus rubens*
II	*Tamarix chinensis*	IIa: *Larrea tridentata-Encelia farinosa*
III	*Tamarix chinensis*	IIIa: *Tessaria sericea-Acacia greggii/Bromus rubens* IIIb: *Prosopis glandulosa-Baccharis salicifolia*
IV	*Tamarix chinensis*	*IVa: Bromus rubens* IVb: *Salix gooddingii*
V	*Tamarix chinensis*	Va: *Lepidium fremontii-Bromus tectorum* Vb: *Salix exigua-Tessaria sericea/Bromus rubens*
VI	*Tamarix chinensis*	VIa: *Salix exigua/Chloracantha spinosa-Bromus rubens* VIb: *Gutierrezia microcephala/Bromus rubens*
VII	*Tamarix chinensis*	VIIa: *Chrysothamnus nauseosus-Atriplex canescens*

Table VIII-3. Results of stepwise linear regressions of breeding bird abundance data against TVV vegetation species data based on 45 patches. All habitat variables were entered into the model independently. Only those habitat variables which contributed significantly ($p \leq 0.05$) are shown.

Species	**Regression Model**	**R^2**
Ash-throated Flycatcher	-	-
Black-chinned Hummingbird	Y = BASAL + EQFE + PRGL	0.406
Bell's Vireo	Y = PHCA + PRGL	0.568
Bewick's Wren	Y = PHAU + (–)ACGR	0.231
Blue-gray Gnatcatcher	Y = PHCA + PRGL	0.289
Brown-headed Cowbird	Y = PFORBS + SAGO + (-)UPLANDS	0.646
Blue Grosbeak	Y = MARSH + (-)PRGL	0.328
Bullock's Oriole	Y = ANNUALS + PFORBS	0.299
Common Yellowthroat	Y = PHAU	0.106
House Finch	Y = BAEM + PFORBS + TACH	0.486
Lesser Goldfinch	Y = ACGR + PRGL	0.278
Lucy's Warbler	Y = PRGL + UPLANDS	0.470
Mourning Dove	Y = PFORBS + TACH	0.468
Song Sparrow	Y = ACGR + CERE + PHCA	0.329
Yellow-breasted Chat	Y = PHCA	0.071
Yellow Warbler	Y = (-)TACH	0.116
Number of Individuals	Y = ANNUALS + PHAU + PHCA	0.267
Number of Species	Y = ANNUALS + PHAU + PHCA	0.344

[1]ACGR=*Acacia greggii*; ANNUALS=annual species; BAEM=*Baccharis emoryi*; BASAL=*Baccharis salicifolia*; BASAR=*Baccharis sarathroides*; CERE=*Celtis reticulat*a; EQFE=*Equisetum xferresii*; FAPA=*Fallugia paradoxa*; FONE=*Forestiera neomexicana*; PFORBS=perennial non-marsh forbs; PGRASS=perennial non-marsh grasses; MARSH=wetland species; PHAU=*Phragmites australis*; PHCA=*Phoradendron californicum*; PRGL=*Prosopis glandulosa*; SAEX=*Salix exigua*; SAGO=*Salix gooddingii*; TACH=*Tamarix chinensis*; TESE=*Tessaria sericea*; UPLANDS=upland shrubs.

Table VIII-4. Results of stepwise linear regressions of winter terrestrial bird abundance data against TVV vegetation species data based on 45 patches. All habitat variables were entered into the model independently. Only those habitat variables which contributed significantly ($p \leq 0.05$) are shown.

Species	**Regression Model**	**R^2**
Bewick's Wren	Y = ACGR	0.171
Bushtit	Y = (-)PRGL	0.093
Canyon Wren	Y = (-)ACGR + (-)PRGL	0.275
Dark-eyed Junco	Y = TACH	0.219
House Finch	Y = EQFE	0.089
Lincoln's Sparrow	Y = PFORBS + TACH	0.279
Marsh Wren	Y = PHAU	0.054
Northern Flicker	Y = CERE + FONE + PERFORBS	0.493
Orange-crowned Warbler	Y = ANNUALS + MARSH	0.096
Phainopepla	-	-
Pinyon Jay	-	-
Ruby-crowned Kinglet	-	-
Red-naped Sapsucker	Y = TESE + (-)PRGL	0.116
Rock Wren	Y = PHCA + PRGL	0.244
Say's Phoebe	Y = PHCA + PRGL	0.273
Song Sparrow	Y = MARSH + PFORBS	0.459
Spotted Towhee	Y = TACH	0.129
Western Bluebird	Y = PHCA	0.192
White-crowned Sparrow	Y = TACH	0.161
Yellow-rumped Warbler	Y = BAEM	0.310
Number of Individuals	Y = PFORBS + (-)UPLANDS	0.275
Number of Species	Y = PFORBS + PHCA + (-)UPLANDS + (-)EQFE	0.384

[1]ACGR=*Acacia greggii*; ANNUALS=annual species; BAEM=*Baccharis emoryi*; BASAL=*Baccharis salicifolia*; BASAR=*Baccharis sarathroides*; CERE=*Celtis reticulat*a; EQFE=*Equisetum xferresii*; FAPA=*Fallugia paradoxa*; FONE=*Forestiera neomexicana*; PFORBS=perennial non-marsh forbs; PGRASS=perennial non-marsh grasses; MARSH=wetland species; PHAU=*Phragmites australis*; PHCA=*Phoradendron californicum*; PRGL=*Prosopis glandulosa*; SAEX=*Salix exigua*; SAGO=*Salix gooddingii*; TACH=*Tamarix chinensis*; TESE=*Tessaria sericea*; UPLANDS=upland shrubs

Table VIII-5. Results of stepwise linear regressions of patch location (river kilometer) against TVV vegetation species data based on 45 patches. All habitat variables were entered into the model independently. Only those habitat variables which contributed significantly ($p \leq 0.05$) are shown.

Dependent Variable	**Independent variable[1]**	**R^2**	**P**
RIVERKILOMETER =	-BAEM	0.153	0.0046
RIVERKILOMETER =	-MARSH	0.115	0.0131
RIVERKILOMETER =	-PFORBS	0.203	0.0011
RIVERKILOMETER =	-SAEX	0.103	0.0182
RIVERKILOMETER =	-TACH	0.346	<0.0001
Best Model =	*(-)BAEM + (-)SAEX + (-)TACH*	*0.538*	*<0.0001*
RIVERKILOMETER =	+ACGR	0.341	<0.0001
RIVERKILOMETER =	+BASAR	0.505	<0.0001
RIVERKILOMETER =	+EQFE	0.134	0.0078
RIVERKILOMETER =	+PGRASS	0.072	0.0412
RIVERKILOMETER =	+PHCA	0.209	0.0010
RIVERKILOMETER =	+PRGL	0.552	<0.0001
RIVERKILOMETER =	+UPLANDS	0.529	<0.0001
Best Model =	*ACGR + BASAR + PHCA + PRGL + UPLANDS*	*0.844*	*<0.0001*
Best Combined Model =	***ACGR + BASAR + PHCA + PRGL + UPLANDS***	***0.844***	***<0.0001***

[1]ACGR=*Acacia greggii*; ANNUALS=annual species; BAEM=*Baccharis emoryi*; BASAL=*Baccharis salicifolia*; BASAR=*Baccharis sarathroides*; CERE=*Celtis reticulata*; EQFE=*Equisetum xferresii*; FAPA=*Fallugia paradoxa*; FONE=*Forestiera neomexicana*; PFORBS=perennial non-marsh forbs; PGRASS=perennial non-marsh grasses; MARSH=wetland species; PHAU=*Phragmites australis*; PHCA=*Phoradendron californicum*; PRGL=*Prosopis glandulosa*; SAEX=*Salix exigua*; SAGO=*Salix gooddingii*; TACH=*Tamarix chinensis*; TESE=*Tessaria sericea*; UPLANDS=upland shrubs.

Table VIII-6. The Kendall τ correlations between vegetation species TVV data and breeding bird species abundance on the first three axes of a detrended correspondence analysis (DCA).

	DCA AXIS I	**DCA AXIS II**	**DCA AXIS III**
Species/Group	**Kendall τ**	**Kendall τ**	**Kendall τ**
TACH	0.659	0.325	-0.124
SAEX	0.294	0.083	0.202
PRGL	-0.669	-0.228	0.016
ACGR	-0.462	-0.517	0.025
BAEM	0.175	0.060	0.171
BASAL	-0.213	-0.343	-0.038
BASAR	-0.623	-0.407	0.024
TESE	-0.243	-0.206	0.419
CERE	0.145	0.081	0.042
FAPA	0.211	0.153	0.211
SAGO	-0.019	0.211	0.115
FONE	0.201	0.163	-0.211
MARSH	0.381	0.144	-0.187
EQFE	-0.159	-0.410	0.208
PHAU	0.089	0.222	0.045
PHCA	-0.289	-0.337	0.069
ANNUALS	0.200	0.164	-0.379
PGRASS	-0.132	-0.459	0.079
PFORBS	0.430	0.135	0.072
UPLANDS	-0.550	-0.382	0.095
ATFL	0.134	0.101	-0.221
BCHU	-0.342	-0.192	0.138
BEVI	-0.587	-0.302	0.017
BEWR	0.180	0.297	-0.010
BGGN	-0.322	-0.053	0.065
BHCO	0.519	0.372	-0.100
BLGR	0.406	0.166	-0.093
BUOR	0.246	0.212	-0.316
COYE	-0.119	-0.096	0.150
HOFI	0.393	0.110	-0.062
LEGO	-0.500	-0.309	0.040
LUWA	-0.343	-0.181	0.108
MODO	0.439	0.237	-0.260
SOSP	-0.415	-0.281	-0.016
YBCH	-0.092	0.013	-0.050
YEWA	-0.147	-0.066	0.157

[1]ACGR=*Acacia greggii*; ANNUALS=annual species; BAEM=*Baccharis emoryi*; BASAL=*Baccharis salicifolia*; BASAR=*Baccharis sarathroides*; CERE=*Celtis reticulata*; EQFE=*Equisetum xferresii*; FAPA=*Fallugia paradoxa*; FONE=*Forestiera neomexicana*; PFORBS=perennial non-marsh forbs; PGRASS=perennial non-marsh grasses; MARSH=wetland species; PHAU=*Phragmites australis*; PHCA=*Phoradendron californicum*; PRGL=*Prosopis glandulosa*; SAEX=*Salix exigua*; SAGO=*Salix gooddingii*; TACH=*Tamarix chinensis*; TESE=*Tessaria sericea*; UPLANDS=upland shrubs.

[2]ATFL=Ash-throated Flycatcher; BCHU=Black-chinned hummingbird; BEVI=Bell's Vireo; BEWR=Bewick's Wren; BGGN=Blue-gray Gnatcatcher; BHCO=Brown-headed Cowbird; BLGR=Blue Grosbeak; BUOR=Bullock's Oriole; COYE=Common Yellowthroat; HOFI=House Finch; LEGO=Lesser Goldfinch; LUWA=Lucy's Warbler; MODO=Mourning Dove; SOSP=Song Sparrow; YBCH=Yellow-breasted Chat; YEWA=Yellow Warbler.

Table VIII-7. The Kendall τ correlations for vegetation species TVV data and winter terrestrial bird species abundance on the first three axes of a detrended correspondence analysis (DCA).

	DCA AXIS I	DCA AXIS II	DCA AXIS III
Vegetation Species/Group	**Kendall τ**	**Kendall τ**	**Kendall τ**
TACH	0.659	0.325	-0.124
SAEX	0.294	0.083	0.202
PRGL	-0.669	-0.228	0.016
ACGR	-0.462	-0.517	0.025
BAEM	0.175	0.060	0.171
BASAL	-0.213	-0.343	-0.038
BASAR	-0.623	-0.407	0.024
TESE	-0.243	-0.206	0.419
CERE	0.145	0.081	0.042
FAPA	0.211	0.153	0.211
SAGO	-0.019	0.211	0.115
FONE	0.201	0.163	-0.211
MARSH	0.381	0.144	-0.187
EQFE	-0.159	-0.410	0.208
PHAU	0.089	0.222	0.045
PHCA	-0.289	-0,337	0.069
ANNUALS	0.200	0.164	-0.379
PGRASS	-0.132	-0.459	0.079
PFORBS	0.430	0.135	0.072
UPLANDS	-0.550	0.160	0.095
Bird Species			
WCSP	0.028	-0.037	0.004
RCKI	-0.039	0.104	-0.059
DEJU	0.253	0.268	-0.128
SOSP	0.171	-0.219	-0.155
BUSH	0.280	0.287	0.100
WEBL	-0.434	-0.195	0.063
BEWR	0.174	0.289	-0.079
PIJA	-0.283	-0.117	-0.146
HOFI	0.132	0.209	-0.077
CANW	0.450	0.261	-0.140
YRWA	0.202	0.269	-0.143
LISP	0.132	0.024	-0.210
ROWR	-0.373	-0.075	0.079
SAPH	-0.370	0.044	0.023
MAWR	-0.053	0.011	0.092
PHAI	-0.307	-0.092	0.035
OCWA	-0.053	0.115	-0.093
RNSA	0.078	-0.012	0.223
SPTO	-0.035	0.035	-0.009
NOFL	0.100	0.046	-0.117

[1]ACGR=*Acacia greggii*; ANNUALS=annual species; BAEM=*Baccharis emoryi*; BASAL=*Baccharis salicifolia*; BASAR=*Baccharis sarathroides*; CERE=*Celtis reticulata*; EQFE=*Equisetum xferresii*; FAPA=*Fallugia paradoxa*; FONE=*Forestiera neomexicana*; PFORBS=perennial non-marsh forbs; PGRASS=perennial non-marsh grasses; MARSH=wetland species; PHAU=*Phragmites australis*; PHCA=*Phoradendron californicum*; PRGL=*Prosopis glandulosa*; SAEX=*Salix exigua*; SAGO=*Salix gooddingii*; TACH=*Tamarix chinensis*; TESE=*Tessaria sericea*; UPLANDS=upland shrubs.

[2]BUSH=Bushtit; CANW=Canyon Wren; DEJU=Dark-eyed Junco; HOFI=House Finch; LISP=Lincoln's Sparrow; MAWR=Marsh Wren; NOFL=Northern Flicker; OCWA=Orange-crowned Warbler; PHAI=Phainopepla; PIJA=Pinyon Jay; RCKI=Ruby-crowned Kinglet; RNSA=Red-naped Sapsucker; ROWR=Rock Wren; SAPH=Say's Phoebe; SOSP=Song Sparrow; SPTO=Spotted Towhee; WCSP=White-crowned Sparrow; WEBL=Western Bluebird; YRWA=Yellow-rumped Warbler.

Table VIII-8. Results of a TWINSPAN classification of 45 patches of riparian vegetation based on one of three data sets, vegetation TVV, winter birds, and breeding birds. The classification down to the first four groups is presented.

Data Set	Group 1	Group 2	Group 3	Group 4
Vegetation TVV	67.1L, 168.8R, 171.0R, 174.2L, 193.8R, 196.0R, 197.6L, 198.0R, 200.4R, 200.5R, 202.5R, 204.1R, 205.0L, 208.7R, 209.0L, 213.6L, 214.0L, 214.2L	43.1L 46.7R, 49.1R, 50.0R, 50.4L, 51.5L, 71.0L, 122.8L, 125.8L, 194.0L 198.2L, 204.5R	-6.5R, 1.0R, 1.6R, 5.2R, 56.0R, 65.3L	-14.2R, -13.6L, -9.4L, -10.0L, -8.4R, -7.0L, -3.2R, -2.5L, 3.7L
Winter Birds	193.8R, 196.0R, 209.0L, 214.2L	168.8R, 171.0R, 194.0L, 198.0R, 198.2L, 200.4R, 200.5R, 202.5R, 204.1R, 204.5R, 205.0L, 214.0L	-9.4L, -6.5R, 1.6R, 3.7L, 5.2R, 43.1L, 46.7R, 49.1R, 50.0R, 50.4L, 51.5L, 56.0R, 65.3L, 67.1L, 71.0L, 125.8L, 174.2L, 197.6L, 208.7R, 213.6L	-14.2R, -13.6L, -10.0L, -8.4R, -7.0L, -2.5L, -3.2R, 1.0R, 122.8L
Breeding Birds	168.8R, 174.2L, 193.8R, 194.0L, 196.0R, 197.6L, 198.0R, 198.2L, 200.5, 202.5R, 204.1R, 204.5R, 205.0L, 208.7R, 209.0L, 213.6L, 214.0L, 214.2L	3.7L, 43.1L, 46.7R, 49.1R, 50.0R, 50.4L, 51.5L, 56.0R, 65.3L, 67.1L, 71.0L, 122.8L, 125.8L, 171.0R, 200.4R	1.0R, 1.6R, 5.2R, 50.0R	-14.2R, -13.6L, -10.0L, -9.4L, -8.4R, -7.0L, -6.5R, -3.2R, -2.5L

Table VIII-9. Results of a TWINSPAN classification of three data sets, vegetation TVV, winter birds, and breeding birds. The classification down to the first four groups is presented.

Data Set	Group 1	Group 2	Group 3	Group 4
Vegetation TVV[1]	ACGR, BASAL, BASAR, PHCA, PRGL, SAGO, UPLANDS	EQFE, PGRASS, TESE	TACH, ANNUALS	BAEM, CERE, FAPA, FONE, MARSH, PFORBS, PHAU, SAEX
Winter Birds[2]	PHAI, PIJA, WEBL	OCWA, ROWR, SAPH	BEWR, LISP, NOFL, RCKI, RNSA, SOSP, SPTO, WCSP	BUSH, CANW, DEJU, HOFI, MAWR, YRWA
Breeding Birds[2]	BEVI, LEGO, SOSP	BCHU, BGGN, COYE LUWA, YBCH, YEWA	ATFL, BEWR, HOFI	BHCO, BLGR, BUOR, MODO

[1]ACGR=*Acacia greggii*; ANNUALS=annual species; BAEM=*Baccharis emoryi*; BASAL=*Baccharis salicifolia*; BASAR=*Baccharis sarathroides*; CERE=*Celtis reticulat*a; EQFE=*Equisetum xferresii*; FAPA=*Fallugia paradoxa*; FONE=*Forestiera neomexicana*; PFORBS=perennial non-marsh forbs; PGRASS=perennial non-marsh grasses; MARSH=wetland species; PHAU=*Phragmites australis*; PHCA=*Phoradendron californicum*; PRGL=*Prosopis glandulosa*; SAEX=*Salix exigua*; SAGO=*Salix gooddingii*; TACH=*Tamarix chinensis*; TESE=*Tessaria sericea*; UPLANDS=upland shrubs.

[2]ATFL=Ash-throated Flycatcher; BCHU=Black-chinned hummingbird; BEVI=Bell's Vireo; BEWR=Bewick's Wren; BGGN=Blue-gray Gnatcatcher; BHCO=Brown-headed Cowbird; BLGR=Blue Grosbeak; BUOR=Bullock's Oriole; BUSH=Bushtit; CANW=Canyon Wren; COYE=Common Yellowthroat; DEJU=Dark-eyed Junco; HOFI=House Finch; LEGO=Lesser Goldfinch; LISP=Lincoln's Sparrow; LUWA=Lucy's Warbler; MAWR=Marsh Wren; MODO=Mourning Dove; NOFL=Northern Flicker; OCWA=Orange-crowned Warbler; PHAI=Phainopepla; PIJA=Pinyon Jay; RCKI=Ruby-crowned Kinglet; RNSA=Red-naped Sapsucker; ROWR=Rock Wren; SAPH=Say's Phoebe; SOSP=Song Sparrow; SPTO=Spotted Towhee; WCSP=White-crowned Sparrow; WEBL=Western Bluebird; YBCH=Yellow-breasted Chat; YEWA=Yellow Warbler; YRWA=Yellow-rumped Warbler.

Table VIII-10. The results of multiple response permutation procedure (MRPP) analyses of different groups of vegetation species, winter birds, and breeding birds among 45 patches of riparian vegetation. The data sets were classified by patch into three geographic groups, Glen Canyon, Marble Canyon, and Grand Canyon, and into patches with both OHWZ and NHWZ vegetation or NHWZ vegetation only. The T value and observed delta and it's significance are shown.

Data Set	Groups	T Value	Observed δ	Expected δ	P
Vegetation	GLCA, GRCA, MACA[1]	-16.819	3.515	4.630	<<0.0001
Winter Birds	GLCA, GRCA, MACA[1]	-9.902	13.731	16.578	<<0.0001
Breeding Birds	GLCA, GRCA, MACA[1]	-16.757	1.848	2.594	<<0.0001
Winter Birds	OHWZ+NHWZ, NHWZ[2]	-11.384	14.266	16.578	<<0.0001
Breeding Birds	OHWZ+NHWZ, NHWZ[2]	-19.359	1.985	2.594	<<0.0001

[1]GLCA=Glen Canyon (RK (–)25 to +2), GRCA=Grand Canyon (RM 120-365), MACA=Marble Canyon (RM 2 to 120)
[2]OHWZ=old high water zone vegetation, NHWZ=new high water zone vegetation

Table VIII-11. The results of Mantel's tests of association of matrices using a Monte Carlo randomization process and Sorenson's coefficient of similarity for three comparisons, winter bird abundance and vegetation TVV data, breeding bird abundance and vegetation TVV data, and winter and breeding bird abundance, among 45 patches of riparian vegetation. The Mantel R, observed Z values, expected Z values, and significance of the test are shown.

Contrast	Mantel R	Observed Z	Expected Z	P
Winter Birds - Vegetation TVV	0.373	694.181	675.995	0.01
Breeding Birds - Vegetation TVV	0.644	486.112	451.107	0.01
Winter Birds - Breeding Birds	0.425	638.812	614.962	0.01

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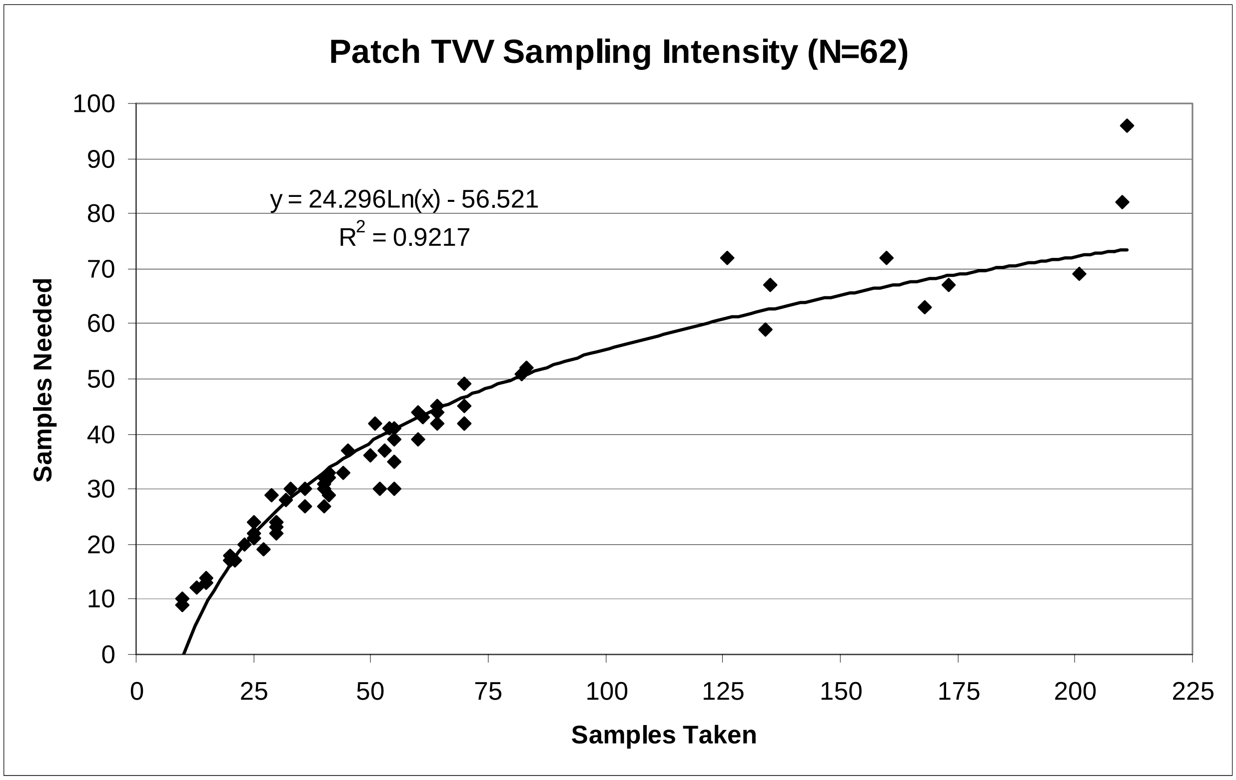


Figure VIII-1. The relationship between sampling intensity (number of TVV samples) and number of samples needed to reduce inter-sample dissimilarity to <5% is shown for 62 patches of riparian vegetation along the Colorado River.

Figure VIII-2. Results of a detrended correspondence analysis (DCA) of vegetation TVV data for 45 patches of vegetation in the study area. The first and second axes are shown. Vectors for breeding bird species are overlaid on the vegetation ordination. The species are BEWR=Bewick's wren, BEVI=Bell's vireo, BCHU=black-chinned hummingbird, BLGR=blue grosbeak, BHCO=brown-headed cowbird, BUOR=Bullock's oriole, HOFI=house finch, LEGO=lesser goldfinch, LUWA=Lucy's warbler, and MODO=mourning dove. The patches are:

GL1 -14.2R
GL2 -13.6R
GL3 –10.0L
GL4 –9.4L
GL5 –8.4R
GL6 –7.0L
GL7 –6.5R
GL8 –3.2R
GL9 –2.5L
GL10 1.0R

MC1 1.6R
MC2 3.7L
MC3 5.2R
MC4 43.1L
MC5 45.5L
MC6 46.7R
MC7 49.1R
MC8 50.0R
MC9 50.4L
MC10 51.5L
MC11 56.0R
MC12 65.3L
MC13 67.1L
MC14 71.0L

GC1 122.8L
GC2 125.5L
GC3 168.8R
GC4 171.0R
GC5 174.2L
GC6 193.8R
GC7 194.0L
GC8 196.0R
GC9 197.6L
GC10 198.0R
GC11 198.2L
GC12 200.4R
GC13 200.5R
GC14 202.5R
GC15 204.1R
GC16 204.5R
GC17 205.0L
GC18 208.7R
GC19 209.0L
GC20 213.6L
GC21 214.0L
GC22 214.2L

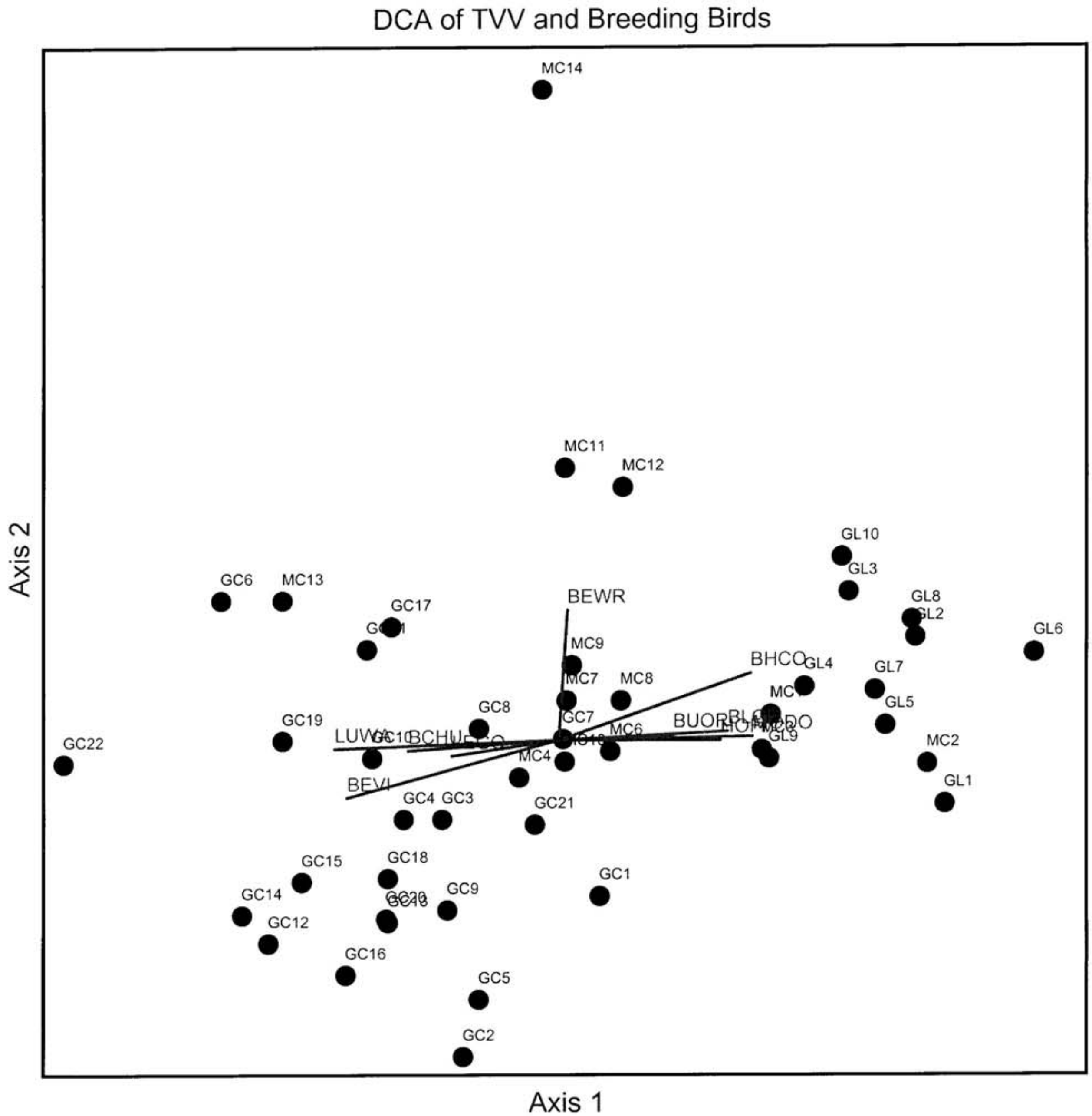

DCA of TVV and Breeding Birds
Axis 2
Axis 1
MC14
MC11
MC12
GL10
GL3
GL8
GL2
GL6
GC6
MC13
GC17
BEWR
MC9
BHCO
GL4
GL7
MC7
MC8
GL5
GC8
GC19
GC7
MC6
GC22
LUWA
BCHU
MC2
MC4
GL9
GL1
BEVI
GC4
GC3
GC21
GC15
GC18
GC1
GC14
GC9
GC12
GC16
GC5
GC2

Figure VIII-3. Results of a detrended correspondence analysis (DCA) of vegetation TVV data for 45 patches of vegetation in the study area. The first and third axes are shown. Vectors for breeding bird species are overlaid on the vegetation ordination. The species are BEWR=Bewick's wren, BCHU=black-chinned hummingbird, BLGR=blue grosbeak, BHCO=brown-headed cowbird, BUOR=Bullock's oriole, HOFI=house finch, LEGO=lesser goldfinch, LUWA=Lucy's warbler, and MODO=mourning dove. The patches are:

GL1 -14.2R
GL2 -13.6R
GL3 –10.0L
GL4 –9.4L
GL5 –8.4R
GL6 –7.0L
GL7 –6.5R
GL8 –3.2R
GL9 –2.5L
GL10 1.0R

MC1 1.6R
MC2 3.7L
MC3 5.2R
MC4 43.1L
MC5 45.5L
MC6 46.7R
MC7 49.1R
MC8 50.0R
MC9 50.4L
MC10 51.5L
MC11 56.0R
MC12 65.3L
MC13 67.1L
MC14 71.0L

GC1 122.8L
GC2 125.5L
GC3 168.8R
GC4 171.0R
GC5 174.2L
GC6 193.8R
GC7 194.0L
GC8 196.0R
GC9 197.6L
GC10 198.0R
GC11 198.2L
GC12 200.4R
GC13 200.5R
GC14 202.5R
GC15 204.1R
GC16 204.5R
GC17 205.0L
GC18 208.7R
GC19 209.0L
GC20 213.6L
GC21 214.0L
GC22 214.2L

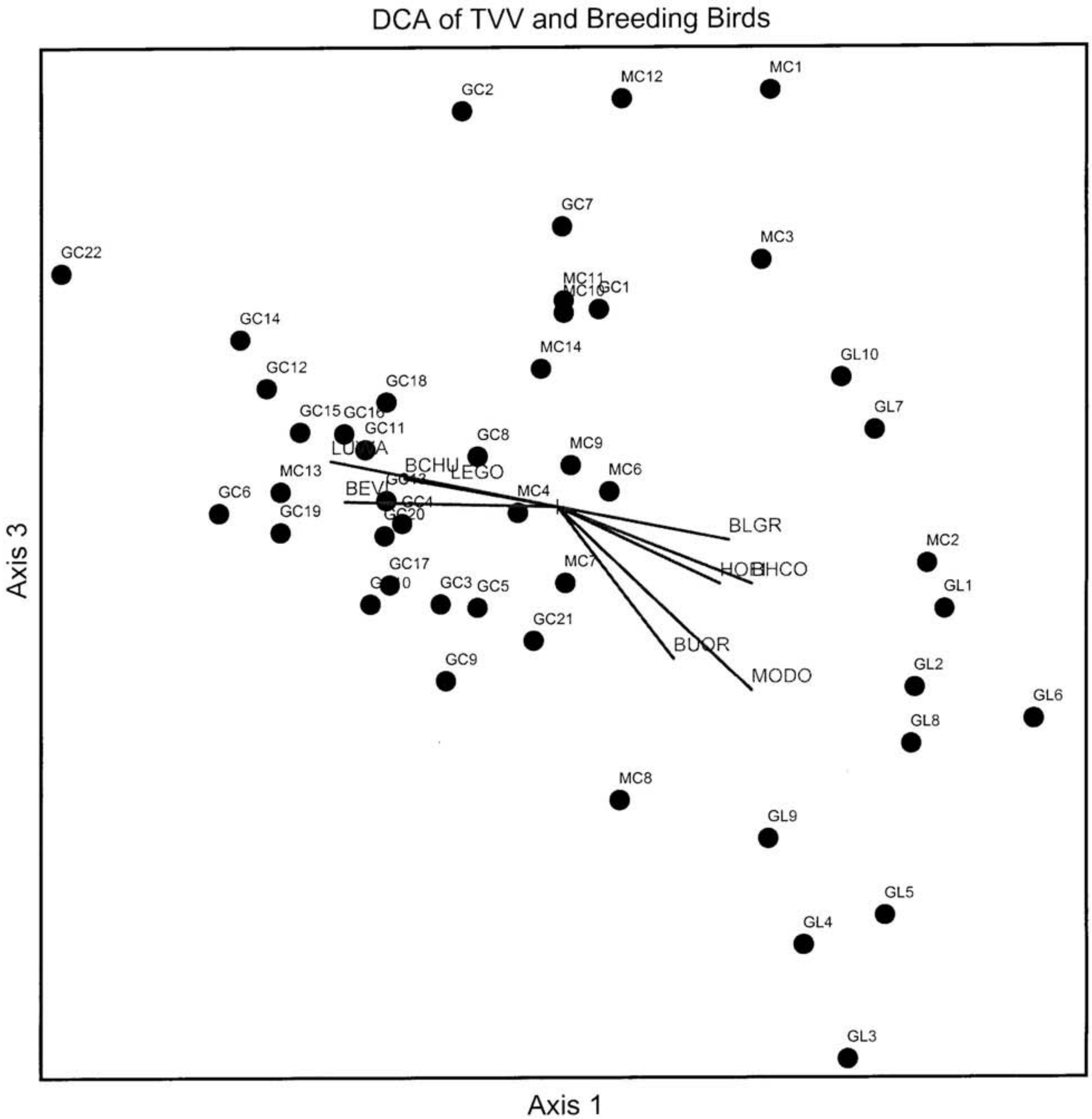

DCA of TVV and Breeding Birds
Axis 3
Axis 1
GC2
MC12
MC1
GC7
MC3
GC22
MC11
MC10
GC1
GC14
MC14
GL10
GC12
GC18
GL7
GC15
GC16
GC11
GC8
MC9
LUWA
BCHU
LEGO
MC6
MC13
BEVI
GC4
MC4
GC6
GC19
GC20
BLGR
MC2
HOBI
BHCO
GC17
MC7
GL1
GC3
GC5
GC21
BUOR
GC9
MODO
GL2
GL6
GL8
MC8
GL9
GL5
GL4
GL3

Figure VIII-4. Results of a detrended correspondence analysis (DCA) of vegetation TVV data for 45 patches of vegetation in the study area. The first and second axes are shown. Vectors for winter terrestrial bird species are overlaid on the vegetation ordination. The species are BEWR=Bewick's wren, CANW=Canyon wren, DEJU=dark-eyed junco, and SAPH=Say's phoebe. The patches are:

GL1 -14.2R
GL2 -13.6R
GL3 –10.0L
GL4 –9.4L
GL5 –8.4R
GL6 –7.0L
GL7 –6.5R
GL8 –3.2R
GL9 –2.5L
GL10 1.0R

MC1 1.6R
MC2 3.7L
MC3 5.2R
MC4 43.1L
MC5 45.5L
MC6 46.7R
MC7 49.1R
MC8 50.0R
MC9 50.4L
MC10 51.5L
MC11 56.0R
MC12 65.3L
MC13 67.1L
MC14 71.0L

GC1 122.8L
GC2 125.5L
GC3 168.8R
GC4 171.0R
GC5 174.2L
GC6 193.8R
GC7 194.0L
GC8 196.0R
GC9 197.6L
GC10 198.0R
GC11 198.2L
GC12 200.4R
GC13 200.5R
GC14 202.5R
GC15 204.1R
GC16 204.5R
GC17 205.0L
GC18 208.7R
GC19 209.0L
GC20 213.6L
GC21 214.0L
GC22 214.2L

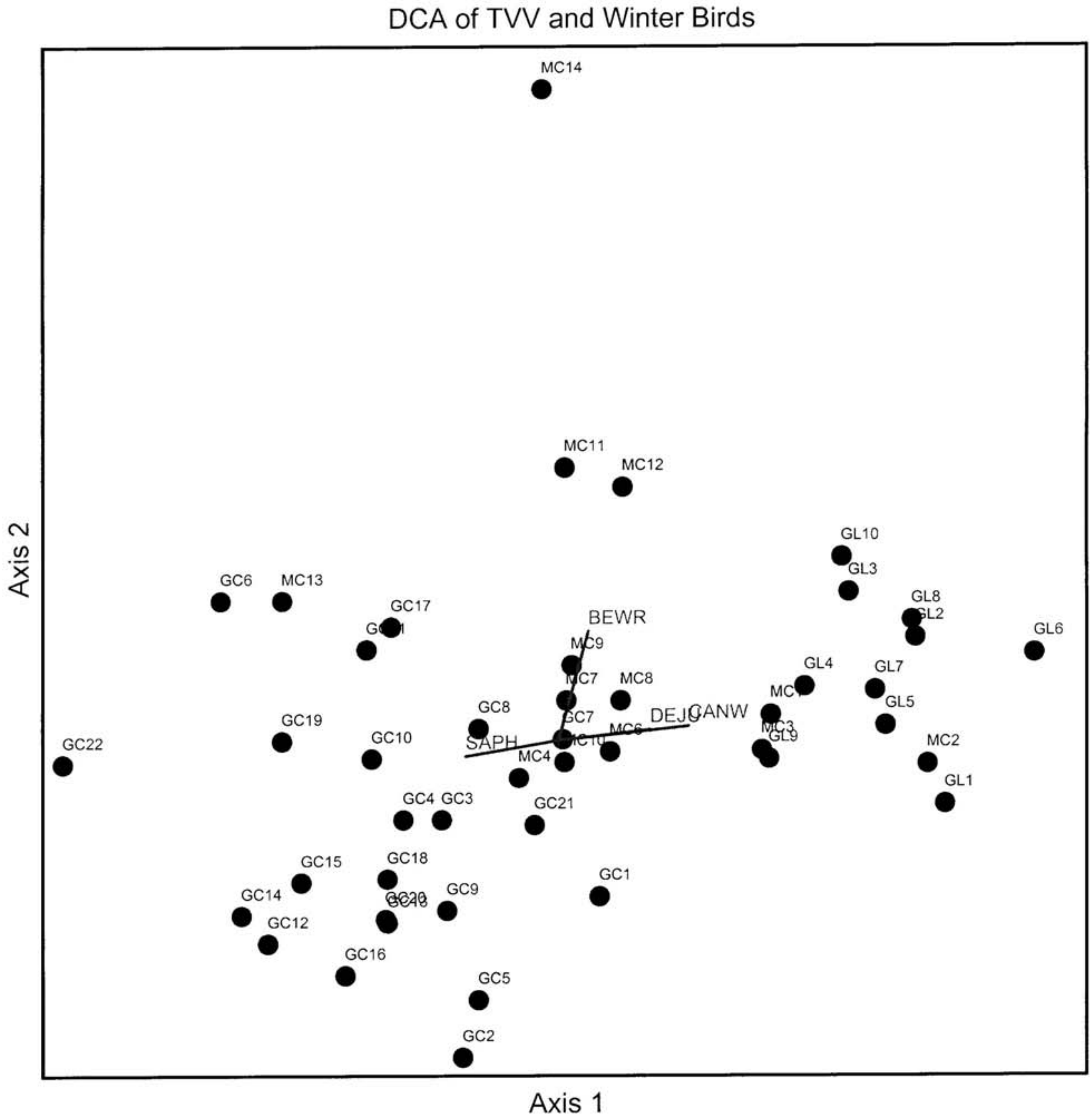
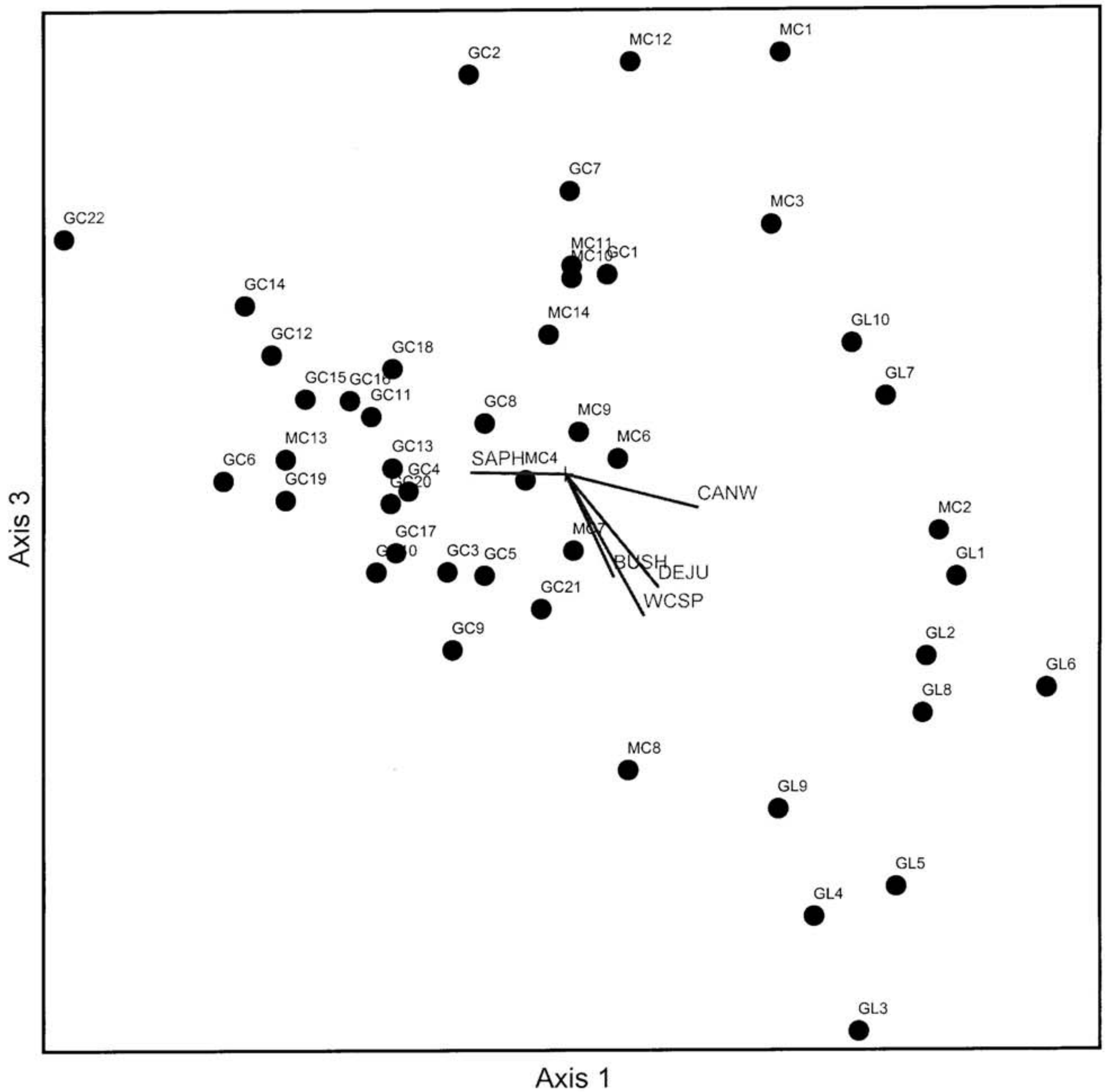

DCA of TVV and Winter Birds
Axis 2
Axis 1
MC14
MC11
MC12
GL10
GL3
GC6
MC13
GC17
GL8
GL2
GL6
BEWR
MC9
GL4
GL7
MC7
MC8
GL5
GC8
GC7
DEJO
CANW
MC3
GC19
GC10
SAPH
MC6
GL9
GC22
MC4
MC2
GL1
GC4
GC3
GC21
GC18
GC15
GC1
GC14
GC9
GC12
GC16
GC5
GC2

Figure VIII-5. Results of a detrended correspondence analysis (DCA) of vegetation TVV data for 45 patches of vegetation in the study area. The first and third axes are shown. Vectors for winter terrestrial bird species are overlaid on the vegetation ordination. The species are CANW=Canyon wren, DEJU=dark-eyed junco, and SAPH=Say's phoebe. The patches are:

GL1 -14.2R	MC1 1.6R	GC1 122.8L
GL2 -13.6R	MC2 3.7L	GC2 125.5L
GL3 –10.0L	MC3 5.2R	GC3 168.8R
GL4 –9.4L	MC4 43.1L	GC4 171.0R
GL5 –8.4R	MC5 45.5L	GC5 174.2L
GL6 –7.0L	MC6 46.7R	GC6 193.8R
GL7 –6.5R	MC7 49.1R	GC7 194.0L
GL8 –3.2R	MC8 50.0R	GC8 196.0R
GL9 –2.5L	MC9 50.4L	GC9 197.6L
GL10 1.0R	MC10 51.5L	GC10 198.0R
	MC11 56.0R	GC11 198.2L
	MC12 65.3L	GC12 200.4R
	MC13 67.1L	GC13 200.5R
	MC14 71.0L	GC14 202.5R
		GC15 204.1R
		GC16 204.5R
		GC17 205.0L
		GC18 208.7R
		GC19 209.0L
		GC20 213.6L
		GC21 214.0L
		GC22 214.2L

DCA of TVV and Winter Birds



CHAPTER IX. POWER TO DETECT CHANGE FOR TERRESTRIAL RIPARIAN SPECIES AND VEGETATION VOLUME

IX-A. Introduction

One of the primary goals of this study is to determine the feasibility of establishing a long-term monitoring program for selected groups of bird species that occupy and utilize that portion of the Colorado River riparian corridor that may be affected by dam operations. Previous chapters have examined winter aquatic, winter terrestrial, and breeding riparian terrestrial species between Glen Canyon Dam and Lake Mead. With the exception of the 2000 Grand Canyon breeding bird data set, which used distance estimation, all methods used to inventory populations have been some form of direct counting as a proxy for true bird abundance. In the case of aquatic species, the counts obtained are likely to be fairly similar to true abundance. However, for terrestrial species there are many inherent problems associated with both area surveys and fixed-radius point counts. The data, in the form of counts of individuals seen or heard while either traversing a patch of vegetation or standing at one or more point count stations, may not reflect true abundance. Bird species vary in their detectability, with relatively quiet retiring species at one end of the spectrum and loud easily visible species at the other end. Distance estimation is one method that attempts to solve this problem of heterogeneous detection rates (see Chapter VIII).

In this chapter, the statistical power of the data to detect change (trends) in selected bird species and TVV volume is examined. In the absence of knowledge on true abundance, detection rates are assumed to provide some proxy index that is positively correlated with true abundance. Power then is the ability of a monitoring program to detect a statistically significant change in detection rates. Change (trend) is the increase or decrease in detection rates for bird species based on either total surveys or point counts over some sampling period. For the purposes of this analysis, the sampling period is considered to be one year, either the period March-July for breeding species, or the period January-February for wintering species. Variances are generated by sampling within each year, either three times for breeding birds or twice for wintering birds.

Power analysis is a necessary and important tool in the establishment of a monitoring program (Steidl et al. 1997; Gibbs 1998). It is particularly critical to determine in the case of endangered species monitoring, as the failure to detect a decline may have disastrous consequences (Taylor and Gerrodette 1993). Most natural wildlife populations vary from year to year in abundance. This variation can result from numerous factors (see chapters I-III). In more temporally variable species, it is often difficult to detect subtle long-term trends because of the “noise” (natural variability) in the species’ populations. A power analysis will provide a measure of how well a monitoring program can detect a trend through such “noise” in the data. In the absence of an estimate of the power of a monitoring program, resource managers and scientists cannot always know if change in a population or species of interest is statistically significant. Furthermore, without adequate power, they may not be able to detect a significant change in a rare species that may be of management importance. This study will use the approach of “retrospective” power analysis (cf., Steidl et al. 1997), in which preliminary baseline data on population numbers and variability is gathered over a period of time, and is then in turn used to design an effective long-term monitoring program, examining factors like sample size considerations, sampling protocols, and duration of data sampling.

IX-B. Methods

Power analysis was performed on the data from point counts for terrestrial riparian species to determine if adequate power exists for the purposes of long-term monitoring of these species. The program MONITOR was used for the analyses (Gibbs 1995). Power is defined as:

$$\text{Power} = 1 - \beta$$

with β the probability of making a Type II error (accepting a false null hypothesis). Power is the ability of a statistical test to yield a statistically significant result (Cohen 1988). 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 the power tests. 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 1000 (see below). Trend projections were set at 5%, 10%, 15%, 20% and 25% (change in bird detections per year) for a future specified time-frame (e.g. 5 or 10 yrs). A two-tailed test was used, testing the null hypothesis that the trend does not differ from zero.

There is a trade-off between power and α such that stringent levels of the latter reduce power. An α of 0.10 could be selected rather than the current level of 0.05. The selection of levels of α and power in a study depends on numerous factors. In many instances, particularly in monitoring changes in wildlife populations, a Type I error may be less costly to management than a Type II error. This follows from the concept that it is less costly to reject the null hypothesis of no change ("crying wolf") than to accept it if false. A manager runs the danger of not detecting change if α is set too high and power is thus too low. Many researchers advocate the relationship of $\alpha = \beta = 0.10$, and a power of 0.90. In this study, I have selected a slightly more stringent level of α with a lower power of 0.80. These values can be changed in future analyses if desired by management or researchers.

Other variables that can be manipulated to improve power include the following: time, number of plots, trend size (effect size), changing to a one-tailed test, number of surveys per count, or selecting "best count" or "highest count" data. For this study, riparian breeding bird species were analyzed under the following set of monitoring parameters, three surveys/year over 10 years, with a two-tailed test. The trends in detection rates (e.g., 5%-25% per year) are relatively large as effect sizes. Values below 10% were not examined primarily because, for most species of birds, variances were too high over the period of the study., i.e., the "noise" in the data made it difficult to detect changes of less than 10% per year with the initial conditions of the power analyses.

Breeding bird data are based on mean summed detection rates and standard deviations by patch, using unbounded data. Individual point counts could not be used as the sampling units because of problems of spatial autocorrelation that could occur when two or more point counts are located in the same local patch of vegetation (Urquhart, pers. comm., 2000). Values were computed for all patches that were sampled on all three trips on at least four years between 1995-2000 (minimum N=12 counts/point/patch). This resulted in a sample of 46 patches. The sixteen most common species detected over the course of the study were examined. For winter birds, all patches that were sampled on all three years and six trips were used, resulting in 20 patches, all below Lee's Ferry. All patches above

Lee's Ferry, as well as many below, were sampled five or fewer times. Because of the smaller sample size, winter bird species data was analyzed for power using a less conservative α of 0.10. The aquatic bird data was not analyzed for power because of the small sample sizes, large variance in the data, and the lack of meaningful sample units ("patches") for comparison. Habitat sampling was analyzed by computing the means and standard deviations for canopy volume using the TVV method (see Chapter X) for all patches sampled.

Because the conclusions and monitoring recommendations of this report depend on the ability of the computer program (MONITOR) to compute results in a stable and repeatable manner, it was subjected first to a series of tests using a field data set. The data used were from the unbounded point count data for ash-throated flycatcher in 46 patches of riparian vegetation sampled between Glen Canyon Dam and Diamond Creek. Power was computed for a 10% change in the number of detections per year, for a two-tailed test and α=0.05. Power results were computed for replications varying from 250, 500, 750 and 1000, then every 500 from 1500 to 5000. Tests were run for three periods of monitoring, 7, 8 and 9 years. The standard error of the mean was computed based on 10 runs for each replication value. The mean power for each replication value was also computed. These were then graphed (see below). Finally, the amount of time taken to compute power over a series of replications was determined.

IX-C. Results

IX-C.1. Stability Test on the Monitor Program

There is a linear relationship, as expected, between the length of time required to run a power test using MONITOR and the number of replications (Figure IX-1). Mean power for three runs (7, 8 and 9 years) stabilized generally at about 1000-1500 replications (Figures IX-2, IX-3, IX-4). The mean error rate declined with increasing number of replications (Figure IX-5), with values beyond 1500-2000 replications being fairly stable. Because of the amount of time needed to run one test, and the number of tests needed (>500), a trade-off was necessary. The level of 1000 replications was thus selected, proving reasonable stability in the results along with reduced time to conduct the analyses (cf. Gibbs 1998). Tests with greater replication can be done for selected species if needed on a case-by-case basis.

IX-C.2. Power Tests for Riparian Breeding Species

For the 16 most commonly detected riparian breeding species, power at five trends (5%-25%), power over varying α levels, and number of patches and years to monitor was computed. Charts for individual species can be found in Appendix F. Summary means and standard deviations for each species are listed in Appendix G.

The current program of patches sampled three times a year can detect a trend of 10% per year in detection rates at reasonable levels of α and β for eight species; Lucy's warbler, house finch, Bell's vireo, Bewick's wren, black-chinned hummingbird, ash-throated flycatcher, yellow-breasted chat, and blue-gray gnatcatcher. At a larger trend of 20%, adequate power exists to detect change in common yellowthroat, yellow warbler, and possibly song sparrow. For the remaining five species, mourning dove, blue grosbeak, Bullock's oriole, lesser goldfinch, and brown-headed cowbird, power is below 0.80, even at an α of 0.10. In order to be confident of detecting changes in these species, the program would have to be modified, either by increasing the number of patches or surveys per year, or by changing the parameters of the statistical power tests. For several species, however, it is unlikely that any modifications can be done to achieve sufficient power. Some species, such as brown-headed cowbird or Bullock's oriole, are simply to rare and patchily distributed to be able to effectively monitor with point count surveys. This is also true of the other16 species of riparian breeders that were not examined.

The number of years under the sampling program to achieve enough power to detect change varied from five years for Lucy's warbler to 30 years for brown-headed cowbird. Increasing the number of patches sampled, surveys per year, or changing to a one-tailed test would reduce the number of years for many species to more manageable lengths. The number of patches sampled per year for 10 years to achieve adequate power varied from 15 for House Finch to 60 for brown-headed cowbird.

IX-C.3 Power Tests for Selected Wintering Terrestrial Species

Table IX-2 summarizes retrospective power tests for the 13 most commonly detected species on winter surveys in the study area. Only 20 patches were sampled on all six trips, all below Lee's Ferry. At an α of 0.10, with 20 patches sampled twice per year for 10 years and a two-tailed test, adequate power exists to detect change in only four species, ruby-crowned kinglet, song sparrow, Bewick's wren and canyon wren. The number of years needed to reach a power of 0.80 for species varied from seven for ruby-crowned kinglet to >50 for marsh wren. The number of patches to reach a power of 0.80 over ten years of monitoring varied from 20 for several species, to 45 for bushtit. If the number of patches sampled was doubled, power increased substantially for all species, and the number of years to monitor to reach a power of 0.80 for species varied from six to 12.

IX-C.4 Power Test for Habitat Analysis

The test of the vegetation monitoring program was based on habitat sampling in 62 patches of vegetation (Appendix G). Table IX-3 shows power for a two-tailed test and an α of 0.05 over monitoring time-frames of three to 10 years. Power for declines and increases in total vegetation volume (TVV) were shown over a range of effect sizes from 1% change per year to 25% change per year. Figures IX-6 and IX-7 graph the power curves for positive and negative changes for the different time-frames. Adequate power exists to detect an increase in TVV for all time frames at various effect sizes. For a three-year monitoring period increases of 15% and decreases of 20% can be detected at a power of 0.80. For a longer time-frame of 10 years, changes of as little 3% TVV per year can be detected with the current data. For an intermediate time-frame of five years, increases of 7% and decreases of 9% per year can be detected.

IX-D. Summary

The power analyses revealed that the 5-year bird and habitat monitoring program has adequate power to detect change in many but not all bird species in the study area. Using the parameters set in the analyses, the breeding bird program has adequate power to detect change in Lucy's warbler, house finch, Bell's vireo, Bewick's wren, black-chinned hummingbird, ash-throated flycatcher, yellow-breasted chat, and blue-gray gnatcatcher. These species represent about 25% of the total breeding riparian species in the study area, but >80% of the total number of individuals. However, there is insufficient power in the program to monitor many bird species, including several relatively widespread but uncommon ones like common yellowthroat, mourning dove, and yellow warbler. Changing aspects of the monitoring program and statistical methods will improve power for a few additional species, but many species are simply too rare to be monitored without a large increase in the number of patches and point counts sampled. Clearly, other ways of monitoring these species is required if they are considered to be of management importance by the federal agencies involved in managing the river corridor.

Perhaps surprisingly, given the small samples, many winter terrestrial bird species can be monitored using the walking survey method. Adequate power after only six surveys among only 20 patches exists to monitor ruby-crowned kinglet, song sparrow, Bewick's wren and canyon wren. With an increase in number of patches to 35-40, many additional species can be effectively monitored. A typical winter trip between 1998-2000 sampled about 40-50 patches, so the current monitoring program appears to be capable of following trends in at least the most common 8-10 species. Again, many rarer species or species of limited distribution cannot be monitored by sampling 40 or more patches of vegetation twice a winter, including dark-eyed junco, house finch, white-crowned sparrow, and yellow-rumped warbler.

There are at least three ways power could be increased to "capture" more of the bird species in the study area, by either increasing the sampling effort in the current program, examining power to detect change in combined "guilds" of species, or changing the specified parameters in the power analyses. Of these three, increasing the sampling effort will cause the greatest increases logistical costs but is most likely to lead to improved power. Using guilds of species, based on such factors as diet, foraging strategies, or nest site selection, could provide adequate power for trend detection, but would provide only coarser-grained data on population trends and miss trends in particular species. However, there may be some instances in which a guild-based approach may be useful. This is discussed in more detail in Chapters XII and XIII. Finally, rather than using a null hypothesis of no change in a population over time, one could use a one-tailed test to test the hypothesis of no declines (or increases) over time. Also, levels of α and β could be manipulated depending on management decisions.

An alternative approach is to monitor selected individual species using more intensive methods such as mist-netting, spot-mapping and reproductive success through nest monitoring. This has been done with some success with southwestern willow flycatcher, but is logistically costly and time-consuming. A program that targets selected rarer species, including those that are federally listed or of management concern, could feasibly monitor three-four such species given current logistical support of the program.

The habitat sampling program using the TVV indicated that all patches sampled (N=62) were sampled adequately, and that excellent power to detect relatively small changes in vegetation volume exists. For example, a change of 10% in TVV could be detected after only five years of sampling. The habitat sampling program, however, is relatively time consuming and logistical complex, and there may be more appropriate ways to monitor the vegetation along the river corridor using TVV sub-sampling in combination with multi-spectral or low-elevation photography (see Chapter XIII).

All the power tests indicate one general feature that is inherent in long-term monitoring programs of bird communities. In order to detect even large changes in bird species abundance, up to 10 or more years of monitoring on an annual basis may be required. In the current study, power to detect change in less than 10 years only exists for a few species, such as Lucy's warbler, Bewick's wren, and ruby-crowned kinglet. Hence, long-term commitment of resources is needed to detect trends in the riparian bird community along the Colorado River (cf. Dunning and Kilgo 2000).

Table IX-1. Results of retrospective power analyses for 16 species of riparian breeding birds based on data generated from point counts sampled between 1995-2000 in 46 patches of riparian vegetation between Glen Canyon Dam and Diamond Creek. For three species found only below Lee's Ferry, Bell's vireo, song sparrow and lesser goldfinch, data from 36 patches in the Grand Canyon was used.

Species	**10%[1]**	**20%[2]**	**α=0.10[3]**	**Years to Sample[4]**	**Patches Occupied[5]**	**Patches Needed[6]**
Lucy's Warbler	1.000	1.000	1.000	5	45	20
House Finch	0.996	1.000	0.998	7	46	15
Bewick's Wren	0.999	1.000	1.000	6	44	20
Bell's Vireo	0.996	1.000	1.000	7	29	25
Black-chinned Hummingbird	0.957	0.998	0.987	8	45	35
Ash-throated Flycatcher	0.947	0.998	0.969	9	46	30
Yellow-breasted Chat	0.904	0.995	0.956	9	41	40
Blue-gray Gnatcatcher	0.900	0.982	0.931	10	39	40
Mourning Dove	0.388	0.604	0.503	17	31	55
Blue Grosbeak	0.458	0.725	0.581	15	35	55
Common Yellowthroat	0.573	0.810	0.724	14	36	50
Yellow Warbler	0.695	0.907	0.809	12	35	50
Bullock's Oriole	0.251	0.373	0.357	28	21	55
Lesser Goldfinch	0.502	0.725	0.517	18	26	45
Song Sparrow	0.550	0.789	0.853	14	22	40
Brown-headed Cowbird	0.231	0.394	0.365	30	22	60

[1]Power to detect a 10% change over 10 years for a two-tailed test, α=0.05, 3 surveys/year
[2]Power to detect a 20% change over 10 years for a two-tailed test, α=0.05, 3 surveys/year
3Power to detect a 10% change over 10 years for a two-tailed test, α=0.10, 3 surveys/year
[4]Years needed to monitor 46 patches in order to reach a power of ≥0.80 to detect a 10% change for a two-tailed test, α=0.05, 3 surveys/year
[5]Number of patches where each species was detected at least once between 1995-2000
[6]Number of patches to monitor in order to reach a power of ≥0.80 to detect a 10% change over 10 years for a two-tailed test, α=0.05, 3 surveys/year

Table IX-2. Results of retrospective power analyses for 13 species of winter terrestrial riparian birds based on data generated from total surveys conducted between 1998-2000 in 20 patches of riparian vegetation between Glen Canyon Dam and Diamond Creek.

Species	**10%[1]**	**Years to Monitor[2]**	**Patches to Monitor[3]**	**10% with 40 Patches[4]**
White-crowned Sparrow	0.312	24	35	9
Ruby-crowned Kinglet	0.969	7	20	6
Dark-eyed Junco	0.325	23	45	12
Song Sparrow	0.902	9	20	6
Bushtit	0.416	18	45	11
Bewick's Wren	0.812	10	20	7
House Finch	0.253	30	40	10
Canyon Wren	0.863	10	20	6
Yellow-rumped Warbler	0.288	33	38	10
Rock Wren	0.661	13	25	6
Lincoln's Sparrow	0.382	20	28	7
Say's Phoebe	0.544	20	29	7
Marsh Wren	0.283	>50	27	7

[1]Power to detect a 10% change over 10 years for a two-tailed test, α=0.10, 2 surveys/year
[2]Years needed to monitor 20 patches in order to reach a power of ≥0.80 to detect a 10% change for a two-tailed test, α=0.10, 2 surveys/year
[3]Number of patches to monitor in order to reach a power of ≥0.80 to detect a 10% change over 10 years for a two-tailed test, α=0.10, 2 surveys/year
[4]Number of years to reach power of ≥0.80 with 40 patches sampled, two-tailed test, α=0.10, 2 surveys/year

Table IX-3. Results of a retrospective power analysis over various time-frames for detecting change in percent in TVV for riparian vegetation along the Colorado River, based on 62 patches. Test parameters included a two-tailed test, one survey/year, an α of 0.05, and replications of 1000.

Change per Year	**3 Yrs**	**4 Yrs**	**5 Yrs**	**6 Yrs**	**7 Yrs**	**8 Yrs**	**9Yrs**	**10 Yrs**
+1%	0.054	0.063	0.086	0.098	0.106	0.135	0.148	0.229
+2%	0.066	0.095	0.126	0.204	0.280	0.394	0.543	0.678
+3%	0.077	0.156	0.229	0.401	0.550	0.750	0.899	0.962
+4%	0.109	0.220	0.390	0.615	0.834	0.955	0.989	0.998
+5%	0.160	0.336	0.576	0.802	0.969	0.996	1.000	1.000
+6%	0.172	0.440	0.739	0.962	0.999	1.000	1.000	1.000
+7%	0.254	0.561	0.852	0.986	1.000	1.000	1.000	1.000
+8%	0.344	0.720	0.953	1.000	1.000	1.000	1.000	1.000
+9%	0.403	0.810	0.976	1.000	1.000	1.000	1.000	1.000
+10%	0.504	0.901	0.999	1.000	1.000	1.000	1.000	1.000
+15%	0.842	0.997	1.000	1.000	1.000	1.000	1.000	1.000
+20%	0.984	1.000	1.000	1.000	1.000	1.000	1.000	1.000
+25%	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
-1%	0.040	0.073	0.060	0.071	0.099	0.140	0.139	0.200
-2%	0.051	0.095	0.126	0.163	0.234	0.324	0.408	0.518
-3%	0.073	0.114	0.200	0.329	0.586	0.586	0.715	0.835
-4%	0.098	0.197	0.311	0.451	0.791	0.791	0.894	0.964
-5%	0.108	0.276	0.418	0.612	0.906	0.906	0.969	0.992
-6%	0.167	0.333	0.541	0.738	0.964	0.964	0.993	0.999
-7%	0.195	0.442	0.633	0.856	0.989	0.989	0.996	1.000
-8%	0.260	0.469	0.758	0.904	0.994	0.994	0.999	1.000
-9%	0.324	0.585	0.811	0.962	0.996	0.999	1.000	1.000
-10%	0.364	0.651	0.899	0.982	0.999	1.000	1.000	1.000
-15%	0.596	0.902	0.993	0.998	1.000	1.000	1.000	1.000
-20%	0.800	0.982	1.000	1.000	1.000	1.000	1.000	1.000
-25%	0.925	0.997	1.000	1.000	1.000	1.000	1.000	1.000

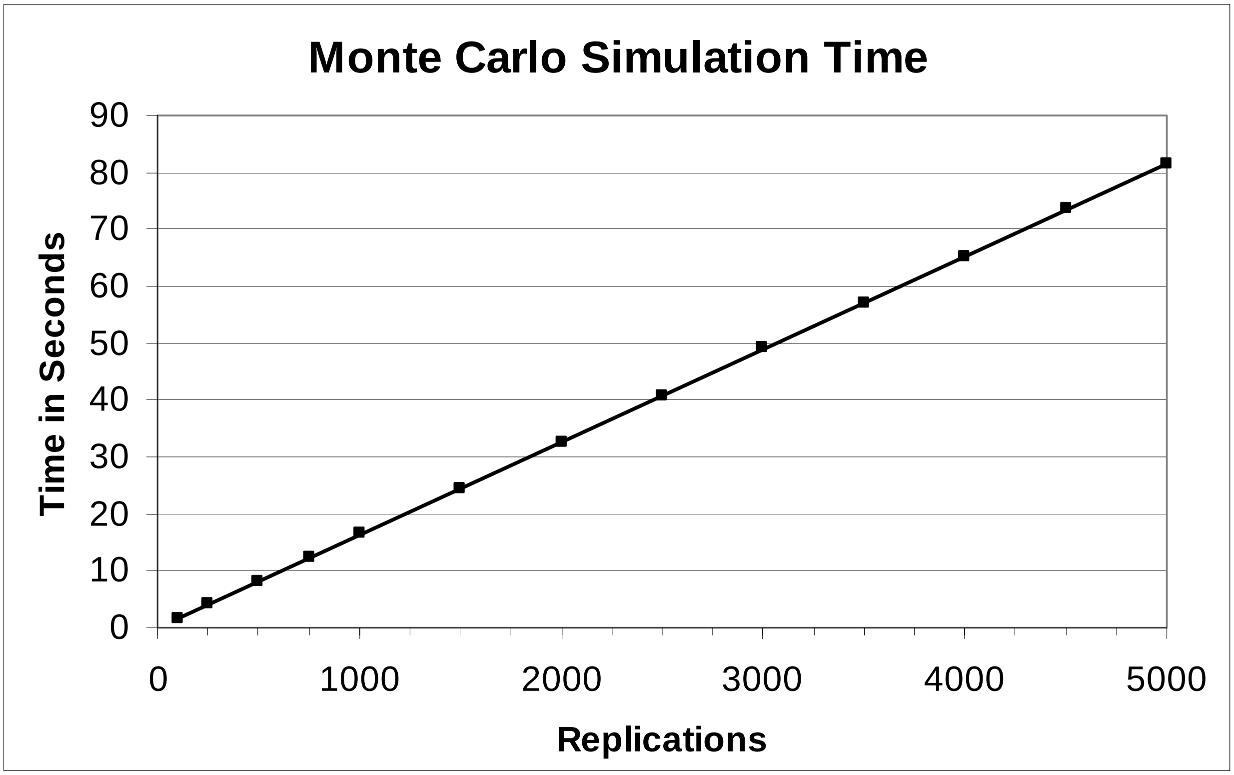


Figure IX-1. The relationship between amount of time to compute a power analysis in seconds and the number of replications selected.

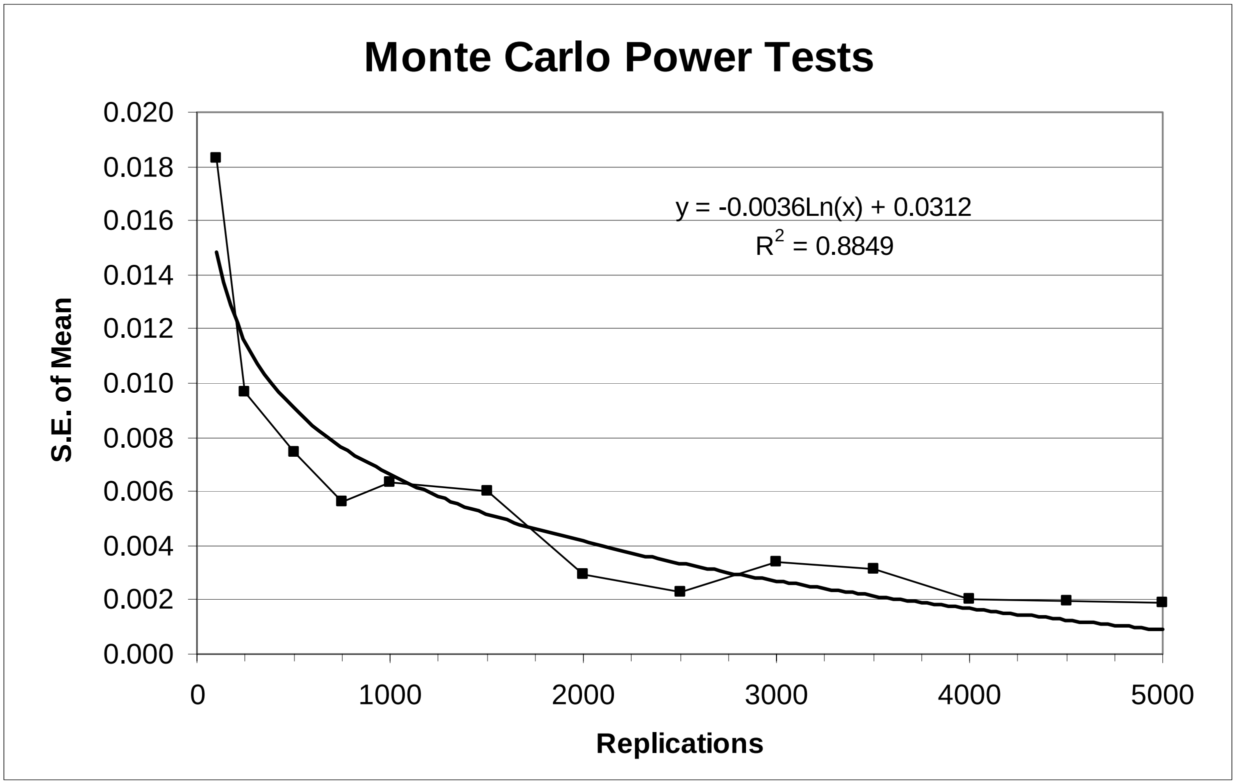


Figure IX-2. The relationship between the decline in the standard error of the mean in power and number of replications in a power analysis. The data is based on ash-throated flycatcher abundance in 46 patches, with a two-tailed test, three surveys/year, and an α of 0.05 for seven years of monitoring.

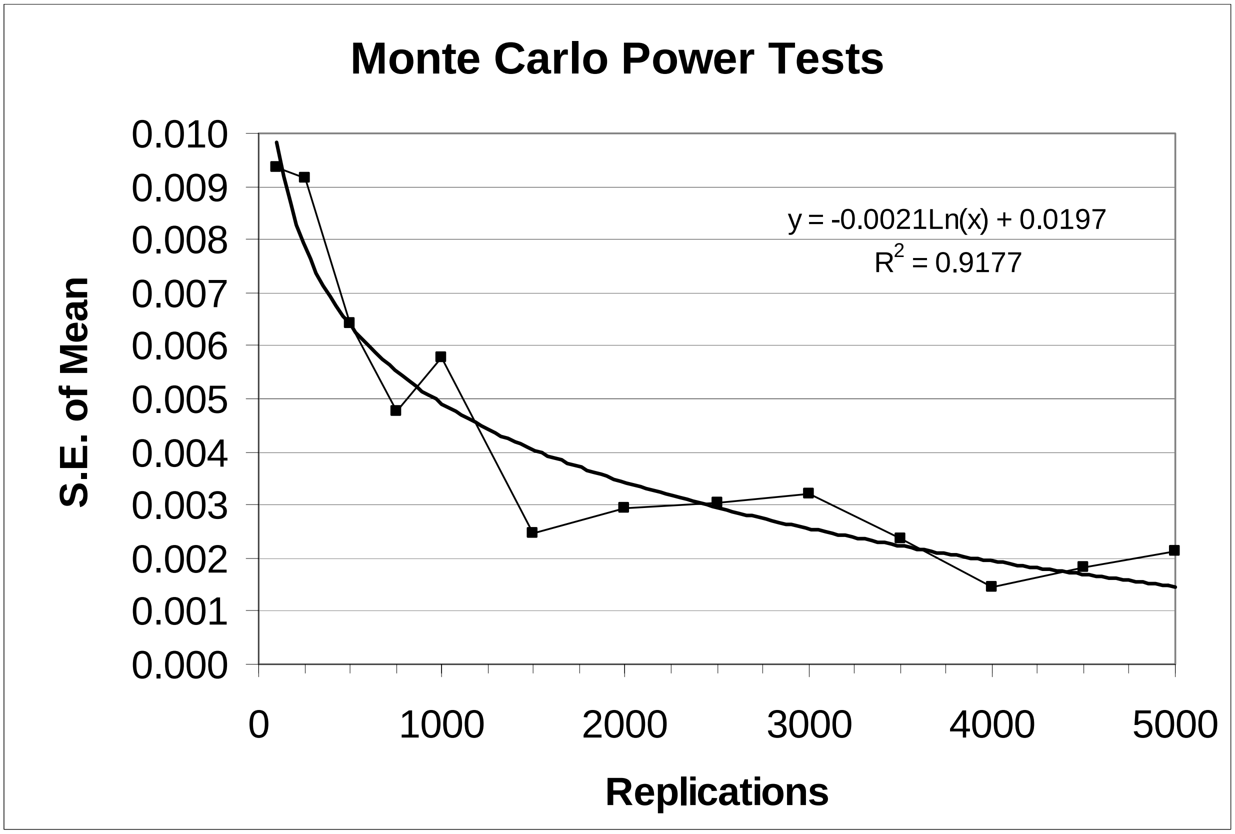


Figure IX-3. The relationship between the decline in the standard error of the mean in power and number of replications in a power analysis. The data is based on ash-throated flycatcher abundance in 46 patches, with a two-tailed test, three surveys/year, and an α of 0.05 for eight years of monitoring.

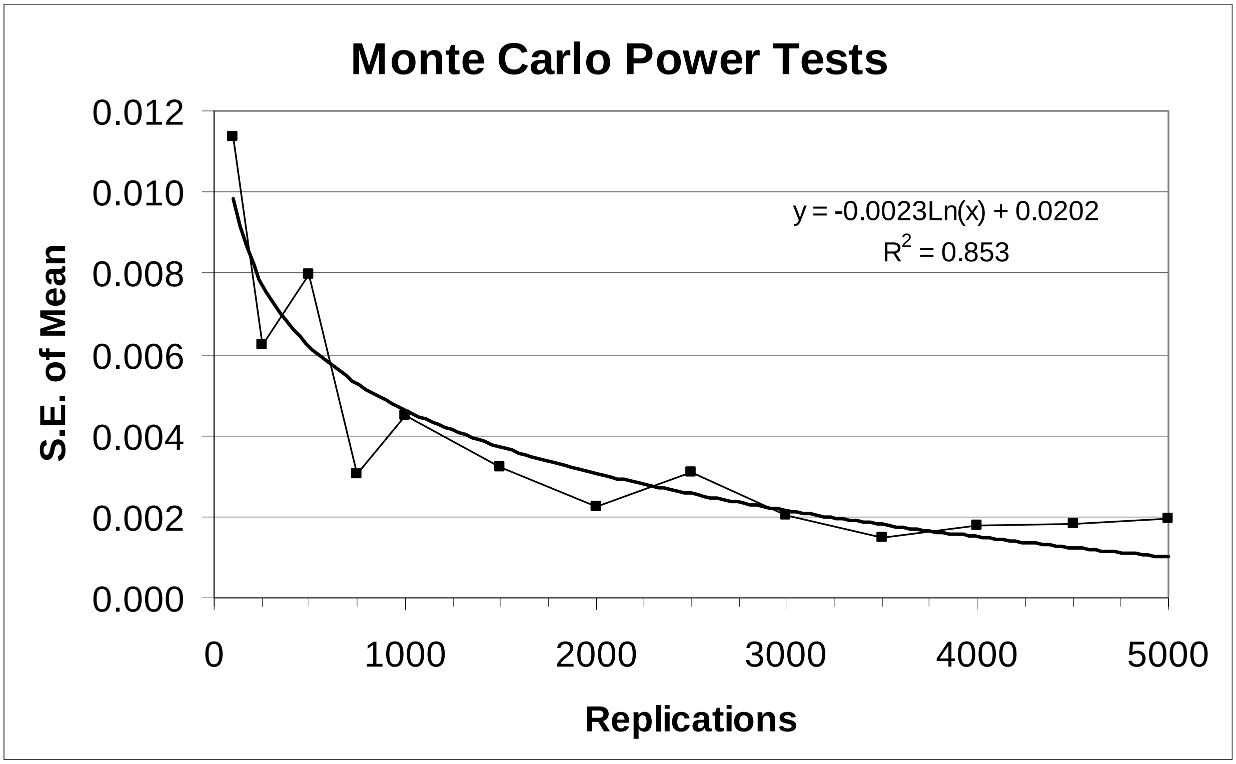


Figure IX-4. The relationship between the decline in the standard error of the mean in power and number of replications in a power analysis. The data is based on ash-throated flycatcher abundance in 46 patches, with a two-tailed test, three surveys/year, and an α of 0.05 for nine years of monitoring.

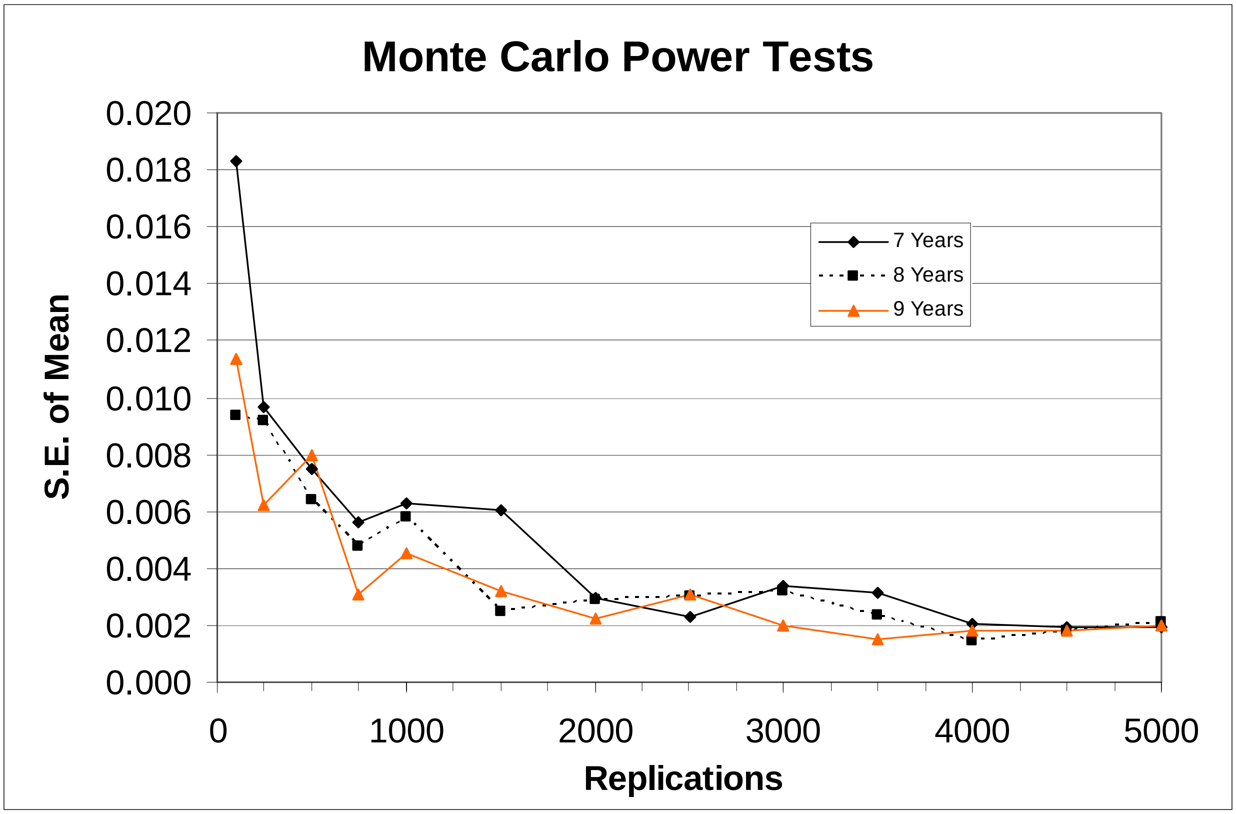


Figure IX-5. A comparison of the decline in the standard error of the mean in power and number of replications in a power analysis for three time-frames, seven, eight and nine years. The data is based on ash-throated flycatcher abundance in 46 patches, with a two-tailed test, three surveys/year, and an α of 0.05.

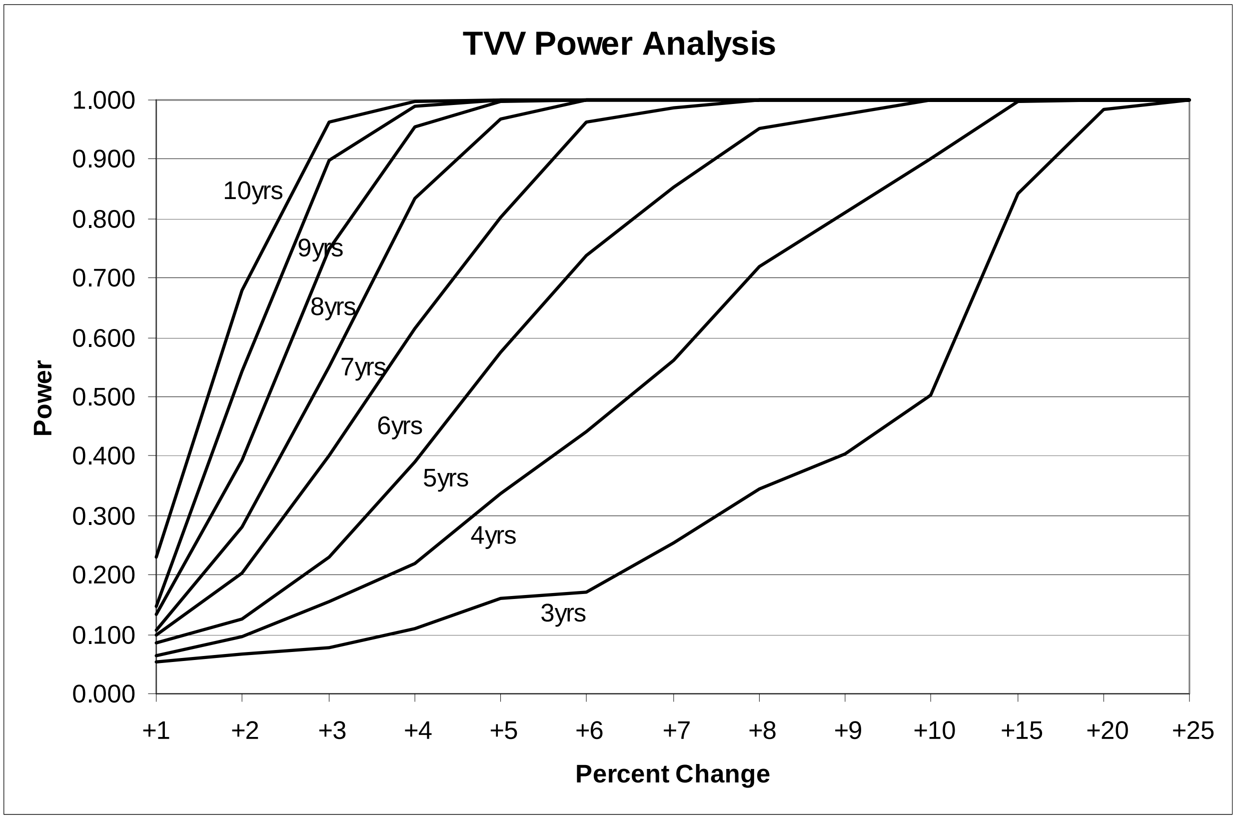


Figure IX-6. Retrospective power curves for positive change in TVV for 62 riparian vegetation patches. Parameters included a two-tailed test, one survey/year, and an α of 0.05 over time-frames from three to 10 years.

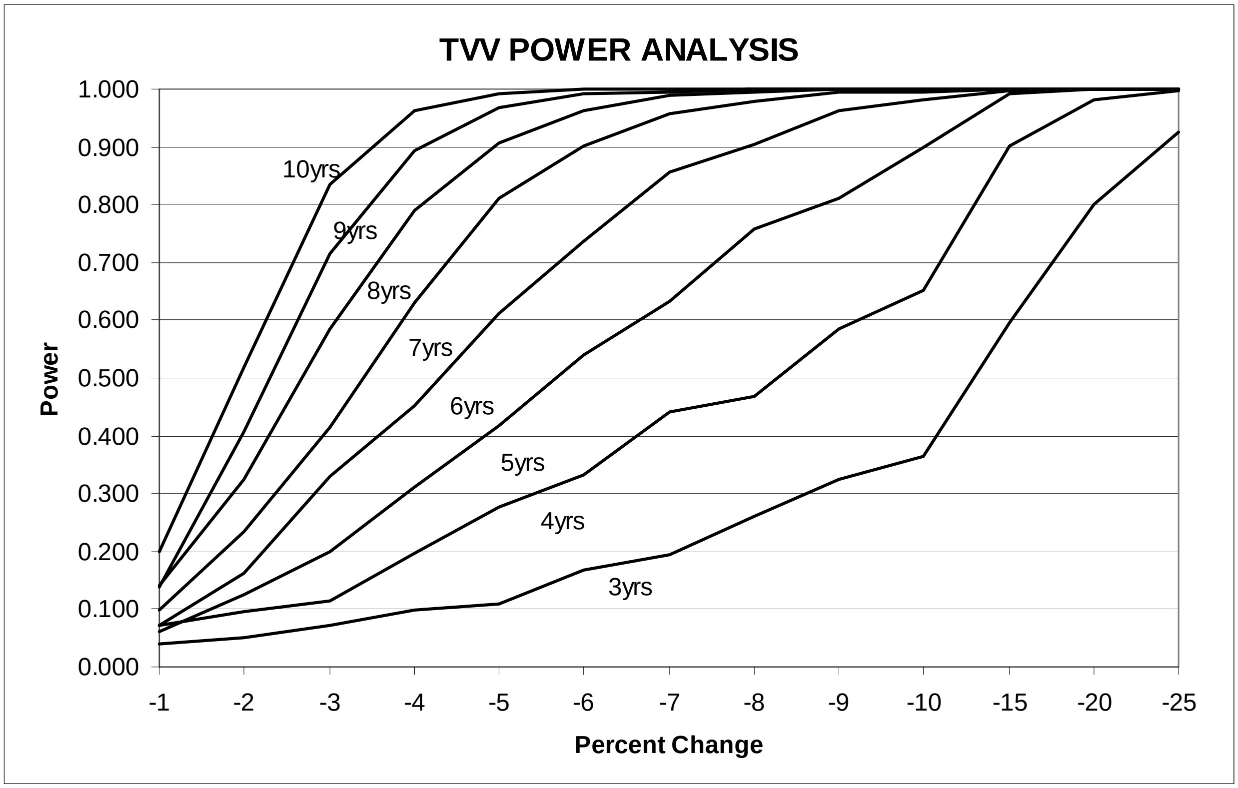


Figure IX-7. Retrospective power curves for negative change in TVV for 62 riparian vegetation patches. Parameters included a two-tailed test, one survey/year, and an α of 0.05 over time-frames form three to 10 years.

CHAPTER X: DENSITY ESTIMATES OF BREEDING BIRDS USING VARIABLE-RADIUS CIRCULAR PLOTS AND DISTANCE ESTIMATION (Jennifer A. Holmes)

X-A. Iintroduction

A variety of counting techniques have been used to count landbirds. Those techniques can be divided into two groups: (1) methods that use counts or maps of bird detections as an index to relative abundance and (2) empirical modeling techniques that estimate bird density (Rosenstock et al. 2002). The first group, known as index counts, tally bird detections during one or more surveys of points, transects, or defined areas (Bibby et al. 1992, Ralph et al. 1995). Index counts include variations of point count methods, which have been extensively used in bird studies in multiple habitats and geographic regions, including BBS surveys (Martin and Geupel 1993, Ralph et al. 1995, Hutto and Young 1999). Using point count surveys, detections are converted to an index value, such as the total number or frequency of detections across sampling units (Verner and Ritter 1985, Hutto et al. 1986). Point count methods can also be used to measure habitat characteristics (e.g. vegetation structure and diversity) around the census station and additional random points in order to monitor breeding habitat characteristics. The second group of techniques was developed with the recognition that some birds are missed during sampling, making it necessary to incorporate some method of figuring out how many birds are missed. Thus, these techniques use field procedures that are similar to index counts, but have an analytic component that models variation in species' detectability to yield direct estimates of density. Examples of these techniques include variable-distance transects (e.g., Emlen 1977), variable circular-plots (VCP; Reynolds et al. 1980), Distance Sampling (e.g., Buckland et al. 1993, Rosenstock et al. 2002), and the Double Observer Approach (Fancy and Sauer 2000).

Because count data figure so prominently in landbird conservation, it is essential that researchers and managers use techniques that can provide “reliable information” (Romesburg 1981). The biases and limitations of index-counting procedures have undergone extensive debate. Until recently, counting techniques that use detectability-based density estimates have not been widely used. Some avian ecologists propose that detectability-based techniques deserve wider application (e.g., Fancy and Sauer 2000, Rosenstock et al. 2002), and many monitoring programs have recently adopted distance sampling for long-term monitoring of songbirds (e.g., the National Park Service, Utah Division of Wildlife, and Monitoring Colorado Birds).

Criticism of index counts centers on the fact that they rely upon assumptions concerning detectability that may be difficult or impossible to meet in most field studies (Rosenstock et al. 2002). For index counts to provide reliable information, one must assume that they have a consistent, positive correlation with actual bird density (i.e., the relationship between the number of birds you detect and the number that is actually present does not change). To meet that assumption, bird detectability must remain constant despite three types of factors that, individually or in combination with other factors, can influence avian counts. First are variables that affect an observer's ability to detect and correctly identify birds. Observer performance varies among and within individuals and is strongly influenced by training, age, experience, motivation, hearing acuity, eyesight, physical health, and fatigue level (Rosenstock et al. 2002). Second are environmental variables that affect bird behavior and observer efficiency. Those include wind velocity, precipitation, temperature, cloud cover, and light intensity (Anderson and Ohmart 1977, Verner 1985), as well as topography and vegetation characteristics (Dawson 1981). The third class of variables affecting detectability is behavioral and physical attributes of bird species and individuals that make them more or less conspicuous to human observers. These include body size, plumage coloration, characteristics of vocalizations (e.g., loudness, rate, sonic frequency), flight behavior, physiological status, flock size, density, age, and sex (Rosenstock et al. 2002). When index counts are conducted on multiple occasions, one must also assume that the detectability is consistent over time. However, many studies have shown that detectability varies at multiple temporal scales (Rosenstock et al. 2002).

To address these potential problems with index counts, standardized sampling protocols have been developed (e.g. Ralph et al. 1995). These protocols may reduce the influence of some confounding factors; however, the critical assumption of constant detectability likely cannot be met in many studies (see Nichols et al. 2000, Rosenstock et al. 2002). Thus, it has been argued that measures of relative abundance derived from index counts represent an uncertain, confounded combination of detectability and density (see Rosenstock et al. 2002). Rosenstock et al. (2002) and Fancy and Sauer (2000) suggest that, given these weaknesses, index counts should not be expected to provide reliable information or a valid basis for inference. Additionally, the Breeding Bird Surveys and other large-scale surveys have come under increasing criticism because of their inability to estimate biases in the detectability of birds, which varies with respect to species, observers, vegetation type and the subsequent failure to incorporate differential detectabilities into trend analyses. In order to provide reliable information it has been recommended that some form of detectability sampling be employed in long-term monitoring programs.

Two commonly used forms of detectability sampling are Distance Sampling and the Double Observer method. Double-observer counting provides a method of modifying point counts to incorporate detectability information (Fancy and Sauer 2000). In this procedure, two observers count at each point. One observer is the "primary," who counts all birds they see or hear. A "secondary" observer records the birds detected by the primary observer, but also notes any birds missed during counting by the primary observer. The two observers alternate roles between points, so that for any area of interest the data will have replicate points at which each observer was primary. Using these data, the proportion of birds missed by each counter can be estimated (Nichols et al. 2000, Fancy and Sauer 2000). This procedure has only recently been implemented for point counts, but it appears to provide reasonable results (Nichols et al. 2000, Fancy and Sauer 2000). Its primary drawback is that it requires 2 people to conduct counts. Alternatively, Distance Sampling requires only one (well-trained) observer.

In practice, the Distance Sampling method is basically the same as unlimited distance point counts, except that for each bird heard or seen during the count, its horizontal distance from the observer is estimated. In the case of line transect sampling, the observer walks down a transect and records either the perpendicular distance to each bird heard or seen, or else records the sighting angle and sighting distance instead of the perpendicular distance. Variable circular plots are a type of distance sampling where the observer stands at a sampling station and records the horizontal distances between the observer and each bird (Fancy and Sauer 2000).

There are a number of limitations of detectability sampling methods even with the best-trained and most highly skilled observers. For example, in many surveys, the majority of birds are heard but not seen, and the observer estimates the distance to a tree or bush or other object where they think the bird is hiding. Distances cannot be estimated accurately in many situations because of habitat complexity or ventriloqual bird voices or other reasons. Also, more than 100 detections are required to develop a good detection function for each species, such that multiple surveys of the same area will be required for all but the most common species in order to get adequate sample sizes (Fancy and Sauer 2000). Thus, detectability sampling such as distance sampling is inappropriate for rare species. Yet, Distance Sampling can be easily used in appropriate habitats (where distances can be reliably measured or estimated) for species likely to be detected in sufficient numbers to enable modeling detectabilities and estimating density.

X.B. Methods and Sampling Design Requirements

Distance sampling is a method that allows the estimation of density of biological populations. Using distance sampling requires that critical assumptions be met. The critical data collected are distances from a *randomly* placed line or point to objects of interest. The points sampled in this study were those previously determined and sampled as part of a long-term monitoring program. They were selected non-randomly; the patches selected for sampling were non-randomly selected, and the placement of points within the patches was non-random (generally down the center of the patch or along the edge). This violates one of the basic requirements for Distance Sampling, eliminates the ability to draw inferences, and introduces considerable bias into the results. Yet, this study can provide information regarding study design considerations for future monitoring.

When establishing sampling points, consideration must be given to possible gradients in density. So spatial stratification of the study area should be considered (Buckland et al. 1993). Along the Colorado River in the Grand Canyon there are likely gradients in densities for many of the bird species. For example, densities of many species likely change from the upper reaches of the river to the lower reaches and also within patches from the rivers edge through the OHWZ. Also, detection probability often varies with topography, habitat type and density of the objects of interest. Furthermore, if more than one observer is used, the design should allow estimation by individual observer. Proper design will help cope with these realities (Buckland et al. 1993), including ensuring that adequate sample sizes are obtained for each layer of stratification.

For sampling birds by point counts, as was done in this study, Buckland et al. (1993) state that a sample size of at least 100 detections is required to adequately model the detection function and estimate density. Thus, at least 100 detections are needed for each stratification layer (e.g., observer, river reach, habitat type).

X.C. Results

In 2000, two observers conducted distance sampling at point counts previously sampled as part of a long-term monitoring project in riparian areas along the Colorado River in Glen and Grand Canyons. The two observers calibrated ocular estimations prior to each river trip and also used laser range finders, when possible, to measure distances to detections. Given the constraints of this study discussed above, I was unable to stratify the data for any species and maintain adequate sample sizes (i.e., $\geq$ 100 detections). Also, only three species, Bell's Vireo (BEVI), Bewick's Wren (BEWR), and Lucy's Warbler (LUWA) had over 100 detections.

Data were not aggregated in any way prior to data entry; the data were ungrouped and the actual distance to each detection was measured using a laser range finder when possible or estimated when vegetation density prevented the use of the range finder. The data for each species were entered into an

EXCEL worksheet where each detection of an individual comprised a row in the dataset. The three columns in the worksheet were: Patch Number, Number of BEVI, BEWR, or LUWA (there were a few detections of clusters of individuals in each species' dataset), and Distance to the bird(s).

Each species' detection function was modeled individually, resulting in a density for that particular species. The data for each species was imported into DISTANCE and analyzed as cluster data based on the fact that a few detections were of two or more animals. Buckland et al. (1993, p. 159) say that if the probability of detection is independent of cluster size and cluster sizes are accurately recorded (or they are estimated without bias at all distances), then the estimate of the expected value of the cluster size, E(s), may be estimated by the mean size of detected clusters. Our data for all three species met these assumptions, so I used the mean size of detected clusters when conducting each of the three analyses.

Once the data were in DISTANCE, I followed the guidelines for the analysis of point count data suggested by Buckland et al. (1993). I plotted histograms of the distance data, using different choices for the cutpoints, and attempted to fit a preliminary model to the data. I examined the histograms for evidence of failure of assumptions. For each of the three species, the data seemed to meet the assumption that all objects at 0 distance from the point were detected. In general, point count data have relatively few distances recorded next to the point, where area surveyed is small, so the fit of the model is not heavily influenced by distances close to zero, whereas the height of the first histogram bar is dominated by small distances (Buckland et al. 1993). The BEVI, BEWR, and LUWA data all had a relatively large number of detections with small distances (Figure X-1 histogram).

I also examined the histograms for evidence of evasive movement and heaping (the observer rounds to convenient values when estimating distances). For each species, there may have been some evasive movement, but, if so, it was slight (see Figure X-1). Also, there did appear to be some heaping. Buckland et al. (1993) suggest, when there is evidence of heaping and some movement away from the observer, appropriate grouping of the data can lead to more robust estimation of density, and that cutpoints for grouping distances from the point should be selected so that large "heaps" fall approximately at the midpoints of the groups. Furthermore, when data are collected with no fixed width, such as ours was, Buckland et al. (1993) suggest truncating the data. For point count data they suggest that roughly 10% of the observations should be truncated or, alternatively, the truncation distance w should be chosen so that $g(w)=0.1$, where $g(w)$ is estimated from the preliminary fit of a plausible model of the data (Buckland et al. 1993).

By looking at a preliminary model of $g(w)$ for BEVI, it appeared that the value of w where $g(w)=0.1$ is approximately 30m. This would have eliminated a large number of detections, leaving far fewer than 100 detections to model. Thus, I opted for truncating 10% of the BEVI detections, which included all observations over 70m. For the BEWR's preliminary model of $g(w)$, the value of w where $g(w)=0.1$ is approximately 26m. This would have eliminated a large number of detections, leaving far less than 100 detections to model. If 10% of the data were truncated, consisting of the farthest detections, all observations over 60m would be eliminated. Looking at the fit of the model with data truncated at 60m it appeared that it would improve the fit if more of the farthest distances were truncated. So I selected the truncation point based on the maximum that could be truncated while still retaining over 100 detections to model. Using this criteria I truncated the data at 40m. For LUWA, truncating 10% of the detections would have resulted in truncating at 60 m. I then looked at a preliminary model of $g(w)$, and it appeared that the value of w where $g(w)=0.1$ is approximately 27m. Truncating at this distance left

248 records to use in modeling and the fit of the curve seemed better, so I selected this truncation distance for modeling the data.

When modeling distance data to estimate detection functions and density, it is the fit of the model to the distance data near the point that is most important (Buckland et al. 1993). This process is iterative; usually analysis will suggest additional exploratory work. "For example, it may become apparent that the fit of one or more models could be improved by selecting a different truncation point *w*, or by grouping ungrouped data, or by changing the choice of group intervals for grouped data" (Buckland et al. 1993). I analyzed the data using this iterative process; by determining the truncation point for each species' dataset, examining the fit of the model using other truncation distances, and looking at a variety of ways to group the data for a good fit of several robust models to the data. I determined the appropriate truncation point and grouped the data using various cutpoints for each species. Having determined the truncation distance and the grouping of the data into intervals, I then analyzed the data using a series of robust models as suggested by Buckland et al. (1993).

XI.C.1. Bell's Vireo

The results of these analyses for the BEVI are shown in Table X-1. The Akaike's Information Criterion (AIC) provides a quantitative method for model selection (Buckland et al. 1993). Based on the AIC values, the Hazard Rate Simple Polynomial (HRSP) model and the Hazard Rate Cosine (HRC) model are equally appropriate models. In fact, the results are identical for these two models.

Goodness of Fit is another useful tool for model selection (Buckland et al. 1993). If model selection was to be based on the Goodness of Fit results alone the HRSP model and the HRC model would again be selected. Additionally, the detection curve is not excessively spiked under this model (Figure X-2). So, after evaluating the adequacy of the various models, I selected the HRSP model to fit the BEVI distance data, truncated at 70 m. to fit the detection function and estimate BEVI density (Figure X-3). The density estimate using this model is 14.03 individuals per hectare; the 95% confidence interval is 9.45-20.82, with a coefficient of variation of 20.2 percent (Table X-1).

XI.C.2. Bewick's Wren

The results of these analyses of the BEWR dataset are shown in Table X-2. Based on the AIC values, the Hazard Rate Simple Polynomial (HRSP) model and the Hazard Rate Cosine (HRC) model are equally appropriate models. In fact, the results are identical for these two models. If model selection was to be based on the Goodness of Fit results alone the Half-normal cosine is only slightly better. Also, in isolation, this approach has severe limitations for choosing a model detection function; selecting the model based on the lowest AIC value is recommended (Buckland et al. 1993). Additionally, the detection curve is not spiked under the HRSP model (Figure X-4). So, after evaluating the adequacy of the various models, I selected the HRSP model to fit the BEWR distance data, truncated at 40 m, to fit the detection function and estimate BEWR density (Figure X-5). The density estimate using this model is 23.05 individuals per hectare; the 95% confidence interval is 12.06-44.04, with a coefficient of variation of 33.6 percent (Table X-2).

XI.C.3. Lucy's Warbler

The distance data for LUWA and the results are shown in Table X-3. Based on the AIC values, the Hazard Rate Simple Polynomial (HRSP) model and the Hazard Rate Cosine (HRC) model are equally appropriate models. If model selection was to be based on the Goodness of Fit results alone the HRSP model and the HRC model would again be selected. Additionally, the detection curve is not excessively spiked under these models (Figure X-6). So, after evaluating the adequacy of the various models, I selected the HRSP model to fit the LUWA distance data, truncated at 27 m, to fit the detection function and estimate LUWA density (Figure X-7). The density estimate using this model is 47.78 individuals per hectare; the 95% confidence interval is 34.16-66.82, with a coefficient of variation of 17.2 percent (Table X-3).

XI-D. Conclusions

It must be emphasized that these results are not reliable based on the fact that the points were non-randomly placed. It is likely that that they overestimate density for each of the species. Also, this data should be stratified by observer and by other variables that take into account probable gradients in density across habitats, and differences in detectability. Undoubtedly, if a larger sample size could have been obtained, along with stratification by observer and perhaps habitat, river mile, or patch size, I could have reduced the variability associated with these estimates.

The basic conclusion of this analysis of distance estimation is that relatively few species can be analyzed by the method in the Grand Canyon region. Only 3-4 species are common enough to meet the minimum population size criterion. Most of the species in the study area were not common enough for the method to be applied. However, as part of a larger monitoring program, such as riparian habitat at the state level, the distance estimation method may be applicable to more species. The peculiarities of working in a long narrow ribbon-like system, with relatively low sample sizes, and complex and interconnected riparian and upland habitats, may preclude extensive use of distance estimation of population abundances in many riparian communities.

Table X-1. Results of analyses of BEVI distance data. The models listed include the combination of Key Function and the Adjustment Term used for each analysis.

Model	X^2 (df)	p-value	AIC	Density Estimate	Log-based 95% confidence interval	% Coef. of Variation
Hazard Rate Simple Polynomial	5.71 (8)	0.68	513.47	14.03	9.45 - 20.82	20.2
Hazard Rate Cosine	5.71 (8)	0.68	513.47	14.03	9.45 - 20.82	20.2
Half-normal Cosine	6.38 (8)	0.61	514.33	16.82	12.02 - 23.52	17.1
Uniform Cosine	6.27 (7)	0.58	516.46	14.43	10.68 - 19.50	15.3
Half-normal Hermite	15.79 (8)	0.05	522.70	11.61	8.54 - 15.77	15.6
Uniform Simple Polynomial	19.86 (7)	0.01	531.46	9.194	6.78 – 12.46	15.4

Table X-2. Results of analyses of BEWR distance data. The models listed include the combination of Key Function and the Adjustment Term used for each analysis.

Model	X^2 (df)	p-value	AIC	Density Estimate	Log-based 95% confidence interval	% Coef. of Variation
Hazard Rate simple polynomial	4.81 (5)	0.44	438.68	23.05	12.06 – 44.04	33.6
Hazard Rate cosine	4.82(5)	0.44	438.68	23.05	12.06 – 44.04	33.6
Half-normal Cosine	4.75 (5)	0.45	438.75	19.64	12.79 - 30.17	22.0
Uniform cosine	7.32 (5)	0.20	440.82	15.13	10.78 - 21.24	17.31
Half-normal hermite polynomial	10.71 (6)	0.10	441.52	13.36	9.74 – 18.31	16.1
Uniform simple polynomial	14.32 (5)	0.01	446.04	10.97	8.15 - 14.76	15.1

Table X-3. Results of analyses of LUWA distance data. The models listed include the combination of Key Function and the Adjustment Term used for each analysis.

Model	X^2 (df)	p-value	AIC	Density Estimate	Log-based 95% confidence interval	% Coef. of Variation
Hazard Rate simple polynomial	.5872 (2)	0.75	771.35	47.78	34.16 - 66.82	17.2
Hazard Rate cosine	.5872 (2)	0.75	771.35	47.78	34.16 - 66.82	17.2
Uniform cosine	1.2249 (2)	0.54	772.01	56.09	41.73 - 75.38	15.1
Half-normal hermite polynomial	4.2659 (3)	0.23	773.00	48.36	37.89 - 23.52	17.1
Half-normal Cosine	4.2659 (3)	0.23	773.00	48.36	37.89 - 23.52	17.1
Uniform simple polynomial	0.9208 (1)	0.34	773.69	53.95	38.38 - 75.84	17.5

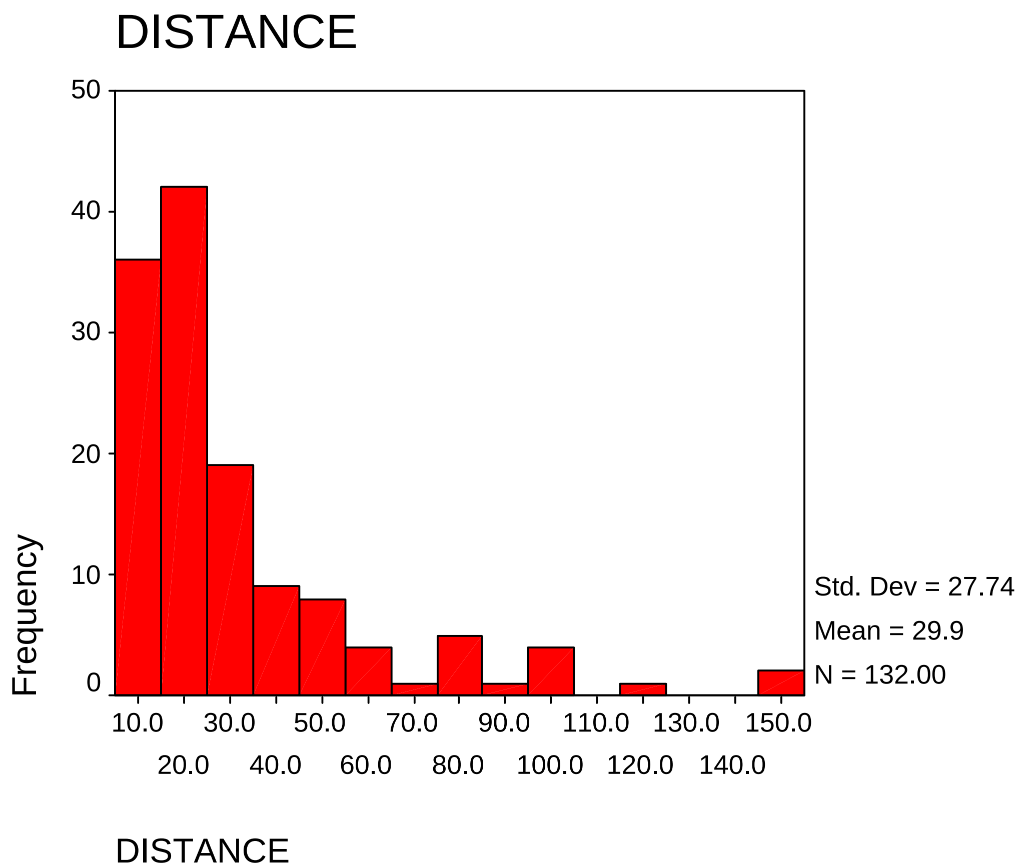


Figure X-1. Histogram of the untruncated Bell's Vireo (BEVI) data.

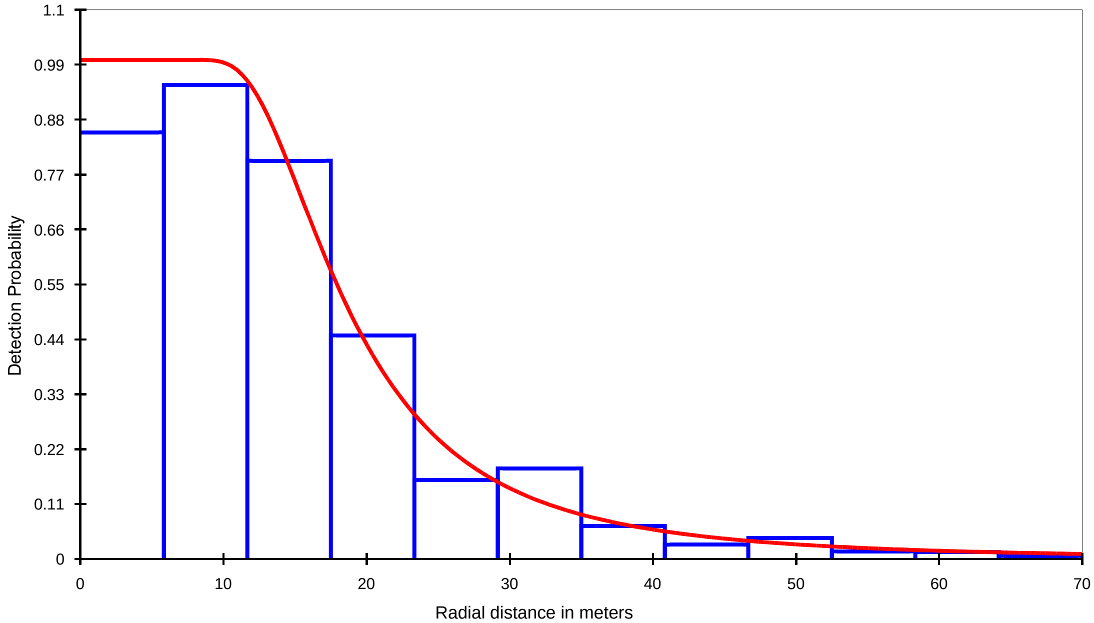


Figure X-2. The fitted detection function for the Hazard Rate Simple Polynomial model fitted to the Bell's Vireo (BEVI) data truncated at 70m.

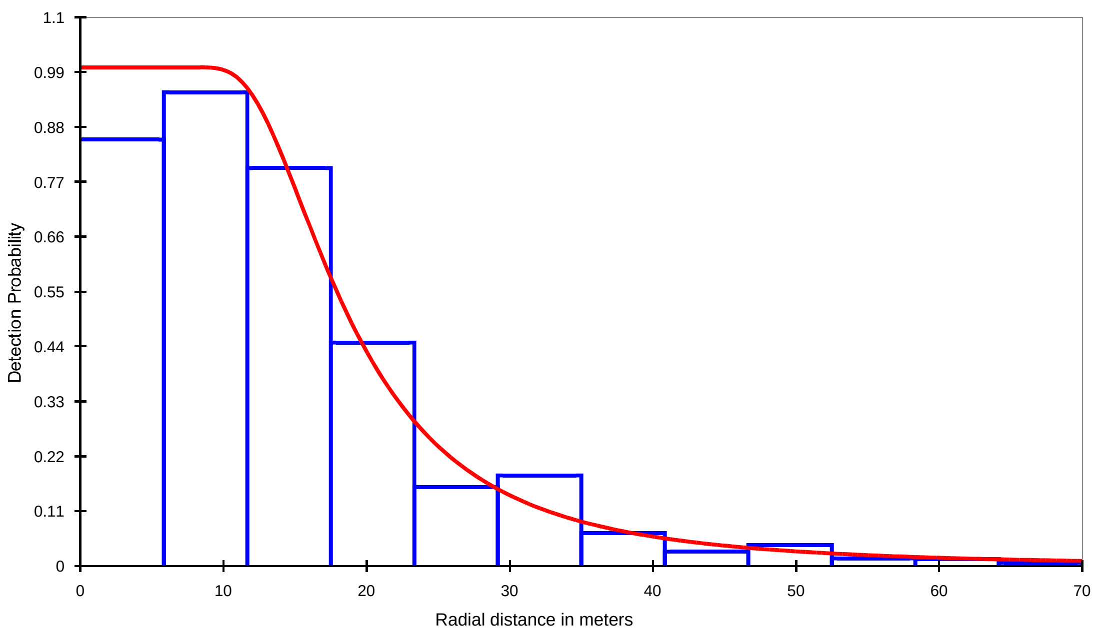


Figure X-3. The fitted detection function for the Hazard Rate Simple Polynomial model fitted to the Bell's Vireo (BEVI) data truncated at 70 m.

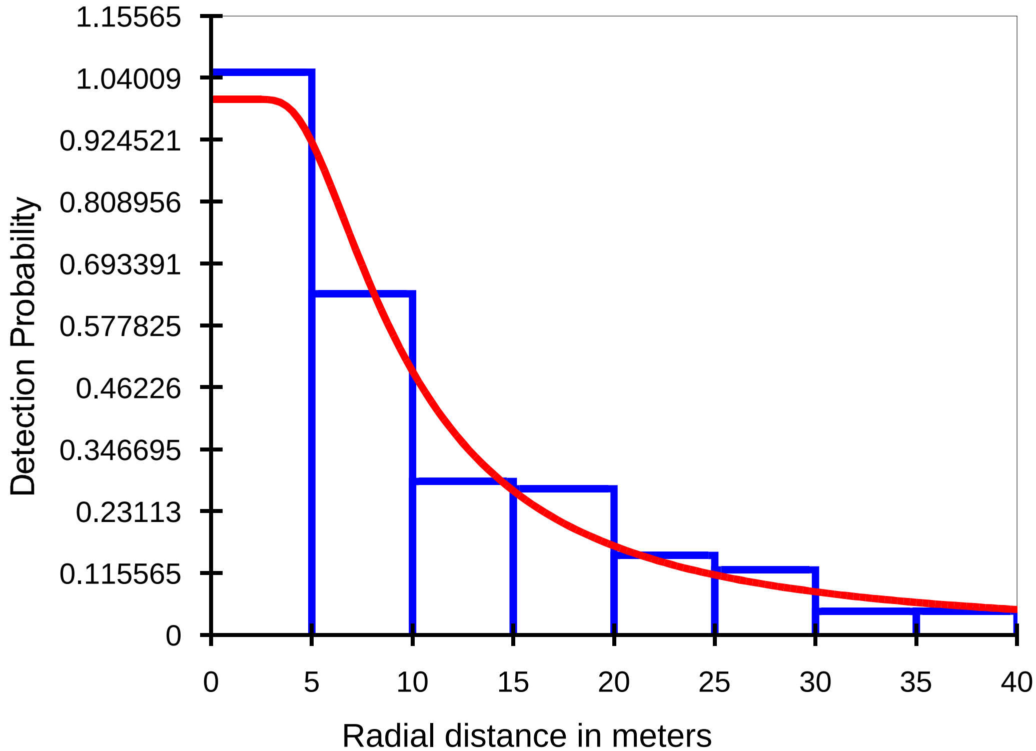


Figure X-4. The fitted detection function for the Hazard Rate Simple Polynomial model fitted to the Bewick's wren (BEWR) data truncated at 40 m.

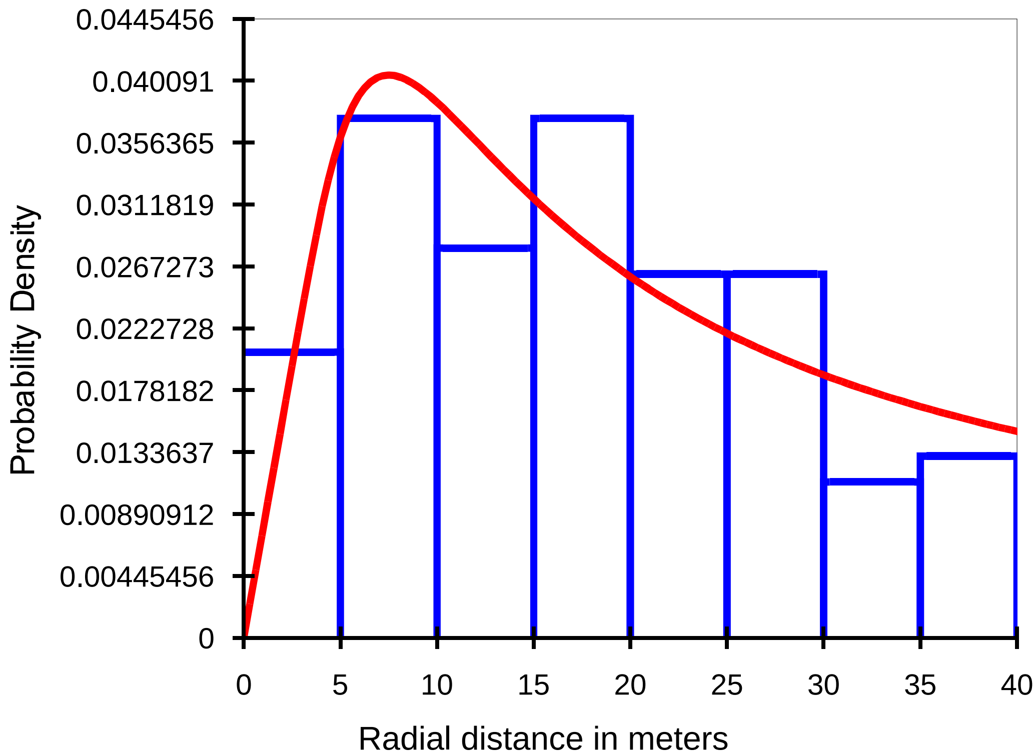


Figure X-5. The fitted detection function for the Hazard Rate Simple Polynomial model fitted to the Bewick's wren (BEWR) data truncated at 40 m.

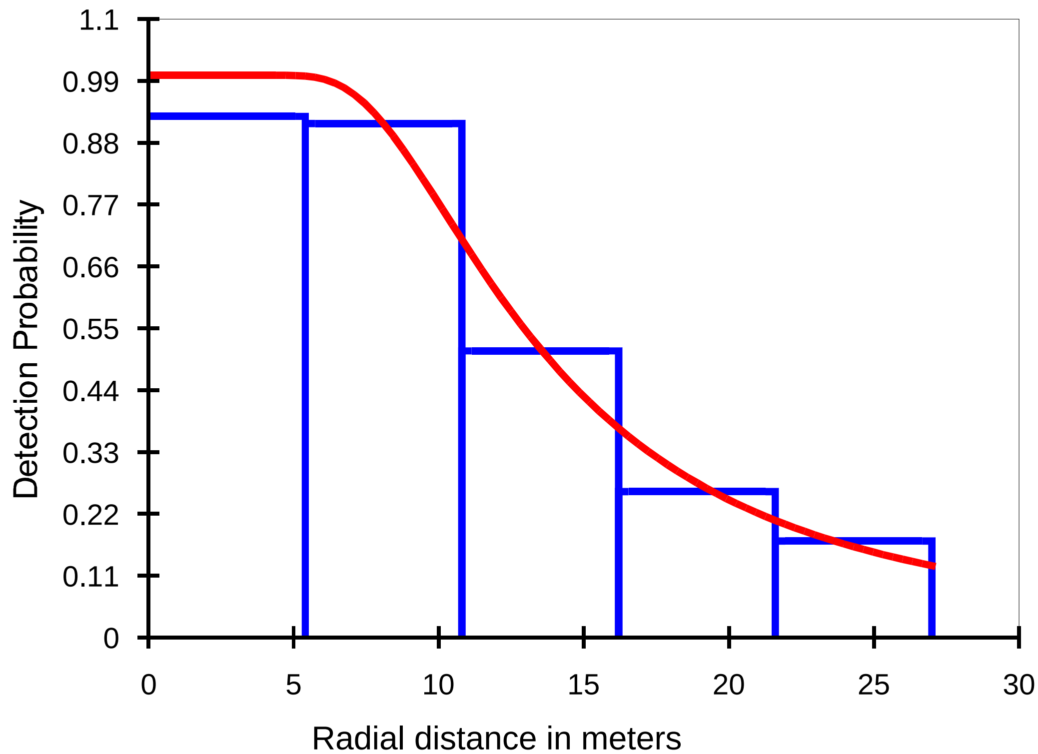


Figure X-6. The fitted detection function for the Hazard Rate Simple Polynomial model fitted to the Lucy's warbler (LUWA) data truncated at 27 m.

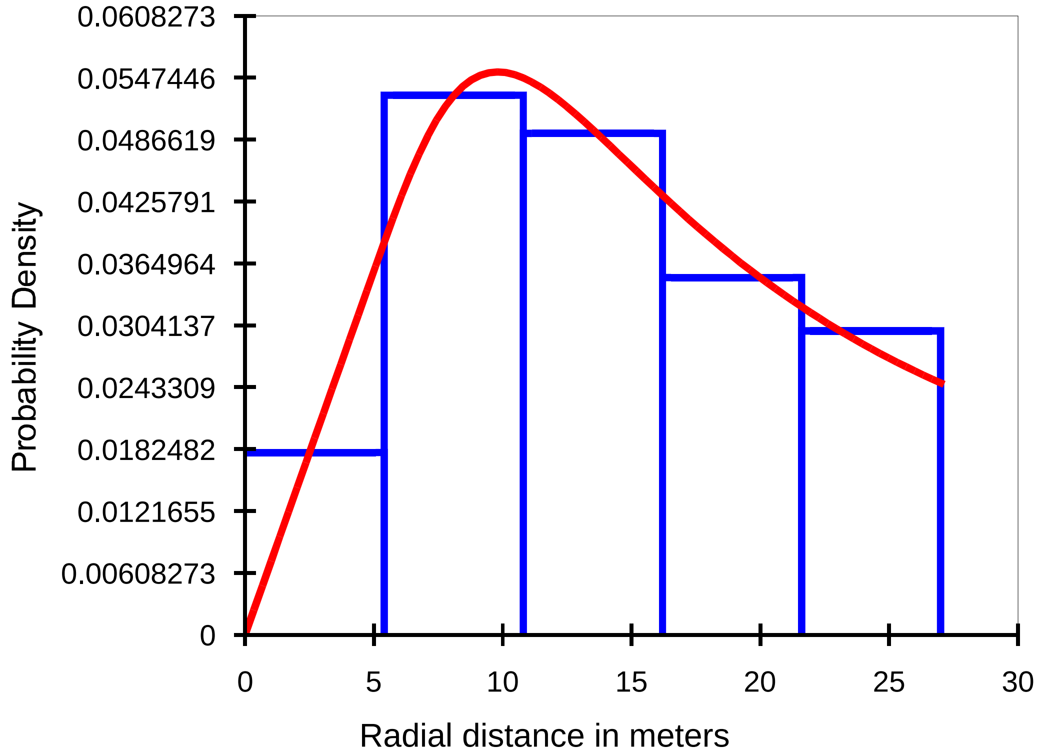


Figure X-7. The fitted detection function for the Hazard Rate Simple Polynomial model fitted to the Lucy's warbler (LUWA) data truncated at 27 m.

CHAPTER XI: NEST MONITORING AND SEARCHES (Jennifer A. Holmes)

A goal of this project is to make recommendations for long-term monitoring of the breeding avifauna of Glen and Grand Canyons. Despite the fact that conservation of bird populations, and biodiversity in general, depends on identification and conservation of habitat conditions that support self-sustaining populations of coexisting species, the breeding biology and habitat information required to make informed conservation decisions is lacking for most species (Martin and Geupel 1993). Detecting avian population trends, (i.e. whether a population is stable, decreasing, or increasing), using only indices of relative abundance such as point count data, can be problematic. Breeding productivity and survival need to be directly monitored to determine self-sustaining (source) and non-self sustaining (sink) populations (Martin 1995). Furthermore, identification of source and sink populations, and the habitat conditions that produce such populations, can provide direct information on habitat conditions required to maintain healthy populations and, thus, can guide management actions (Martin 1995, Hutto and Young 2002). Considering the potential value in monitoring breeding productivity, during the 2000 breeding season surveys, I assessed the feasibility of monitoring breeding productivity in the riparian patches along the river. Specifically, I wanted to determine if it was possible to easily acquire an adequate number of nests with which to monitor productivity. In general, about 20 nests (per species and habitat of concern) are needed for an accurate estimate of nesting success (Martin and Geupel 1993, Hensler and Nichols 1981).

We conducted nest searches of all species in three patches to get an indication of possible sample sizes. Nest-searching involved mostly untrained volunteers, with the help of a few experienced biologists on each trip. Despite the limited number of searchers, and the limited hours spent searching, 148 nests of 15 species were found (Table XI-1).

The number of nests found per species roughly reflects the emphasis placed on each species while nest-searching. For instance, I was particularly interested in finding the nests of those species that have been known to nest in both the OHWZ vegetation and NHWZ vegetation. Thus, the surveyors preferentially followed these species. Also, it is important to note that the greater number of nests found in OHWZ versus NHWZ vegetation is likely due, in large part, to the greater availability of NHWZ vegetation.

Of the species listed in Table XI-1, the Lucy's Warbler, which ranks 12th on the "Prioritization List of Arizona's Breeding Native Terrestrial Birds" in the Arizona Partners in Flight Bird Conservation Plan (Latta et al. 1999), is of particular interest. Throughout its limited distribution, it breeds most often in lowland riparian mesquite woodlands (Johnson et al. 1997), a declining habitat type in Arizona (Latte et al. 1999). Yet, it had also been known to nest in tamarisk (salt cedar). In the Grand Canyon the surveyors found that Lucy's Warblers use tamarisk extensively for nesting, especially older stands. In fact, 53% (out of 58 total) of the Lucy's Warbler nests found were located in the Tamarisk that now constitutes much of the NHWZ vegetation. Furthermore, of all the North American wood warblers it is probably the least known, despite the fact it breeds in some of the densest concentrations of any noncolonial nesting species in North America (Johnson et al. 1997). In fact, the highest reported density of Lucy's Warblers, (94.1 nests/ 40 hectares), was at Cardenas Marsh on the Colorado River (1982-1994; Johnson et al. 1997), which was one of our nest-searching sites. Because of this species' high density, the team found more than the suggested minimum of 20 nests in both the NHWZ and the OHWZ. Thus, it is a prime candidate for effectively monitoring productivity in the two habitats, determining whether each constitute source or sink habitats, and, consequently, providing direct information on habitat conditions needed to maintain healthy populations. As Sogge et al. (1998) state, "Though this species was the most abundant we found in the canyon, it should be a candidate for long-term population monitoring". It could be a species of future concern for several reasons. It has relatively small geographic range, occurring only in the southwestern U.S. and northern Sonora, Mexico. It is a habitat specialist of heavily impacted riparian habitat, and is further specialized by its close association with mesquite. It is on the edge of its range in the canyon, a place where the future of riparian mesquite habitat is in question under current dam management (Anderson and Ruffner 1988). Whether it can sustain its numbers while nesting and foraging in a new riparian plant community remains to be seen."

This pilot study indicated that it is possible to obtain adequate sample sizes with which to monitor nest success. Yet, to adequately monitor nest success and determine source and sink habitats, the status of individual nests needs to be checked every 3-4 days to determine if it is still active or has failed and to calculate nest success rates (Martin and Geupel 1993, Mayfield 1975). For these reasons nest monitoring and estimating nest productivity are logistically constrained along the Colorado River ecosystem, mainly due to the numbers of days required at each site to determine nest success.

Table XI-1. Number of nests in new high water zone (NHWZ), old high water zone (OHWZ), and rock walls per species along the Colorado River is selected riparian patches.

SPECIES	OHWZ	NHWZ	ROCK WALL	TOTAL
Black-chinned Hummingbird	2	23	0	25
Ash-throated Flycatcher	1	1	0	2
Common Raven	0	0	1	1
Bewick's Wren	0	6	0	6
Blue-gray Gnatcatcher	9	5	0	14
Phainopepla	1	1	0	2
Bell's Vireo	3	5	0	8
Lucy's Warbler	21	31	6	58
Yellow Warbler	1	11	0	12
Common Yellowthroat	0	2	0	2
Yellow-breasted Chat	0	12	0	12
Summer Tanager	0	1	0	1
Blue Grosbeak	0	2	0	2
Hooded Oriole	0	2	0	2
House Finch	0	1	0	1
Total	38	103	7	**148**

PART C: CONCLUSIONS AND RECOMMENDATIONS

CHAPTER XII: CONCLUSIONS

This chapter summarizes the principal findings of the previous seven results chapters. Summaries and conclusions are presented for each chapter, conceptual models are presented for bird communities, and then integrated. Finally, comparisons are made with other regional and southwestern riparian bird community research conducted in the Colorado River Basin.

XII.A. Winter Aquatic Birds

The aquatic bird community along the Colorado River from Glen Canyon Dam to Lake Mead is a dynamic assemblage of species that appear to be primarily responding to river gradients of turbidity and primary and secondary productivity. Imposed on this pattern are year to year differences in overall numbers presumably resulting from climate and breeding success to the north of the study area on the principal breeding grounds of the aquatic species, as well as overall productivity and climate conditions within the study area. Despite the unpredictable changes in abundance from year to year, there is an fairly stable and predictable assemblage of species that occur every winter, in addition to a larger set of rare species that cannot be predicted to occur every year, or even every several years (cf. LaRue et al. 2001b). Currently, it is not known where the wintering birds come from, although it is likely that many are from breeding and staging areas such as Bear River Bird Refuge in northern Utah and adjacent portions of other states, directly north of the Colorado River and study area. Some bird populations on the river may interact with and move between other wintering groups on Lake Powell and upriver portions of the Colorado River as well (cf. Spence 1998). This aquatic bird community clearly developed as a response to the presence of Glen Canyon Dam and its consequences in down river productivity (Stevens et al. 1997; Spence and Bobowski 2003).

Aquatic wintering birds are overall a good indicator of aquatic productivity of the Colorado River, with certain exceptions such as American wigeon and Canada goose that can successfully over-winter in urban areas such as golf courses. Two primary foraging guilds are represented, diving species that consume primarily fish and invertebrates within the water column or on the river bed, and dabbling species that forage in cobble bars and shallower areas where they can reach aquatic vegetation and its associated invertebrates. Dam operations can have both direct and indirect effects on these two guilds. Direct effects can occur through water releases that either cover or open up foraging beds for dabbling species, or change the distribution of prey species (small fish) in the water column of the river. Also, at higher discharges river currents increase in velocity, and probably increase foraging costs by species in both guilds. Indirect effects include longer-term changes in primarily and secondary productivity as a result of discharge regimes over periods of months or years, as well as scouring and sedimentation by controlled floods.

A conceptual model for the winter aquatic bird community was developed (Figure XII-1) showing some of the principal drivers and responses. For convenience and because of the focus of this study on the effects of dam operations, anthropogenic influences are grouped into two drivers, dam operations and all other anthropogenic disturbances (hunting, habitat loss, recreation, etc.). For clarity and simplicity, this and the other models presented below do not show cross-linkages at the same level. In addition to human-related drivers, climate is considered the other major driver. More direct stressors include hunting, recreation activities, the presence and spread of exotic aquatic species, wet/dry climate cycles, winter climate conditions, and dam releases. Five principal responses or processes are included, harvest of waterfowl, overall bird productivity, migration dynamics, aquatic productivity, and river water levels. These in turn produce as outcomes the abundance and composition of the aquatic bird community and some specified place and/or time, and the resource base in the Colorado River itself. From these community-level structures, metrics can be developed for monitoring purposes.

In addition to dam operations effects, bird productivity on the breeding grounds, and weather conditions (storms, winter severity) that affect migration patterns, also influence the aquatic bird community in the study area. The spread of exotic species such as the New Zealand mud snail, which will have unknown but potentially severe consequences for primary and secondary productivity in the river, can also affect aquatic birds. Water releases from the dam also have direct consequences on the aquatic community (Spence 1996a; unpublished data) as birds are forced to move within the river corridor or to leave it entirely. Local storms that increase river turbidity can also directly affect foraging success for diving species. All these factors interact in complex ways in determining the composition and abundance of the winter aquatic community in the study area. Despite this, there are direct links between dam operations and aquatic birds through effects on primary and secondary productivity, both for the winter community as well as breeding species. Thus the aquatic birds of the Colorado River may be a useful resource to monitor as part of the Grand Canyon Monitoring and Research Center's mandate. Since >50% of the birds occur at or above Lee's Ferry in a typical winter, this resource group can be easily monitored. Power analysis tests will need to be developed to determine how to structure any future monitoring program.

XII.B. Winter Terrestrial Birds

The winter terrestrial bird community in the study area is more diverse than the breeding bird community. During the six surveys between 1998 and 2000 75 species of bird were recorded from patches of riparian vegetation in the study area. These included several species new to the region or to the winter season in the Grand Canyon (Appendix B; LaRue et al. 2001b). There were many surprises, such as the presence of several rail species, *Empidonax* flycatchers, Hutton's vireo, prairie warbler, and streak-backed oriole. In the mild winters of the study period (1998-2000), several species that typically do not over-winter in the region were found, such as house wren, blue-gray gnatcatcher, hermit thrush, common yellowthroat and fox sparrow.

Despite high year to year variability in some species, and the unpredictable occurrence of many rare species, there appears to be some predictable aspects to the winter bird community. There were significant similarities between breeding and wintering communities as revealed by MRPP analysis and the Mantel's test, and with vegetation structure as well. Winter birds using the riparian habitat along the Colorado River appear to be responding to the same habitat variables as the breeding birds are, although the relationships were overall somewhat weaker based on the multiple stepwise regression results. Groups of winter species reflected to a large extent the location of patches, with a group of species encountered primarily in the lower canyon, a second group primarily in Marble Canyon patches, and a third group most common in the Glen Canyon reach. Hence, in addition to the presence of a fairly predictable group of winter resident species, there is also significant abundance and compositional differences at the reach level in the winter bird community within the study area.

Winter terrestrial birds are strongly influenced by a variety of factors outside the study area. The principal ones are presented in a conceptual model for the winter bird community in Figure XII-2. The principal effects of dam operations act through changes in riparian habitat and the resource base, including insects, seeds and fruits. In addition, other anthropogenic disturbances and climate also affect the composition of the winter terrestrial bird community in the study area. Principal disturbances include habitat changes or loss, either on the breeding grounds or during migration, and study area recreation (primarily above Lee's Ferry). Climate plays a major role, either directly through over-wintering survival within the study area, or through impacts on breeding and migratory habitat. Responses can include changes in bird survivorship rates or changes in migration patterns. There is currently few data available that can be used to more firmly establish the linkages between dam operations and responses within the model. Spence (1996a) noted that winter bird numbers dropped significantly during and after the 1996 controlled flood in the Glen Canyon stretch, at a time prior to the primary period of outward migration in later April and May.

There is adequate power to detect change in several winter bird species in the study area. However, three years of data are probably insufficient to characterize the variability in winter bird abundance, and additional surveys would provide a better picture of year-to-year variability in the study area. In the past, emphasis has been placed on breeding bird communities within the study area, as well as elsewhere in North America. However, *a priori*, there is no reason why over-wintering bird communities are somehow of "lesser" significance to NPS management. Part of the lack of data may be because there are problems associated with the development of objective and effective protocols to monitor winter birds, particularly since point count methods are unlikely to pick up quiet or non-vocalizing species. However, point counts have been used to census winter birds (e.g., Avery and van Riper 1989; White et al. 1996).

XII.C. Riparian Breeding Birds

The riparian breeding bird community along the Colorado River between Glen Canyon Dam and Diamond Creek appears not to have changed appreciably in species composition since studies were initiated in the early 1980's. The relative ranking for most species also appears not to have changed much, except perhaps for black-chinned hummingbird and blue-gray gnatcatcher. Beyond this, there is little that can be done to compare the data of Brown (1987, 1989) and Sogge et al. (1998) with the current study. Differences in bird sampling methods, the particular patches sampled, and overall sample size considerations make comparisons difficult if not invalid. Although it could have been argued that the method used by Brown (1989) should have been used in the present study, power analyses clearly indicate that the sample size of the earlier program (10 patches) was unlikely to have sufficient power to detect change in any species.

Considerable variation in abundance existed for most species within the study area in both time and space. At least one significant month or year difference was found for species richness, total bird abundance, and all individual species except Bell's vireo, Bewick's wren, brown-headed cowbird, Lucy's warbler and song sparrow. Most species also showed significant differences in abundance in different reaches of the river corridor. All these differences will have a tendency to confound any analysis of trends and within-study area distributions for long-term monitoring. Both temporal and spatial variability will have to be factored into any predictive equations relating time, habitat data, and bird data.

The power analyses indicated that there was not sufficient power at reasonable levels of α and β to detect change in 24 of 32 riparian species. Eight of these species, black phoebe, cliff swallow, northern mockingbird, black-headed grosbeak, lazuli bunting, indigo bunting, red-winged blackbird, and willow flycatcher, however, were extremely rare and were not detected every year. Two additional species, northern rough-winged swallow and crissal thrasher, were not detected at all between 1996-2000 on breeding bird survey trips. There remains a group of 14 species that occurred every year in the study area but that were too rare to monitor using point counts, mourning dove, Costa's hummingbird, brown-crested flycatcher, bushtit, blue grosbeak, common yellowthroat, yellow warbler, phainopepla, song sparrow, Bullock's oriole, hooded oriole, great-tailed grackle, brown-headed cowbird, and lesser goldfinch. A few of these may be successfully monitored if certain parameters of the power tests are relaxed, particularly yellow warbler and song sparrow, but most remain too rare to monitor.

There were only eight species for which power was adequate to detect change, black-chinned hummingbird, ash-throated flycatcher, Bewick's wren, Bell's vireo, blue-gray gnatcatcher, Lucy's warbler, yellow-breasted chat, and house finch. The number of patches and years needed to detect change varied from 20 patches over five years for Lucy's warbler to 10 years and 40 patches for blue-gray gnatcatcher. Because so few species can be effectively monitored with the current monitoring protocol of 40-60 patches sampled three times a year, changes in the program protocols may be needed if the National Park Service and GCMRC decide that more of the bird community in the study area needs to be represented. There are several ways this can be done (see below and Chapter XIII). One possibility is to combine species into guilds based on some criterion such as ecology or range. An example is shown in Figure XII-4, where the bird data have been combined into two guilds, neotropical migrants that winter primarily south of the US-Mexico border (10 species), and short distance migrants or residents that primarily winter in the region or to the south in Arizona (six species). Combining the breeding bird data in this manner will greatly improve the statistical power in the program, albeit at a loss of species-level resolution. As can be seen in Figure XII-4, there were no significant trends in detection rates since 1995 in the study area for either guild (the slopes of the regressions were not significantly different from zero).

A preliminary conceptual model for the breeding riparian terrestrial bird community is presented in Figure XII-3. As in the other two models, three primary drivers are identified, dam operations, other anthropogenic effects, and climate. Although other major drivers could be included (e.g., major flooding and mass-wasting events), they tend to be strongly correlated with climate events, and have been subsumed under the climate driver as a linkage from climate to habitat dynamics. Six major stressors are identified, study area recreation, breeding habitat (vegetation) dynamics, migratory habitat changes, winter habitat climate, winter habitat changes, and dam releases. These in turn produce responses in migration dynamics, bird productivity, breeding habitat food base, and breeding habitat quality and extent (including changes in exotics). Three indicator groups are identified, breeding bird abundance, resource base (seeds, fruits and insects), and habitat structure.

As can be seen from the above model, breeding bird abundance within the study area is affected by numerous other variables outside the study area. Principal among these are winter and migratory habitat changes and winter habitat climate, which can strongly influence bird survivorship. Dam operations affect birds primarily through effects on breeding habitat and impacts to recreation. Under normal ROD operations, these impacts are likely to be fairly minor compared with climate and habitat changes outside the Colorado River corridor. The major impacts of dam operations are the planned or unplanned floods, including those in 1983 and 1996. These floods can scour out much of the riparian vegetation in the study area. Past flooding, particularly that in 1983, may explain many of the differences found in the breeding bird communities between the mid-1980's and the present study, as riparian vegetation extent was much reduced after the 1983 event.

This conceptual model is very preliminary. Future work may reveal additional linkages and stressors, or indicate that some of those identified in the model need to be revised or broken into more than element. Also, work on sub-models for vegetation succession, spread of exotic species, predation, cowbird parasitism, differences in prey bases and bird foraging strategies, and other potentially important variables should be developed.

XII.D. Riparian Habitat

Using the TVV method, riparian vegetation was adequately sampled from xx patches between Glen Canyon Dam and upper Lake Mead. Good power also exists in the TVV data, with changes as small as 1% detectable over a period of 3 or more years. The use of TVV data by species also allowed some modeling to be done in terms of species preferences in habitat characters and plant species. This adds to the considerable amount of information already available on habitat-bird relationships in the study area developed by Sogge et al. (1998). There currently is sufficient data to develop predictive models of species presence and relative abundance for many species along the river corridor.

One un-anticipated result was that both the breeding bird community and wintering bird community appeared to be responding to the same set of vegetation variables. This should be explored further, as the MRPP and Mantel's tests remain quite preliminary. *A priori* there is no reason why such strikingly different bird communities should be responding to the same habitat relationships, as the two assemblages differ substantially in habitat needs, including requirements for food and shelter, and additionally in appropriate nesting structure for breeding birds.

XII.E. Power Analyses

This summary focuses primarily on the power tests themselves, and the various ways that power could be improved in the bird monitoring program. Because power is inadequate for many bird species in the study area, changes in either the monitoring protocols or in the power analysis parameters are needed if there they are to be monitored.

<u>XII.E.1. Changes in the Monitoring Protocols</u>

Increasing the number of surveys per year would increase statistical power. This program sampled breeding birds three times a year, winter terrestrial birds twice a year, and aquatic birds twice a year. Increasing the number of trips, however, will greatly increase logistics costs for GCMRC.

The number of patches sampled on a trip could be increased over the typical 45-60 patches that were visited per trip in the past. One problem with doing this, however, is that in order to sample enough patches in the morning either a sport boat would be needed, or the number of bird teams would need to be increased to two. If only point counts were done, and two surveyors with two boats were available, many more patches could be sampled each day.

Another promising way to increase power in the program is to focus on groups of species such as ecological or migratory guilds. Although one would lose species-specific information that may be of interest to NPS management or the GCMRC program, the power of the program is likely to increase significantly. An example of this was shown in section XII.C above for breeding birds.

In this study mean bird detection rates averaged over several years were used. An alternative approach, used by Sogge et al. (1998), is to select highest counts for individual species, perhaps averaged across years. One problem with this approach is that, depending on the time of year, young of year may be counted as well as territorial adults. This confounds the analysis for breeding birds because it combines adults with yearly bird productivity, thus inflating values. Careful observations while in the field, however, may alleviate this problem to some extent. Experienced observors can often identify birds to age by behaviour and plumage characteristics.

By selecting a larger effect size, adequate power may be obtained. Change of only 1-5% can be detected for very few species in the current program. Larger effect sizes of 10%-20% or more could be used. However, a bird population that is declining by 20% a year is likely to be in serious trouble in a very short time because of the magnitude of the change. In these cases monitoring may be too late for management decisions that could potentially reverse such a decline.

At longer time-frames of 10-15 or more years power will increase to the point that many bird species in the study area could be effectively monitored using some form of the current monitoring design. Such long-term commitments of time and resources are still rare in bird ecology, although the NRC has long advocated just this for the Adaptive Management Program (NRC 1987, 1996, 1999).

XII.E.2. Changes in the Power Analysis Parameters

Depending on how the long-term monitoring program is to be structured by the NPS and the GCMRC program, power tests could be conducted under a different set of parameters. First, power would improve considerably if a one-tailed test is used rather than a two-tailed test. If declines are of more concern that increases, testing the null hypothesis of no declines using a one-tailed test may be appropriate.

Values of beta and alpha could also be manipulated to change power, although doing so depends strongly on the contrasting costs and benefits of type I and type II errors and their consequences in bird monitoring within the study area.

XII.F. Distance Estimation of Breeding Birds

Distance estimation has recently been advocated as the primary monitoring method for breeding birds by the National Park Service Inventory and Monitoring Program, among others (Fancy and Sauer 2000). The basic methodology and assumptions can be found in Buckland et al. (2001). Distance estimation was used in 2000 to determine whether it would be a useful method in the Grand Canyon region. However, because of previous design of the program, samples were not randomly placed, thus violating one of the assumptions of distance estimation. Only three species were detected often enough to reach sample size criteria in the method; Lucy's warbler, Bell's vireo, and Bewick's wren. It is likely that if sampling had been done in the Glen Canyon stretch in 200, that house finch would also have met the sample size criterion.

The conclusion is that very few species in the river corridor can be monitored using distance estimation. The implementation of a random sampling design will probably not improve this situation, because of density gradients in bird populations. Random sampling will sample smaller patches that will likely decrease overall detection rates. However, with intensive enough sampling (>100 patches or "samples") it may be possible to develop reliable density estimates for the four most common species on the river corridor.

XII.G. Nest Searches

Nest searches have been conducted in the study area since the early days of GCES I (Brown 1994), and are fairly large data set has been collected. These data need to be synthesized and perhaps extended through additional research (see Chapter XIII. Recommendations). However, its use as a monitoring tool is logistically and financially prohibititive. In order to determine nest success, parasitism rates, and productivity nests would have to be monitored much more often than once a month, and probably at least once every 3-4 days. Thus crews would need to camp at individual sites for most of the breeding season.

XII.H. Comparisons with Other Riparian Bird Programs

The principal studies of breeding birds and wintering birds in riparian vegetation along the Colorado River include Brown (1989), Rosenberg et al. (1991), Fagan (1994), Sogge et al. (1998), Dickson et al. (2000) and LaRue et al. (2001a; unpublished data). Quantitative information is available from most of these studies. Comparisons between seven regional breeding season riparian bird communities are made in Table XII-1, based on the above studies. Sites include two canyons each in Arches NP, Canyonlands NP, and Natural Bridges NM, side canyons off of Lake Powell in Glen Canyon NRA, the Escalante River riparian zone within Glen Canyon NRA, the current study, and the lower Colorado River Valley from Lake Mead to Yuma.

Natural Bridges NM sites were the highest in elevation (>1800 meters), and this is reflected in the appearance of such as species as black-capped chickadee, house wren and orange-crowned warbler. Canyonlands and Arches riparian communities were very similar to those around Lake Powell, except for the occasional presence of species like plumbeous vireo and warbling vireo, and increased abundance of species like lazuli bunting, black-headed grosbeak and spotted towhee. Lucy's warbler becomes rare above Glen Canyon, at least in side canyons and smaller tributaries. The Escalante River is a large and well developed riparian zone, and supports a mix of species from the avifauna both above Lake Powell as well as below Glen Canyon Dam. It is characterized by extensive stands of *Populus fremontii*, and supports good populations of ash-throated flycatcher, Lucy's warbler, yellow warbler, yellow-breasted chat, blue grosbeak, Bullock's oriole, and lesser goldfinch.

The lower portions of the study area in the lower Grand Canyon show many similarities with the lower Colorado River Valley, including the presence of ladder-backed woodpecker, Costa's hummingbird, brown-crested flycatcher, Bell's vireo, crissal thrahser (mostly winter in the study area), summer tanager, song sparrow, and hooded oriole. A group of species also occurs that is restricted to the lower river valley, including verdin, black-tailed gnatcatcher, and northern cardinal. Some species, inexplicably, breed in the lower river valley in marshes associated with the river corridor but are only migrants or winter residents in the upper portions of the Colorado River riparian system, such as marsh wren, red-winged blackbird, and yellow-headed blackbird.

Much less is know about winter terrestrial bird communities in riparian zones along the Colorado River and in it's side canyons. Other than the current study, the only other local work is that of LaRue et al. (2001a), based on three years of inventory work on the bird communities at Glen Canyon NRA (NPS unpublished data). Also, extensive information is available for winter birds in the lower Colorado River Valley from Rosenberg et al. (1991). Ten canyons in the lower portions of the San Juan Arm of Lake Powell were surveyed using the area survey method in the winter of 1998. Results of these surveys, along with data from the current study and Rosenberg et al. (1991) are presented in Table XII-2. Principal differences between the tributary canyons off of Lake Powell and the Colorado River studies were the presence of chukar, juniper titmouse and western scrub-jay, all permanent residents of the rocky and narrow side canyons and their mix of riparian, Gambel's oak, and desert shrub communities. The Colorado River winter avifauna between Glen Canyon Dam and upper Lake Mead is strikingly similar to the lower valley, differing primarily in the rather inexplicable absence of red-naped sapsucker in the latter region, and the absence of pinyon jays and rarity of western bluebirds. The abundance of many winter species is much greater in the lower valley compared with the study area. Typically only a few individuals of species abundant wintering species such as Anna's hummingbirds, crissal thrashers Lincoln's sparrow and red-winged blackbird occur above Lake Mead.

Table XII-1. Characteristic terrestrial breeding riparian species from selected studies in the Colorado River Basin. C = common, U = uncommon, R = rare. NABR = Natural Bridges NM, ARCH = Arches NP, CANY = Canyonlands NP, GLTR = Glen Canyon NRA tributaries, CORI = Colorado River (study area), GCTR = Grand Canyon NP tributaries, LOVA = Lower Colorado River Valley.

Species	NABR[1]	ARCH[1]	CANY[1]	ESRI[2]	GLTR[2]	CORI[3]	GCTR[4]	LOVA[5]
Abert's Towhee	-	-	-	-	-	-	-	C
Anna's Hummingbird	-	-	-	-	-	R	-	U
American Robin	R	R	-	R	-	-	-	-
Ash-throated Flycatcher	C	C	C	C	C	C	C	C
Bell's Vireo	-	-	-	-	-	C	U	C
Bewick's Wren	R	R	R	R	C	C	C	U
Black Phoebe	-	-	-	R	R	U	U	C
Black-capped Chickadee	U	-	R	-	-	-	-	-
Black-chinned Hummingbird	U	U	C	C	C	C	C	C
Black-headed Grosbeak	R	R	-	U	-	R	R	-
Black-tailed Gnatcatcher	-	-	-	-	-	-	-	C
Blue-gray Gnatcatcher	C	U	C	U	U	C	C	-
Blue Grosbeak	-	C	R	C	U	U	-	C
Brown-crested Flycatcher	-	-	-	-	-	R	-	U
Brown-headed Cowbird	-	R	R	U	R	U	-	C
Bullock's Oriole	R	R	R	U	R	U	R	C
Common Yellowthroat	U	-	U	C	C	U	C	C
Costa's Hummingbird	-	-	-	-	-	R	R	R
Crissal Thrasher	-	-	-	-	-	R	-	C
Great-tailed Grackle	-	-	-	-	-	R	-	C
Hooded Oriole	-	-	-	-	-	R	R	U
House Finch	R	U	U	C	C	C	C	C
House Wren	R	-	-	-	-	-	-	-
Indigo Bunting	-	-	-	-	-	R	R	U
Ladder-backed Woodpecker	-	-	-	-	-	R	R	U
Lazuli Bunting	-	U	-	U	R	R	R	R
Lesser Goldfinch	-	U	U	C	U	U	U	-
Lucy's Warbler	-	-	R	U	U	C	C	C
Marsh Wren	-	-	-	-	-	-	-	C
Mourning Dove	U	C	C	C	C	U	C	C
Northern Cardinal	-	-	-	-	-	-	-	R
Orange-crowned Warbler	R	-	-	-	-	-	-	-
Plumbeous Vireo	C	R	U	U	-	-	-	-
Red-winged Blackbird	-	-	-	-	-	R	R	C
Song Sparrow	-	-	-	-	-	C	U	C
Spotted Towhee	C	U	C	C	U	-	U	-
Summer Tanager	-	-	-	-	-	R	R	U
Verdin	-	-	-	-	-	-	R	C
Warbling Vireo	U	R	R	R	-	-	-	-
Western Scrub-Jay	R	U	U	U	R	-	-	-
Willow Flycatcher	-	-	-	R	-	R	R	R
Yellow-breasted Chat	R	-	U	C	R	C	-	C
Yellow-headed Blackbird	-	-	-	-	-	-	-	C
Yellow Warbler	R	R	R	C	R	U	U	R

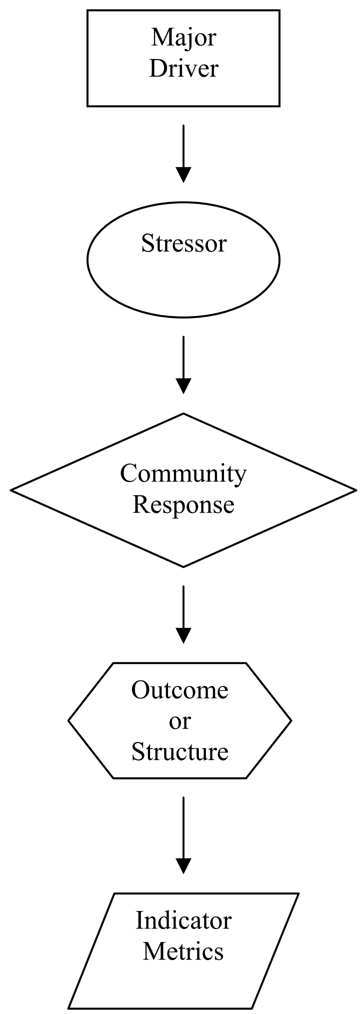
[1]Fagan 1994; [2]GLCA unpublished data; [3]this study; [4]Dickson et al. 2000; [5]Rosenberg et al. 1991

Table XII-2. . Characteristic terrestrial winter riparian species from the study area and side canyons off Lake Powell, and their status in the lower Colorado River Valley. C = common, U = uncommon, R = rare. GLTR = Glen Canyon NRA tributaries, CORI = Colorado River (study area), LOVA = Lower Colorado River Valley.

Species	**CORI[1]**	**GLTR[2]**	**LOVA[3]**
American Pipit	U	-	C
Anna's Hummingbird	R	-	U
Bewick's Wren	C	C	U
Black Phoebe	R	-	C
Bushtit	C	C	R
Canyon Wren	C	C	U
Chukar	-	U	-
Crissal Thrasher	R	-	C
Dark-eyed Junco	U	C	U
Hermit Thrush	R	-	R
Horned Lark	R	-	C
House Finch	C	U	C
Lesser Goldfinch	R	R	C
Lincoln's Sparrow	R	R	C
Loggerhead Shrike	R	R	C
Juniper Titmouse	-	U	-
Marsh Wren	U	R	C
Mountain Chickadee	R	R	R
Mourning Dove	C	-	C
Northern Flicker	R	R	C
Orange-crowned Warbler	R	-	U
Phainopepla	U	-	C
Pinyon Jay	U	-	-
Red-naped Sapsucker	R	R	-
Red-winged Blackbird	R	-	C
Rock Wren	U	U	U
Ruby-crowned Kinglet	C	C	C
Say's Phoebe	U	R	C
Song Sparrow	C	U	C
Townsend's Solitaire	R	-	R
Western Bluebird	C	-	R
White-crowned Sparrow	C	R	C
Winter Wren	R	R	R
Yellow-rumped Warbler	U	R	C

[1]This study; [2]GLCA unpublished data; [3]Rosenberg et al. 1991

Figure XII-1. Conceptual model of the winter aquatic bird community on the Colorado River in the study area. The different polygon shapes are identified below. The dotted lines indicate breeding season populations and effects for mallard and common merganser.



Grand and Glen Canyon Colorado River
Aquatic Bird Conceptual Model

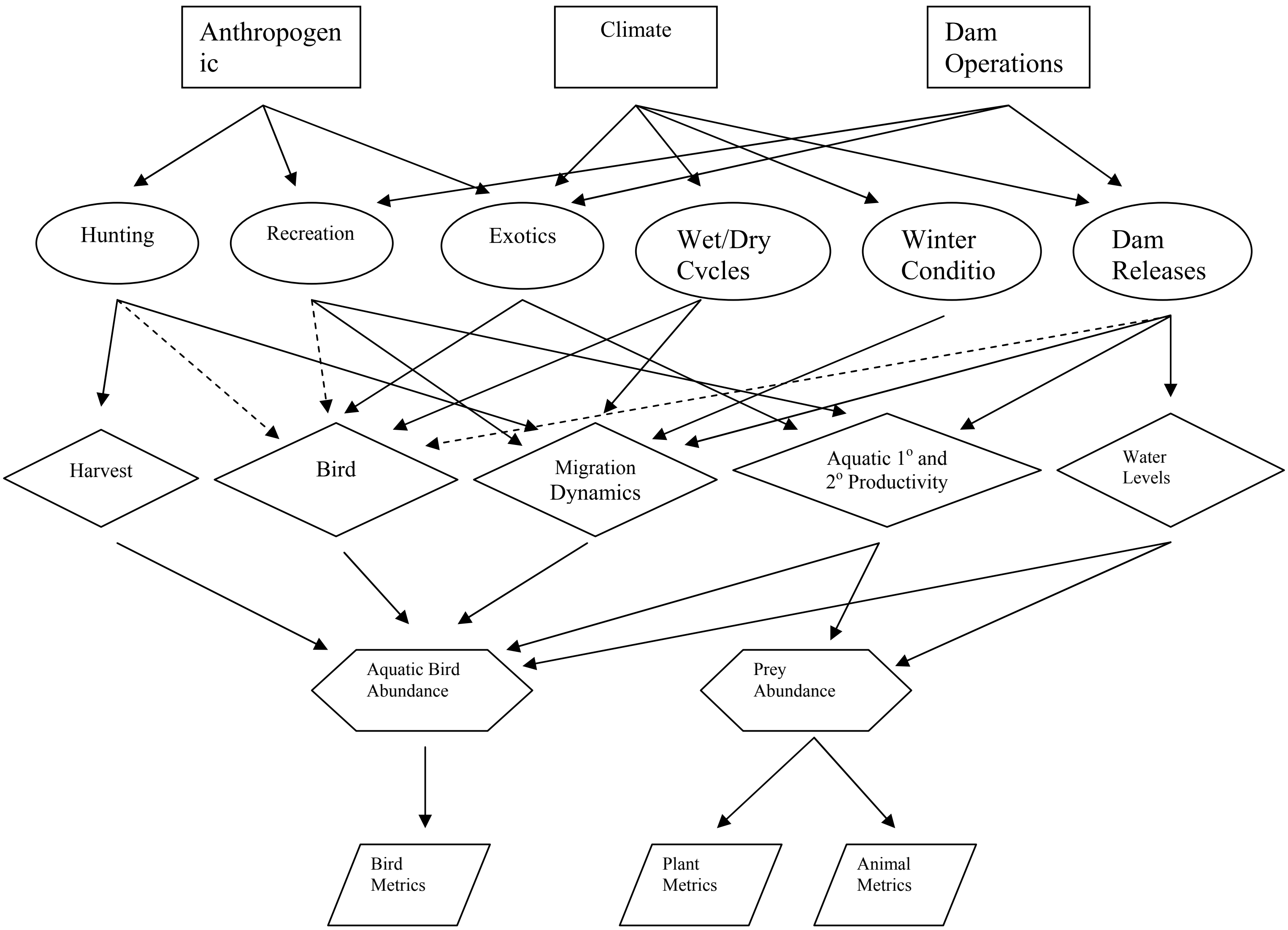
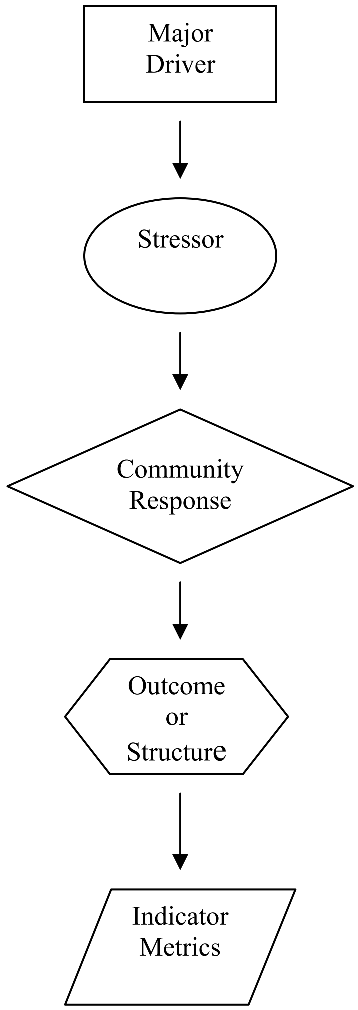


Figure XII-2. Conceptual model of the winter terrestrial bird community on the Colorado River in the study area. The different polygon shapes are identified below.



Grand and Glen Canyon Colorado River
Winter Terrestrial Bird Conceptual Model

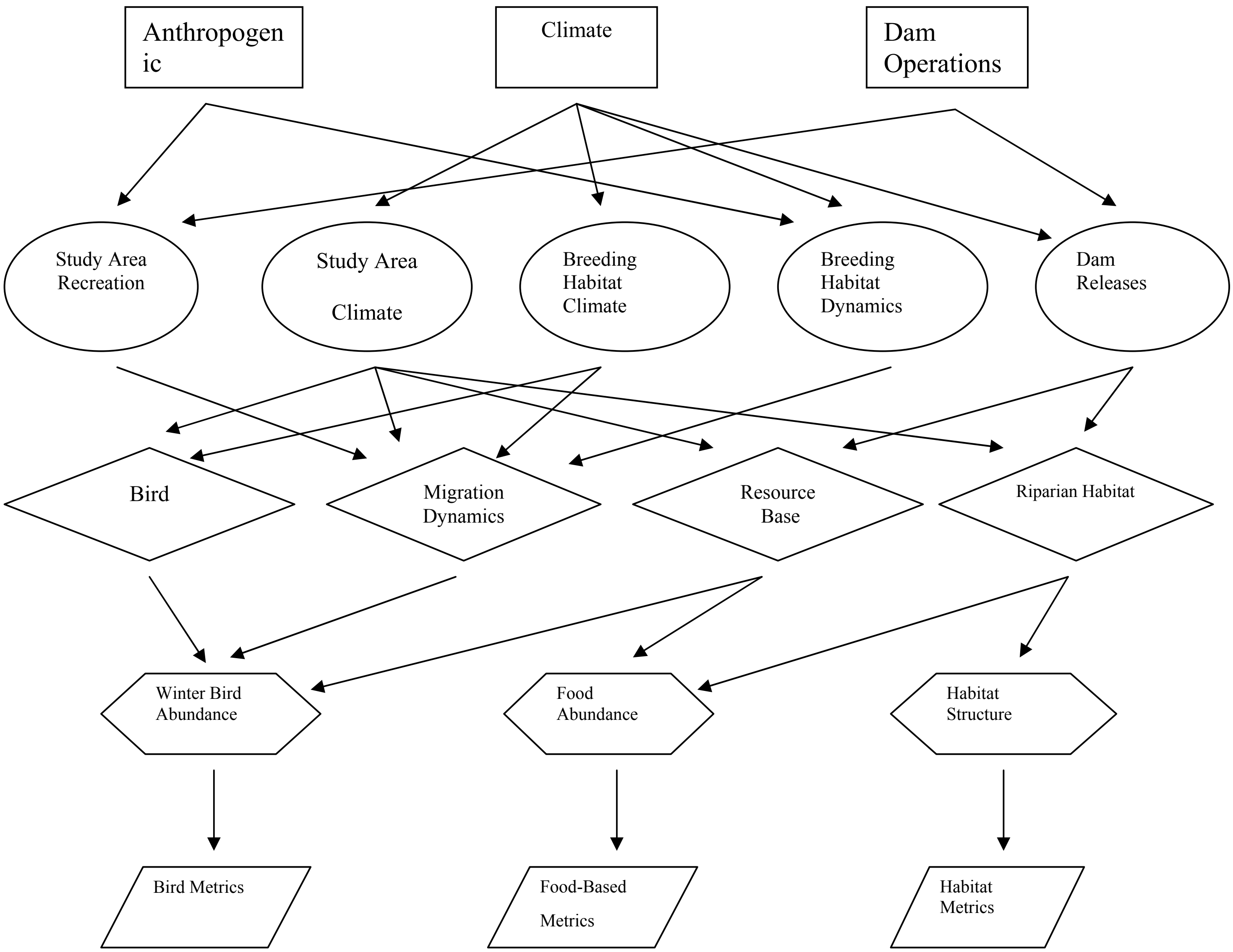
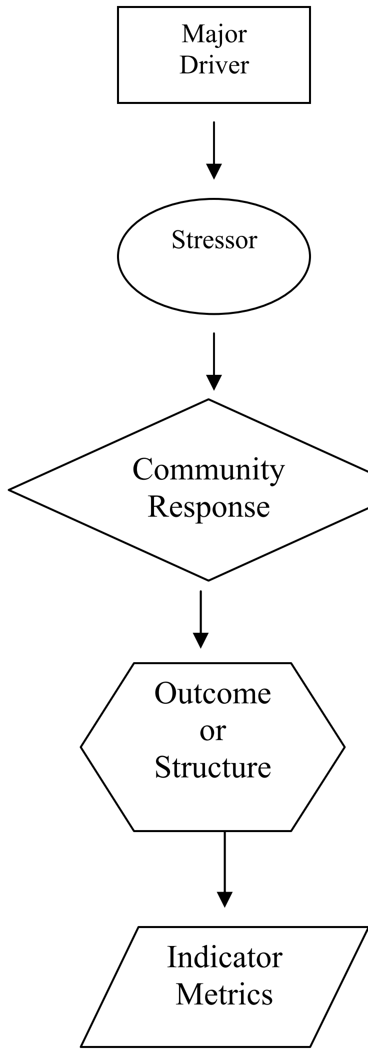
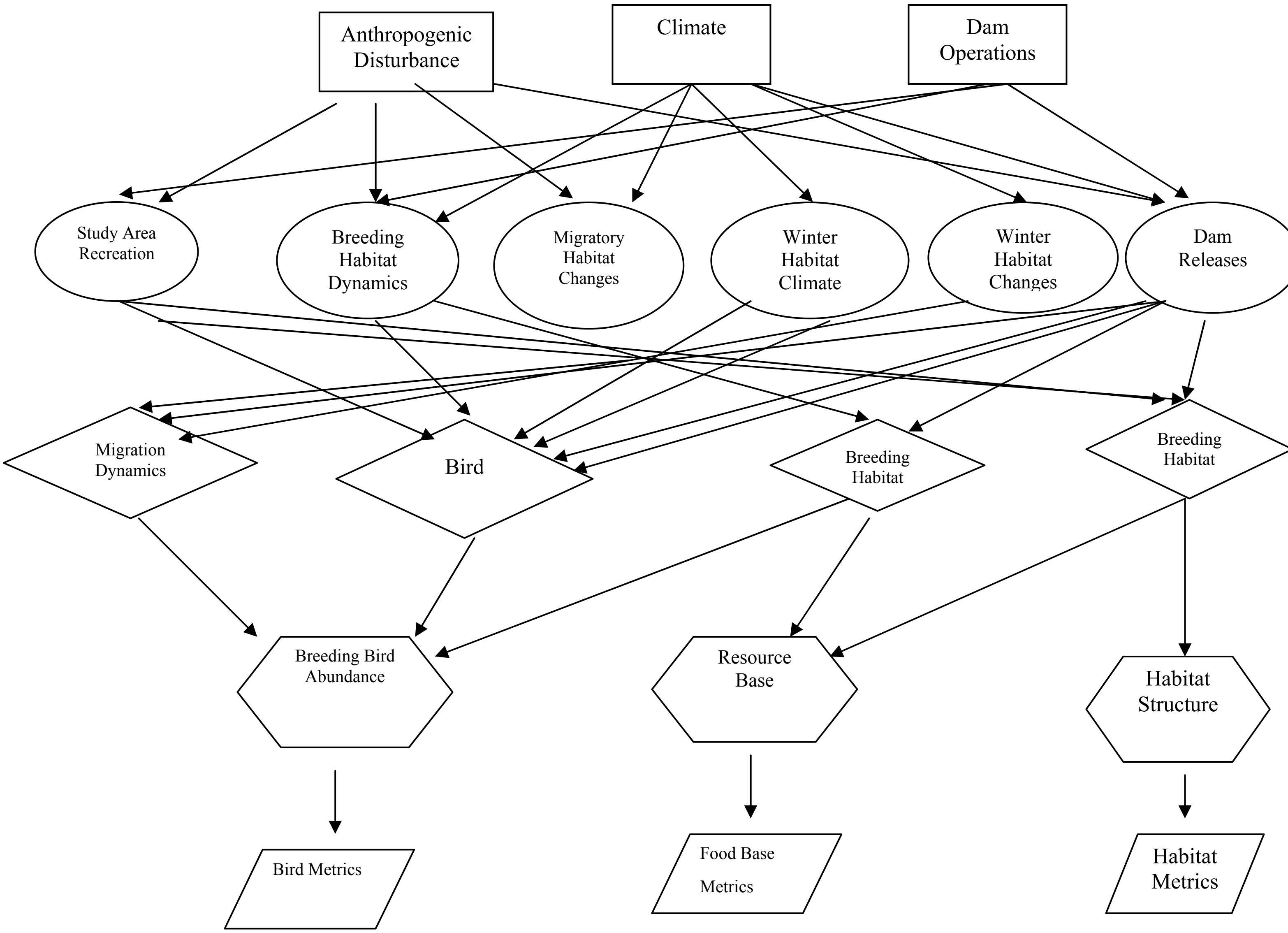


Figure XII-3. Conceptual model of the breeding terrestrial riparian bird community on the Colorado River in the study area. The different polygon shapes are identified below.



Grand and Glen Canyon Colorado River Breeding Riparian Bird Conceptual Model



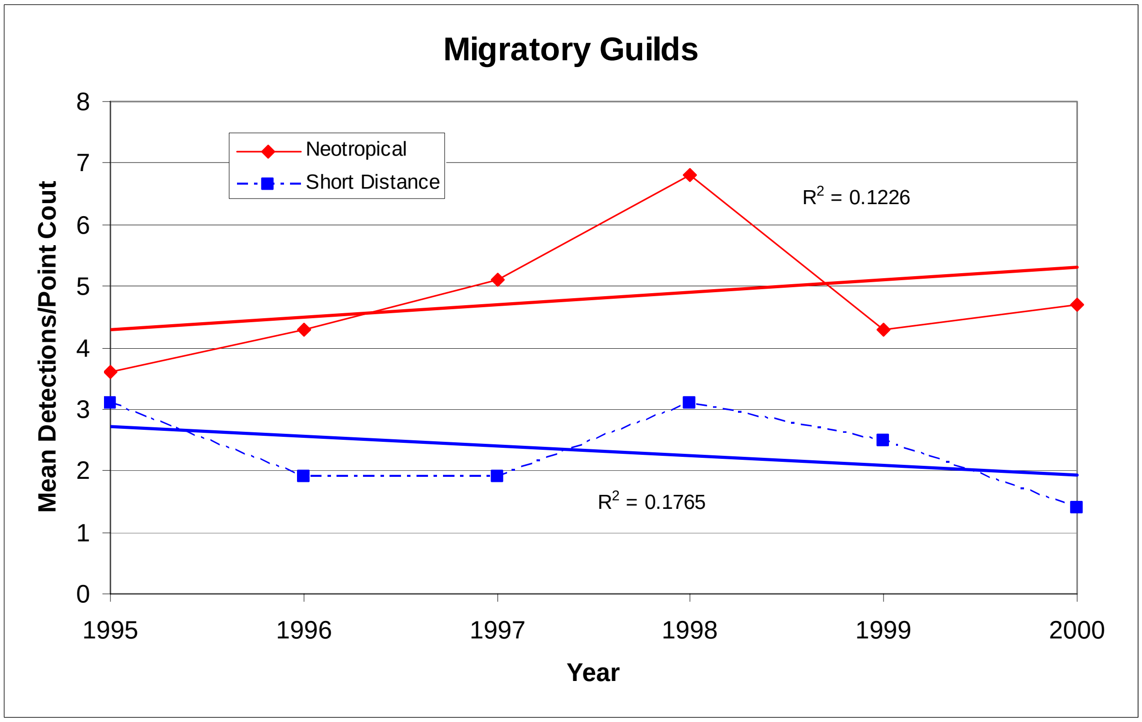


Figure XII-4. The trends in two guilds of breeding bird species in the study area are plotted for the years 1995 to 2000. Neotropical migrants include Lucy's warbler, Bell's vireo, black-chinned hummingbird, ash-throated flycatcher, yellow-breasted chat, blue-gray gnatcatcher, blue grosbeak, common yellowthroat, yellow warbler and Bullock's oriole. Short distance migrants and resident species include Bewick's wren, house finch, brown-headed cowbird, lesser goldfinch, mourning dove, and song sparrow.

CHAPTER XIII: RECOMMENDATIONS

This study reports on five years of avifaunal baseline monitoring between Glen Canyon Dam and Lake Mead. Earlier chapters have summarized data collected on winter aquatic, winter terrestrial, and breeding riparian birds, habitat characterization, distance estimation, nest searches, and various power analyses. In this final chapter various suggestions and recommendations are made for the Adaptive Management Program (AMP) and Grand Canyon Monitoring and Research Center (GCMRC) regarding future monitoring of the avifauna of the Colorado River corridor.

Because of the peculiar nature of the study area, and riparian zones in general, it is difficult to develop a monitoring program for terrestrial riparian birds that has adequate power to detect change over reasonable time-frames (5-15 years). Riparian vegetation along the Colorado River is scattered in patches of various sizes, is extremely heterogeneous, and dynamic. Much riparian vegetation consists of thin open linear patches of tamarisk and other woody species. Bird populations tend to be relatively low in these situations. Only where large dense patches occur do sufficient numbers of birds occur to monitor.

Another potential problem in detecting trends in birds is that the river corridor shows significant differences in bird communities and riparian vegetation between Glen Canyon Dam and upper Lake Mead. There are at least four relatively distinct groups, corresponding to Glen Canyon, Marble Canyon, the lower canyon below RK280, and upper Lake Mead. All analyses conducted on the first three groups showed significant compositional differences. Because of this, trends in specific populations of some riparian species may differ between reaches.

The monitoring program conducted from 1996 to 2000 lacked sufficient power to detect potential trends in most riparian species. There are various ways in which the program could be modified to include many of these rarer species. Perhaps the most promising is to combine bird data into guilds based on foraging, nesting or migration (cf. NRC 1999). For example, birds could be grouped into residents and migrants, OHWZ vs. NHWZ foragers, or through foraging behaviors. Winter terrestrial birds include both foliage gleaning insectivores and ground-foraging granivores. Additional research is needed before the nature of some of these groupings can be determined, however.

Two species of neotropical migrants, Lucy's warbler and Bell's vireo, are common in the study area and can be relatively easily monitored with sufficient power. These two species are on the Partner's in Flight list for Arizona, as species of concern with relatively small geographic ranges. Most other riparian migrants are common and not on the PIF list. In addition to these two migrant species, two other common resident species, Bewick's wren and house finch, can also be monitored with sufficient power. Thus a program could be established that focuses on these four species, two neotropical migrants and two residents. This would provide data on the trends in two PIF species, and contrast them with trends from two common resident species.

Since migrant species respond to numerous factors outside the study area, contrasts between residents and migrants (both riparian and upland) could be made to possibly control for some of these factors. For example, long-term climate trends, such as drought, would presumably affect upland and riparian species differently, with upland species more likely to be affected early by severe drought compared with riparian species.

The data has been synthesized from this study into a series of points and recommendations to the AMP and GCMRC below.

1. To what extent are birds <u>directly</u> affected by Glen Canyon Dam operations?

The results of this study, as well as previous research on breeding birds within the study area, indicate that most bird species are not directly affected by dam operations. This means that there is a direct causal link between specific dam operations and more or less immediate responses in bird populations (as detected by point counts or other surveys). Rather, with some exceptions the majority of species are indirectly related through changes in resource availability (e.g., emergence of aquatic insects) and riparian vegetation dynamics. The exceptions include aquatic birds and black phoebe. Aquatic birds such as diving and dabbling waterfowl or shorebirds can be directly affected by dam operations and changes in river flows through a variety of mechanisms. These include drowning of nests, as has been documented in mallard and black phoebe, or affects on foraging behavior through changes in river current velocities and depth to foraging areas.

For breeding, upland and winter bird communities, the most obvious impacts are through the effects of river flows and their fluctuations on riparian vegetation, principally in the new high water zone (NHWZ). Given this, and the fact that bird species show strong correlations with various vegetation parameters, monitoring riparian vegetation may provide sufficient data to determine the future status of most bird species within the river corridor. Given also that most species except permanent residents are affected by numerous factors outside the study area, the AMP may prefer not to monitor most bird populations. There is one caveat associated with this conclusion, however. Simply monitoring habitat quality and extent may miss potential changes in selected bird species caused by factors within the study area other than riparian vegetation dynamics. For example, the invasion of a new exotic plant species may have direct and profound consequences on some bird species. Second, monitoring habitat does not provide data on the abundance of brown-headed cowbird in the study area. This species may in fact be increasing, and previous studies have shown that it parasitizes many species in the riparian zone and often in high numbers at nests. However, the 1996-2000 program lacked sufficient power to detect changes in this species in the near and medium term (5-15 years). Thus simply monitoring riparian vegetation may miss potentially profound changes in some bird species.

The conclusion of this section is that aquatic birds may be the best avifaunal group on the Colorado River to monitor for potential affects of Glen Canyon Dam operations, perhaps combined with riparian vegetation monitoring. Since >50% of all aquatic birds occur at or above Lee's Ferry, they could be easily monitored in this stretch alone without the extensive logistical and monetary requirements for a down river trip.

2. Are birds a "core" variable to monitor through the GCMRC program?

We feel that the AMP should make a determination as to whether birds are a "core" resource value to be monitored, as is the case for sediment, water quality, primary productivity, vegetation, fish, and cultural resources. The monetary and logistical resources dedicated to avifaunal work in the study area since GCES I, combined with high public interest and NPS mandates, suggest to us that they could be considered a core resource. However, unlike most other monitored resources, as noted above birds are for the most part indirectly related to dam operations, and there are many confounding factors in interpreting trends.

3. Avifauna monitoring requires a long-term commitment.

With the exception of the 6-7 most common species, short-term changes (3-10 years) in detection rates cannot be tracked with the current program. In order to detect changes in bird populations, a long-term view is necessary. Populations fluctuate from year to year for a variety of reasons, and long-term data sets are often needed to detect significant trends. The data from Point Reyes Bird Observatory makes this point well (G.R. Geupel, pers. comm. 2001). Long-term declines (>20 years) in some species in California may be related to factors controlled by the Pacific Decadal Oscillation (PDO), which typically changes about every 20-25 years. A change in the sign of the PDO may actually result in a reversal of the trend for some species. There thus needs to be long-term institutional commitment in many bird monitoring programs for meaningful data to be collected and trends analyzed.

4. The AMP program needs to develop goals and "threshold values" for management actions.

Long-term monitoring implies goals and threshold values, which when exceeded typically initiate some sort of management action. For example, if the number of Lucy's warblers dropped below some threshold value, indicating a significant trend (decline), some type management action and/or research would be done to determine the causes of the decline and to attempt to reverse it if possible. To date, no such threshold values have been developed in the study area. There is probably sufficient baseline data to make an initial attempt at developing such values for some species, especially those that are common or whose populations appear not to fluctuate significantly between years. The AMP and GCMRC, however, simply cannot continue collecting bird data in the absence of goals and objectives.

5. What should a monitoring program consist of?

Because of the problems associated with monitoring along a logistically difficult linear strip such as the Colorado River, any long-term monitoring program developed for terrestrial birds (especially breeding birds) requires a great deal of care in order to satisfy statistical assumptions (e.g., randomness) and statistical power. Urquhart et al. (1998) have suggested some promising approaches to detecting trends over time. It is likely that any future monitoring program will have to solve the problem of sample size, placement of plots (subjective or random), stratification of the study area, counting methods, and other methodological considerations. At the very least, the following factors need to be taken into account in developing a riparian breeding bird monitoring program:

A) What are the goals of a bird monitoring program (e.g, do inferences to the entire system need to be made)?

B) How to develop sufficient power to detect trends?

C) Do large patches where most birds occur accurately represent the avifaunal composition and potential trends in the entire study area?

D) How do compositional differences within the study area affect trend detections and program design? Does sampling have to be stratified by major reach? If so, can adequate sample sizes be reached to provide adequate power?

E) What type of monitoring method will be used (distance estimation requires different designs than simple point counts)?

F) How would factors outside the study area that affect migrant species be controlled for in order to detect effects of dam operations?

Research may be required to answer some of these questions (see below).

6. There are several research questions that need to be answered.

Some research has already been conducted on specific aspects of riparian bird ecology in the study area, such as brown-headed cowbird parasitism (Brown 1994), the relationships between species richness and riparian vegetation (Brown 1989; Sogge et al. 1998; this study), and the diet of insectivorous riparian species (Yard et al. 2004). However, many aspects of the bird ecology of the study area remain to be researched. Some of the most urgent research needs are listed below.

A) Research is needed on how breeding riparian species partition foraging in the two different riparian zones (OHWZ and NWZ) and adjacent uplands.

B) More detailed and quantitative conceptual models for the avifauna of the study area are needed in order to focus research and answer monitoring questions.

C) More information is needed regarding productivity (nest success, fledging rates, etc.) for the riparian breeding birds in order to link model-based predictions using habitat parameters (e.g., patch size, shape, composition) and bird trends. This will require work in selected study areas using nest searches and mist-netting to determine productivity in different types of riparian vegetation.

D) Can a correlation or link be made between simple detection counts at point count stations and true bird abundance as shown by mist-netting and distance estimation? If this link could be established, then simple counts based on detection rates could be used as a monitoring tool.

E) Where do the wintering aquatic birds come from? If breeding grounds and migratory populations can be determined, a much better understanding of winter aquatic bird dynamics on the Colorado River can be gained.

F) Are “resident” species such as Bewick’s wren or song sparrow truly residents, or are different populations involved, with in and out migration in the study area?

G) How site-faithful are individuals of riparian breeding species. Do the same individuals return every year to the same patch, or are there within-study area between-patch movements?

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APPENDIX A

A summary of the patches of riparian vegetation visited in the Colorado River corridor from Glen Canyon Dam to Lake Mead. Surveys of patches from four programs are included, 1984-1985 (Brown 1988), 1993-1995 (Hualapai Nation and SWCA 1995), 1993-1995 USGS (Sogge et al. 1998), and the current study (1996-2000). For each patch, its location along the river corridor, the number and types of bird surveys done is listed. For the 1996-2000 data set, the patches in which vegetation structure was sampled using the TVV method are listed. All three methods were used during the USGS project at a variety of patches, but are not broken down by type in the appendix.

Survey types are: b=boat, p=point count, w=timed walking area search.

			Number of	BROWN	HUALAPAI NATION	USGS/BRD	NPS	NPS
			Point Count	Breeding Birds	Breedings Birds	Breeding Birds	Breeding Birds	Breeding Birds
	Patch	Reach	Stations	1984-1985	1993-1995	1993-1995	1996	1997
P1	(-)14.5L	1	1					3p/3w
P2	(-)14.2R	1	3				9p	9p/3w
P3	(-)13.6R	1	1				3p	3p/3w
P4	(-)10.0L	1	2				6p	6p/3w
P5	(-)9.4L	1	1				3p	3p/3w
P6	(-)8.9L	1	1				3p	3p/3w
P7	(-)8.4R	1	3				9p	9p/3w
P8	(-)7.5L	1	1					3p/3w
P9	(-)7.0L	1	2	w			6p	6p/3w
P10	(-)6.5R	1	1				3p	3p/3w
P11	(-)6.0R	1	1					3p/3w
P12	(-)3.8L	1	1					3p/3w
P13	(-)3.2R	1	4				12p	11p/3w
P14	(-)2.5L	1	3				9p	9p/6w
P15	(-)0.4R	1	1	w			3p	3p/3w
	LF							
P16	1.0R	2	2			X	5p/3w	6p/3w
P17	1.6R	2	3			X	5p/3w	9p/2w
P18	2.0L	2				X		
P19	3.7L	2	1			X	2p/1w	3p/2w
P20	5.1L	2				X		
P21	5.2R	2	2			X	3p/2w	4p/2w
P22	5.6R	2						
P23	5.8R	2	1			X		2p/2w
P24	6.5R	2	1					
P25	6.8L	2	1					
P26	6.8R	2	1					
P27	7.2R	2	1					
P28	9.2R	2	1					
P29	9.7R	2	1					
P30	11.0L	3						
P31	38.6L	4	1					
P32	40.6R	5	1					
P33	40.8L	5	1					
P34	40.1R	5						
P35	42.5L	5						
P36	43.1L	5	2				4p/2w	6p/3w
P37	43.6L	5						
P38	45.5L	5	3					9p/2w
P39	45.5R	5						
P40	46.0L	5						
P41	46.0R	5						
P42	46.5L	5						
P43	46.7R	5	4	w		X	11p/3w	12p/2w
P44	47.0R	5						
P45	47.5L	5				X		
P46	48.5L	5				X		
P47	49.1R	5	2			X	5p/3w	6p/2w
P48	49.2L	5				X		
P49	49.7L	5						
P50	50.0L	5						
P51	50.0R	5	2			X	6p/3w	6p/2w

P52	50.1L	5			
P53	50.4L	5	3	6p/3w	9p/2w
P54	51.5L	5	2	4p/2w	6p/2w
P55	52.5R	5			
P56	53.0R	5			

			Number of	BROWN	HUALAPAI NATION	USGS/BRD	NPS	NPS
			Point Count	Breeding Birds	Breedings Birds	Breeding Birds	Breeding Birds	Breeding Birds
	Patch	Reach	Stations	1984-1985	1993-1995	1993-1995	1996	1997
P57	55.6R	5						
P58	56.0R	5	2				4p/1w	5p/2w
P59	56.3R	5						
P60	58.7L	5						1p
P61	65.3L	6	2				6p/2w	6p/2w
P62	67.1L	6	2				6p/2w	6p/2w
P63	68.0R	6						
P64	71.0L	6	2	w			6p/2w	6p/2w
P65	73.9R	6				X		
P66	74.1R	6				X		
P67	74.3R	6				X		
P68	74.4L	6	4			X	4p/1w	12p/3w
P69	74.4R	6				X		
P70	75.9R	6				X		
P71	76.0L	6				X		
P72	76.5L	6				X		
P73	87.5R	7						
P74	95.7L	7				X		
P75	95.9L	7				X		
P76	97.4R	7				X		
P77	97.4L	7				X		
P78	97.5L	7				X		
P79	97.6L	7				X		
P80	100.0R	7				X		
P81	108.8R	7	1	w		X	2p	
P82	112.0R	7				X		
P83	117.5R	8				X		
P84	119.5R	8				X		
P85	119.6L	8				X		
P86	122.8L	8	2	w		X	2p/1w	4p/2w
P87	125.5L	9	1			X		2p/2w
P88	131.3R	9				X		
P89	136.5R	9						
P90	141.0R	10	1					
P91	166.5L	11	3	w	w		12p/1w	7p/2w
P92	167.0R	11				X		
P93	167.2L	11				X		
P94	167.7R	11				X		
P95	168.5L	11				X		
P96	168.8R	11	2			X	6p/2w	4p/2w
P97	171.0R	11	1	w		X	1p/1w	3p/2w
P98	171.1R	11	1	w		X	1p/1w	2w
P99	172.2L	11	2			X		2p/2w
P100	173.1R	11				X		
P101	174.2L	11	2			X	6p	4p/2w
P102	174.4R	11	1			X		
P103	174.7R	11				X		
P104	182.7L	11						
P105	191.5R	11						
P106	192.0L	11						
P107	193.8R	11	2				6p/1w	6p/3w
P108	194.0L	11	2				4p/1w	7p/3w

P109	196.0R	11	4				12p/1w	12p/3w
P110	196.5L	11						
P111	197.6L	11	2			X	6p/2w	6p/2w
P112	198.0R	11	3	w	w	X	9p/2w	9p/3w

	Patch	Reach	Number of Point Count Stations	BROWN Breeding Birds 1984-1985	HUALAPAI NATION Breedings Birds 1993-1995	USGS/BRD Breeding Birds 1993-1995	NPS Breeding Birds 1996	NPS Breeding Birds 1997
P113	198.2L	11	3			X	6p/2w	9p/2w
P114	198.3R	11				X		
P115	199.5R	11				X		
P116	200.0L	11				X		
P117	200.4L	11						
P118	200.4R	11	1			X	1p	3p/3w
P119	200.5R	11	1			X	1p	3p/3w
P120	202.5R	11	1			X	3p/2w	3p/3w
P121	203.0L	11						
P122	204.1R	11	4			X	12p/2w	12p/3w
P123	204.5R	11	5			X	15p/2w	15p/3w
P124	205.0L	11	3				6p/2w	9p/3w
P125	205.8R	11				X		
P126	206.5L	11				X		
P127	206.6R	11				X		
P128	207.5L	11						
P129	208.7R	11	2			X	6p/2w	6p/3w
P130	209.0L	11	3	w	w		9p/2w	9p/3w
P131	213.6L	12	1			X	3p/2w	3p/3w
P132	214.0L	12	1			X	2p/2w	3p/3w
P133	214.0R	12						
P134	214.2L	12	1			X	2p/1w	3p/3w
P135	219.9R	12		w				
P136	220.3L	12		w				
P137	224.0L	12				X		
P138	224.1R	12				X		
P139	243.2L	13	2		w		6p/1w	4p
P140	246.0L	13	3		w		9p/2w	6p
P141	249.0L	13	1				1p	
P142	260.0L	13	4		w		7p/3w	10p
P143	260.0R	13	2		w		6p/3w	6p
P144	264.5L	13	10		w		30p/3w	24p

	NPS	NPS	NPS	NPS	NPS	NPS	NPS
	Breeding Birds	Breeding Birds	Breeding Birds	Winter Birds	Winter Birds	Winter Birds	TVV Vegetation
Patch	**1998**	**1999**	**2000**	**1998**	**1999**	**2000**	**1997-1999**
(-)14.5L	2p/2w	3p			1w	1w	X
(-)14.2R	6p/2w	9p		1w	1w	1w	X
(-)13.6R	2p/2w	3p		3w	1w	1w	X
(-)10.0L	4p/2w	6p		2w	1w	1w	X
(-)9.4L	2p/2w	3p		1w	1w	1w	X
(-)8.9L	2p/2w	3p		1w	1w	1w	X
(-)8.4R	6p/2w	9p		2w	1w		X
(-)7.5L	2p/2w	3p			1w	1w	X
(-)7.0L	4p/2w	6p		2w	1w	1w	X
(-)6.5R	3p/3w	3p		1w	2w	2w	X
(-)6.0R	2p/2w	3p				1w	X
(-)3.8L	2p/2w	3p		1w	1w		
(-)3.2R	8p/2w	12p		1w		1w	X
(-)2.5L	6p/2w	9p		1w		1w	X
(-)0.4R	2p/2w	3p		1w		1w	
LF							
1.0R	4p/3w	6p/3w	6p	2w	2w	2w	
1.6R	6p/3w	9p/3w	9p	2w	2w	2w	X
2.0L							
3.7L	2p/2w	3p/3w	3p	1w	2w	2w	X
5.1L							
5.2R	4p/3w	6p/3w	6p	2w	2w	1w	X
5.6R		1p					
5.8R	1p/1w	3p/3w	2p	1w	1w	1w	X
6.5R		3p/3w					X
6.8L	2p/1w	6p/3w				1w	X
6.8R	2p	2p					X
7.2R	1p	3p/3w					X
9.2R	1p/1w	2p/2w			1w		X
9.7R	1p/1w	2p/3w					X
11.0L						1w	
38.6L	1p/1w	2p/2w			1w	2w	X
40.6R	1p/1w	3p/3w			1w	1w	X
40.8L	1p/1w	3p/3w					X
40.1R					1w		
42.5L					2w		
43.1L	6p/3w	6p/3w		1w	1w	2w	X
43.6L				1w			
45.5L	9p/3w	9p/3w		2w	2w	2w	X
45.5R				2w			
46.0L					1w		
46.0R					1w		
46.5L					1w		
46.7R	12p/3w	12p/3w	12p	2w	2w	2w	X
47.0R					1w		
47.5L							
48.5L							
49.1R	4p/3w	6p/3w	6p	2w	2w	2w	X
49.2L							
49.7L					1w		
50.0L					1w		
50.0R	6p/3w	6p/3w	6p	2w	2w	2w	X

50.1L					1w		
50.4L	9p/3w	9p/3w	8p	2w	2w	2w	X
51.5L	6p/3w	6p3w	6p	2w	2w	2w	X
52.5R					1w		
53.0R					3w		

	NPS	NPS	NPS	NPS	NPS	NPS	NPS
	Breeding Birds	Breeding Birds	Breeding Birds	Winter Birds	Winter Birds	Winter Birds	TVV
Patch	1998	1999	2000	1998	1999	2000	1997-1999
55.6R				2w	1w	1w	
56.0R	6p/3w	4p/2w	6p		1w	1w	X
56.3R					1w		
58.7L							
65.3L	6p/3w	6p/2w		1w	2w	2w	X
67.1L	6p/3w	6p/3w		2w	2w	2w	X
68.0R				2w			
71.0L	6p/3w	6p/2w	6p	2w	2w	2w	X
73.9R							
74.1R							
74.3R							
74.4L	4p/1w	3p/1w					X
74.4R							
75.9R							
76.0L							
76.5L							
87.5R					1w		
95.7L							
95.9L							
97.4R							
97.4L							
97.5L							
97.6L							
100.0R							
108.8R							
112.0R							
117.5R							
119.5R							
119.6L							
122.8L	6p/3w	6p/3w	6p	1w	2w	2w	X
125.5L	3p/3w	2p/3w	2p	1w	1w		X
131.3R							
136.5R							
141.0R			2p/2w				
166.5L							
167.0R							
167.2L							
167.7R							
168.5L							
168.8R	6p/3w	6p/3w	6p	3w	2w	3w	X
171.0R	3p/3w	3p/2w	3p	1w	2w	2w	X
171.1R	3p/3w	3p/2w	3p	1w	2w	1w	
172.2L	6p/3w	6p/2w	6p	2w	1w	2w	X
173.1R							
174.2L	6p/3w	6p/2w	6p	1w	2w	2w	X
174.4R	1p	1p/1w		1w	1w	1w	X
174.7R							
182.7L					2w	1w	
191.5R					2w		
192.0L					2w		
193.8R	5p/3w	6p/3w	6p	2w	2w		X
194.0L	5p/3w	6p/2w	6p	2w	2w	2w	X
196.0R	12p/3w	12p/2w	11p	2w	3w	2w	X

196.5L					2w		
197.6L	5p/3w	6p/3w	4p	2w	1w	2w	X
198.0R	9p/3w	9p/3w	9p	2w	2w	1w	X

	NPS	NPS	NPS	NPS	NPS	NPS	NPS
	Breeding Birds	Breeding Birds	Breeding Birds	Winter Birds	Winter Birds	Winter Birds	TVV
Patch	1998	1999	2000	1998	1999	2000	1997-1999
198.2L	9p/3w	9p/3w	9p	2w	2w	2w	X
198.3R							
199.5R							
200.0L				1w	1w		
200.4L	2p			1w			
200.4R	2p/2w	3p/3w	3p	1w	2w	1w	X
200.5R	2w	3p/3w	3p	1w	2w	2w	X
202.5R	2p/3w	2p/3w	3p	2w	2w	2w	X
203.0L							
204.1R	12p/3w	12p/3w	12p	2w		2w	X
204.5R	15p/3w	14p/4w	12p	2w		2w	X
205.0L	9p/3w	9p/3w	6p	2w		2w	X
205.8R							
206.5L							
206.6R							
207.5L					1w		
208.7R	6p/3w	4p/2w	4p	2w	2w	1w	X
209.0L	9p/3w	9p/2w	9p	3w	3w	2w	X
213.6L	2p/2w	3p/4w		2w	2w	2w	X
214.0L	2p/1w	4p/2w		2w	2w	2w	X
214.0R	1w						
214.2L	2p/2w	2p/3w		2w	1w	2w	X
219.9R							
220.3L							
224.0L							
224.1R							
243.2L	4p/2w			2w	1w	2w	X
246.0L	3p/2w			2w/1b	3w	2w	X
249.0L							
260.0L	2w			2b	2b	2b	X
260.0R				1b			X
264.5L				1w/1b			X

APPENDIX B

Annotated Checklist of the Winter Avifauna along the Colorado River,
Glen Canyon Dam to upper Lake Mead

The checklist is based on all species sightings made on six river trips, one each month in January and February of 1998, 1999 and 2000. The species sequence is that of the AOU 7th Edition (1998). The number in parentheses at the end of each account is the total number of individuals recorded on the six trips by the primary survey method (floating surveys or area searches), with a few exceptions as noted. Reaches are numbered according to the Schmidt and Graf (1990) classification (see Table IV-2). Details of the rarer and more unusual species can be found in LaRue et al. (2001b). The study area is defined as the river corridor from Glen Canyon Dam to Separation Canyon, and upper Lake Mead to Pearce Ferry. The region is defined as the greater Grand Canyon region including Grand Canyon National Park, the upper portions of Lake Mead National Recreation Area, the Glen Canyon portion of Glen Canyon National Recreation Area, as well as adjacent portions of the Kaibab National Forest, the Arizona Strip of the Bureau of Land Management, and the Hualapai and Navajo Indian Reservations (Brown et al. 1987, LaRue et al. 2001b). Citations of previous records are BCJ=Brown et al. (1984, 1987), LSG=LaRue et al. (2001a), LDBSS=LaRue et al. (2001b), SFW=Sogge et al. (1998), and SBBK=Stevens et al. (1997). The four-letter acronyms used in the Excel databases for the winter birdS (terrestrial and aquatic) is listed after the common name.

GAVIIDAE: Loons

1. Gavia pacifica (Pacific Loon; PALO). One record of a bird at Lee's Ferry (reach 1) on 12 February 2000 represents the second winter record in the study area (1).

2. Gavia immer (Common Loon; COLO). One record of a single bird at Lee's Ferry (reach 1) on 12 February 1999. LDBSS and SFW report several additional records from the river corridor (1).

PODICIPEDIDAE: Grebes

3. Podylimbus podiceps (Pied-billed Grebe; PBGR). A rare winter resident in reaches 1 and 2 and on upper Lake Mead (20).

4. Podiceps auritus (Horned Grebe' HOGR). Extremely rare. Two birds on 9 January 1998 at Lee's Ferry (reach 1), and a single bird on upper upper Lake Mead on 19 January 2000. These birds represent the first winter records in the study area (3).

5. Podiceps nigricollis (Eared Grebe; EAGR). A single bird was seen in reach 6 on 11 January 1999. BCJ, LSG, LDBSS and SBBK report several other winter records (1).

6. Aechmophorus occidentalis (Western Grebe; WEGR). An uncommon winter resident on upper Lake Mead, mostly near Pearce Ferry. A single bird was seen at RK 84 (reach 5) on 10 January 1999 and again on 14 February 1999 (22).

7. Aechmophorus clarkii (Clark's Grebe; CLGR). A common winter resident on upper Lake Mead, and greatly outnumbering Western Grebe (201).

PHALACROCORACIDAE: Comorants

8. Phalacrocorax auritus (Double-crested Comorant; DCCO). An uncommon winter resident in reach 1 and probably a permanent resident on upper Lake Mead. A flock of up to 25 individuals has been wintering at the base of Glen Canyon Dam since 1998 (82).

ARDEIDAE: Herons, bitterns and allies

9. Ixobrychus exilis (Least Bittern; LEBI). A single bird was seen at Quartermaster Marsh at RK 426 (reach 13) on 20 January 1998. This is the first record for the region (1).

10. Ardea herodias (Great Blue Heron; GBHE). A common winter resident and rare summer resident throughout most of the river corridor except very rare in reaches 4 and 8. A small breeding colony has established at Lee's Ferry, with one pair in 1998, two pairs in 1999, three pairs in 2000, and four pairs in 2001. The species also breeds on upper Lake Mead according to BCJ and SBBK (182).

11. Nycticorax nycticorax (Black-crowned Night Heron; BCNH). A single bird was found at RK 438 (reach 13) on 19 January 1999 (1).

CATHARTIDAE: New World Vultures

12. Cathartes aurea (Turkey Vulture; TUVU). A single bird was seen at RK 263 (reach 10) on 18 February 1999 (1).

ANATIDAE: Ducks, geese and swans

13. Branta canadensis (Canada Goose; CAGO). An uncommon winter resident in January along the river corridor, with only a single bird seen on the three February trips. Most individuals were found in reaches 5 and 6 above the Little Colorado River (278).

14. Cygnus buccinator (Trumpeter Swan; TRSW). A pair of marked birds from the Wyoming Swan Restoration Project were seen at RK 10 (reach 2) on 12 January 1998 and at RK 17 on 8 January 1999 (4).

15. Anas strepera (Gadwall; GADW). The most common wintering dabbler in the study area, concentrated in reaches 1 and 2, absent below the Little Colorado River, then re-appearing on upper Lake Mead (1870).

16. Anas americana (American Wigeon; AMWI). A common winter resident in the study area, primarily in reaches 1 and 2. Rare on upper Lake Mead (1391).

17. Anas platyrhynchos (Mallard; MALL). A common permanent resident in the upper portions of the river corridor, mostly in reaches 1 and 2, but remaining fairly common to reach 6, then re-appearing in reaches 11 to 13. Mallard is generally the only duck encountered in the more turbid reaches of the Colorado River (1697).

18. Anas discors (Blue-winged Teal; BWTE). A single record of five seen on upper Lake Mead on 23 February 2000. BCJ and SFW do not document any winter records, although SBBK record the species from unspecified locations in winter (5).

19. Anas cyanoptera (Cinnamon Teal; CITE). An uncommon winter resident in the upper reaches, rare on upper Lake Mead (31).

20. Anas clypeata (Northern Shoveler; NOSH). A single record of a pair in reach 1 on 3 January 2000. BCJ, SFW and SBBK record it as rare in winter in the study area (2).

21. Anas acuta (Northern Pintail; NOPI). A single record of seven seen in reach 2 on 12 February 2000. BCJ, SFW and SBBK record it as rare to uncommon in winter in the study area (7).

22. Anas crecca (Green-winged Teal; GWTE). A fairly common winter resident throughout most of the river corridor, particularly in reaches 5 and upper Lake Mead (484).

23. Aythya valisineria (Canvasback; CANV). Two records, single birds in reach 1 on 13 February 1998 and in reach 2 on 8 January 2000. BCJ do not document winter records, while SFW note that it occurs "occasionally" at Lee's Ferry. SBBK record it from unspecified locations in the study area in winter (2).

24. Aythya american (Redhead; REDH). A common winter resident in reaches 1 and 2, very rare elsewhere. Of 225 birds detected, 222 occurred in the first two reaches (225).

25. Aythya collaris (Ring-necked Duck; RNDU). A common to abundant winter resident in reaches 1 and 2, extremely rare in reaches 5 and 6 (1103).

26. Aythya marila (Greater Scaup; GRSC). An uncommon winter resident in reach 1 and very rare in reach 2. The wintering population of this species below Glen Canyon Dam generally represents the largest concentration in the state of Arizona (96).

27. Aythya affinis (Lesser Scaup; LESC). A common to abundant winter resident in reaches 1 and 2 and rare to reach 5. Absent below reach 5 and on upper Lake Mead. This species is one of the more common diving ducks in the study area in winter (2369).

28. Clangula hyemalis (Long-tailed Duck; LTDU). One record at the base of Glen Canyon Dam (reach 1) on 2 January 1999. Neither BCJ nor SFW report this species, while SBBK records it in winter from unspecified locations. LSG record an additional four winter records from Glen Canyon (1).

29. Bucephala albeola (Bufflehead; BUFF). A common to abundant winter resident in reaches 1 and 2, very rare elsewhere in the river corridor, and absent from upper Lake Mead (1609).

30. Bucephala clangula (Common Goldeneye; COGO). An abundant winter resident in the upper reaches of the study area down to reach 5 (Little Colorado River), occasional below to reach 12, but absent on upper Lake Mead. This is the most common diving duck on the river corridor in winter (6883).

31. Bucephala islandica (Barrow's Goldeneye; BAGO). An uncommon winter resident in reach 1. A single record at RM 106 (reach 6) of a female is the first record of this species for Grand Canyon National Park (207).

32. Lophodytes cucullatus (Hooded Merganser; HOME). Very rare, with four records all in reach 1. Two birds on 9 January 1998 and again on 13 February 1998 were likely to have been the same individuals. The other two records include one seen on 2 March 1999 and one seen on 3 January 2000. Neither BCJ nor SFW report this species, while SBBK records it in winter from unspecified locations (6).

33. Mergus merganser (Common Merganser; COME). A common permanent resident from reaches 1 through 5, then rare down to reach 12, and absent on upper Lake Mead. This is one of the few aquatic species found along the river corridor below the Little Colorado River (704).

34. Mergus serrator (Red-breasted Merganser; RBME). A single record of four birds seen at RK –10 (reach 1) on 13 February 1998 represents the first winter record from the study area (4).

35. Oxyura jamiacensis (Ruddy Duck; RUDU). A fairly rare winter resident in reaches 1 and 2, with a single record of a bird in reach 5 on 10 January 2000 (38).

ACCIPITRIDAE: Hawks, kites, eagles and allies

36. Haliaeetus leucocephalus (Bald Eagle; BAEA). A common winter resident in the upper portions of the river corridor in reaches 3-5, but rare in reach 1. Occasionally detected in other reaches, including three birds recorded on upper Lake Mead. The most common winter raptor in the study area, although not as widely distributed as red-tailed hawk (98).

37. Circus cyaneus (Northern Harrier; NOHA). An extremely rare winter resident with three records, single birds at RK -5 (reach 1) on 13 February 1999, at RK 48 (reach 4) on 17 February 1998, and at RK -11 (reach 1) on 3 February 2000. BCJ and SFW also recorded this species in winter in the study area (3).

38. Accipiter striatus (Sharp-shinned hawk; SSHA). An uncommon winter resident throughout the study area, with 22 records during the study. BCJ and SFW reported an additional four records (22).

39. Accipiter cooperi (Cooper's Hawk; COHA). A rare winter resident throughout the river corridor, with seven records. These are the first winter records from the river corridor (7).

40. Buteo lineatus (Red-shouldered Hawk; RSHA). A single record of a bird at Quartermaster Marsh (reach 13) on 26-27 February 1998. This represents the second record for the study area (1).

41. Buteo jamaicensis (Red-tailed Hawk; RTHA). A common permanent resident throughout the study area. The second most common raptor along the river corridor in winter (89).

42. Aquila chrysaetos (Golden Eagle; GOEA). An uncommon and sparsely distributed permanent resident throughout the study area. Most records are from the upper reaches of the canyon where the birds may be more easily spotted (24).

FALCONIDAE: Falcons

43. Falco sparverius (American Kestrel; AMKE). An uncommon winter resident throughout the study area (24).

44. Falco peregrinus (Peregrine Falcon; PEFA). An extremely rare permanent resident with three records, one at RK 17 (reach 2) on 17 February 1998, one at RK 388 (reach 13) on 18 January 2000, and two at RK 326 (reach 11) on 20 February 2000. SFW reported one additional winter record (4).

ODONTOPHORIDAE: New World Quails

45. Callipepla gambelii (Gambel's Quail; GAQU). A single record of eight birds at RK 336 (reach 11) on 17 January 1999. SFW reported the species from the same general area in 1994 and it may be resident at this location (8).

RALLIDAE: Rails

46. Rallus limicola (Virginia Rail; VIRA). Extremely rare with three records, one seen at RK -14 on 2 January 1999, one heard at RK 396 (Spencer's Canyon) on 21 January 1998, and one (possibly two) head at RK 85 on 10 January 2000. These are the first winter records for the study area (3).

47. Porzana carolina (Sora; SORA). Rare. Five records of 14 different individuals were obtained, all in reach 13 between RK 420-426, and most at Quartermaster Marsh and Spencer's Canyon. Remarkable was a concentration of nine birds at Quartermaster Marsh on 27 February 1998. These represent the fist winter records for the study area (14).

48. Gallinula chloropus (Common Moorhen; COMO). Extremely rare. Multiple records of what were probably the three same individuals occurred at Quartermaster Marsh on 22 January, 27 February, and 13 May of 1998. These represent the first winter records in the study area (3).

49. Fulica americana (American Coot; AMCO). A common to abundant winter resident in reaches 1, 2 and 13. Occasionally birds are found in other reaches (3299).

SCOLOPACIDAE: Sandpipers and allies

50. Tringa melanoleuca (Greater Yellowlegs; GRYE). Extremely rare, with two records of single birds at RK 332 on 15 January 2000 and at RK 336 on 17 January 2000. These may have been of the same individual. A bird at Lees Ferry on 2 March 2000 was presumably an early migrant. This species was not reported in winter in the study area by BCJ, LDBSS or SFW, however SBBK included unspecified winter data on this species (2).

51. Actitis macularia (Spotted Sandpiper; SPSA). A rare to locally uncommon winter resident and rare summer breeder, with records from reaches 4 through 7, mostly in reaches 5 and 6. Of the 13 individuals, eight were seen in 2000. LDBSS reported one previous record from the study area in winter. Not reported in winter by BCJ or SFW, although SBBK included unspecified winter data on this species (13).

52. Gallinago delicata (Wilson's Snipe; WISN). Extremely rare with three records, single birds at Spencer's Canyon (reach 13) on 22 January 1998, Spencer's Canyon (reach 13) on 23 February 1999, and at RK -14 (reach 1) on 2 January 1999. SFW reported two additional winter records (3).

CUCULIDAE: Cuckoos

53. Geococcyx californianus (Greater Roadrunner; GRRO). Extremely rare, with two records of single birds, one at RK 337 on 21 January 1998, and one at RK 396 on 26 February 1998. BCJ reports it as being uncommon permanent resident along the river corridor, while LDBSS and SFW noted several records, but none from winter (2).

SRIGIDAE: Typical owls

54. Otus kennicottii (Western Screech-Owl; WSOW). Extremely rare winter resident with two records, single birds at RK 423 (reach 13) on 26 February 1998 and at RK 91 (reach 5) on 13 February 1999. BCJ report it as rare on the river corridor in winter (2).

55. Bubo virginianus (Great Horned Owl; GHOW). Uncommon permanent resident throughout the study area. During the course of the project birds were occasionally heard at river camps (3).

CAPRIMULGIDAE: Nighhawks

56. Phalaenoptilus nuttallii (Common Poorwill; COPO). One bird was seen at Spencer's Canyon (reach 13) on 22 February 1999. This represents the first winter record for the region (1).

TROCHILIDAE: Hummingbirds

57. Calypte anna (Anna's Hummingbird; ANHU). A rare winter resident in reaches 11 and 13 with records of four males at RK 316 and RK 319 on 16 January 1999, RK 323 on 17 January 1999, and at Spencer's Canyon on 19 January 2000. These birds, plus one in April of 1999 (LDBSS), represent the first records for the study area. The bird at Spencer's Canyon was visiting sapsucker holes in Gooddings willow (*Salix gooddingii*) (4).

58. Calyptae costae (Costa's Hummingbird; COHU). A common early breeder below reach 10 in the study area, with four records in February of males on territory (4).

ALCEDINIDAE: Typical Kingfishers

59. Ceryle alcyon (Belted Kingfisher; BEKI). An uncommon winter resident in reach 1 and rare in reach 13, but not detected in the other reaches of the study area. BCJ report it as being rare along the river corridor in winter (10).

PICIDAE: Woodpeckers

60. Sphyrapicus varius (Yellow-bellied Sapsucker; YBSA). A single bird at RK 1.6 (reach 2) on 12 February 1999 represents only the second record of this species in the region (LDBSS) (1).

61. Sphyrapicus nuchalis (Red-naped Sapsucker; RNSA). An uncommon winter resident throughout the river corridor in dense new high water zone vegetation. This species is quiet and easily overlooked, and may be more common than the records indicate (15).

62. Picoides scalaris (Ladder-backed Woodpecker; LBWO). A rare permanent resident below reach 10 in the study area. SFW suggest that it moves into the study area in February from upland vegetation, but three of the four records are from January in riparian vegetation between RK 322 and 330. Two unidentified woodpeckers seen briefly from a distance at RK 83L in dense old high water zone mesquite may have been this species (4).

63. Picoides villosus (Hairy Woodpecker; HAWO). Extremely rare with two records of single birds at RK 9 (reach 2) on 8 January 1998 and at RK 81 (reach 5) on 10 January 1999. BCJ reports one additional winter record from the river corridor, and the species has also been documented in winter in Glen Canyon by LSG (2).

64. Colaptes auratus (Northern Flicker; NOFL). An uncommon winter resident in dense riparian patches throughout the river corridor. All birds were of the red-shafted form. The totals reflect both area and boat surveys (22).

TYRANNIDAE: New World Flycatchers

65. Empidonax hammondii (Hammond's Flycatcher; HAFL). One record of a bird at RK 312 (reach 11) on 23 February 1998 represents the first winter record from the study area as well as northern Arizona (1).

66. Empidonax oberholseri (Gray Flycatcher; GRFL). One record of a bird at RK 334 (reach 11) on 21 February 1998 is the first winter record of the species in the study area and the region (1).

67. Empidonax oberholseri (Dusky Flycatcher; DUFL). One record of a bird RK 79 (reach 5) is the first winter record of the species in the study area and the region (1).

68. Sayornis nigricans (Black Phoebe; BLPH). A fairly common permanent resident in the lower reaches of the study area, particularly below reach 8. Although generally absent above ca. RK 175, birds have recently begun to over-winter in the Glen Canyon reach, where breeding has been documented since 1997 (LDBSS, LSG). Black phoebe's are most common along rocky shorelines of the river in the study area. The totals reflect both boat and area surveys (101).

69. Sayornis saya (Say's Phoebe; SAPH). A common permanent resident throughout the study area. Say's phoebe's were most commonly detected along the river shore where they were easily seen and heard. They were less common in the denser riparian patches. The species was much more common all three years in February than in January, suggesting that many may have been early migrants (93).

LANIIDAE: Shrikes

70. Lanius ludovicianus (Loggerhead Shrike; LOSH). Rare winter resident with scattered records from most portions of the study area. These represent the first documented winter records for the river corridor. The totals reflect both area and boat surveys (12).

VIREONIDAE: Vireos

71. Vireo huttoni (Hutton's Vireo; HUVI). A bird observed singing at RK 329 (reach 11) on 21 February 1999 represents the first record for the study area and the region and the northernmost record in Arizona (1).

CORVIDAE: Crows and Jays

72. Cyanocitta stelleri (Steller's Jay; STJA). A single record of a bird at RK 108 on 19 February 1998. BCJ report it as occasional on the river corridor in winter (1).

73. Gymnorhinus cyanocephalus (Pinyon Jay; PIJA). An uncommon winter resident in reaches 10 and 11. Jays generally occur as flocks that move widely throughout the lower canyon. One flock of ca. 60 birds flew directly over the boat at RK 185 on 18 January 1998. The totals reflect both boat and area surveys (274).

74. Corvus corax (Common Raven; CORA). A common permanent resident throughout the study area, generally associated with the more popular river camps. The totals reflect both boat and area surveys (60).

ALAUDIDAE: Larks

75. Eremophila alpestris (Horned Lark; HOLA). A flock of 50 seen at RK 3 on 8 January 2000 apparently represents the first winter record for the study area (50).

HIRUNDINIDAE: Swallows

76. Tachycineta bicolor (Tree Swallow; TRSW). Extremely rare with two records, one seen at RK 328 on 24 February 1998 and two at RK 359 on 25 February 1998. These probably represent early migrants, and are the earliest spring records for this species from the region (3)

77. Tachycineta thalassina (Violet-green Swallow; VGSW). Extremely rare with four records, three at RK 240 (reach 10) on 18 February 2000, three at Spencer's Canyon (reach 13) on 23 February 2000, a single bird at RK 435 on 23 February 2000, and a single bird at Quartermaster Marsh (reach 13) on 23 February 1999 represent the first winter records in the study area, and are probably all early migrants.

According to BCJ, the earliest and latest dates for this species in the river corridor are 3 March to 31 October (8).

78. Stelgidopteryx serripennis (Northern Rough-winged Swallow; NRWS). Extremely rare with four records, a single bird at RK 336 (reach 11) on 21 February 1999, six between Quartermaster Marsh and Pearce Ferry (reach 13) on 26-27 February 1999, one at RK 426 (reach 13) on 23 February 2000, and three at RK 435 on 23 February 2000 represent the first winter records for the study area, and were probably all early migrants. LSG report one additional winter record of a bird at Lee's Ferry on 16 January 2000 (11).

PARIDAE: Chickadees and Titmice

79. Poecile gambeli (Mountain Chickadee; MOCH). Rare winter resident in reaches 1-4. Not found below the Little Colorado River in the study area. All sightings of this species were in 1999 (8).

AEGITHALIDAE: Long-tailed Tits

80. Psaltriparus minimus (Bushtit; BUSH). A locally common winter resident throughout the study area, but particularly common in reaches 1, 5 and 11. Bushtits always occur in flocks ranging from a few birds to 65 in one case, and move rapidly through new high water zone vegetation foraging. They were particularly common along the river corridor in 2000 (676).

TROGLODYTIDAE: Wrens

81. Salpinctes obsoletus (Rock Wren; ROWR). A fairly common permanent resident throughout the study area. Most birds were detected by their calls, and were heard mostly in upland vegetation (98).

82. Catherpes mexicanus (Canyon Wren; CANW). A common permanent resident throughout the study area in all habitats, but concentrated in the uplands (200).

83. Thryomanes bewickii (Bewick's Wren’ BEWR). A common permanent resident throughout the study area, with the majority of detections in the new and old high water zones (309).

84. Troglodytes aedon (House Wren; HOWR). Extremely rare winter resident with seven records, single birds at RK 327, RK 329 and RK 336 on 17 January 1999, single birds at Spencer’s Canyon (reach 13) on 18 January 1999 and 26 February 1998, and single birds at RK 336 on 20 January 1998 and 21 February 1999 (7).

85. Troglodytes troglodytes (Winter Wren; WIWR). An uncommon winter resident throughout the study area with 26 birds detected in 1998 and 1999. Also reported by BCJ, LSG and SFW (26).

86. Cistothorus palustris (Marsh Wren; MAWR). A locally common winter resident in marsh vegetation and associated river margin coyote willow-seepwillow scrub throughout the study area where suitable habitat occurs. Although SFW did not detect any in winter, BCJ indicate that it is rare in winter on the river corridor (86).

CINCLIDAE: Dippers

87. Cinclus mexicanus (Ammerican Dipper; AMDI). A locally common winter resident, especially in reaches 4 and 11, but found throughout the study area (43).

REGULIDAE: Kinglets

88. Regulus satrapa (Golden-crowned Kinglet; GCKI). One record of a bird at Quartermaster Marsh (reach 13) on 19 January 1999. SFW and LSG document additional winter records, all from Lee's Ferry or above (1).

89. Regulus calendula (Ruby-crowned Kinglet; RCKI). A common to abundant winter resident in the study area. Ruby-crowned kinglets are the most widespread species in riparian vegetation along the river corridor, and almost every patch of new high water zone scrub supports one or more birds (872).

SYLVIIDAE: Old World Warblers and Gnatcatchers

90. Polioptila caerulea (Blue-gray Gnatcatcher; BGGN). A single record of two birds at RK 329 on 21 February 1999. BCJ and LSG report four additional winter records from the river corridor. This species apparently winters locally in the region, with an additional record of two birds from Wahweap on Lake Powell on 3 January 2001 (2).

TURDIDAE: Thrushes

91. Sialia mexicana (Western Bluebird; WEBL). A fairly common winter resident in reach 11, where dense old high water zone stands of mesquite and catclaw support mistletoe (*Phoradendron californicum*). Bluebirds were especially common in reach 11 in 1999. The totals reflect both area and boat surveys (373).

92. Sialia currucoides (Mountain Bluebird; MOBL). A single record of a bird at RK 330 on 21 February 1999 represents the second winter record from the study area (SFW) (1).

93. Myadestes townsendi (Townsend's Solitaire; TOSO). A rare winter resident in reach 11 where dense infestations of mistletoe (*Phoradendron californicum*) occur. BCJ report it to be uncommon in late winter on the river corridor. The totals reflect both area and boat surveys (8).

94. Catharus guttatus (Hermit Thrush; HETH). A rare winter resident throughout the study area, but most common in reaches 11 and 13. BCJ, LSG and SFW report three additional winter records from the river corridor. The totals reflect both area and boat surveys (15).

95. Turdus migratorius (American Robin; AMRO). A rare winter resident throughout the study area (6).

MIMIDAE: Mockingbirds and Thrashers

96. Mimus polyglottos (Northern Mockingbird; NOMO). Extremely rare, with two records of single birds at RK 336 (reach 11) on 18 January 1999 and RK 312 (reach 11) on 15 January 2000. These are the first winter records for the study area (2).

97. Oreoscoptes montanus (Sage Thrasher; SATH). A bird seen at RK 316 on 20 February 1999 represents the first winter record and only the third record for the study area (1).

98. Toxostoma crissale (Crissal Thrasher; CRTH). Extremely rare permanent resident, primarily below reach 10 in the study area. Three records during the study period, single birds at Spencer's Canyon (reach 1) on 22 January 1998 and 26 February 1998, and seven at RK 426 on 27 February 1998. LSG and SFW report two additional winter records from the river corridor (9).

MOTACILLIDAE: Wagtails and Pipits

99. Anthus rubescens (American Pipit; AMPI). An uncommon winter resident throughout the study area, generally found at the river's edge. Most sightings were from boat surveys (87).

PTILOGONATIDAE: Silky-flycatchers

100. Phainopepla nitens (Phainopepla; PHAI). A locally common winter resident and spring breeder in reach 11 where dense infestations of mistletoe (*Phoradendron californicum*) occur in the old high water zone. By February the males are on territories and are actively defending mistletoe patches from Townsend's solitaires and western bluebirds (52).

PARULIDAE: Wood-warblers

101. Vermivora celata (Orange-crowned Warbler; OCWA). An uncommon to rare winter resident in reaches 11 through 13, where generally found in dense new high water zone scrub. Rare elsewhere in the study area in winter. The 36 records represent the first winter records of orange-crowned warbler in the study area (36).

102. Dendroica coronata (Yellow-rumped Warbler; YRWA). A fairly common winter resident in larger patches of riparian vegetation throughout the study area, and particularly common in reaches 1, 2, 5, 11 and 13. Both subspecies occur, with up to 30% of wintering birds being the Myrtle's subspecies (*D. c. coronata*). Most individuals were detected in new high water zone vegetation. The totals reflect both area and boat surveys (229).

103. Dendroica discolor (Prairie Warbler; PRWA). An adult male at Spencer's Canyon (reach 13) on 22 January and 28 February 1998 represents the first record for the study area and the region (1).

104. Geothlypis trichas (Common Yellowthroat; COYE). An adult male at RK 80 on 10 January and 14 February 1999 represents the first winter record from the study area and the region (1).

EMBERIZIDAE: Buntings, sparrows and towhees

105. Pipilio maculatus (Spotted Towhee; SPTO). An uncommon winter resident throughout the study area (40).

106. Aimophila ruficeps (Rufous-crowned Sparrow; RCSP). An uncommon to sparsely distributed permanent resident throughout the study area, most common in the upper reaches (15).

107. Spizella passerina (Chipping Sparrow; CHSP). Extremely rare winter resident with four records, two at RK 336 (reach 11) on 21 January 1998 and 25 February 1998, and one on 18 January 1999, and two at RK 315 (reach 11) on 23 February 1998. BCJ report two additional winter records from the study area (7).

108. Spizella breweri (Brewer's Sparrow; BRSP). Extremely rare winter resident, with three records, one at RK 8 (reach 2) on 12 January 1998, 25 at RK –5 (reach 1) on 13 February 1998, and two at RK 90 (reach 5) on 19 February 1998. These represent the first winter records for the study area and region (28).

*109. Amphispiza bil*ineata (Black-throated Sparrow; BTSP). A rare winter resident in the study area, primarily below Phantom Ranch. BCJ report one previous winter record for Grand Canyon NP, but these represent the first winter records for the study area. LSG document recent winter records from the Page area (22).

110. Amphispiza belli (Sage Sparrow; SASP). A single record of a bird at RK 329 on 18 January 1999 represents the first winter record for the study area (1).

111. Passerella iliaca (Fox Sparrow; FOSP). An individual at RK –14 represents the second winter record from the river corridor and the region. The bird was of the "slate-colored" subspecies (1).

112. Melospiza melodia (Song Sparrow; SOSP). A common winter resident throughout the study area and local summer resident below reach 5 in the study area, primarily in new high water zone scrub and marsh vegetation (376).

113. Melospiza lincolnii (Lincoln's Sparrow; LISP). An uncommon to rare winter resident throughout the study area in new high water zone vegetation. BCJ and SFW document several additional winter records from the river corridor. The species appears to winter in the study area at least some years. Lincoln's sparrows were much more common in 1998 than in the two subsequent years (71).

114. Melospiza georgiana (Swamp Sparrow; SWSP). Extremely rare winter resident with five records, individuals at RK –14 (reach 1) on 4 February 2000, RK 2.5 (reach 2) on 17 February 1998, RK 141 (reach 7) on 20 February 1998, RK 329 (reach 11) on 24 February 1998, and RK 336 (reach 11) on 25 February 1998. These represent the first winter records of this species in the study area (5).

115. Zonotrichia albicollis (White-throated Sparrow; WTSP). A single record of an individual of the "tan-striped" subspecies at Phantom Ranch (reach 7) on 15 January 1998. BCJ and SFW do not report any winter records, but LSG report two winter records from Glen Canyon (1).

116. Zonotrichia leucophrys (White-crowned Sparrow; WCSP). A locally abundant winter resident in reach 1, and occasional in reaches 2 and 11, but rare elsewhere. White-crowned sparrows are primarily found in the Glen Canyon reach in the winter, where they generally occur in large flocks in stands of four-wing saltbush (*Atriplex canescens*) on older river terraces adjacent to the new high water zone. The species was significantly rarer in 1999 compared with 1998 and 2000 (991).

117. Zonotrichia atricapilla (Golden-crowned Sparrow; GCSP). Extremely rare with three records, one at RK –14 (reach 1) on 8 January 1998, one at RK 219 (reach 7) on 20 January 1998, and one at RK 219 (reach 9) on 16 January 1998. BCJ report one additional record from the study area in winter (3).

118. Junco hyemalis (Dark-eyed Junco; DEJU). An uncommon to locally common winter resident found throughout the river corridor. Individuals of four subspecies occur, including slate-colored and gray-headed, although the majority were either Oregon or pink-sided (580).

ICTERIDAE: Blackbirds

119. Agelaius phoeniceus (Red-winged Blackbird RWBL). A rare winter resident in the study area, primarily on Lake Mead (reach 13). A flock of 70 birds was seen at RK 426 (reach 13) on 22 January 1998, and a second flock of 35 were at RK 415 (reach 13) on 19 January 2000 (109).

120. Icterus pustulatus (Streak-backed Oriole; SBOR). A bird was seen and heard at Spencer's Canyon (reach 13) on 22 January 1998. This is the first record of this primarily Mexican species from the region and northern Arizona (1).

121. Quiscalus mexicanus (Great-tailed grackle; GTGR). Extremely rare permanent resident with five records of birds between RK 418-420 (reach13). Most sightings were associated with the river level helicopter platform and associated structures just downstream from Quartermaster Marsh, and included pairs (9).

FRINGILLIDAE: Finches

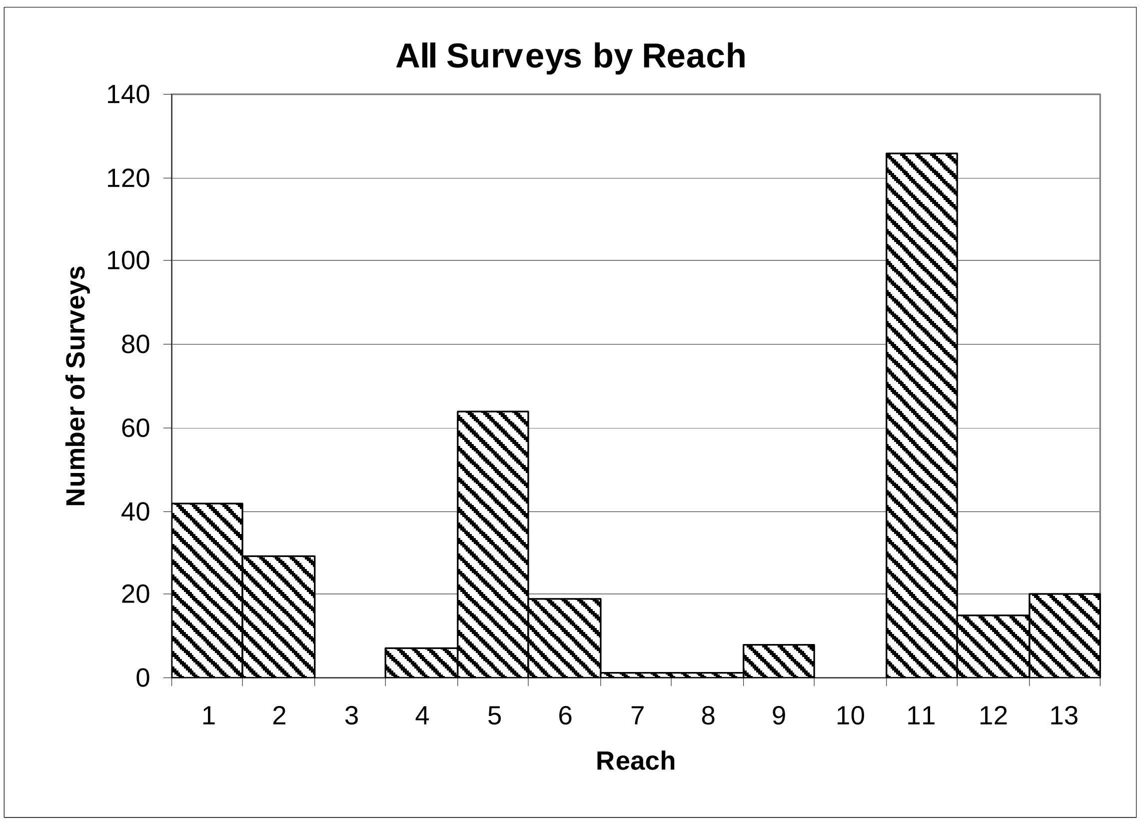
122. Carpodaucus mexicanus (House Finch; HOFI). A locally common permanent resident in the study area, primarily in reaches 1,2 5, 11 and 12. House finch was much more abundant in 1999 than in 1998 and 2000 (302).

123. Loxia curvirostra (Red Crossbill; RECR). A bird seen and heard calling at RK 83 (reach 5) on 13 January 1998 represents the first record from the study area and river corridor (1).

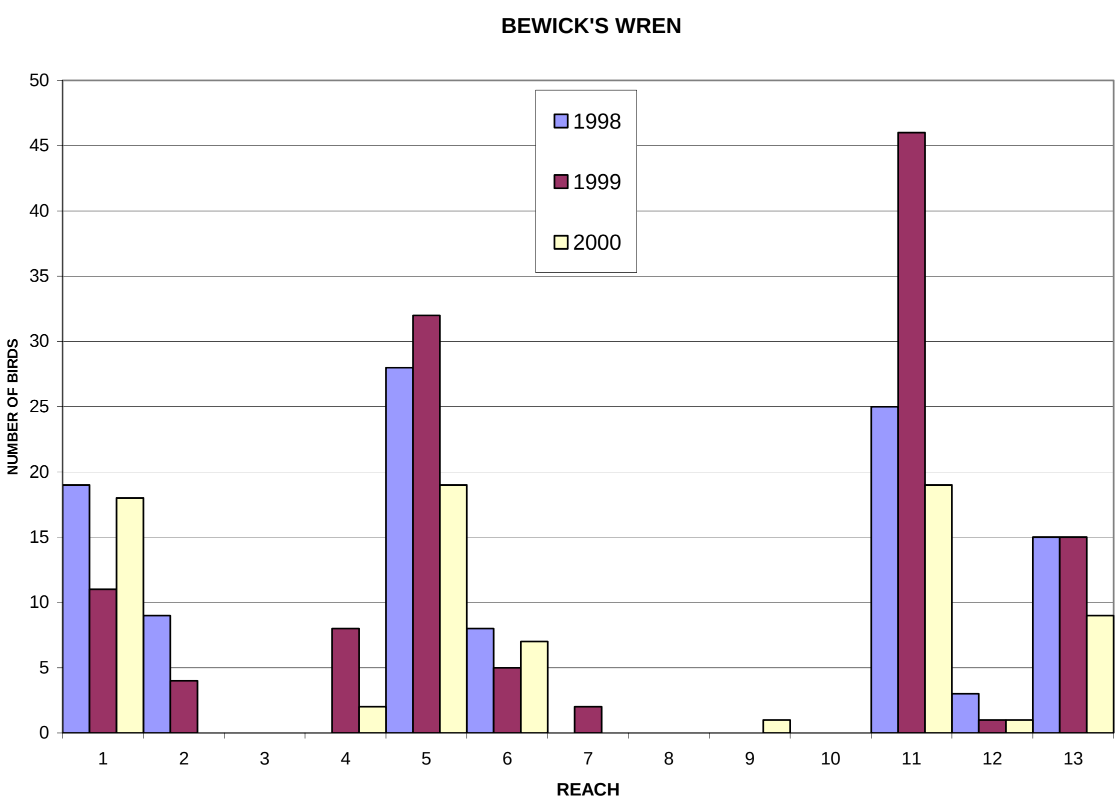
124. Carduelis psaltria (Lesser Goldfinch; LEGO). Extremely rare with two records, 2 birds at 1.6K (reach 2) on 8 Janaury 2000, and 1 bird at RK 89 on 11 January 2000. Although BCJ report it as rare in winter along the river corridor, SFW did not find the species (3).

APPENDIX C

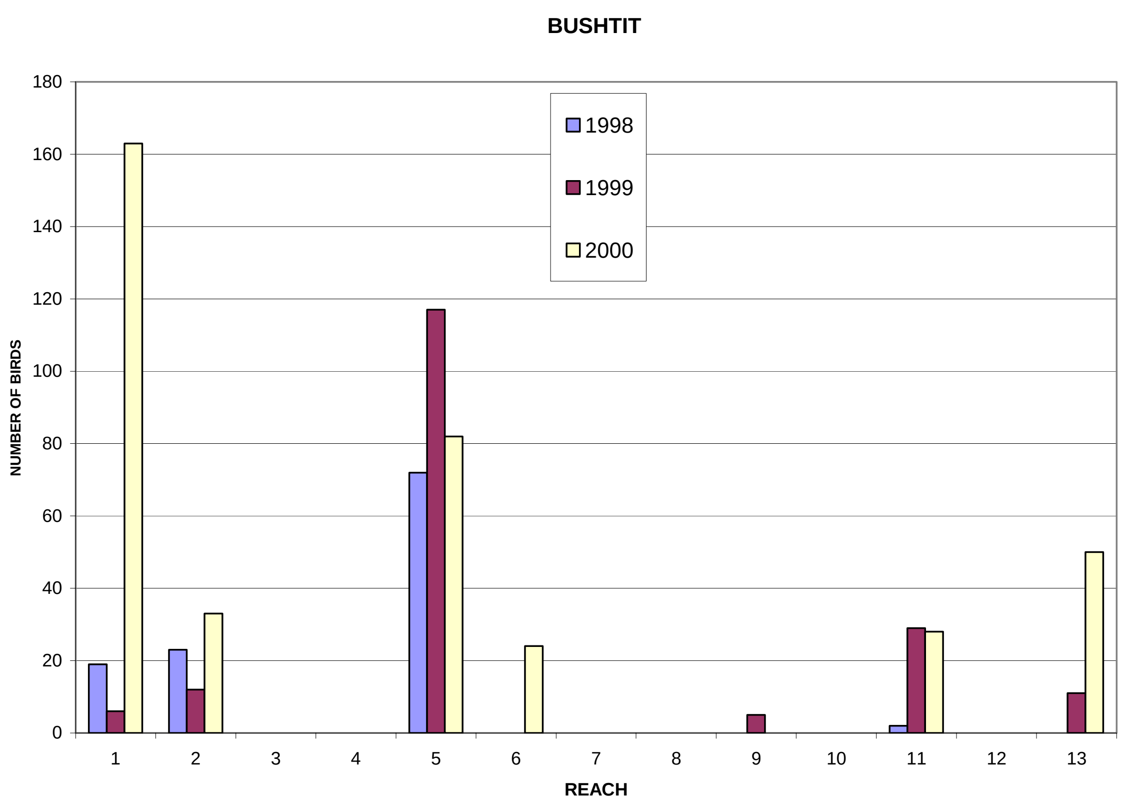
Summaries for the 15 most common winter terrestrial bird species along the Colorado River from Glen Canyon Dam to upper Lake Mead are presented. For each species, a table summarizing total numbers detected, mean numbers detected per patch, minimum and maximum numbers detected per patch, number of patches found in, and numbers detected in three principal habitats for each of the three years 1998-2000. Each year summary is based on two trips, one each in January and February. A chart graphing abundance by reach for each year is also included. Reaches are numbered from 1-13 and are from Schmidt and Graf (1990). The graph below shows the number of area searches done over the three years of the study organized by reach.



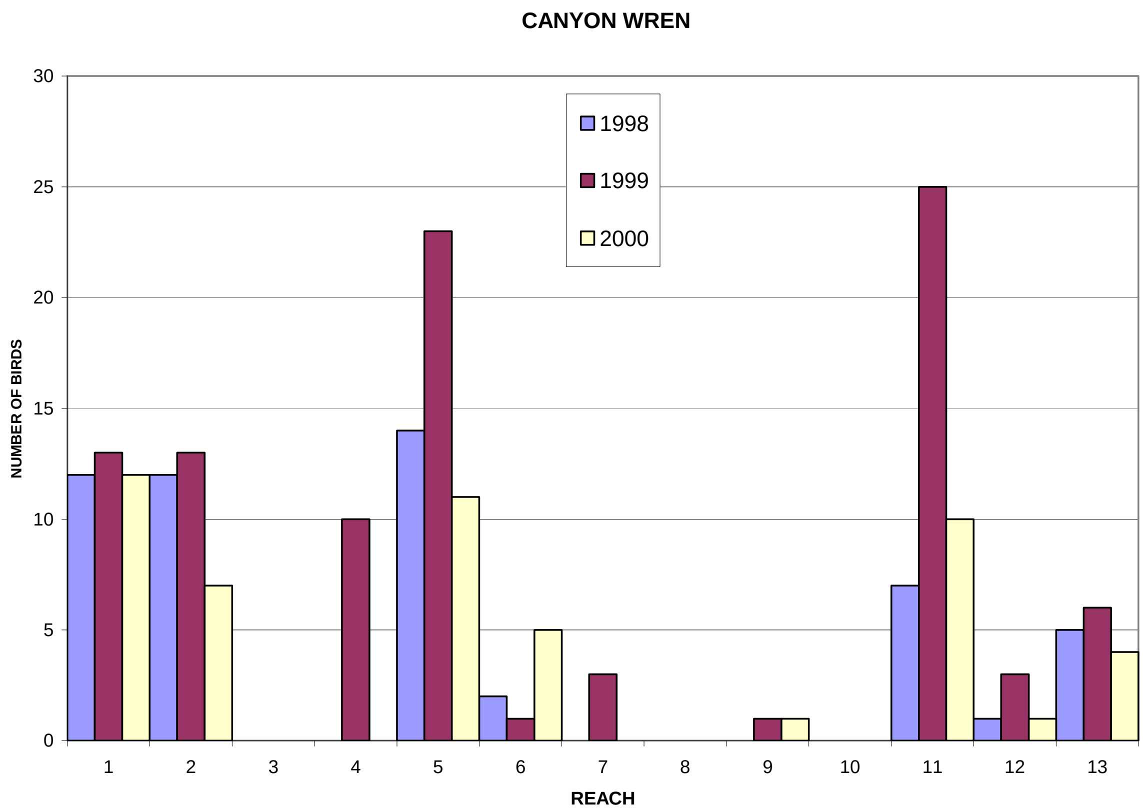
BEWICK'S WREN	1998	1999	2000
Total Abundance	107	124	75
Mean Individuals/Patch	1.021 (1.315)	1 (0.125)	0.75 (0.103)
Min-Max Individuals/Patch	0-6	0-12	0-5
Total Individuals in NHWZ	72	66	58
Total Individuals in OHWZ	25	52	13
Total Individuals in Upland	1	8	4
Total Individuals in January	53	44	32
Total Individuals in February	54	80	43
Number of Patches Found In	35	58	39
Total Patches Surveyed	103	128	100



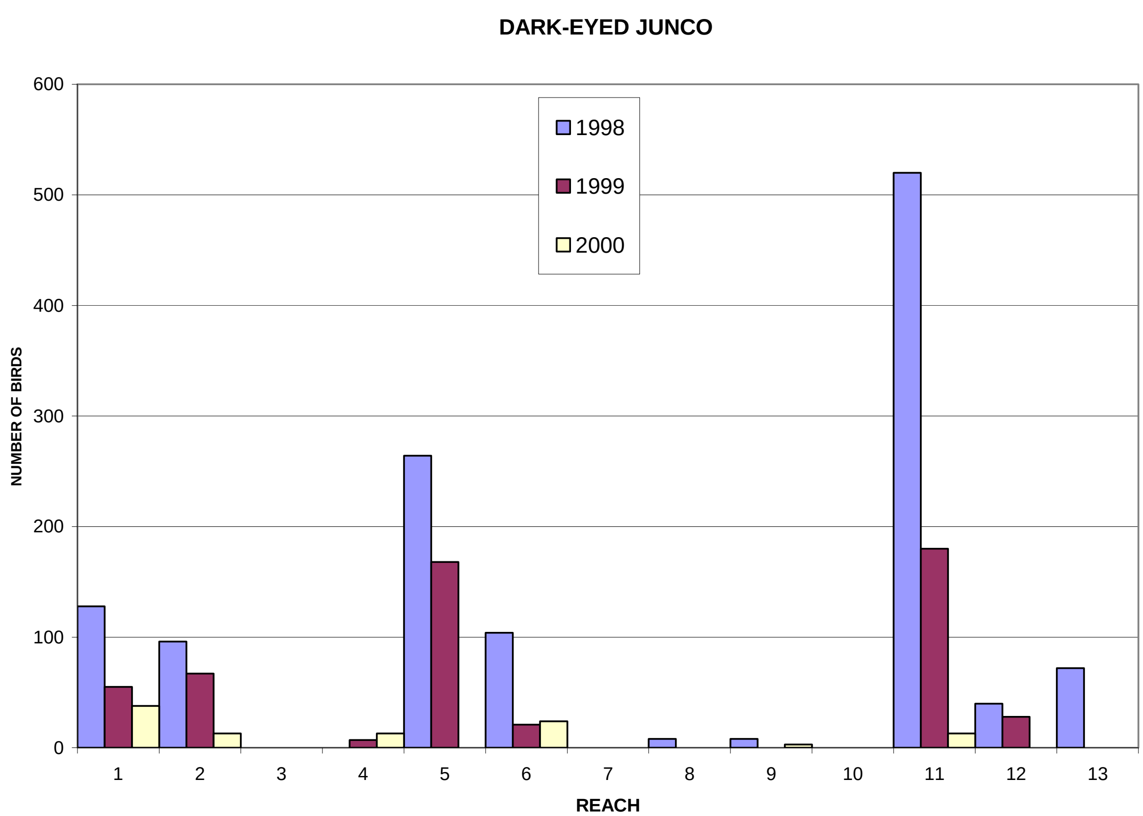
BUSHTIT	1998	1999	2000
Total Abundance	116	180	380
Mean Individuals/Patch	1.18	1.45 (0.42)	3.8
Min-Max Individuals/Patch	0-23	0-28	0-65
Total Individuals in NHWZ	103	113	307
Total Individuals in OHWZ	13	36	73
Total Individuals in Upland	0	26	0
Total Individuals in January	67	62	121
Total Individuals in February	49	118	259
Number of Patches Found In	10	15	21
Total Patches Surveyed	103	128	100



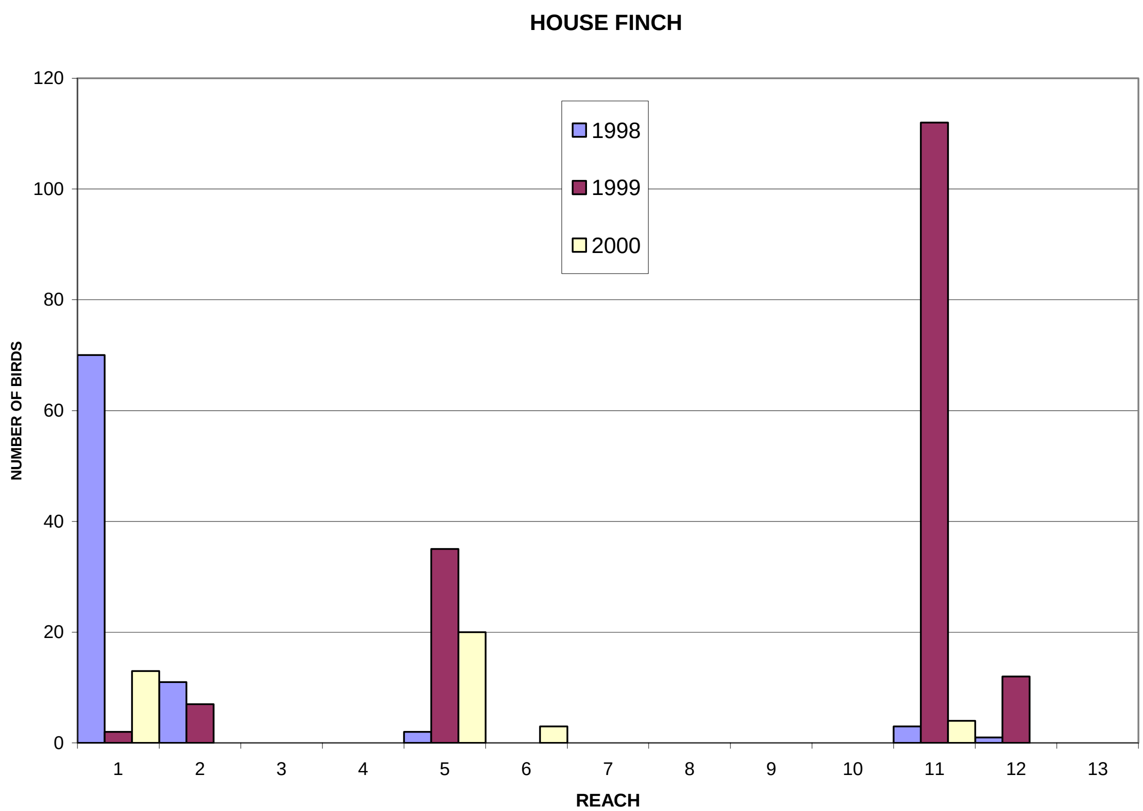
CANYON WREN	1998	1999	2000
Total Abundance	53	98	49
Mean Individuals/Patch	0.528 (0.075)	0.822 (0.099)	0.49 (0.0674)
Min-Max Individuals/Patch	0-3	0-5	0-3
Total Individuals in NHWZ	10	15	14
Total Individuals in OHWZ	10	24	6
Total Individuals in Upland	31	60	31
Total Individuals in January	28	53	20
Total Individuals in February	25	45	29
Number of Patches Found In	29	50	31
Total Patches Surveyed	103	128	100



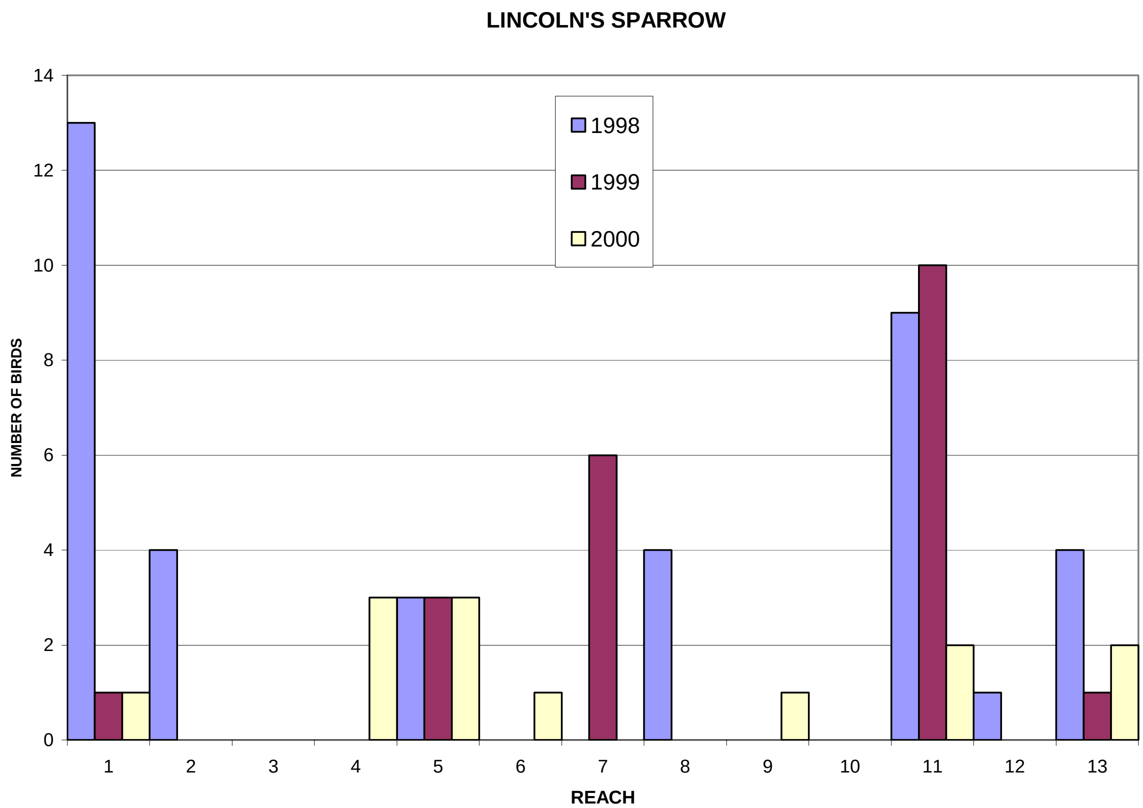
DARK-EYED JUNCO	1998	1999	2000
Total Abundance	278	259	47
Mean Individuals/Patch	0.615 (0.053)	2.008 (0.462)	0.464 (0.192)
Min-Max Individuals/Patch	0-7	0-35	0-15
Total Individuals in NHWZ	237	107	45
Total Individuals in OHWZ	29	114	2
Total Individuals in Upland	2	22	0
Total Individuals in January	159	174	25
Total Individuals in February	119	85	22
Number of Patches Found In	21	4	10
Total Patches Surveyed	103	128	100



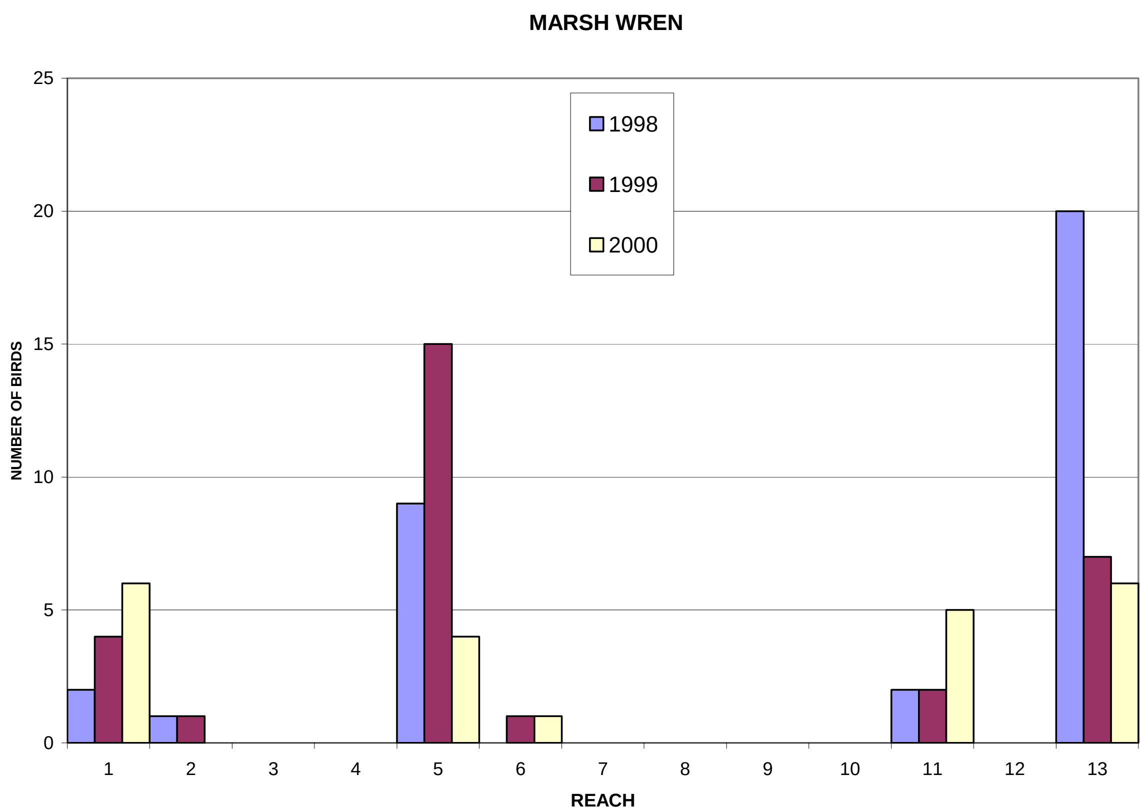
HOUSE FINCH	1998	1999	2000
Total Abundance	87	168	40
Mean Individuals/Patch	0.913 (0.473)	1.354 (0.605)	0.4 (0.144)
Min-Max Individuals/Patch	0-40	0-70	0-12
Total Individuals in NHWZ	75	14	22
Total Individuals in OHWZ	3	106	11
Total Individuals in Upland	3	44	8
Total Individuals in January	43	44	21
Total Individuals in February	44	124	19
Number of Patches Found In	12	18	12
Total Patches Surveyed	103	128	100



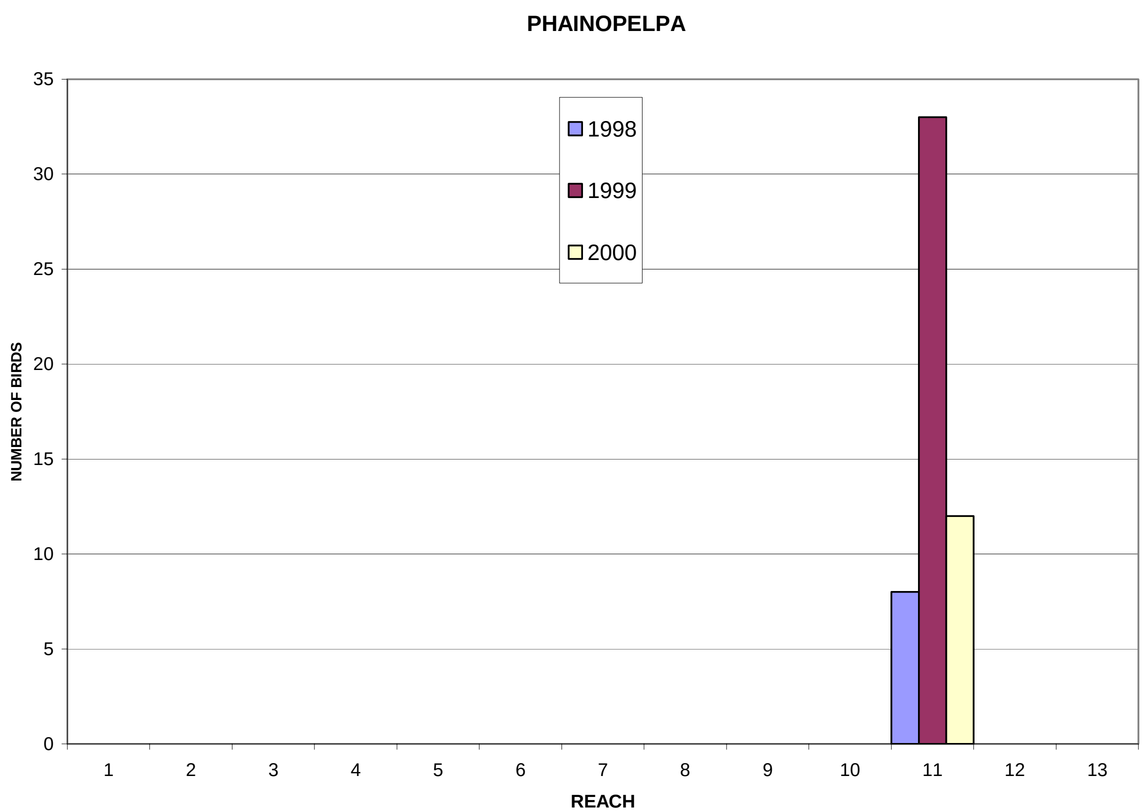
LINCOLN'S SPARROW	1998	1999	2000
Total Abundance	38	21	12
Mean Individuals/Patch	0.037 (0.806)	0.169 (0.056)	0.12 (0.035)
Min-Max Individuals/Patch	0-4	0-6	0-2
Total Individuals in NHWZ	32	17	6
Total Individuals in OHWZ	3	4	5
Total Individuals in Upland	1	0	1
Total Individuals in January	26	4	5
Total Individuals in February	12	17	7
Number of Patches Found In	20	15	9
Total Patches Surveyed	103	128	100



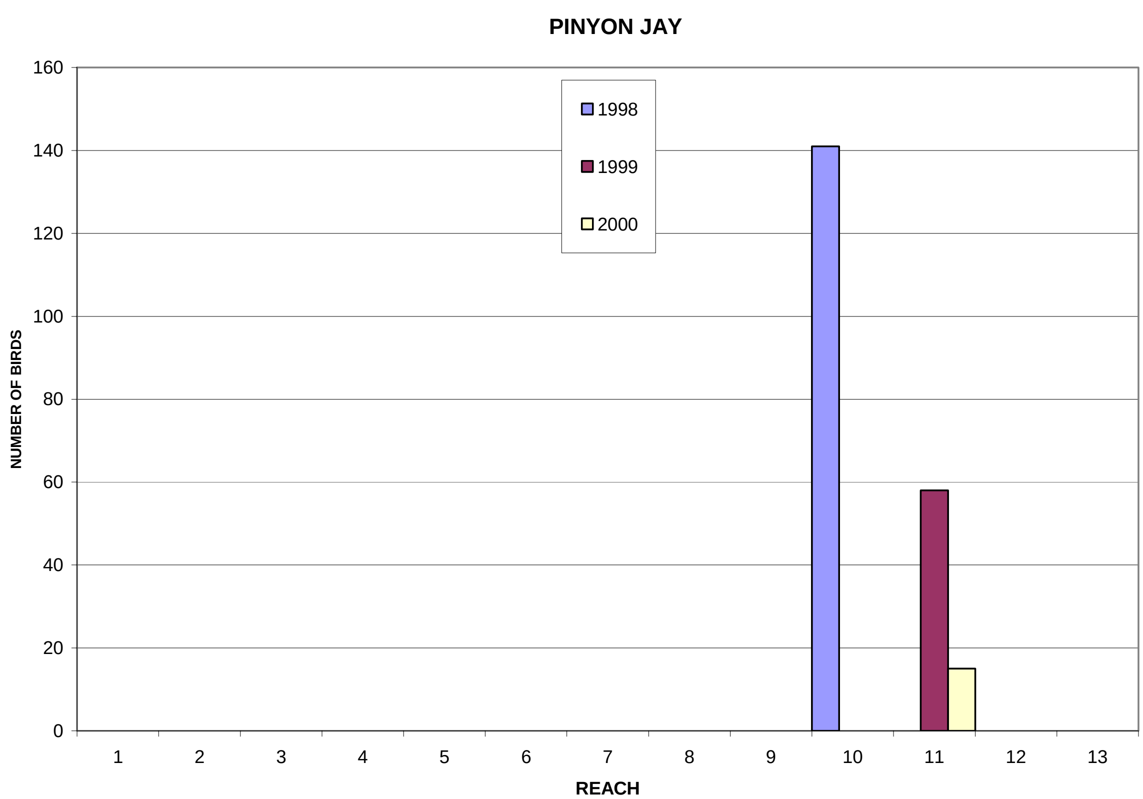
MARSH WREN	1998	1999	2000
Total Abundance	34	30	22
Mean Individuals/Patch	0.215 (0.0714)	0.25 (0.070)	0.22 (0.057)
Min-Max Individuals/Patch	0-4	0-6	0-3
Total Individuals in NHWZ	32	30	21
Total Individuals in OHWZ	0	0	0
Total Individuals in Upland	0	0	1
Total Individuals in January	22	16	12
Total Individuals in February	12	14	10
Number of Patches Found In	9	15	15
Total Patches Surveyed	103	128	100



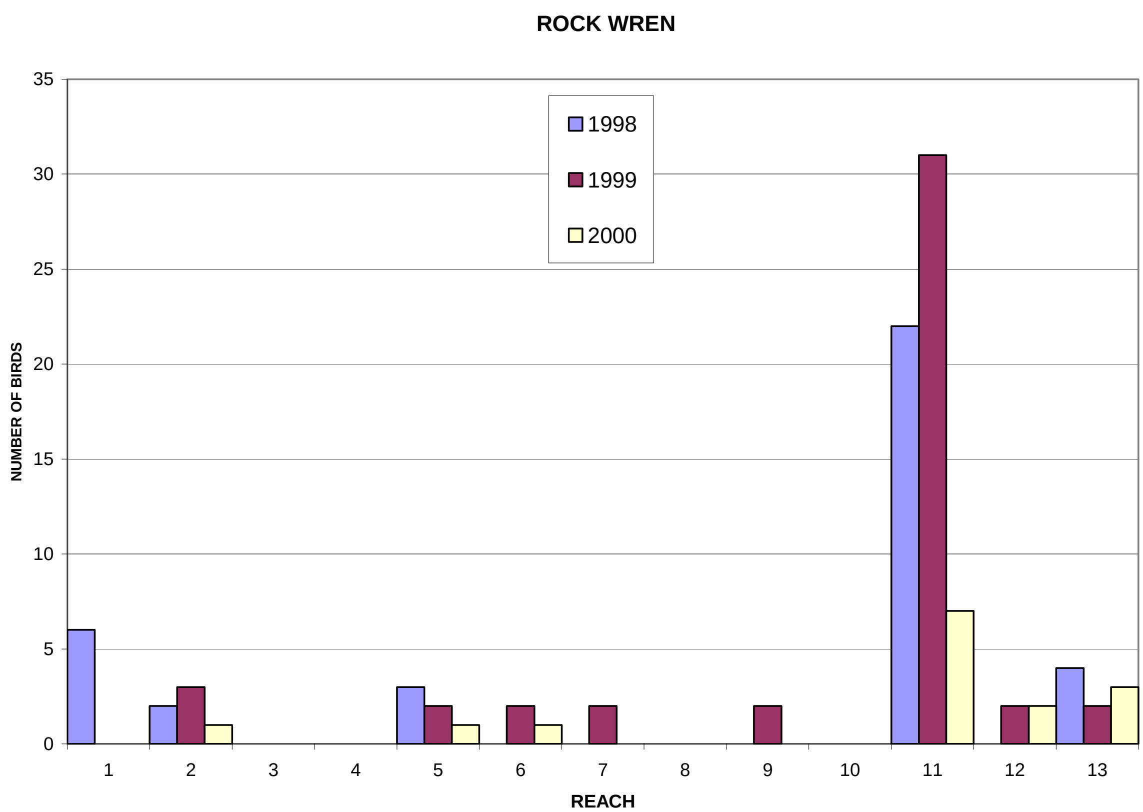
PHAINOPEPLA	1998	1999	2000
Total Abundance	7	33	12
Mean Individuals/Patch	0.075 (0.048)	0.266 (0.103)	0.12 (0.0607)
Min-Max Individuals/Patch	0-4	0-7	0-4
Total Individuals in NHWZ	3	0	0
Total Individuals in OHWZ	4	33	12
Total Individuals in Upland	0	0	0
Total Individuals in January	5	16	6
Total Individuals in February	2	17	6
Number of Patches Found In	2	7	2
Total Patches Surveyed	103	128	100



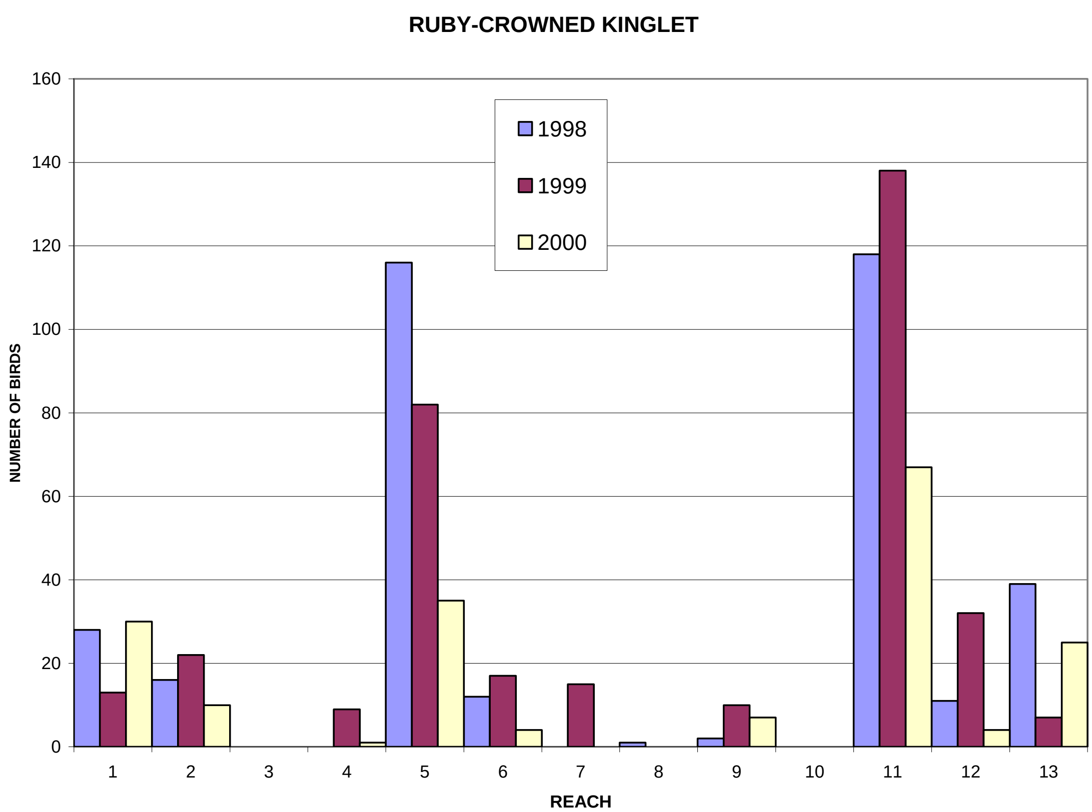
PINYON JAY	**1998**	**1999**	**2000**
Total Abundance	141	58	15
Mean Individuals/Patch	1.516 (1.069)	0.467 (0.298)	0.15 (0.15)
Min-Max Individuals/Patch	0-80	0-31	0-15
Total Individuals in NHWZ	0	0	0
Total Individuals in OHWZ	1	51	10
Total Individuals in Upland	140	7	15
Total Individuals in January	80	2	0
Total Individuals in February	61	56	15
Number of Patches Found In	2	3	1
Total Patches Surveyed	103	128	100



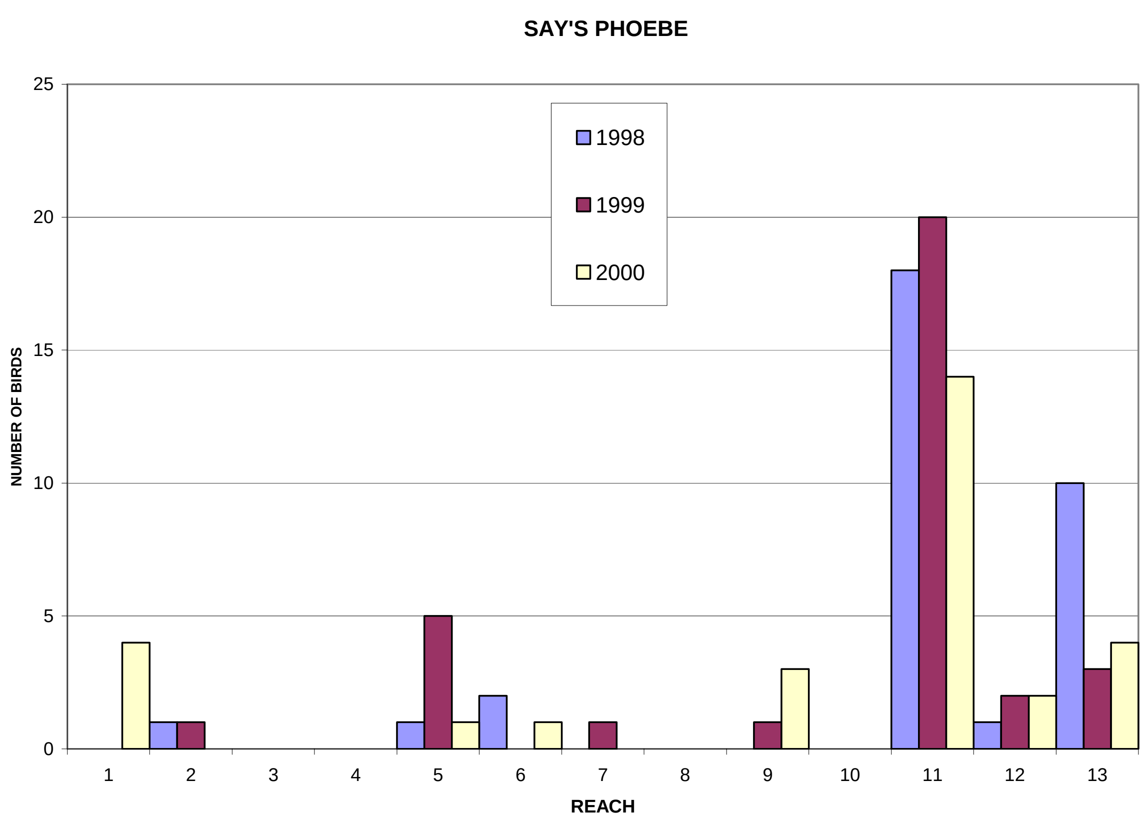
ROCK WREN	1998	1999	2000
Total Abundance	37	46	15
Mean Individuals/Patch	0.037 (0.076)	0.370 (0.074)	0.15 (0.038)
Min-Max Individuals/Patch	0-4	0-6	0-2
Total Individuals in NHWZ	1	3	1
Total Individuals in OHWZ	2	13	3
Total Individuals in Upland	34	30	12
Total Individuals in January	11	20	8
Total Individuals in February	26	26	7
Number of Patches Found In	21	24	13
Total Patches Surveyed	103	128	100



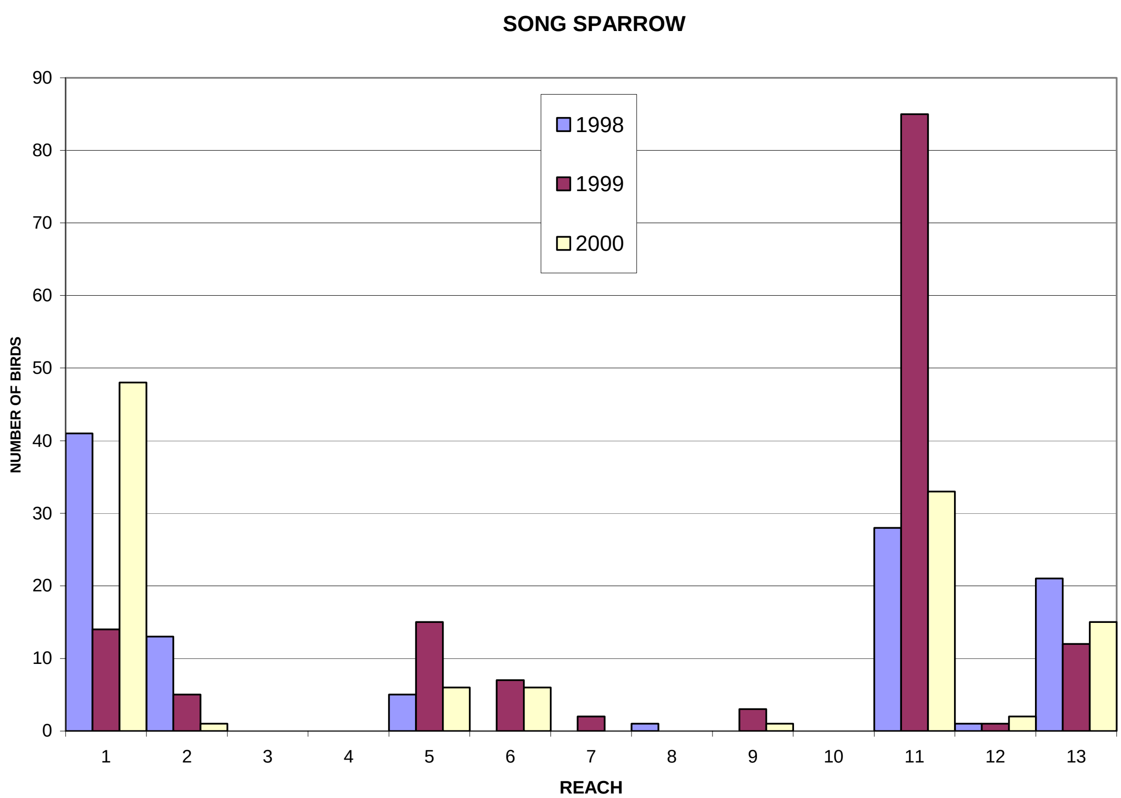
RUBY-CROWNED KINGLET	1998	1999	2000
Total Abundance	349	344	179
Mean Individuals/Patch	3.59 (0.472)	0.137 (0.070)	1.83 (0.216)
Min-Max Individuals/Patch	0-29	0-6	0-13
Total Individuals in NHWZ	263	189	130
Total Individuals in OHWZ	65	136	46
Total Individuals in Upland	1	17	6
Total Individuals in January	162	175	97
Total Individuals in February	187	169	86
Number of Patches Found In	54	71	53
Total Patches Surveyed	103	128	100



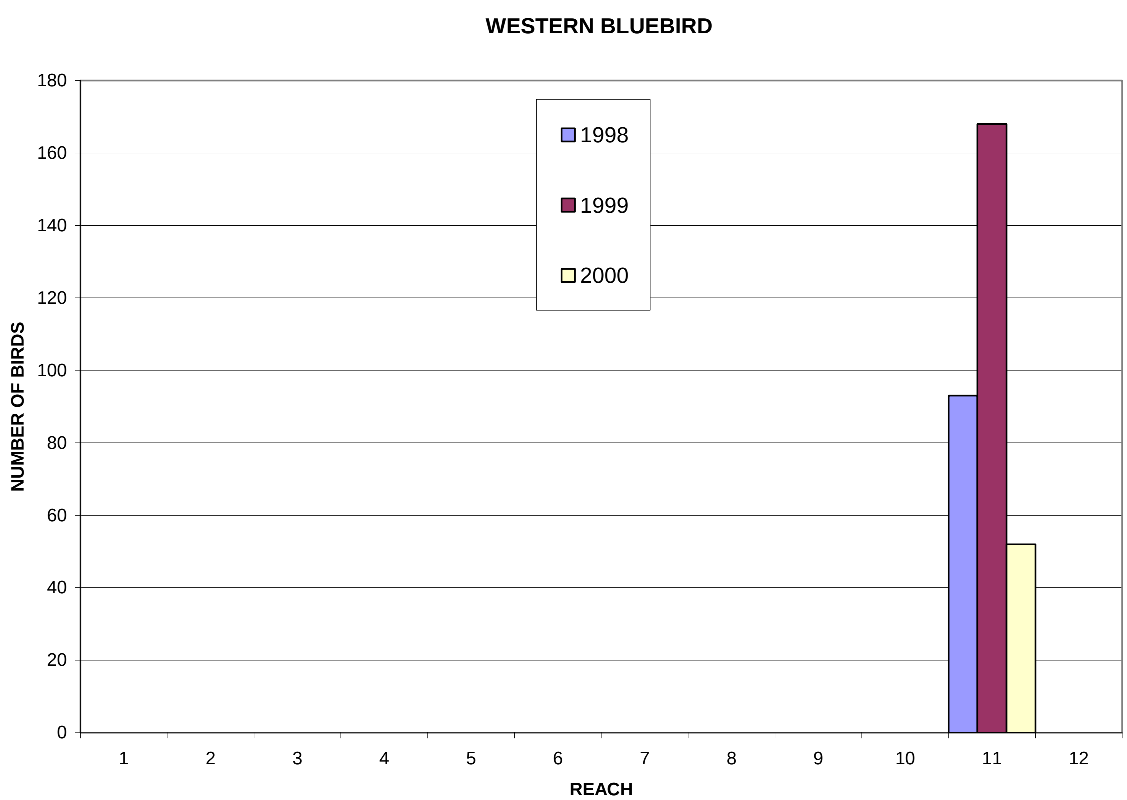
SAY'S PHOEBE	1998	1999	2000
Total Abundance	33	33	27
Mean Individuals/Patch	0.290 (0.075)	0.266 (0.051)	0.27 (0.048)
Min-Max Individuals/Patch	0-4	0-4	0-2
Total Individuals in NHWZ	20	16	14
Total Individuals in OHWZ	7	6	6
Total Individuals in Upland	2	6	9
Total Individuals in January	8	13	4
Total Individuals in February	25	20	23
Number of Patches Found In	13	25	24
Total Patches Surveyed	103	128	100



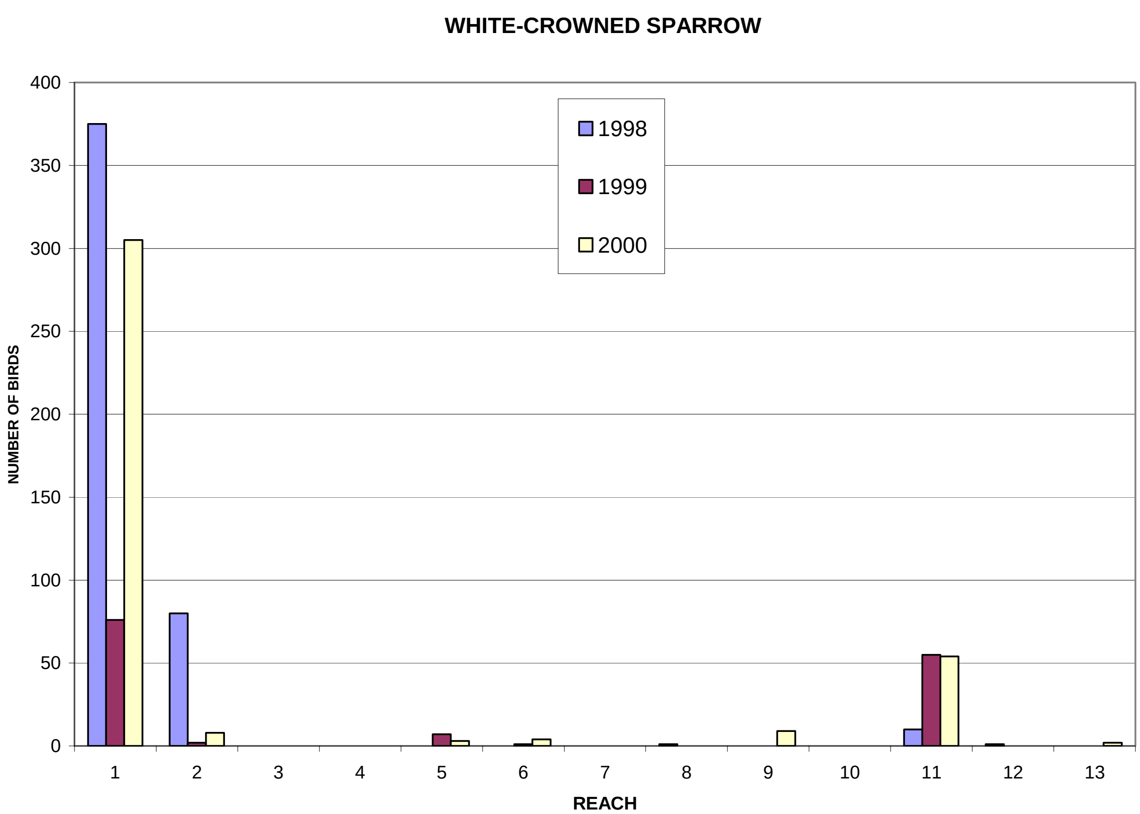
SONG SPARROW	1998	1999	2000
Total Abundance	110	144	112
Mean Individuals/Patch	0.935 (0.206)	1.169 (0.167)	1.12 (0.206)
Min-Max Individuals/Patch	0-14	0-12	0-12
Total Individuals in NHWZ	98	107	97
Total Individuals in OHWZ	5	34	6
Total Individuals in Upland	3	2	10
Total Individuals in January	63	83	33
Total Individuals in February	47	61	79
Number of Patches Found In	30	46	39
Total Patches Surveyed	103	128	100



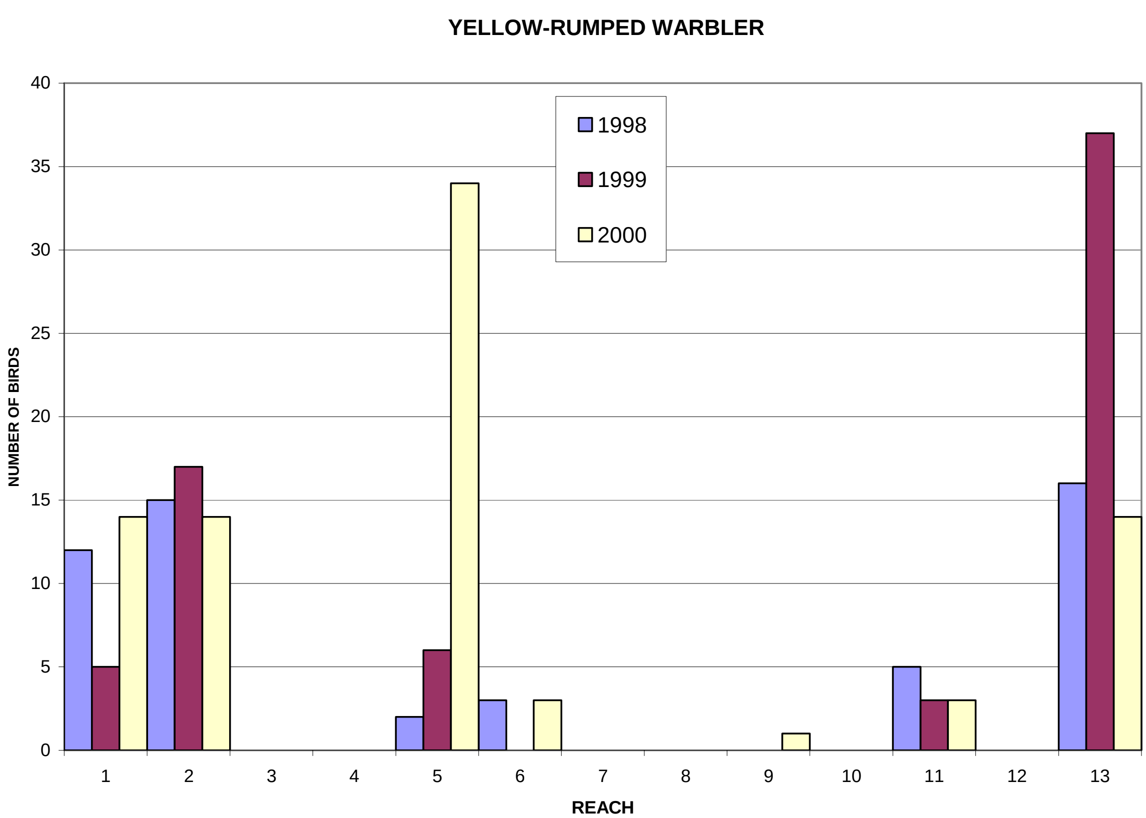
WESTERN BLUEBIRD	1998	1999	2000
Total Abundance	93	168	52
Mean Individuals/Patch	1 (0.342)	1.354 (0.440)	0.52 (0.219)
Min-Max Individuals/Patch	0-22	0-42	0-14
Total Individuals in NHWZ	36	35	17
Total Individuals in OHWZ	48	102	34
Total Individuals in Upland	6	0	3
Total Individuals in January	29	110	20
Total Individuals in February	64	58	32
Number of Patches Found In	8	12	6
Total Patches Surveyed	103	128	100



WHITE-CROWNED SPARROW	1998	1999	2000
Total Abundance	467	141	383
Mean Individuals/Patch (SE)	4.32 (1.68)	1.20 (0.49)	3.87 (1.32)
Min-Max Individuals/Patch	0-103	0-54	0-85
Total Individuals in NHWZ	264	15	67
Total Individuals in OHWZ	55	51	51
Total Individuals in Upland	144	75	270
Total Individuals in January	257	95	57
Total Individuals in February	210	46	326
Number of Patches Found In	17	18	28
Total Patches Surveyed	103	128	100



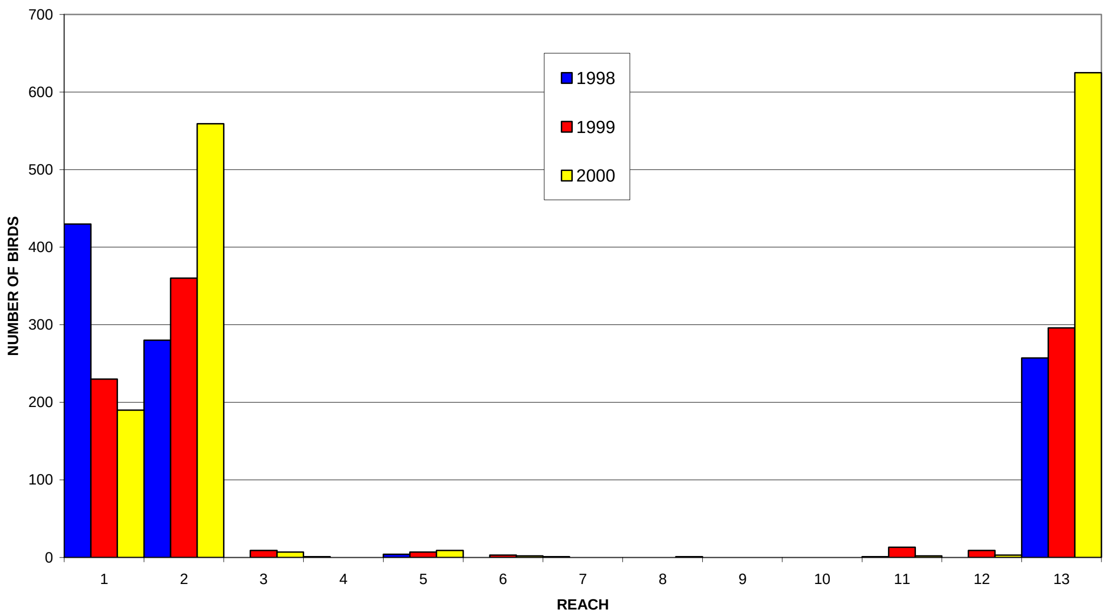
YELLOW-RUMPED WARBLER	1998	1999	2000
Total Abundance	53	68	82
Mean Individuals/Patch	0.412 (0.144)	0.548 (0.029)	0.82 (0.246)
Min-Max Individuals/Patch	0-11	0-35	0-14
Total Individuals in NHWZ	43	63	68
Total Individuals in OHWZ	5	4	15
Total Individuals in Upland	0	1	6
Total Individuals in January	26	19	48
Total Individuals in February	27	49	34
Number of Patches Found In	17	15	20
Total Patches Surveyed	103	128	100



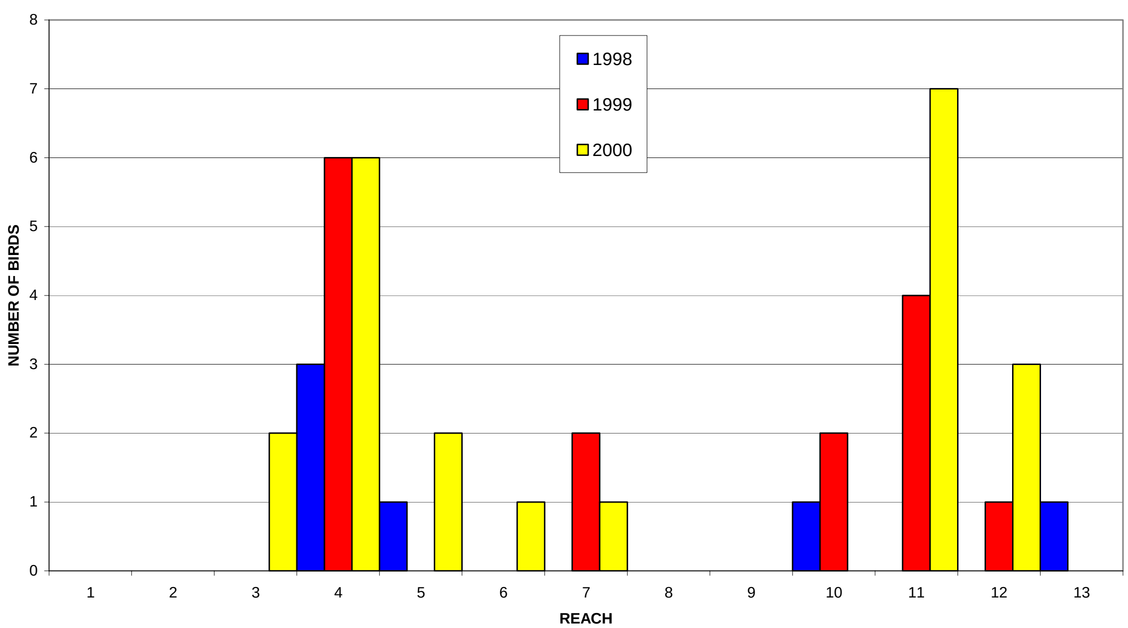
APPENDIX D

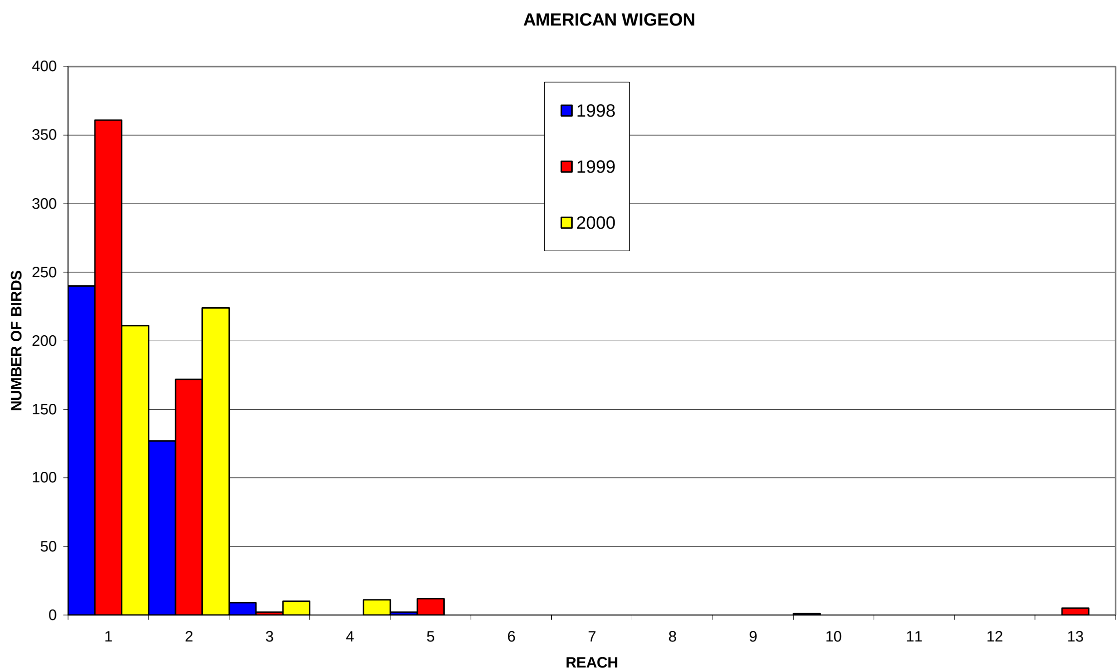
Summaries for the 18 most common winter aquatic bird species along the Colorado River from Glen Canyon Dam to upper Lake Mead are presented. For each species, a chart graphing abundance by reach for each year is shown. Summary charts of the distribution of three additional species, spotted sandpiper, belted kingfisher, and American dipper are also included. Reaches are numbered from 1-13 and are from Schmidt and Graf (1990).

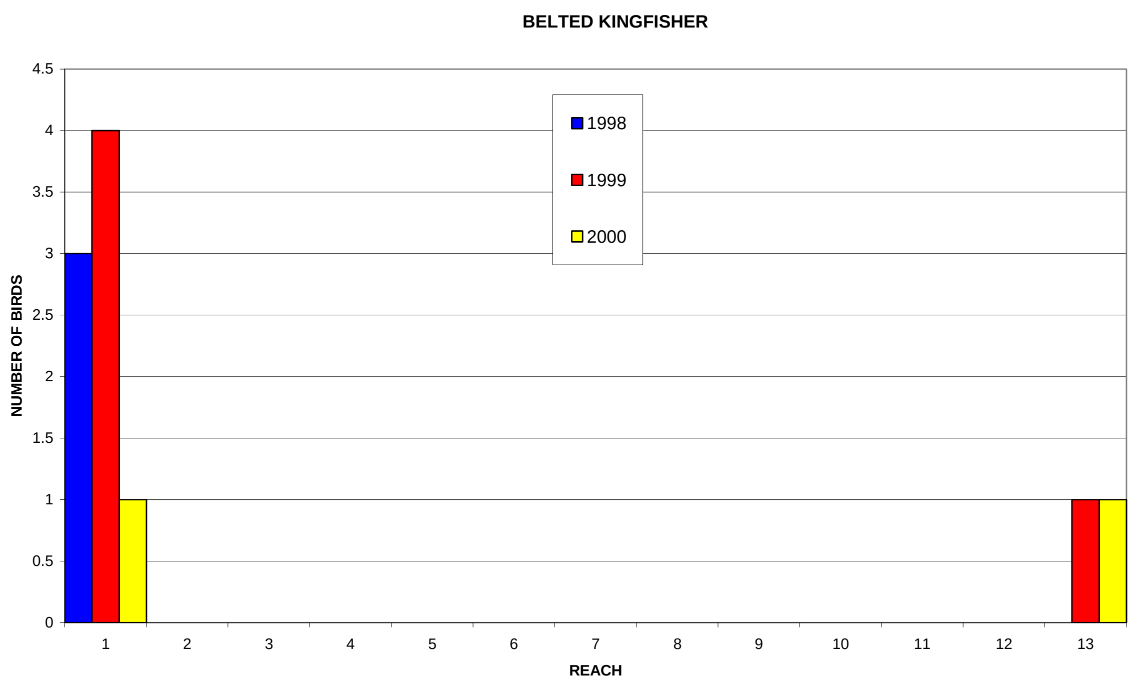
AMERICAN COOT

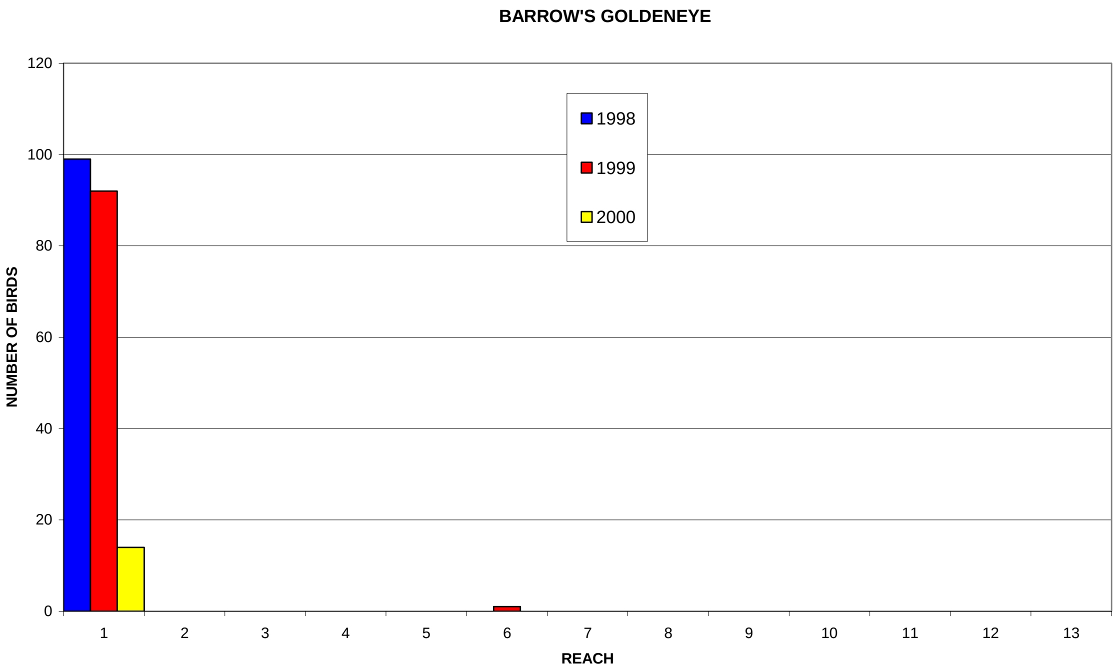


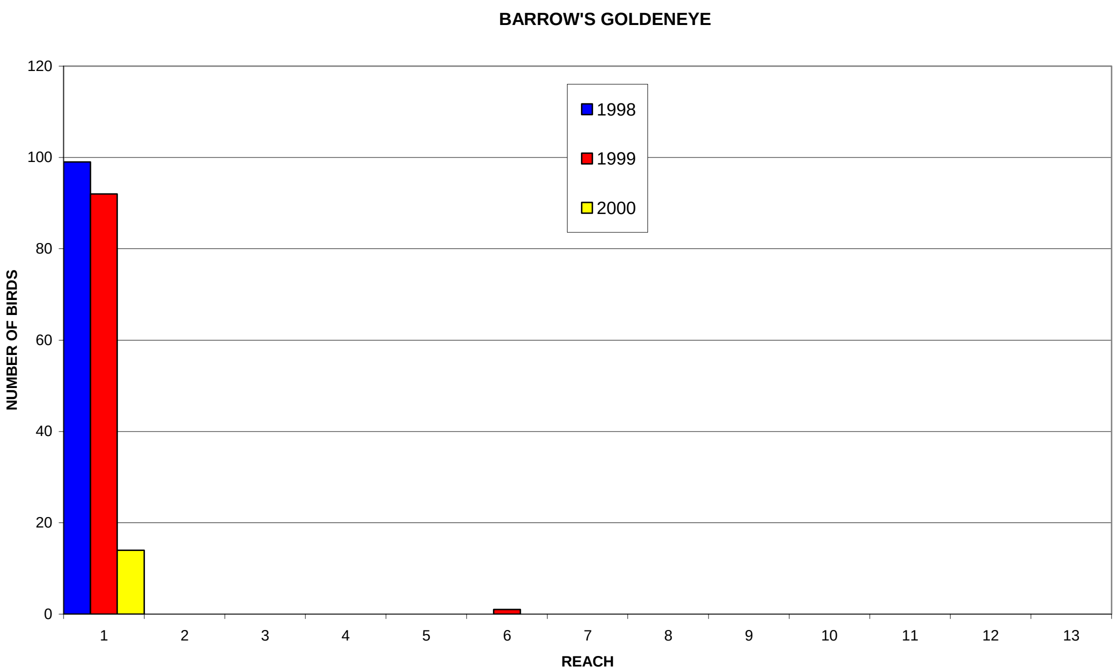
AMERICAN DIPPER

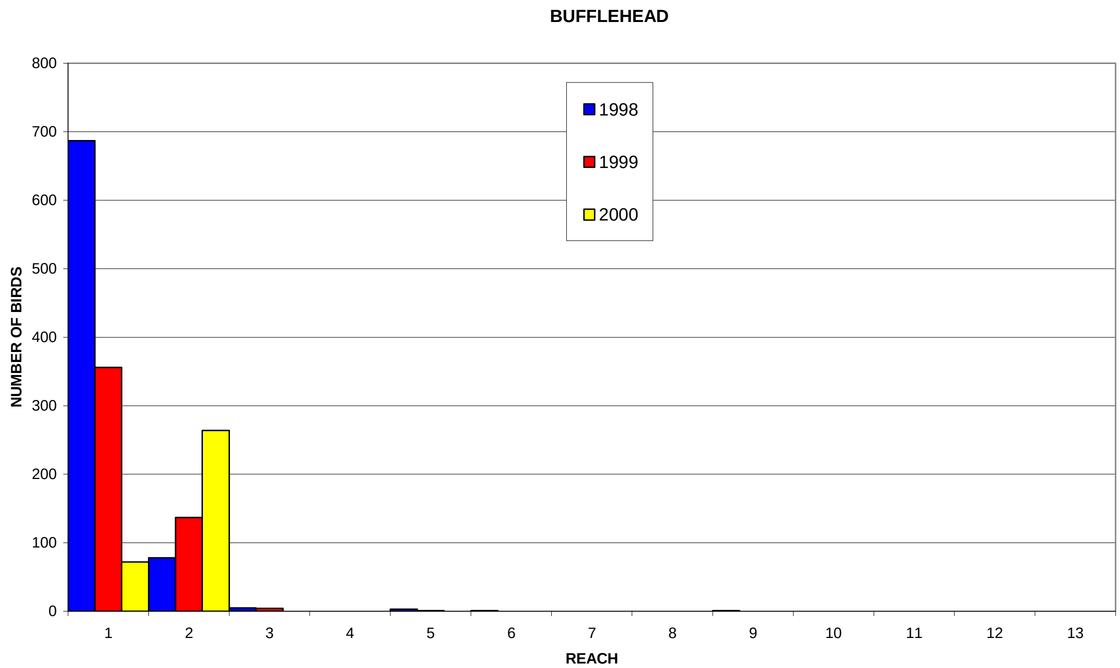


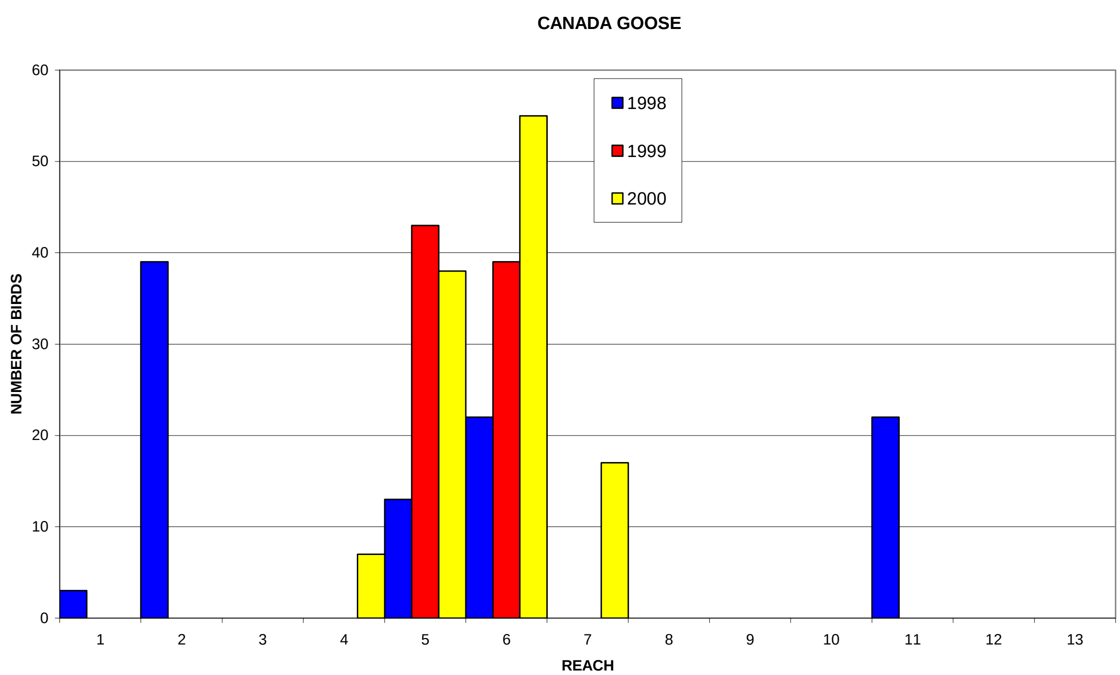

AMERICAN WIGEON
NUMBER OF BIRDS
400
350
300
250
200
150
100
50
0
1998
1999
2000
1
2
3
4
5
6
7
8
9
10
11
12
13
REACH

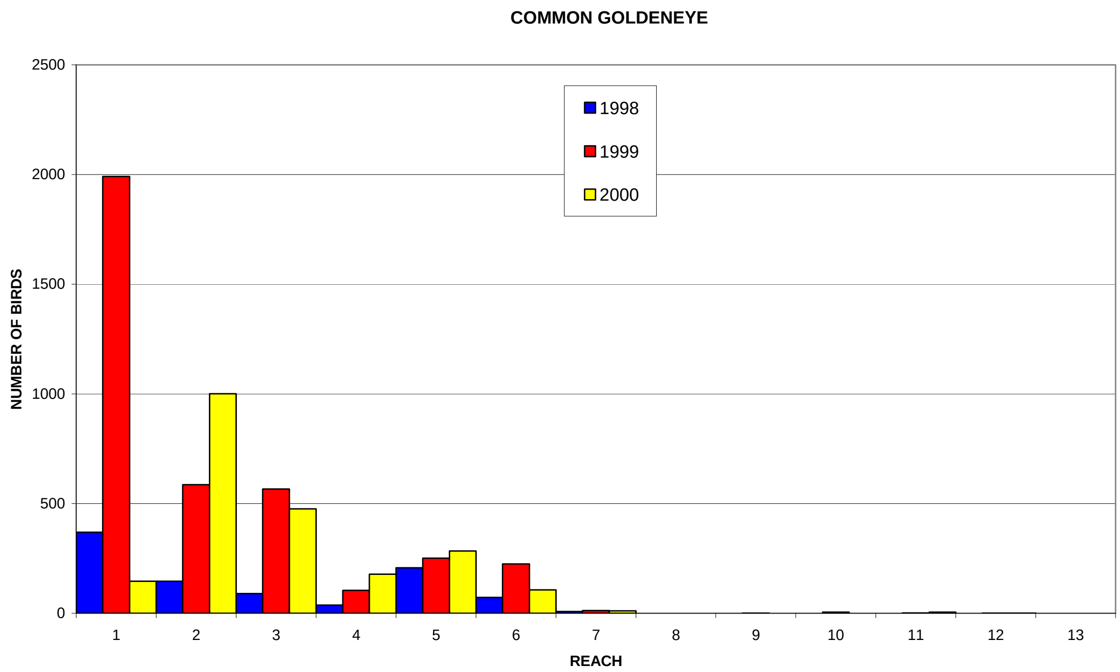

BELTED KINGFISHER
NUMBER OF BIRDS
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1998
1999
2000
1
2
3
4
5
6
7
8
9
10
11
12
13
REACH

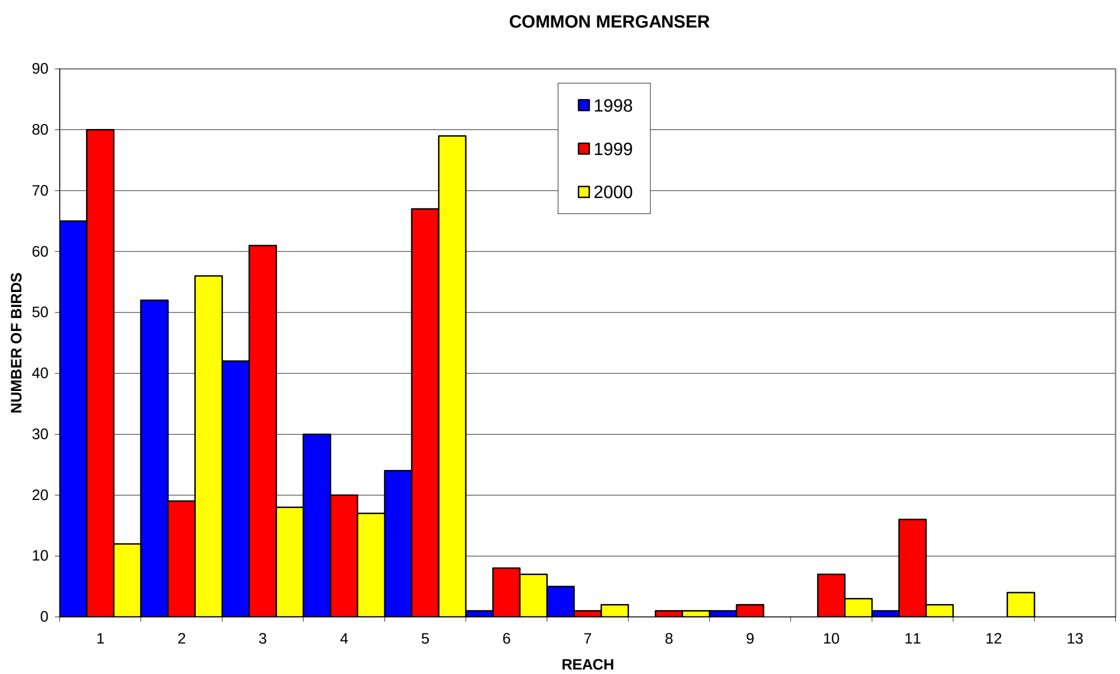

BARROW'S GOLDENEYE
1998
1999
2000
NUMBER OF BIRDS
REACH
0
20
40
60
80
100
120
1
2
3
4
5
6
7
8
9
10
11
12
13

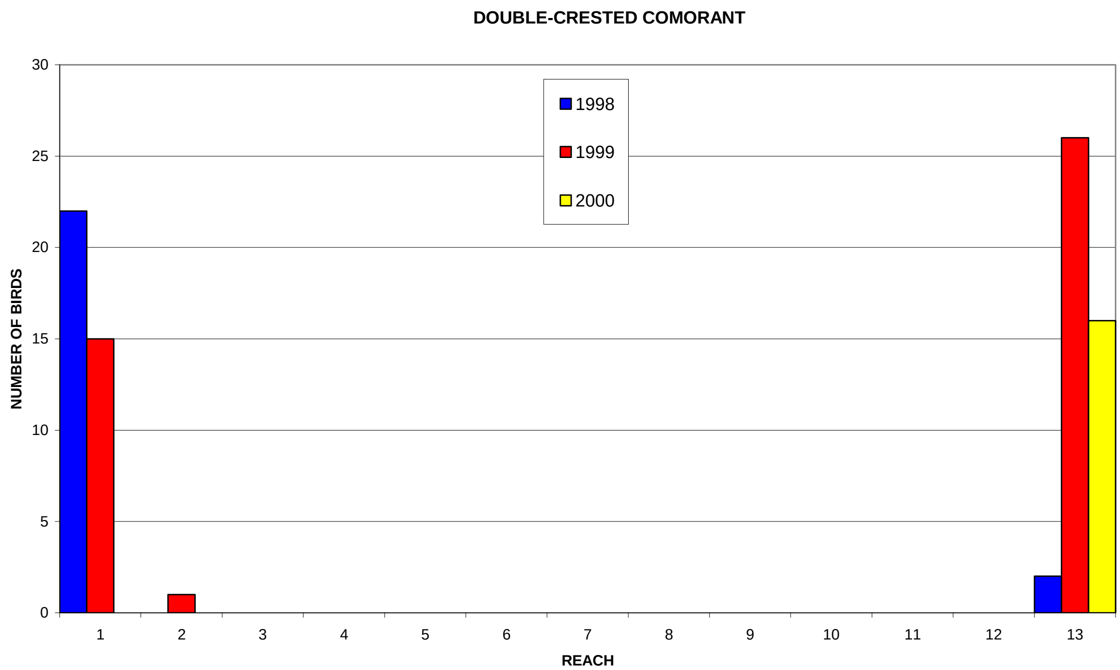

BARROW'S GOLDENEYE
1998
1999
2000
NUMBER OF BIRDS
REACH
0
20
40
60
80
100
120
1
2
3
4
5
6
7
8
9
10
11
12
13

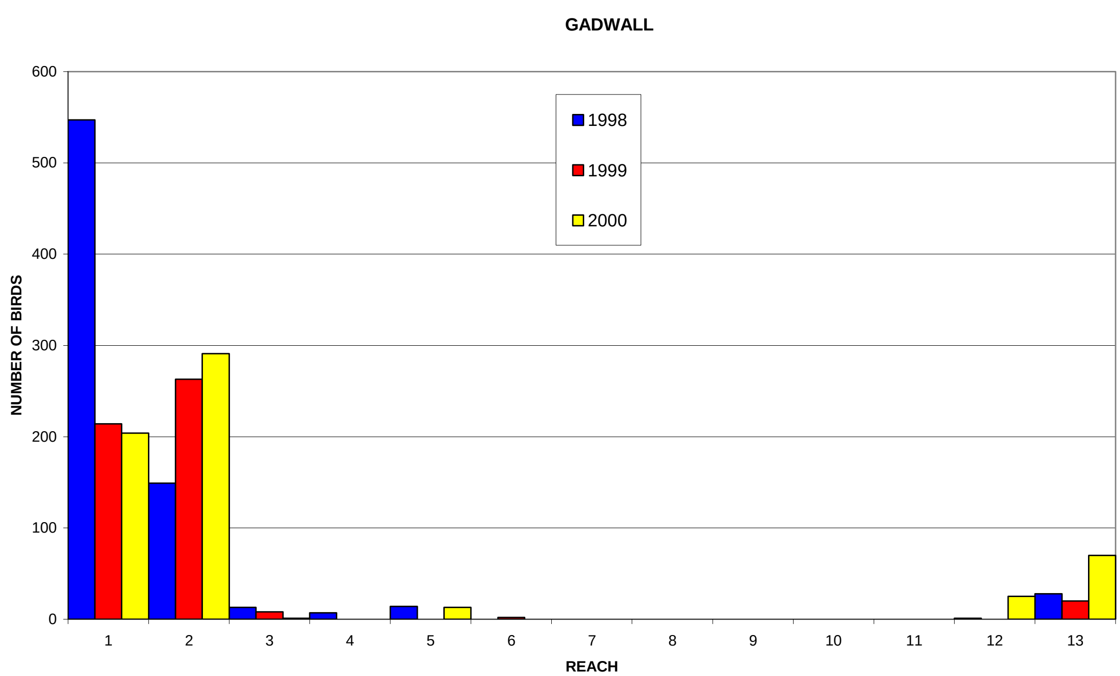

BUFFLEHEAD
1998
1999
2000
NUMBER OF BIRDS
0
100
200
300
400
500
600
700
800
1
2
3
4
5
6
7
8
9
10
11
12
13
REACH

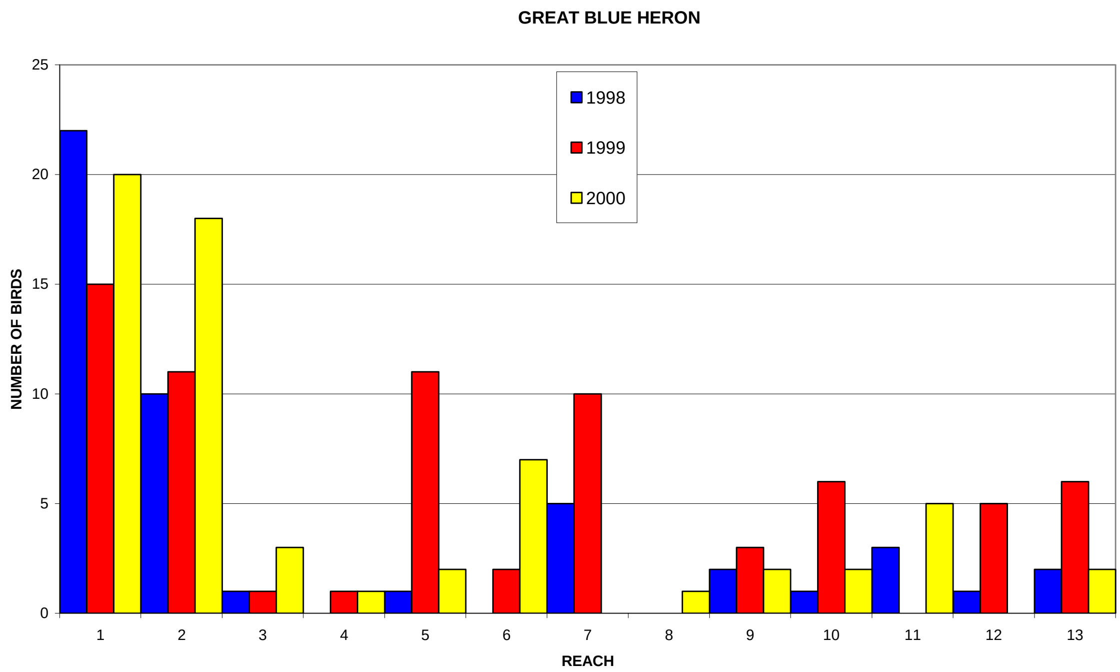

CANADA GOOSE
1998
1999
2000
NUMBER OF BIRDS
0
10
20
30
40
50
60
1
2
3
4
5
6
7
8
9
10
11
12
13
REACH

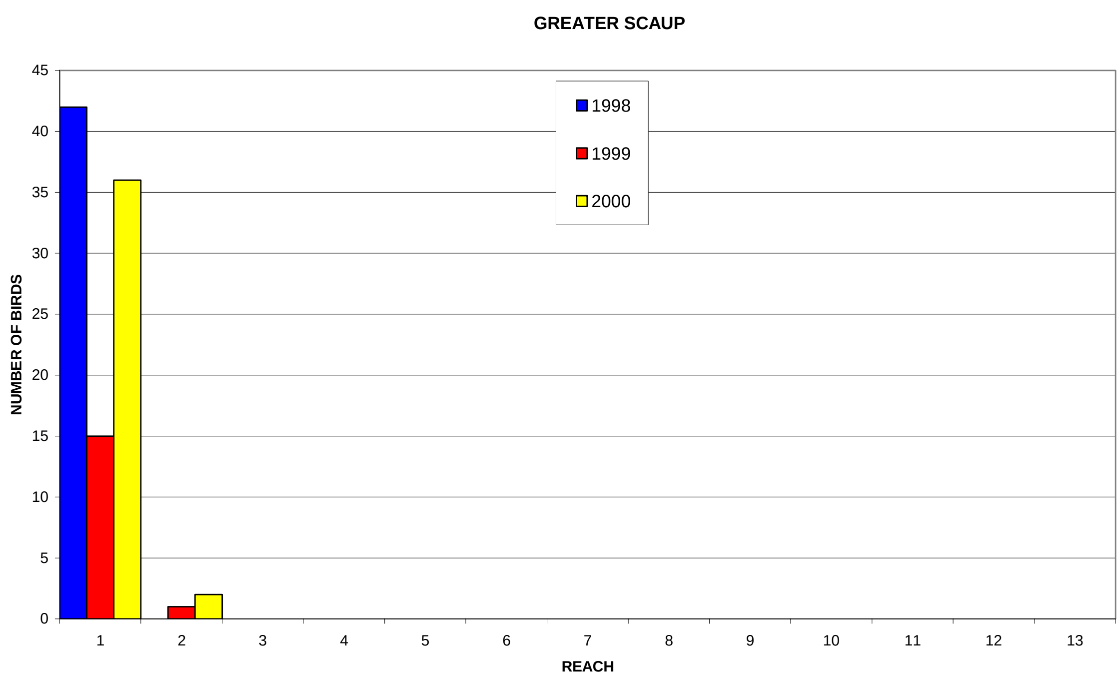

COMMON GOLDENEYE
NUMBER OF BIRDS
0
500
1000
1500
2000
2500
1998
1999
2000
1
2
3
4
5
6
7
8
9
10
11
12
13
REACH

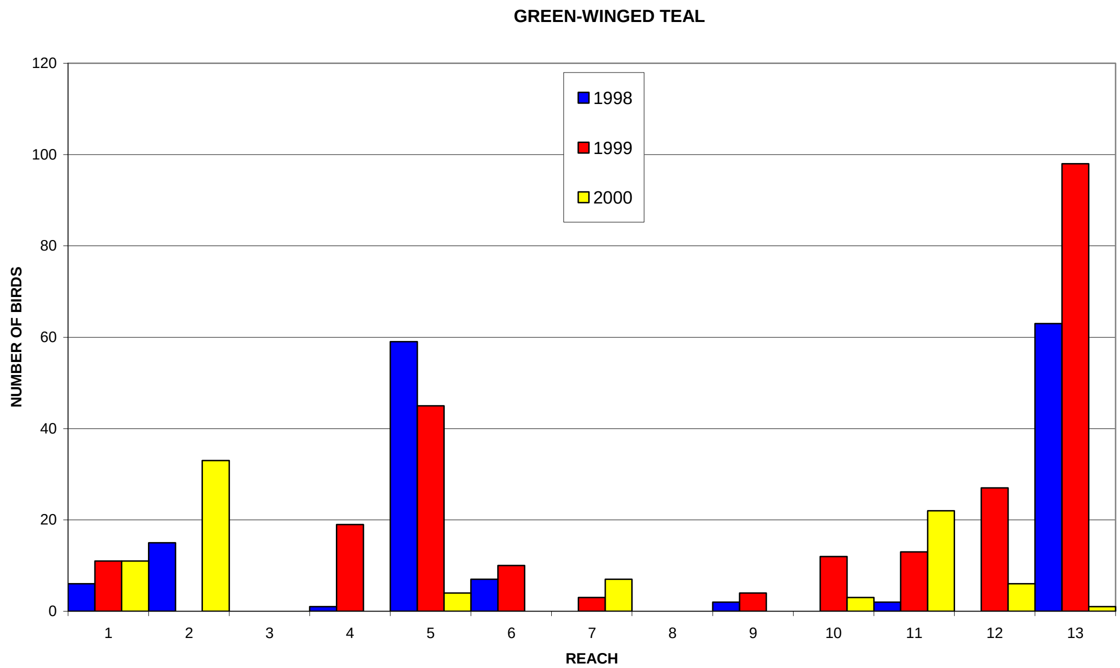

COMMON MERGANSER
NUMBER OF BIRDS
0
10
20
30
40
50
60
70
80
90
1998
1999
2000
1
2
3
4
5
6
7
8
9
10
11
12
13
REACH

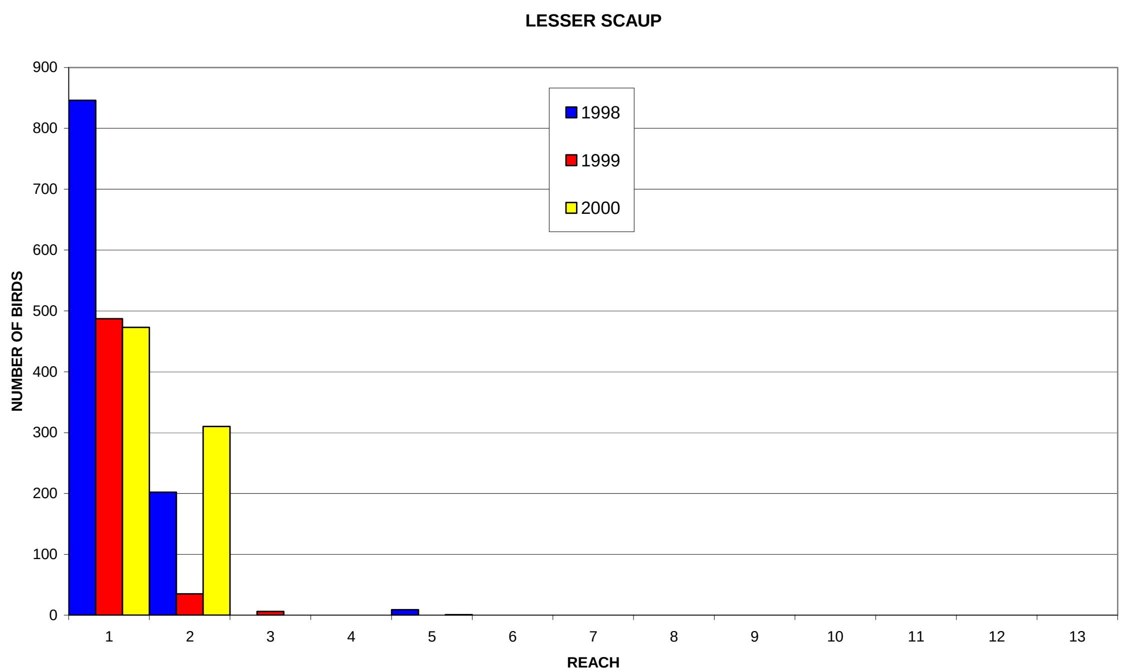

DOUBLE-CRESTED COMORANT
NUMBER OF BIRDS
0
5
10
15
20
25
30
1998
1999
2000
1 2 3 4 5 6 7 8 9 10 11 12 13
REACH

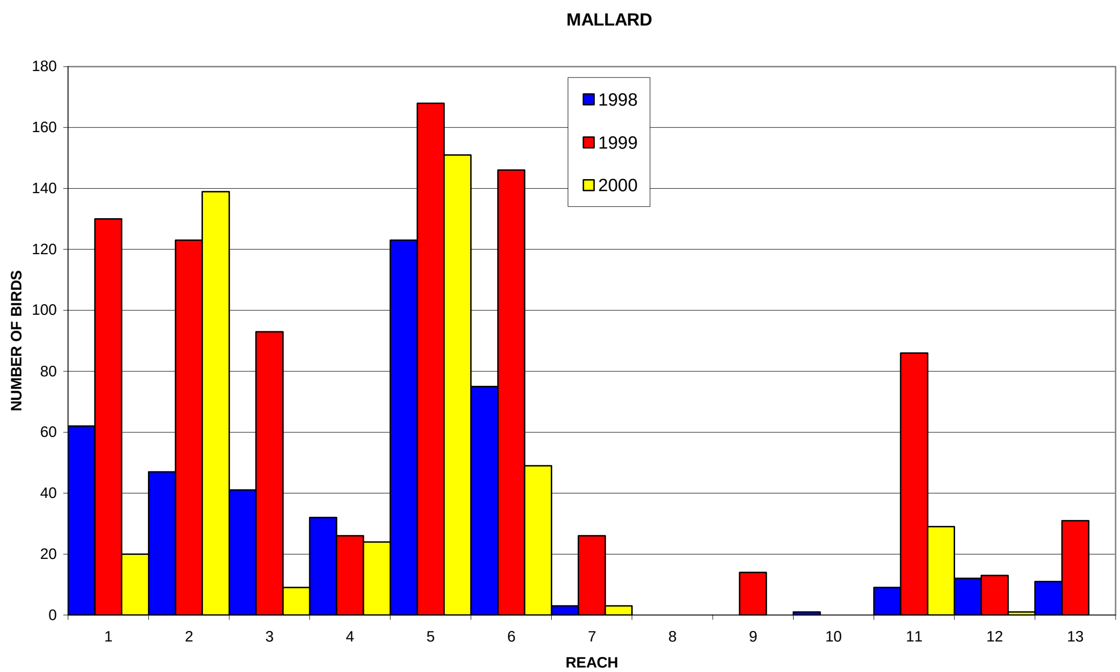

GADWALL
NUMBER OF BIRDS
0
100
200
300
400
500
600
1998
1999
2000
1 2 3 4 5 6 7 8 9 10 11 12 13
REACH

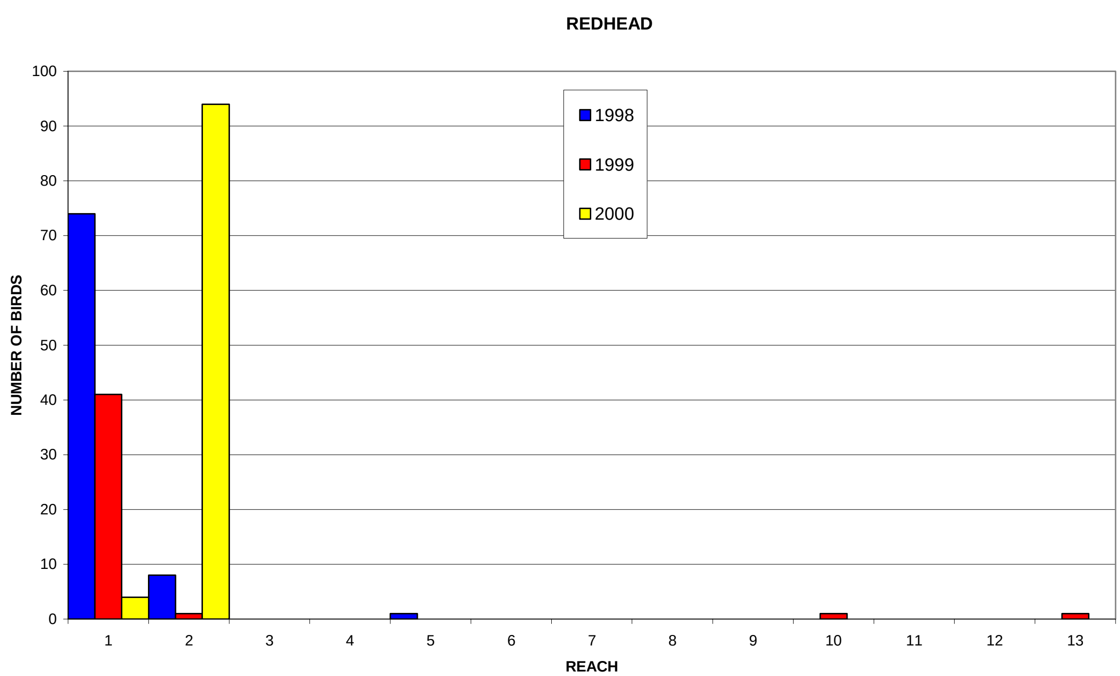

GREAT BLUE HERON
NUMBER OF BIRDS
REACH
1998
1999
2000
0
5
10
15
20
25
1
2
3
4
5
6
7
8
9
10
11
12
13

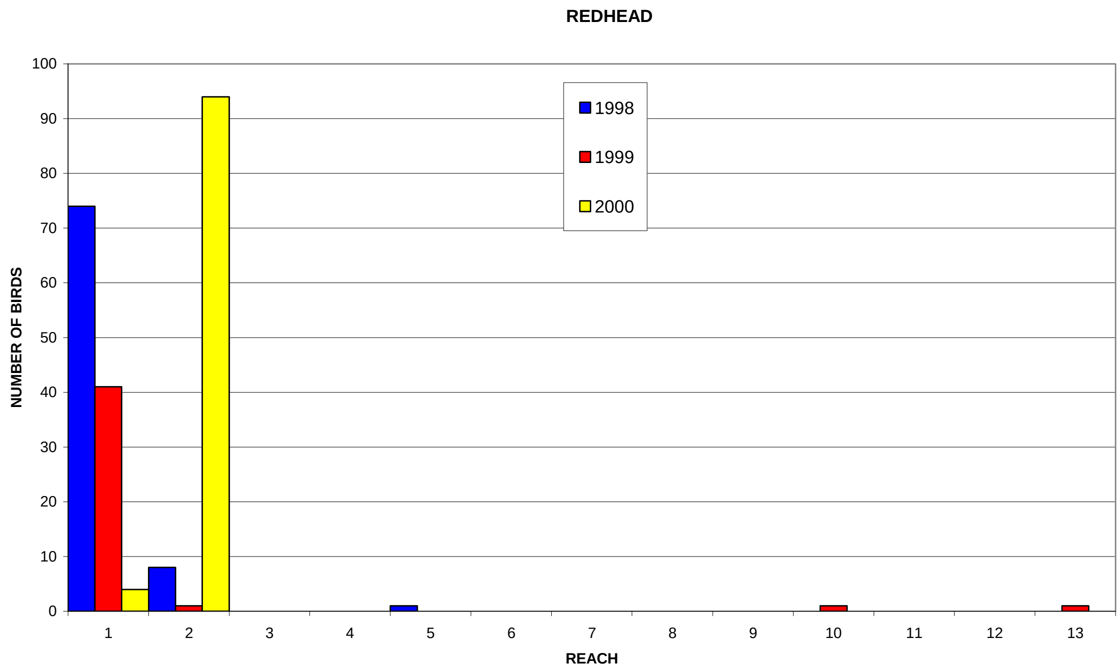

GREATER SCAUP
NUMBER OF BIRDS
REACH
1998
1999
2000
0
5
10
15
20
25
30
35
40
45
1
2
3
4
5
6
7
8
9
10
11
12
13

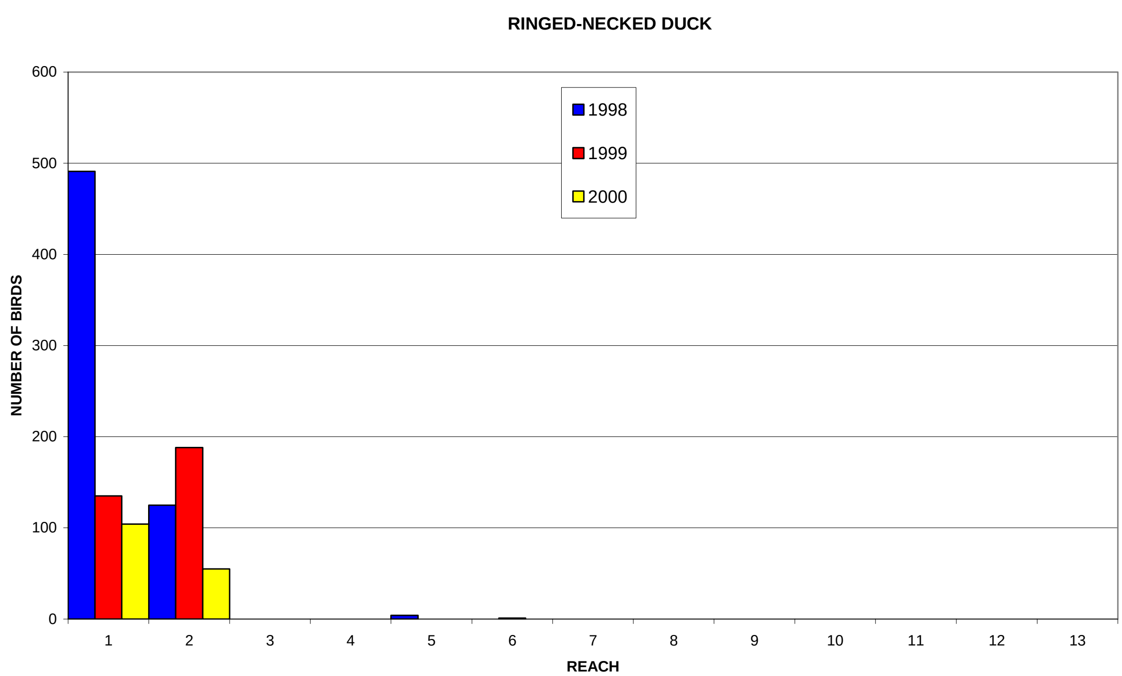

GREEN-WINGED TEAL
NUMBER OF BIRDS
REACH
1998
1999
2000
0
20
40
60
80
100
120
1 2 3 4 5 6 7 8 9 10 11 12 13

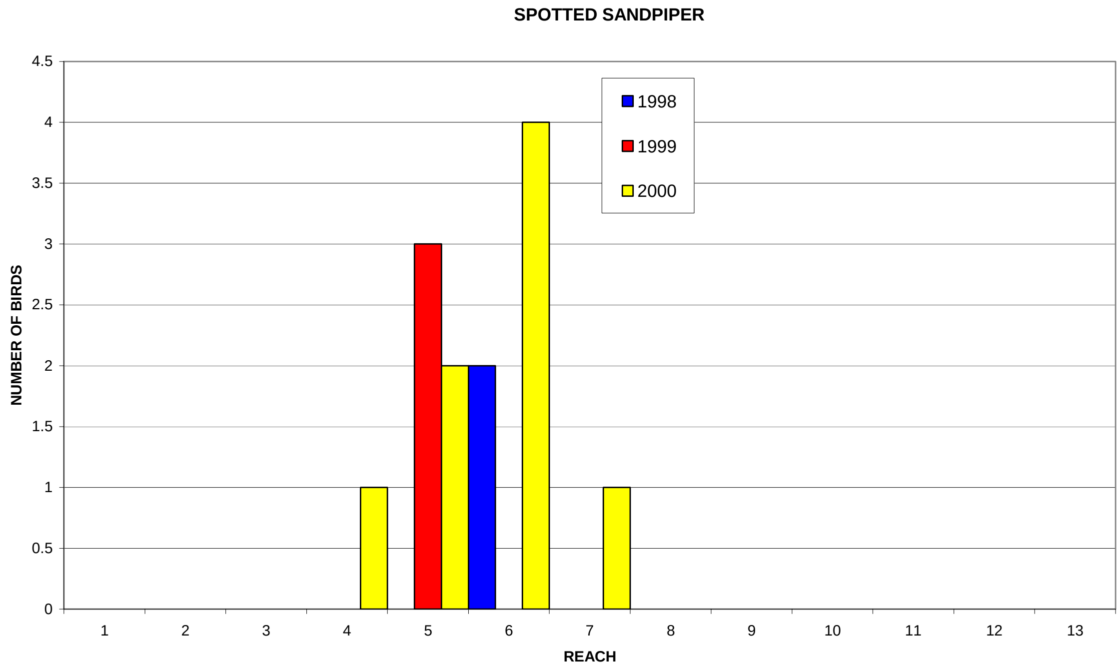

LESSER SCAUP
NUMBER OF BIRDS
REACH
1998
1999
2000
0
100
200
300
400
500
600
700
800
900
1 2 3 4 5 6 7 8 9 10 11 12 13


MALLARD
1998
1999
2000
NUMBER OF BIRDS
REACH
0
20
40
60
80
100
120
140
160
180
1
2
3
4
5
6
7
8
9
10
11
12
13


REDHEAD
1998
1999
2000
NUMBER OF BIRDS
REACH
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11
12
13


REDHEAD
NUMBER OF BIRDS
100
90
80
70
60
50
40
30
20
10
0
1998
1999
2000
1
2
3
4
5
6
7
8
9
10
11
12
13
REACH


RINGED-NECKED DUCK
NUMBER OF BIRDS
600
500
400
300
200
100
0
1998
1999
2000
1
2
3
4
5
6
7
8
9
10
11
12
13
REACH


SPOTTED SANDPIPER
NUMBER OF BIRDS
REACH
1998
1999
2000
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
1
2
3
4
5
6
7
8
9
10
11
12
13

APPENDIX E

During the course of the three-year winter surveys, observations of raptors were made and recorded as part of either the boat or area search surveys. All raptor observations are organized below by number of birds per reach. Nine species of winter raptors were recorded during the study (Table E-1), bald eagle, golden eagle, red-tailed hawk, red-shouldered hawk, Cooper's Hawk, sharp-shinned hawk, northern harrier, American kestrel, and peregrine falcon. Summary charts of the distribution by reach for the five most common species, bald eagle, golden eagle, red-tailed hawk, sharp-shinned hawk, and American kestrel, are included. Also included is a chart of all raptors seen by reach. All raptor observations have been entered into an Excel spreadsheet as "*Raptor.GCMRC.xl*". Appendix B discusses each species.

Table E-1. Summary of all raptor observations during the winter surveys on the Colorado River between Glen Canyon Dam and upper Lake Mead 1998-2000. Reach designation is from Schmidt and Graf (1990).

Reach	**BAEA**	**GOEA**	**RTHA**	**RSHA**	**COHA**	**SSHA**	**NOHA**	**AMKE**	**PEFA**	**Totals**
1	2	4	1	0	1	1	1	1	0	**11**
2	6	3	19	0	1	2	1	0	0	**32**
3	16	3	4	0	0	4	0	5	1	**33**
4	25	2	0	0	0	2	1	1	0	**31**
5	33	2	4	0	2	5	0	4	0	**50**
6	6	7	6	0	0	4	0	4	0	**27**
7	5	0	9	0	1	0	0	0	0	**15**
8	1	1	1	0	0	0	0	2	0	**5**
9	0	0	2	0	0	0	0	1	0	**3**
10	0	1	1	0	0	0	0	1	0	**3**
11	1	0	23	0	2	0	0	1	2	**29**
12	0	0	8	0	0	4	0	2	0	**14**
13	3	1	11	1	0	0	0	2	1	**29**
Totals	**98**	**24**	**89**	**1**	**7**	**22**	**3**	**24**	**4**	**272**

Appendix F

List of breeding or potentially breeding terrestrial riparian species along the Colorado River from Glen Canyon Dam to Lake Mead

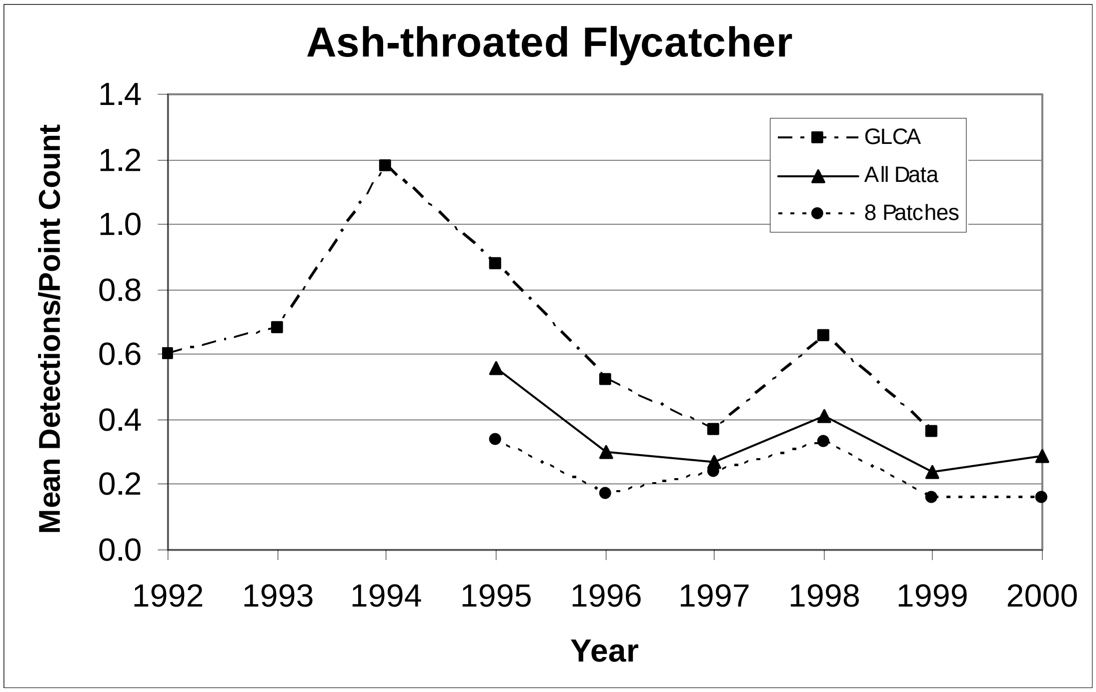
Each species that is known to breed in riparian vegetation along the river corridor is listed below. In addition, a few species that have been detected at least twice within a year but not yet known to breed are included. The minimum breeding criteria used for each species is derived primarily from Sogge et al. (1998) with minor modifications and additions, and are on a per-patch basis. The format for each species account consists of the minimum breeding criteria, whether or not a breeding record exists for the study area, a summary of the species population trends, and a summary of statistical power. Six charts are provided for selected species. The first three charts are based on abundance of the species, including one of mean detection rates per year for three data sets (all data 1995-2000, 8 patches 1995-2000, and Glen Canyon 1992-1999), a second of overall mean detection rates by reach designation (1996-1999 data), and the third of overall monthly detection rates (1996-1999 data). The remaining three charts summarize power tests for each species.

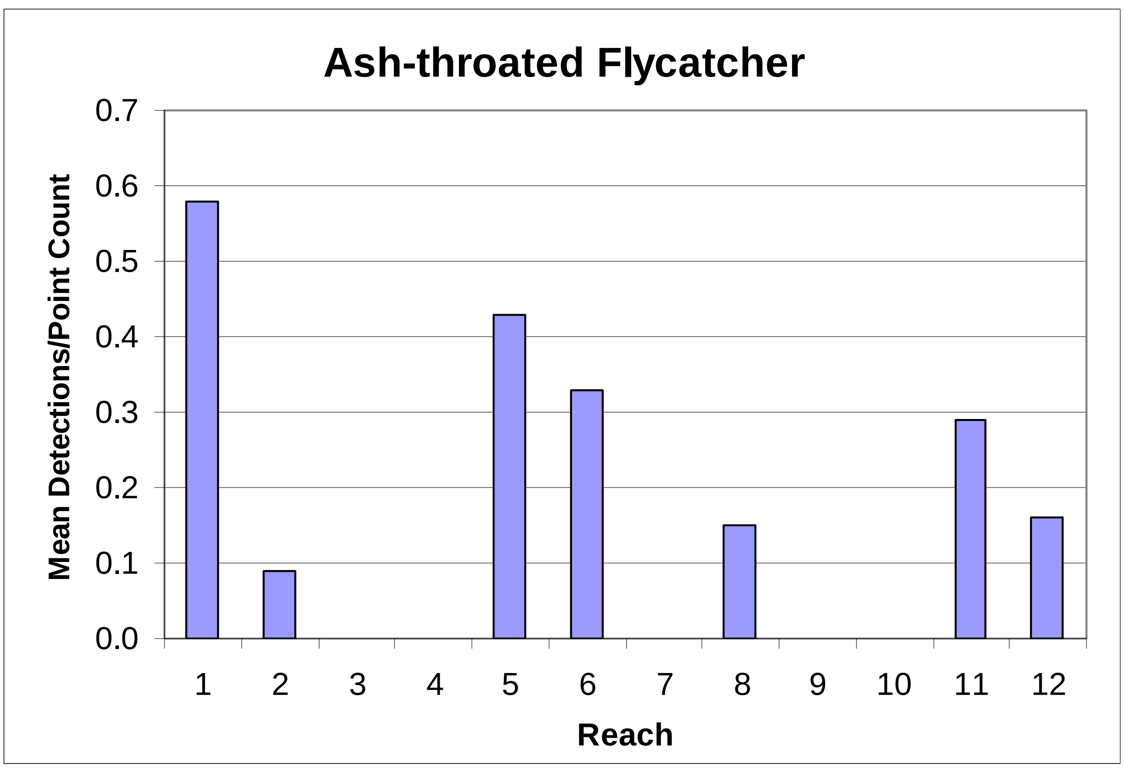
1. Ash-throated Flycatcher (*Myiarchus cinerascens*)

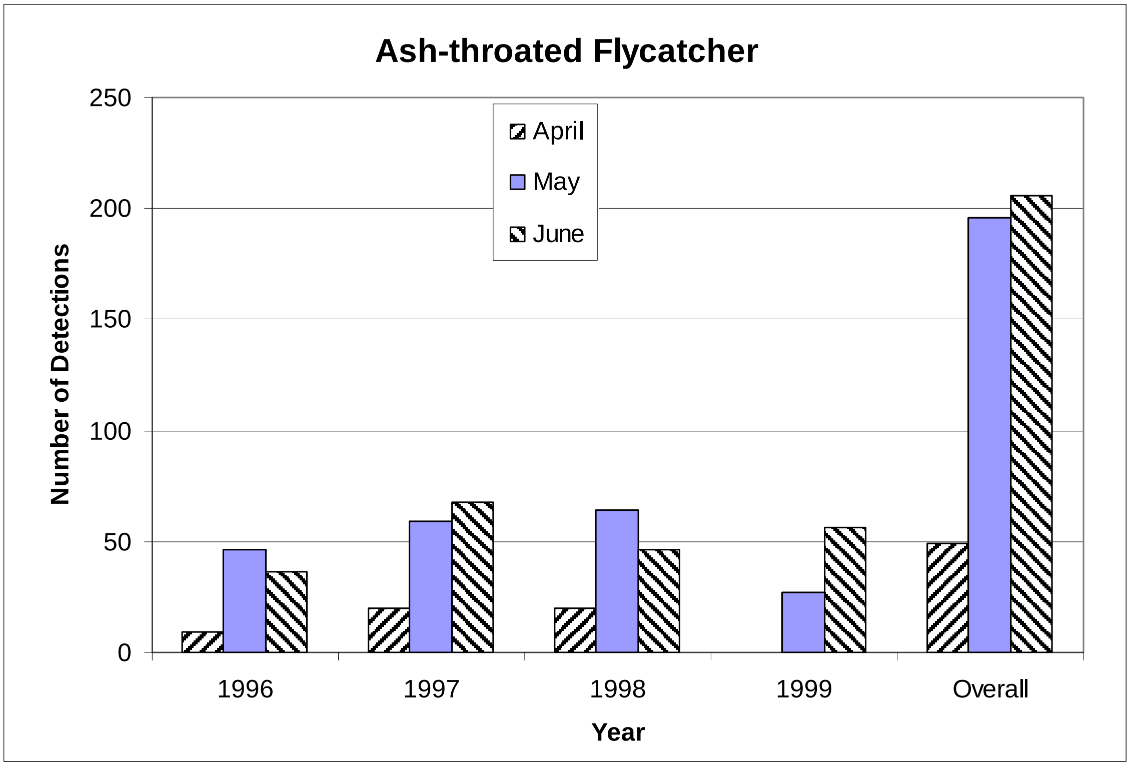
Minimum Breeding Criterion: detected on two visits April-June
Breeding Status: spring-summer breeder

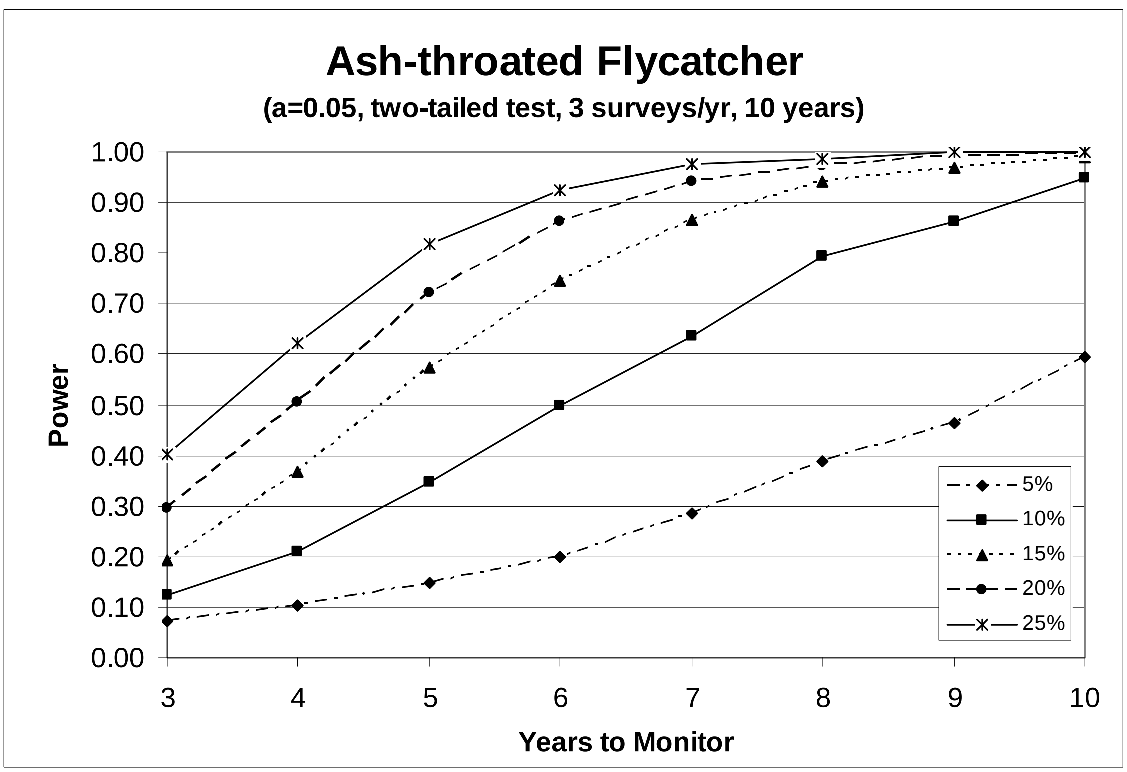
Summary
Ash-throated flycatcher is a fairly common breeding species along the river corridor, and is easily detected because of its loud calls. The species is most common in reaches 1, 5, 6 and 11. The bulk of the population appears in May, with detections remaining fairly constant through June. The data suggest an overall decline since 1992 in the Glen Canyon reach, from an estimated (linear regression) mean detection rate of 0.8 birds/point count to 0.4 birds/point count, a decline of 100%. Grand Canyon data indicate a significant decline from 1996 to 2000 based on an analysis of 29 patches (Table VII-5).

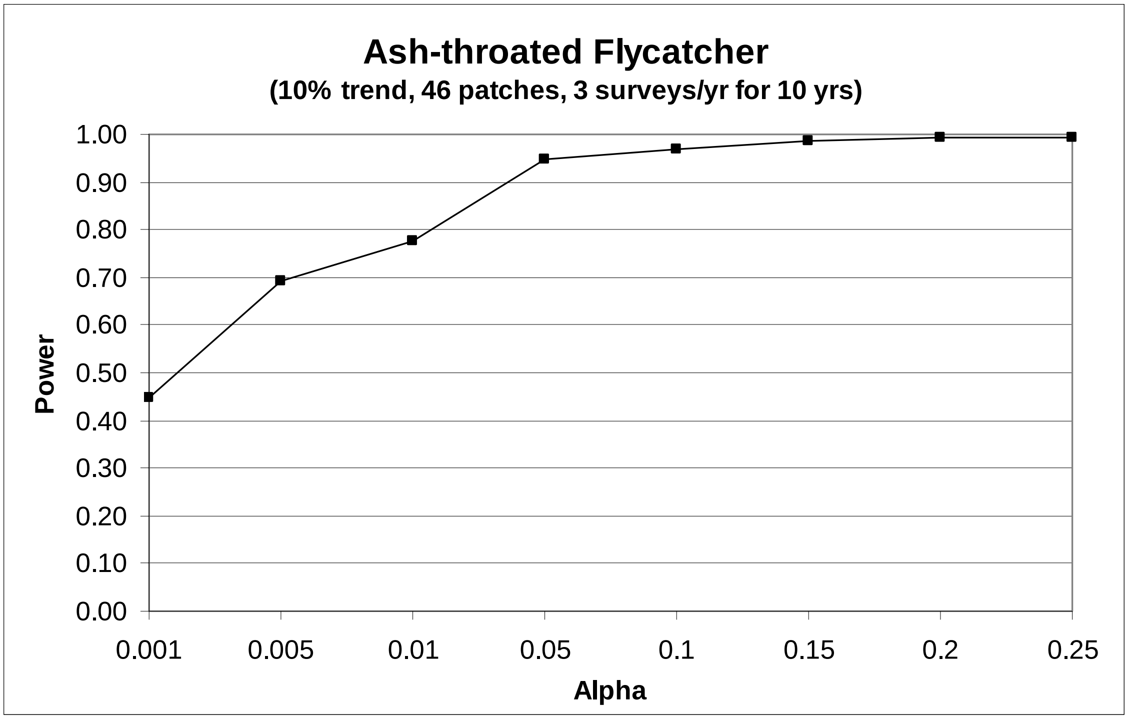
Power To Detect Change
There is adequate power in the current program to detect a 25% change/year after 5 years, a 20% change/year after six years, a 15% change/year after 7 years, and a 10% change/year after 9 years. A 5% change cannot be detected within 10 years. At an alpha of 0.05, there is adequate power to detect change after 10 years by monitoring at least 30 patches of riparian vegetation.

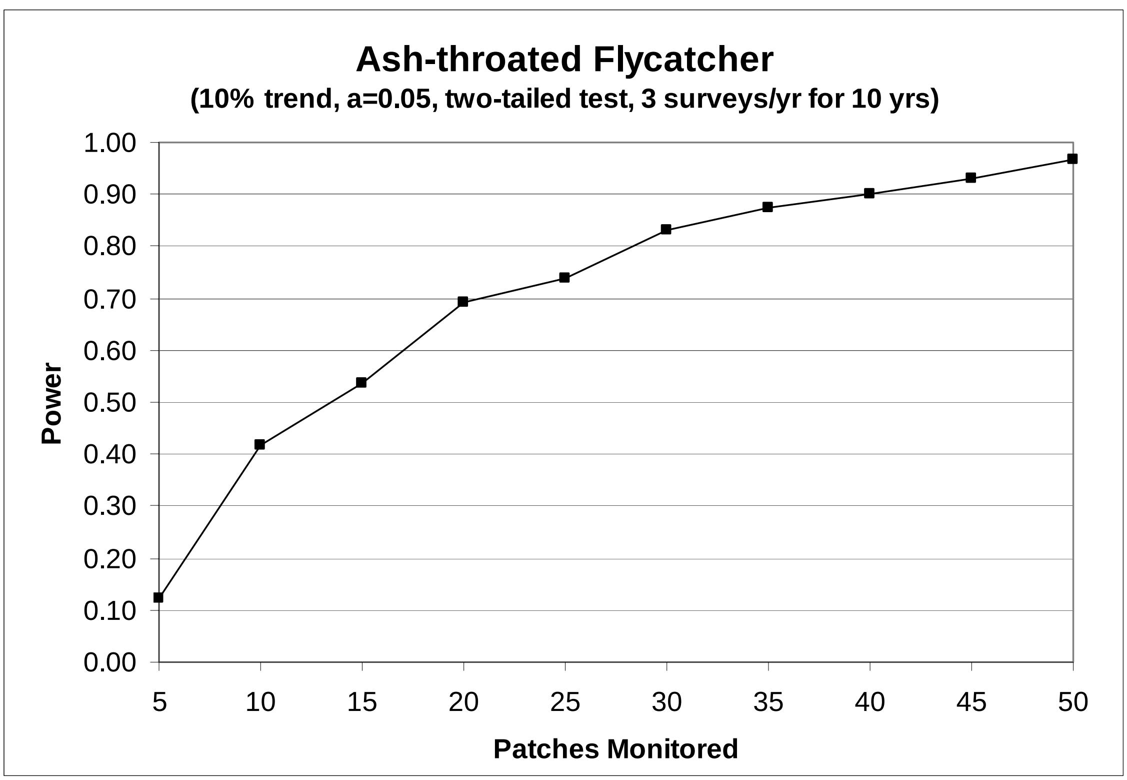

Ash-throated Flycatcher
Mean Detections/Point Count
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
GLCA
All Data
8 Patches
1992
1993
1994
1995
1996
1997
1998
1999
2000
Year


Ash-throated Flycatcher
Mean Detections/Point Count
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
9
10
11
12
Reach


Ash-throated Flycatcher
April
May
June
Number of Detections
250
200
150
100
50
0
1996
1997
1998
1999
Overall
Year


Ash-throated Flycatcher
(a=0.05, two-tailed test, 3 surveys/yr, 10 years)
Power
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3
4
5
6
7
8
9
10
Years to Monitor
5%
10%
15%
20%
25%


Ash-throated Flycatcher
(10% trend, 46 patches, 3 surveys/yr for 10 yrs)
Power
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.001
0.005
0.01
0.05
0.1
0.15
0.2
0.25
Alpha


Ash-throated Flycatcher
(10% trend, a=0.05, two-tailed test, 3 surveys/yr for 10 yrs)
Power
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
5
10
15
20
25
30
35
40
45
50
Patches Monitored

2. <u>Bell's Vireo</u> (*Vireo bellii*)

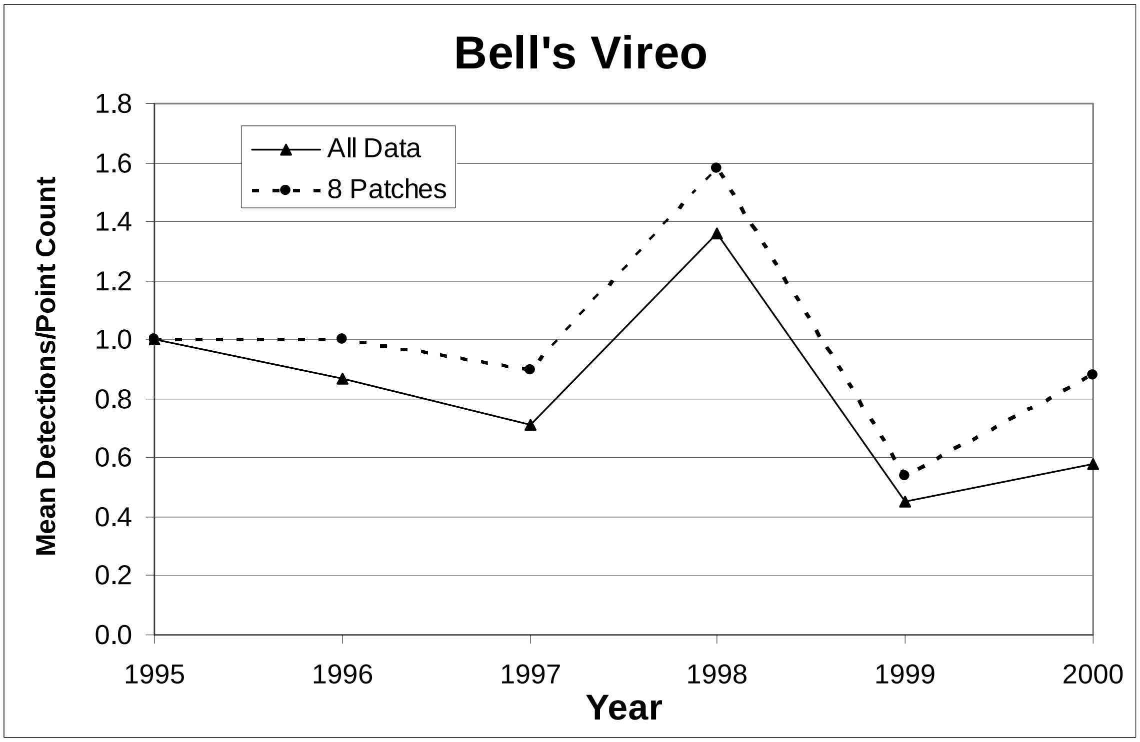
Minimum Breeding Criterion: detected on two visits April-June
Breeding Status: spring-summer breeder

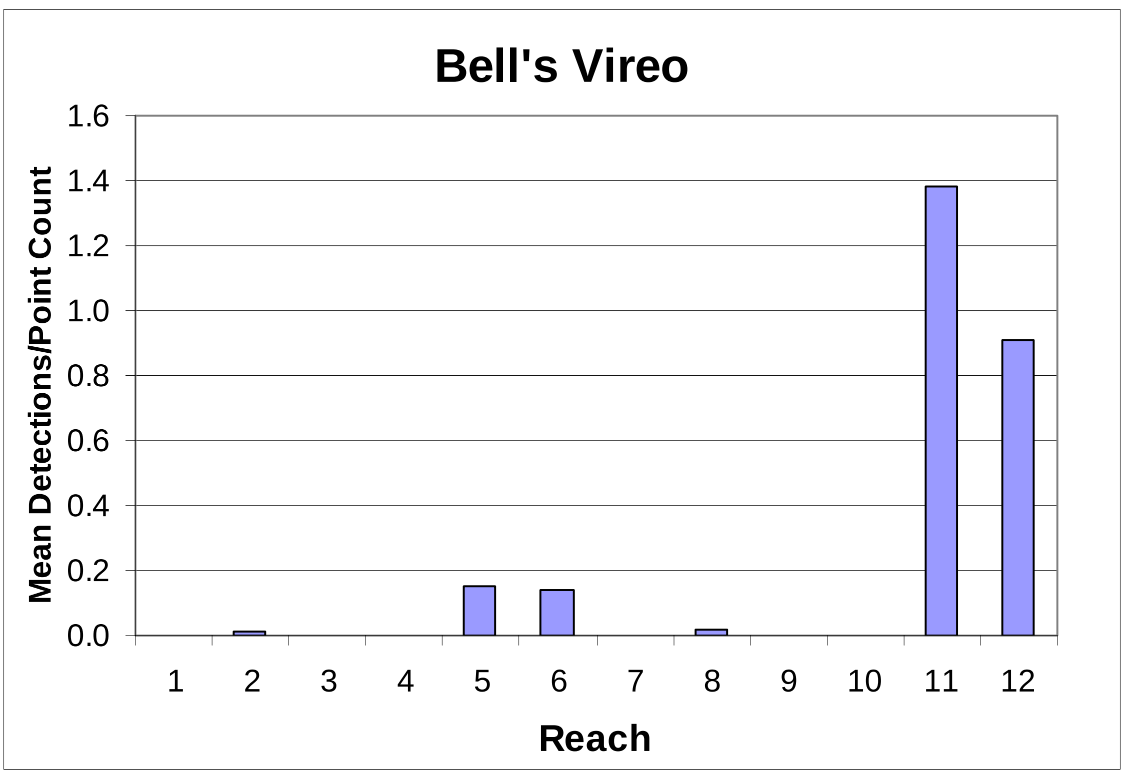
Summary

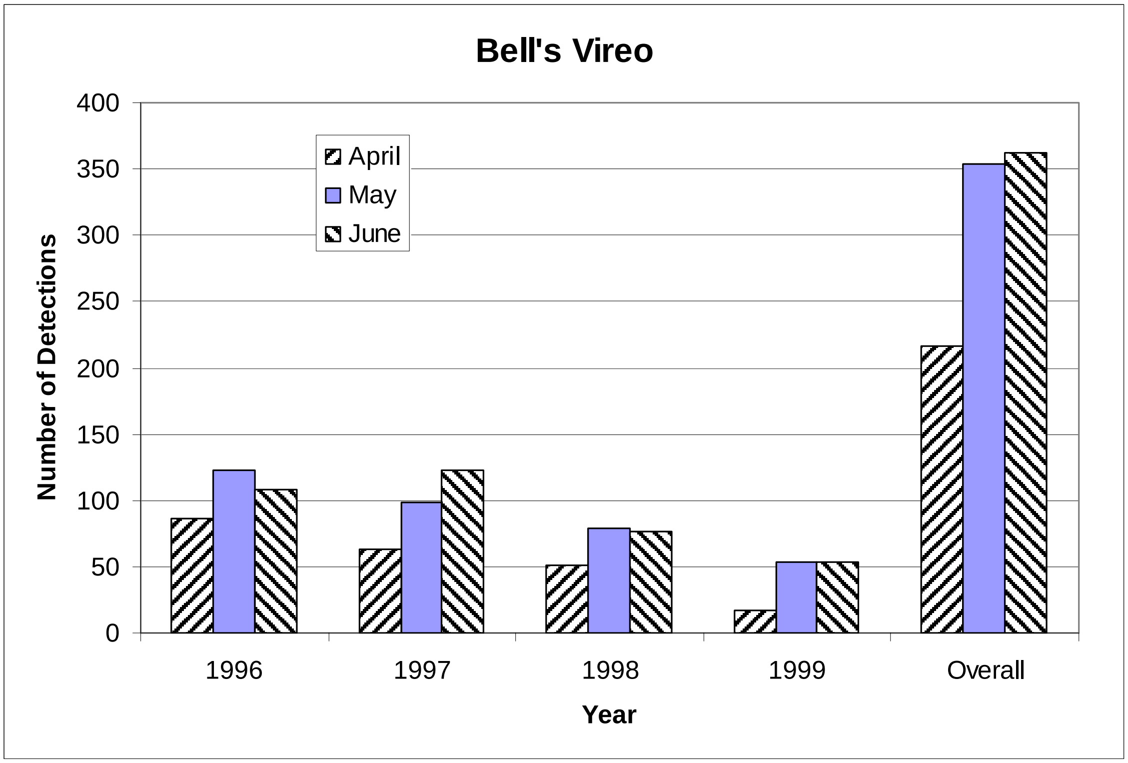
Bell's vireo is an abundant breeding species in the lower portions of the river corridor (reaches 11, 12), with a few records from Marble Canyon (reaches 5, 6). Detection rates are highest in May and June. There were two records of birds from the Glen Canyon reach (reach 1) between 1996-1999, single birds on 7 July 1997 at –2.5L and on 26 May 1999 at –7.0L.

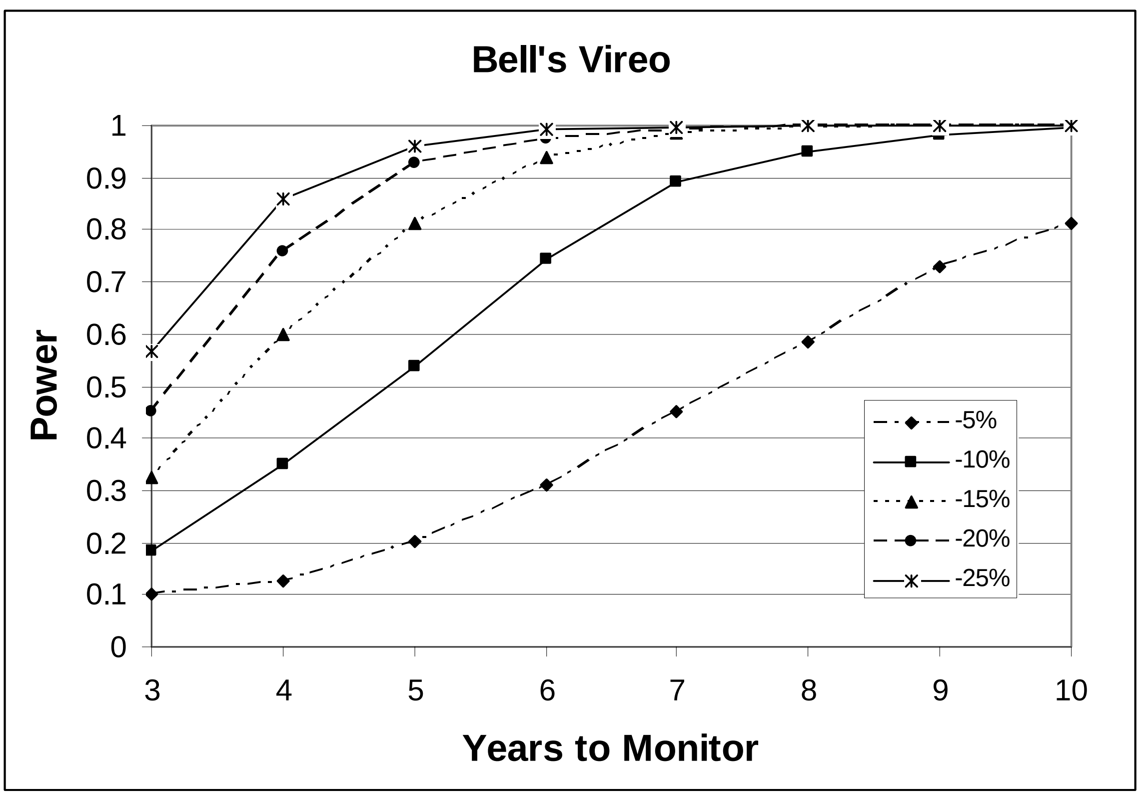
Power To Detect Change

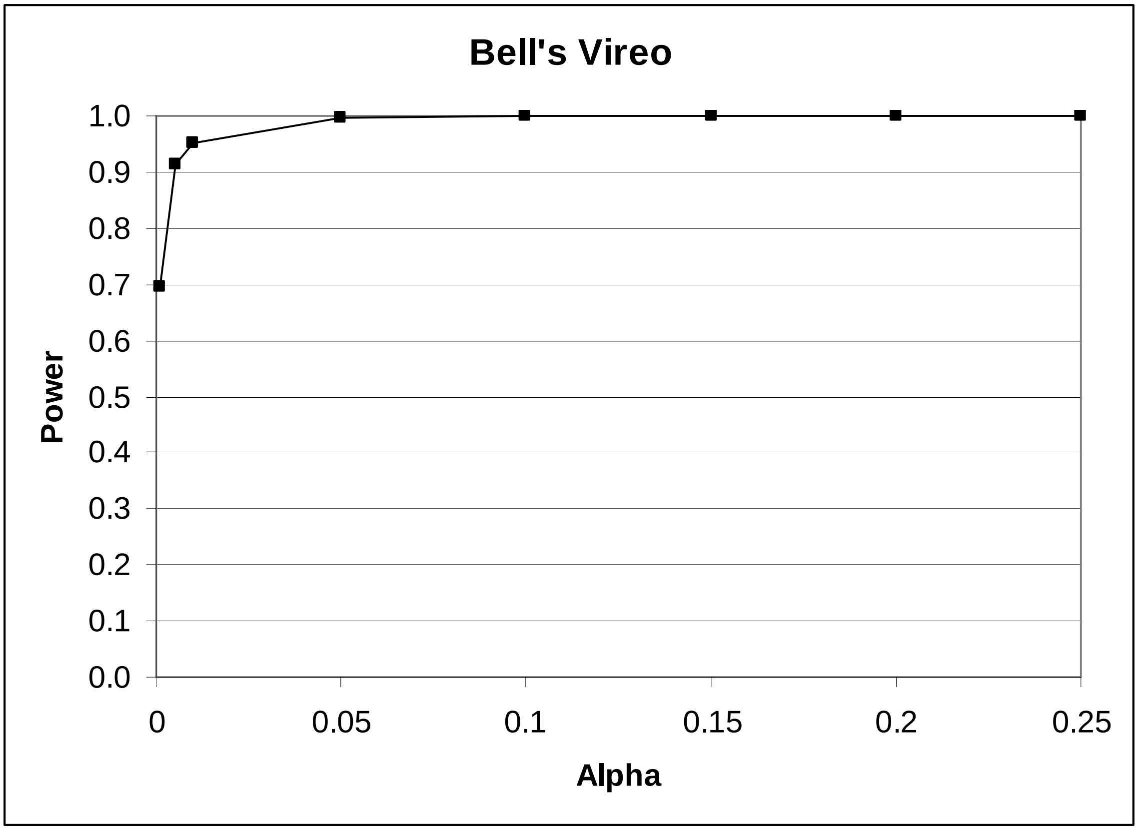
There is adequate power in the current program to detect a 25% change/year after 4 years, a 20% change/year after 5 years, a 15% change/year after 5 years, and a 10% change/year after 7 years. A 5% change can be detected after 10 years. At an alpha of 0.05, there is adequate power to detect change after 10 years by monitoring at least 25 patches of riparian vegetation.

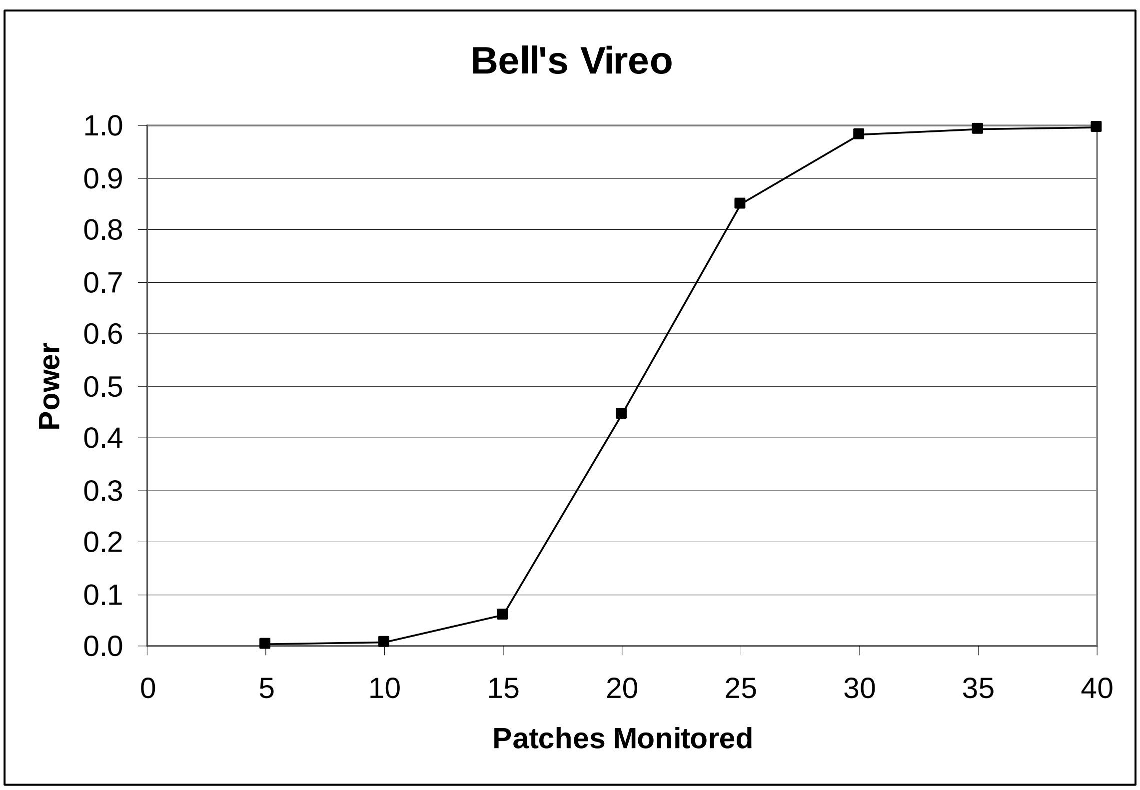

Bell's Vireo
Mean Detections/Point Count
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
All Data
8 Patches
1995
1996
1997
1998
1999
2000
Year


Bell's Vireo
Mean Detections/Point Count
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
7
8
9
10
11
12
Reach


Bell's Vireo
400
350
300
250
200
150
100
50
0
Number of Detections
April
May
June
1996
1997
1998
1999
Overall
Year


Bell's Vireo
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Power
-5%
-10%
-15%
-20%
-25%
3
4
5
6
7
8
9
10
Years to Monitor


Bell's Vireo
Power
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
0.05
0.1
0.15
0.2
0.25
Alpha


Bell's Vireo
Power
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
30
35
40
Patches Monitored

3. Bewick's Wren (*Thryomanes bewickii*)

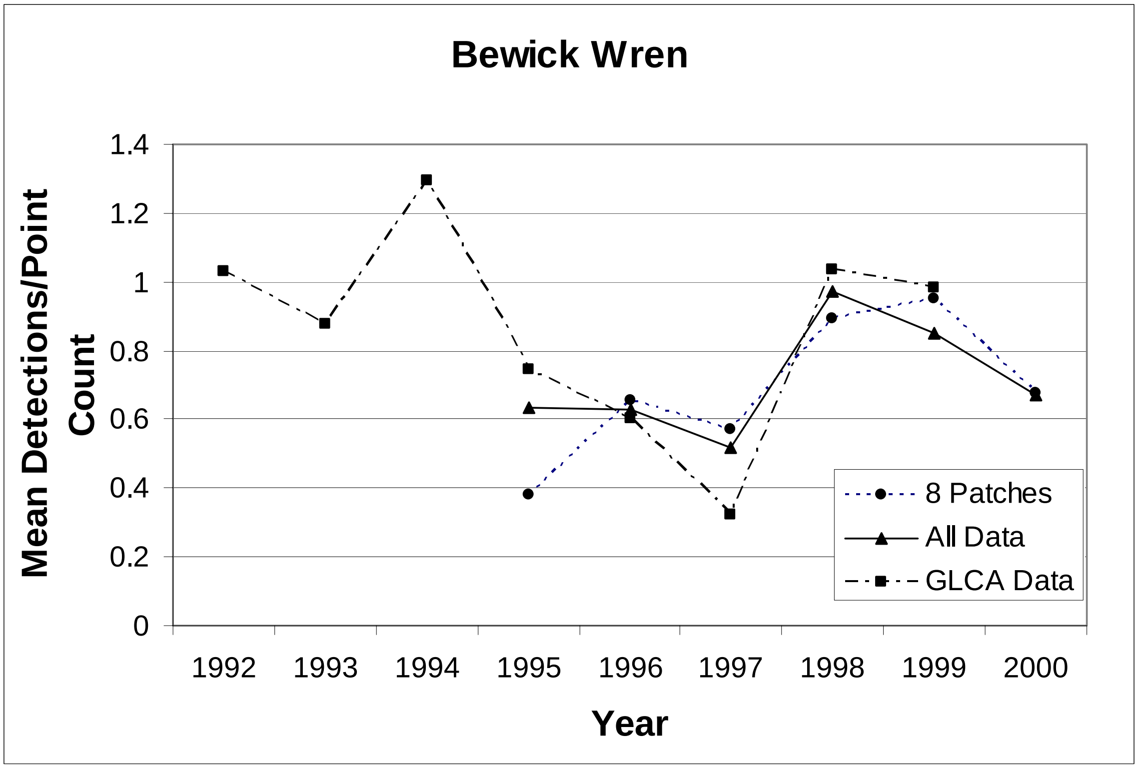
Minimum Breeding Criterion: detected on two visits April-June
Breeding Status: permanent resident and breeder

Summary

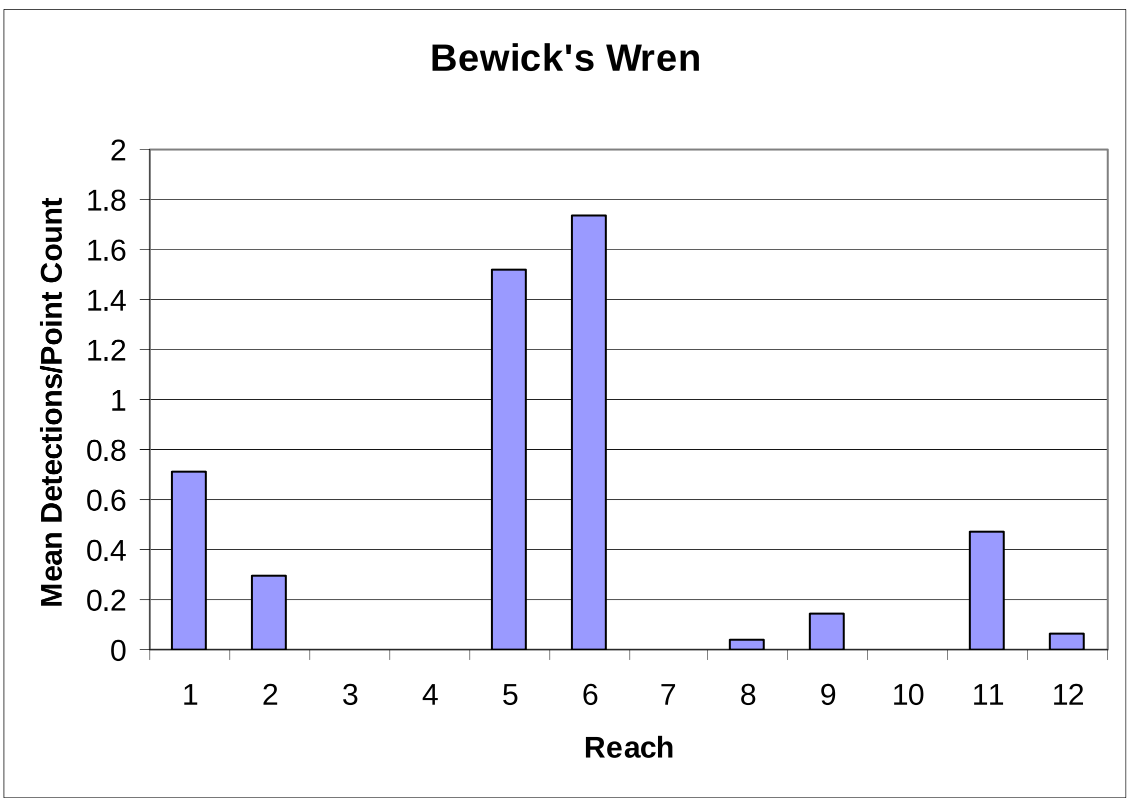
Bewick's wren is a common breeding species in most of the river corridor, although becoming less common in the lower two reaches. Detection rates were not significantly different between months or years for the species.

Power To Detect Change

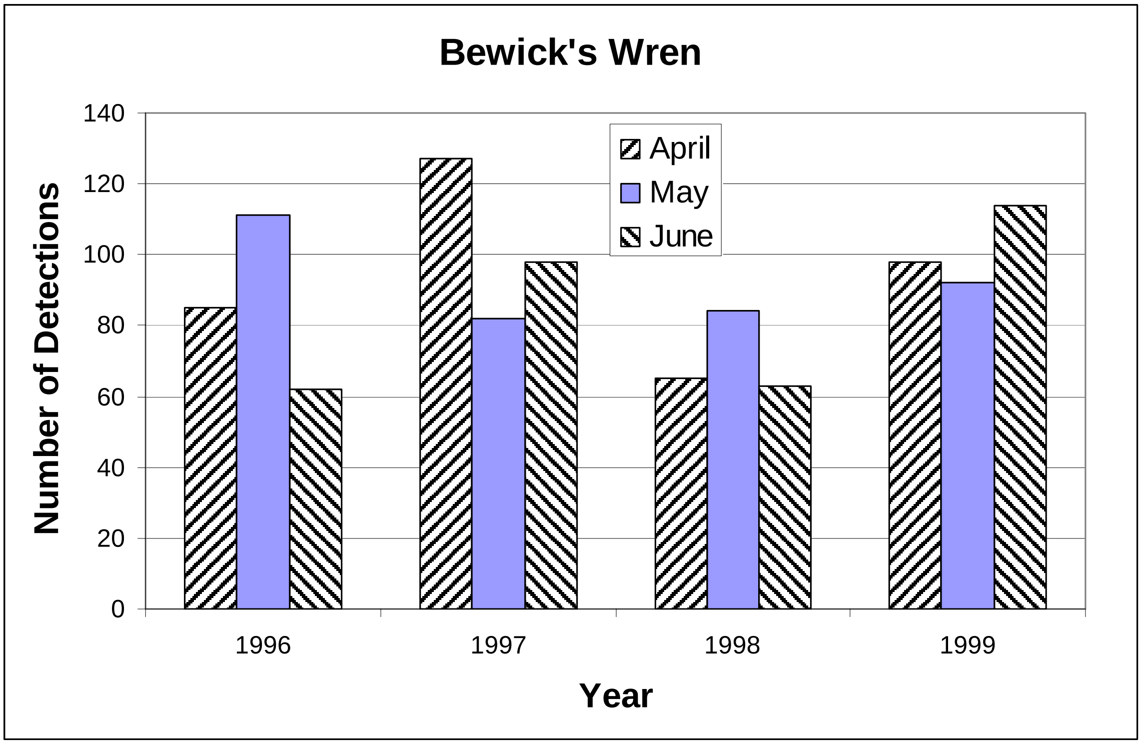
There is adequate power in the current program to detect a 25% change/year after 3 years, a 20% change/year after 4 years, a 15% change/year after 5 years, a 10% change/year after 6 years, and a 5% change after 9 years. At an alpha of 0.05, there is adequate power to detect change after 10 years by monitoring at least 20 patches of riparian vegetation.

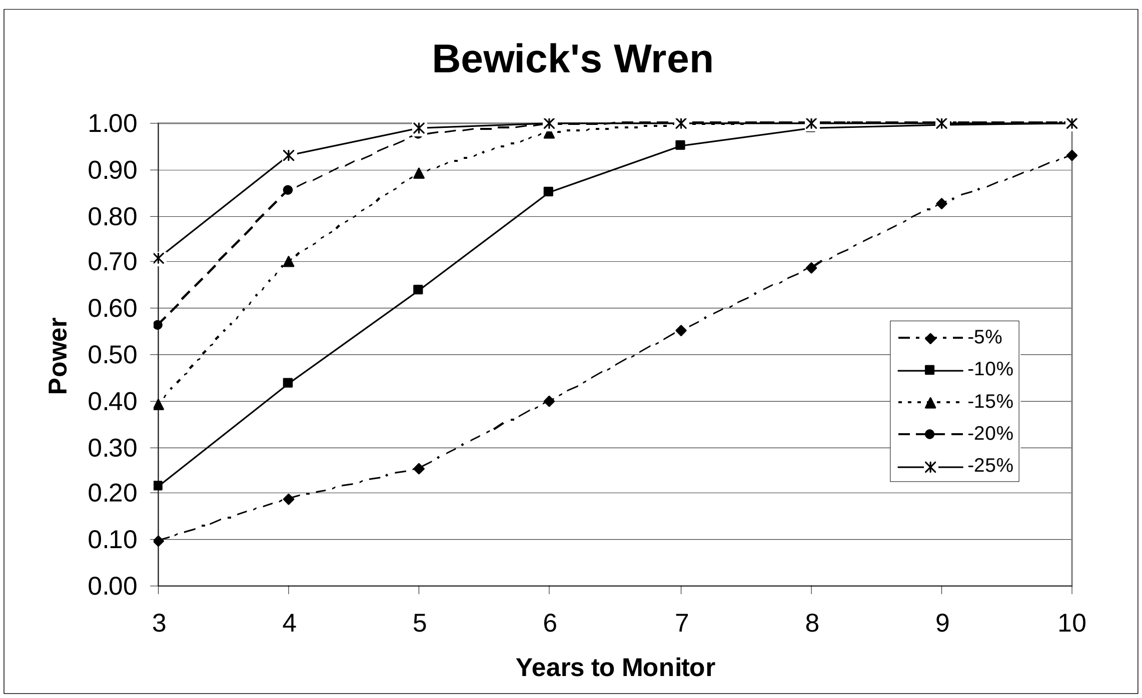


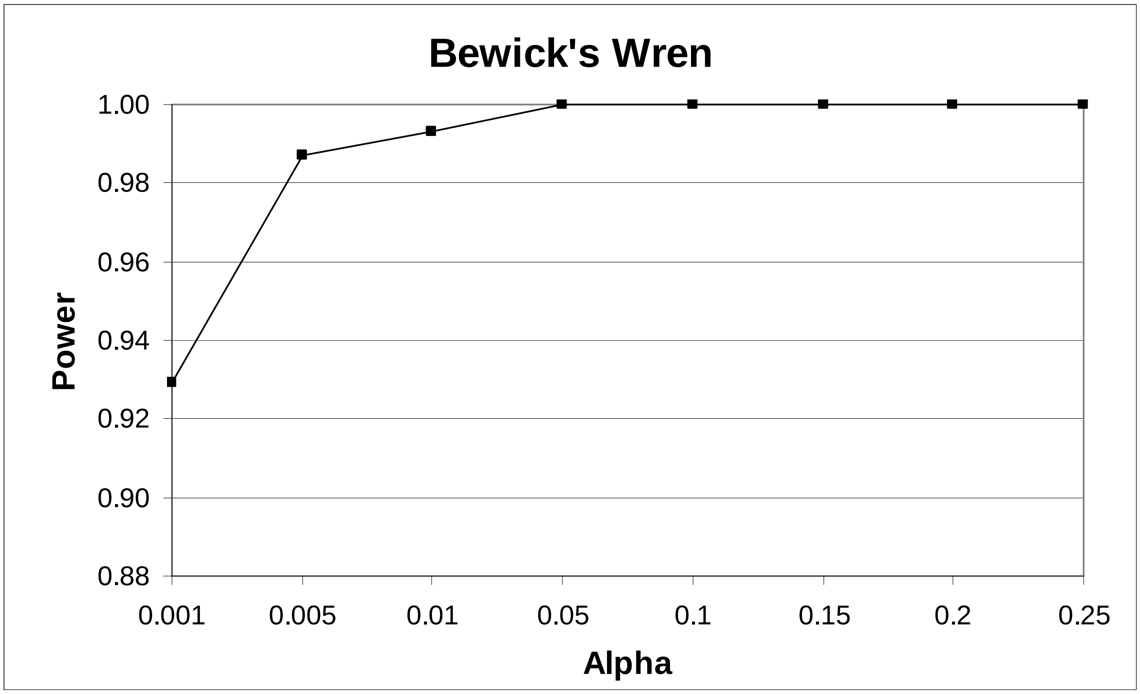
Bewick Wren
Mean Detections/Point Count
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1992
1993
1994
1995
1996
1997
1998
1999
2000
Year
8 Patches
All Data
GLCA Data



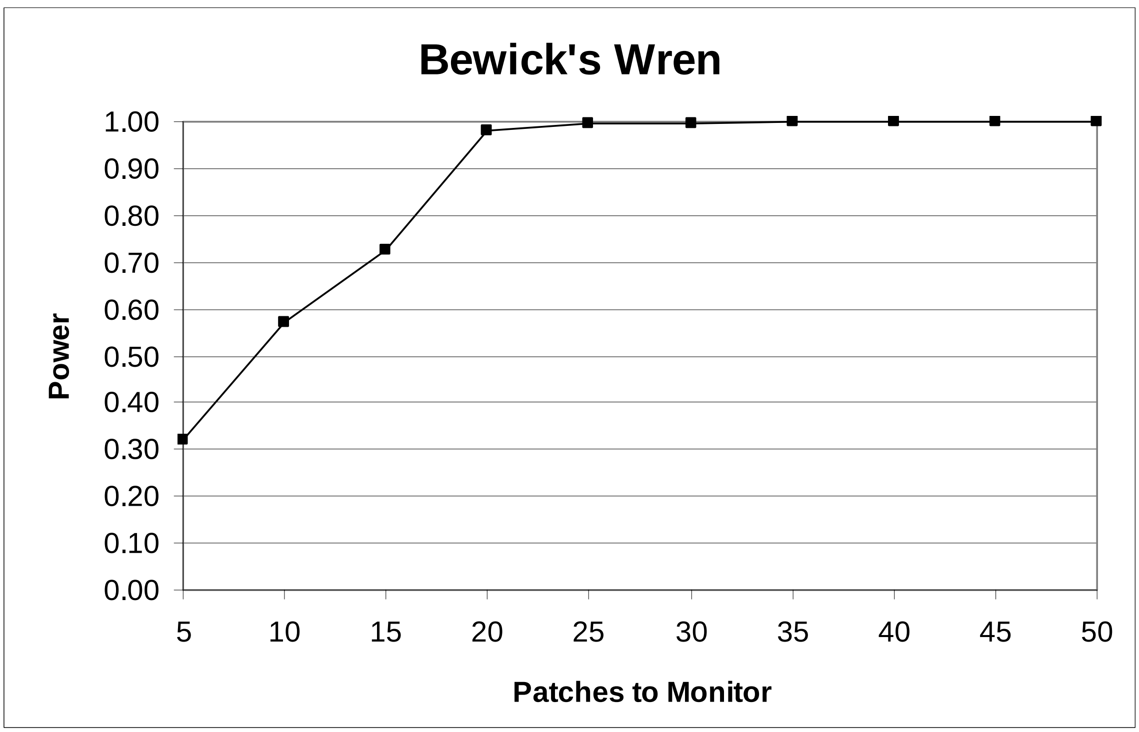
Bewick's Wren
Mean Detections/Point Count
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
10
11
12
Reach


Bewick's Wren
140
120
100
80
60
40
20
0
Number of Detections
April
May
June
1996
1997
1998
1999
Year


Bewick's Wren
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Power
-5%
-10%
-15%
-20%
-25%
3
4
5
6
7
8
9
10
Years to Monitor



Bewick's Wren
1.00
0.98
0.96
0.94
0.92
0.90
0.88
Power
0.001
0.005
0.01
0.05
0.1
0.15
0.2
0.25
Alpha



Bewick's Wren
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Power
5
10
15
20
25
30
35
40
45
50
Patches to Monitor

4. Black Phoebe (*Sayornis nigricans*)

Minimum Breeding Criterion: detected on two visits April-June
Breeding Status: spring-summer breeder

Summary

Black phoebe is an uncommon spring breeder along the river, principally downstream of the Little Colorado River, wherever appropriate nesting habitat occurs. The species was rarely recorded on breeding bird surveys, as it tended to favor rocky areas and cliffs directly at the rivers edge. This species is the only riparian breeder in the study area that is strongly impacted by dam operations. Black phoebes typically place their nest within a few feet of the river surface, and the nests are vulnerable to flooding if dam releases are increased. This species has shown a significant increase upriver from the lower portions of the study area in Glen Canyon in recent years (Spence and LaRue, unpublished data), and is becoming increasingly common in side canyons off of Lake Powell.

5. Black-chinned Hummingbird (*Archilochus alexandri*)

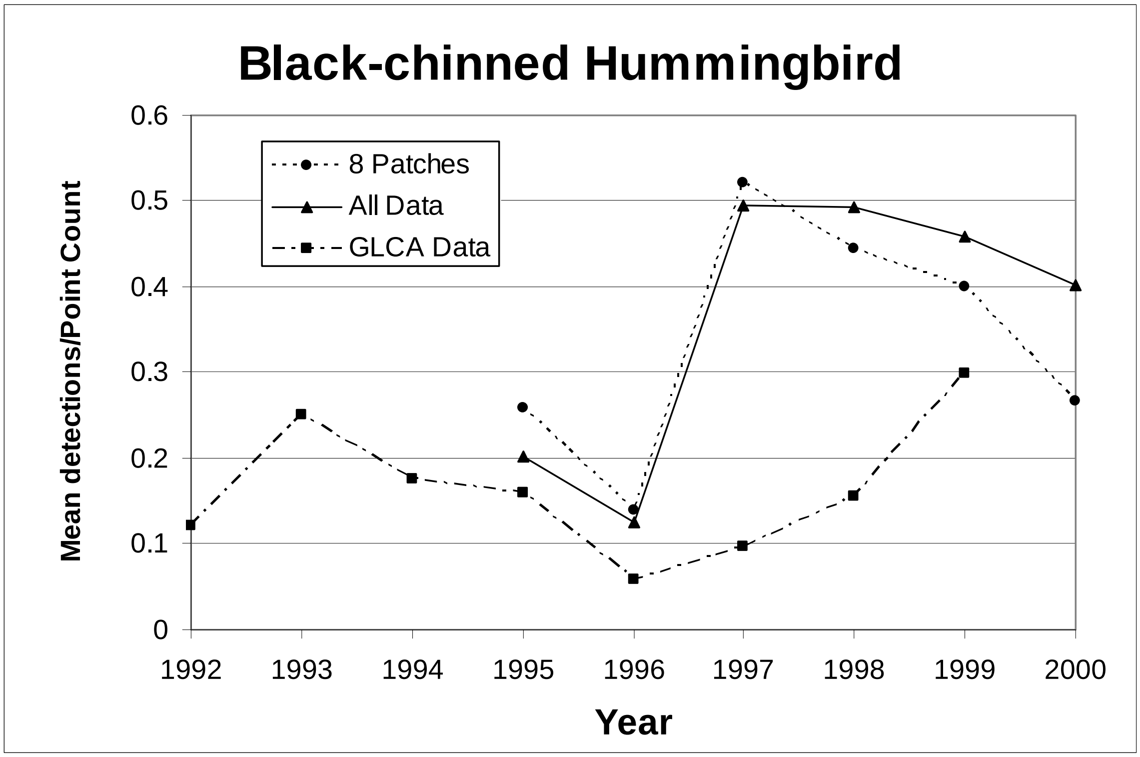
Minimum breeding criterion: detected on one visit April-June
Breeding Status: spring-summer breeder

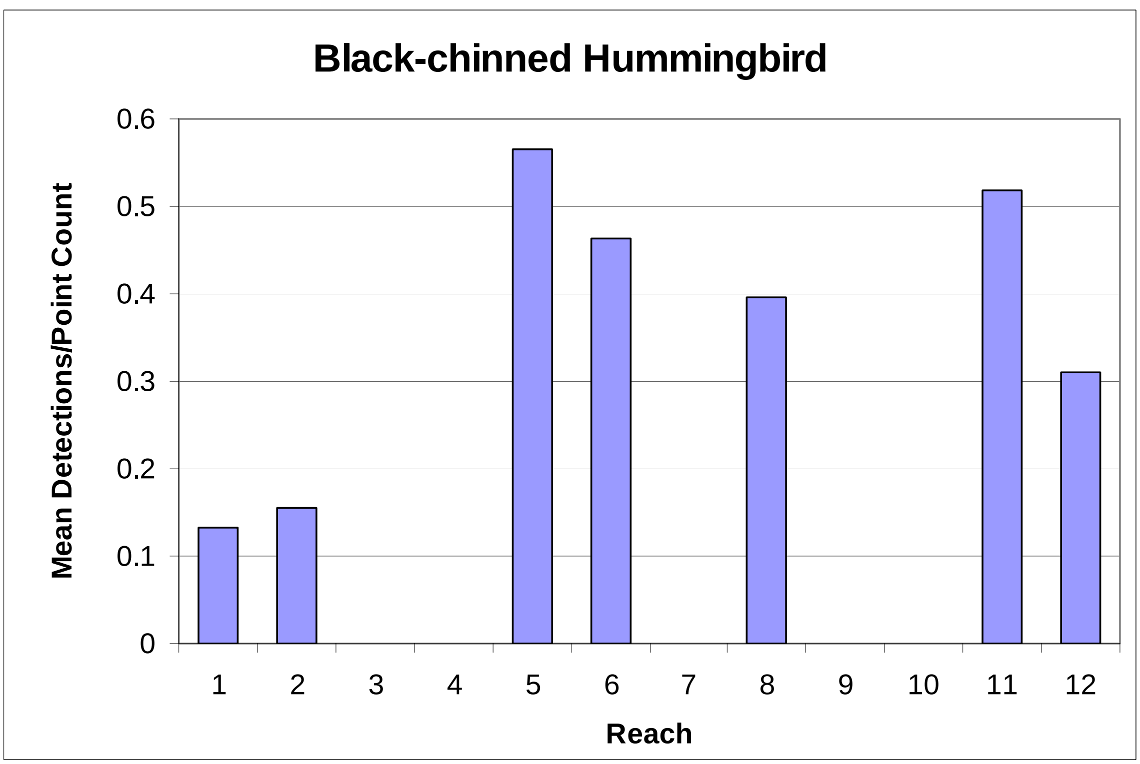
Summary

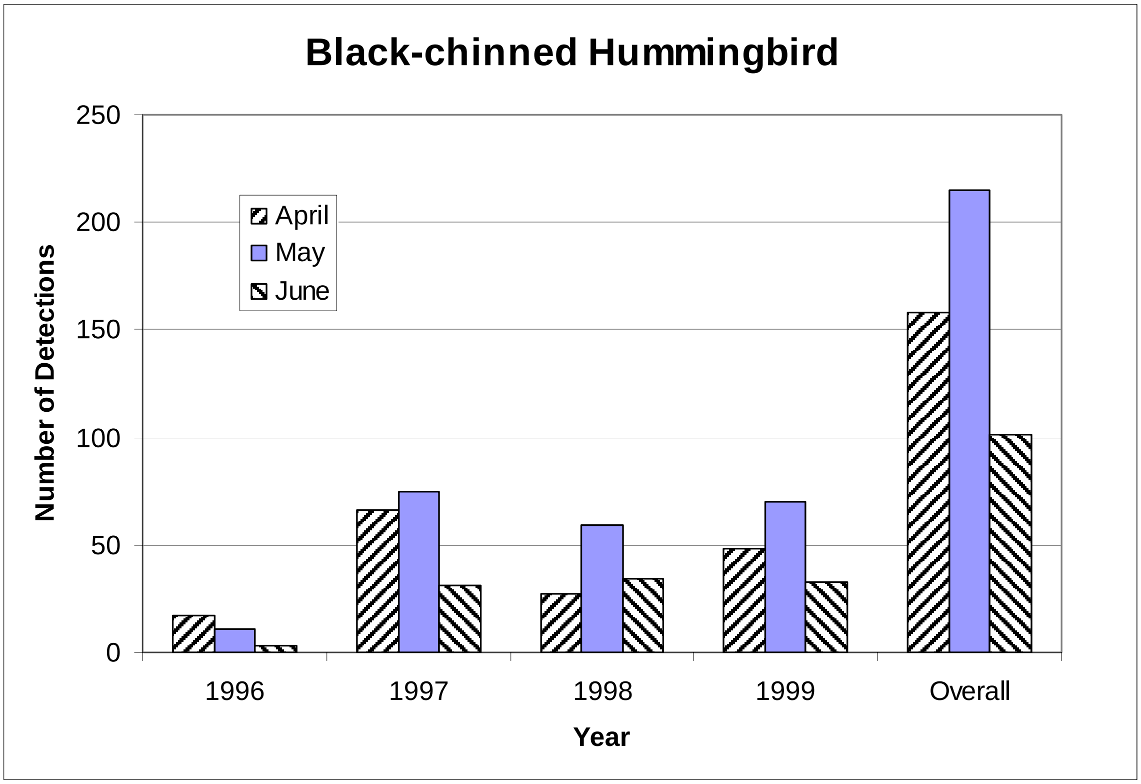
Black-chinned hummingbird is a fairly common breeding species throughout the river corridor, but often overlooked except during courtship. It is generally more commonly detected below about RK 65. The species is somewhat more common in April and especially May surveys, although there is a lot of variation by year. Black-chinned hummingbird showed highly significant differences between years and between months during the study. Presumably these fluctuations are due to changes in resource availability (flowers) either within the study area or on wintering grounds. During drought years this species becomes quite scarce in the region. Far fewer birds were detected in June compared with April and May.

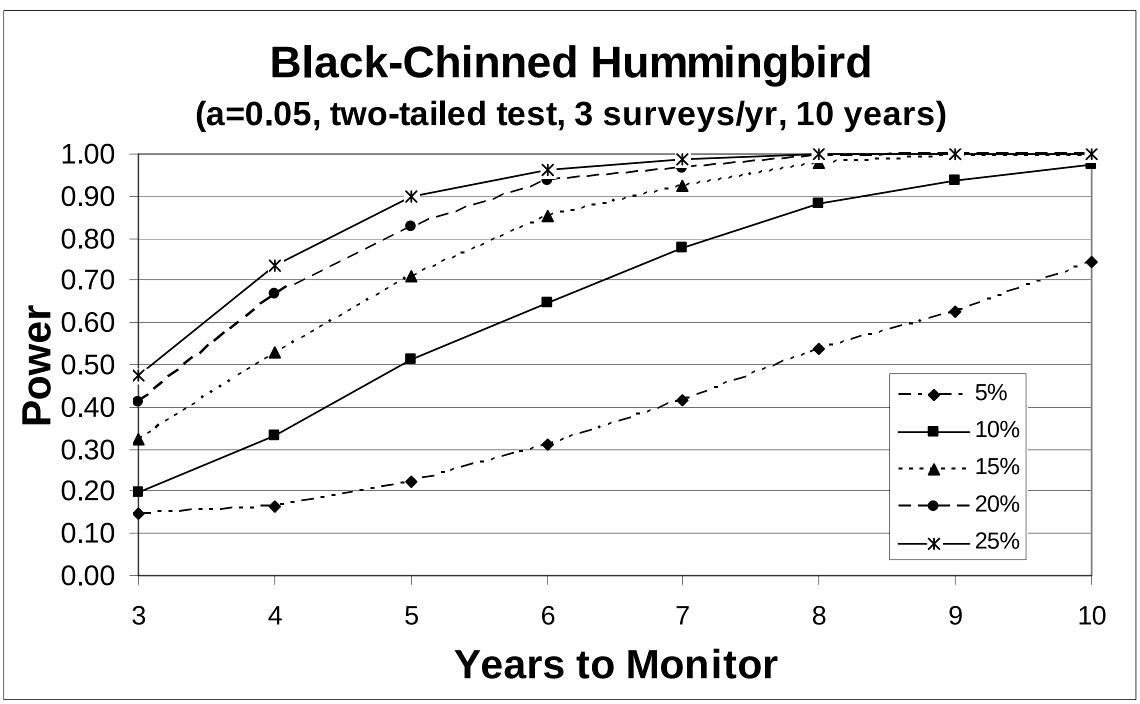
Power to Detect Change

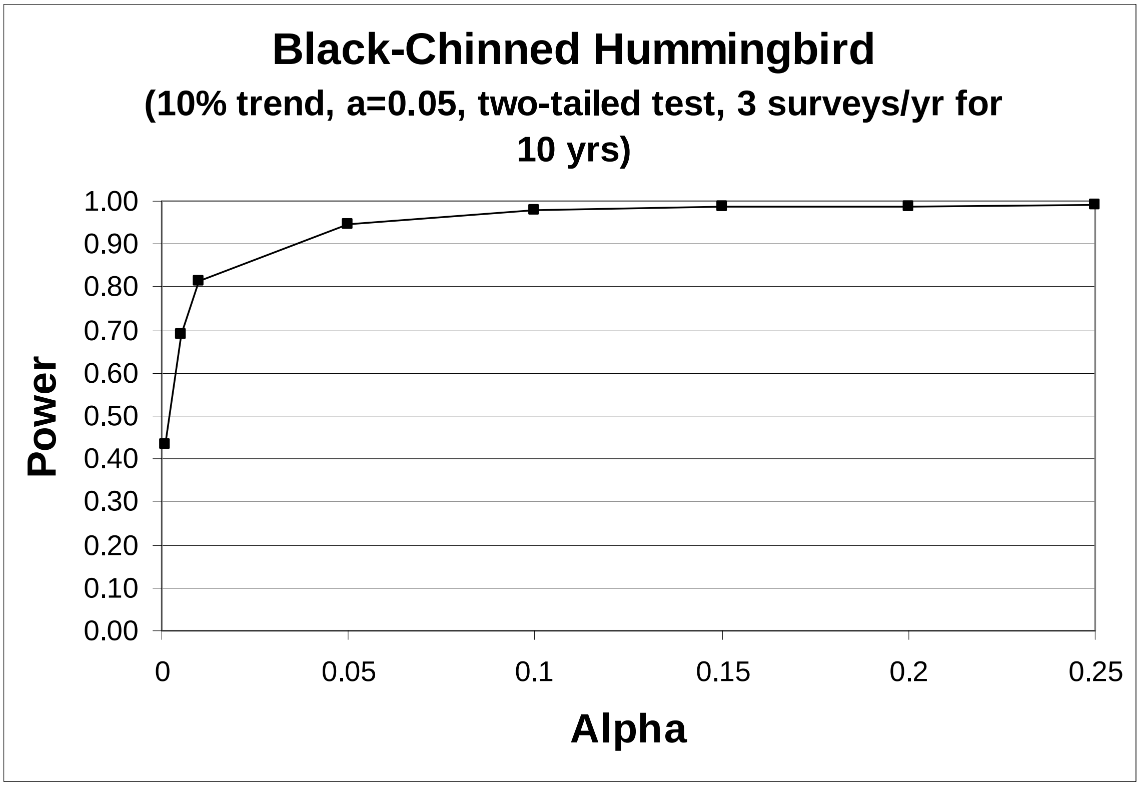
There is adequate power in the current program to detect a 25% change/year after 5 years, a 20% change/year after 5 years, a 15% change/year after 6 years, a 10% change/year after 8 years, but not to detect a 5% change up to 10 years. At an alpha of 0.05, there is adequate power to detect change after 10 years by monitoring at least 35 patches of riparian vegetation.

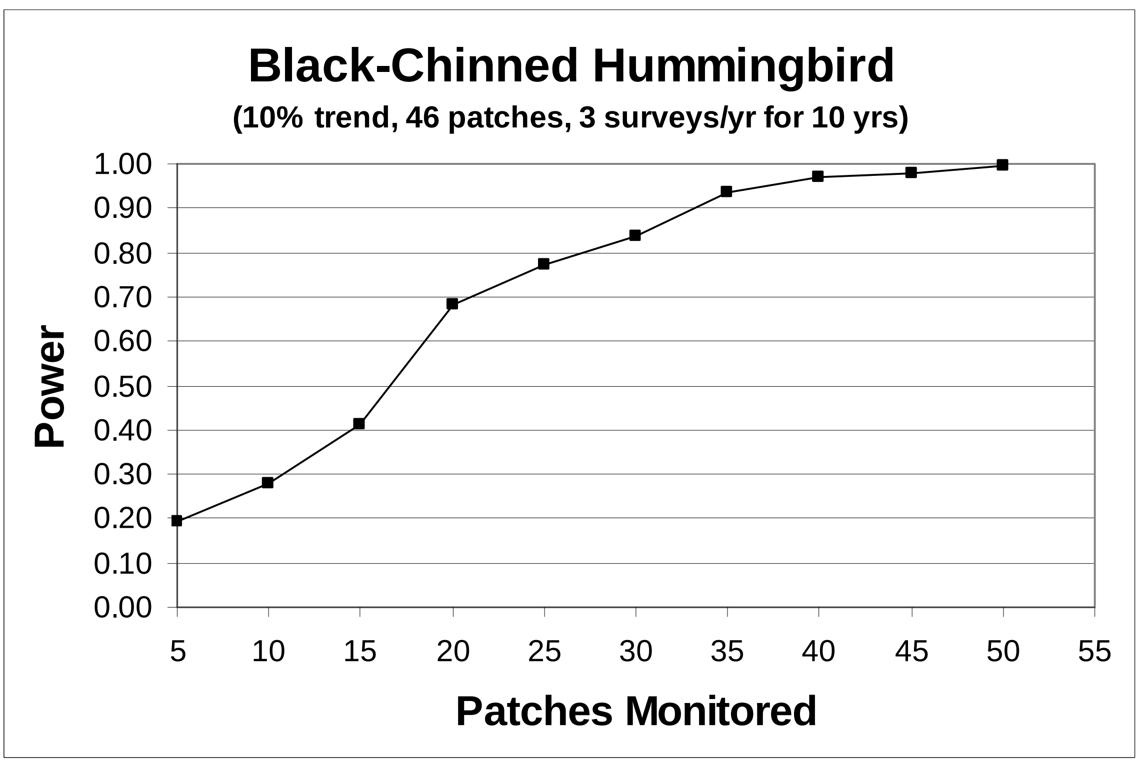

Black-chinned Hummingbird
Mean detections/Point Count
0.6
0.5
0.4
0.3
0.2
0.1
0
8 Patches
All Data
GLCA Data
1992
1993
1994
1995
1996
1997
1998
1999
2000
Year


Black-chinned Hummingbird
Mean Detections/Point Count
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
10
11
12
Reach


Black-chinned Hummingbird
Number of Detections
250
200
150
100
50
0
April
May
June
1996
1997
1998
1999
Overall
Year


Black-Chinned Hummingbird
(a=0.05, two-tailed test, 3 surveys/yr, 10 years)
Power
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
5%
10%
15%
20%
25%
3
4
5
6
7
8
9
10
Years to Monitor


Black-Chinned Hummingbird
(10% trend, a=0.05, two-tailed test, 3 surveys/yr for 10 yrs)
Power
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
0.05
0.1
0.15
0.2
0.25
Alpha


Black-Chinned Hummingbird
(10% trend, 46 patches, 3 surveys/yr for 10 yrs)
Power
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
5
10
15
20
25
30
35
40
45
50
55
Patches Monitored

6. Blue-gray Gnatcatcher (*Polioptila caerulea*)

Minimum Breeding Criterion: detected on two trips April-June.
Breeding Status: spring-summer breeder

Summary

This species was originally common in the study area based on the studies of Brown (1987, 1989), but has become increasingly uncommon (or less easily detected) in recent years, particularly above Lee's Ferry. It is more easily found in May and June compared with April. There were no significant differences in detection rates for this species between 1996-2000 within the Grand Canyon, but significant declines have occurred in Glen Canyon since 1993. However, the decline below Lee's Ferry in this species becomes significant if 1995 data is included.

Power to Detect Change

There is adequate power in the current program to detect a 25% change/year after 6 years, a 20% change/year after 7 years, a 15% change/year after 8 years, a 10% change/year after 10 years, but not to detect a 5% change up to 10 years. At an alpha of 0.05, there is adequate power to detect change after 10 years by monitoring at least 40 patches of riparian vegetation.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

7. Black-headed Grosbeak (*Pheucticus melanocephalus*)

Minimum Breeding Criterion:
Breeding Status: possible spring-summer breeder

Summary

Black-headed grosbeak was very rarely recorded during the study, with singing birds only recorded in the Glen Canyon stretch. It is unlikely that this species actually breeds along the Colorado River below the dam. Regionally, the species is most common in higher elevation areas, and is a common breeder where pinyon-juniper woodlands are adjacent to deciduous riparian and Gambel's oak vegetation.

8. Blue Grosbeak (*Guiraca caerulea*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: summer breeder

Summary

Blue grosbeak is most common in the Glen Canyon reach, but is found in other portions of the study area as well. This species is a late breeder in the study area, and was most commonly detected on June trips. Including all data, blue grosbeak was significantly less common in 1996 compared with subsequent years. Below Lee's Ferry there were no significant differences between years.

Power to Detect Change

There is not adequate power in the current program to detect change for this species unless at least 55 patches with detected birds are sampled per year. However, the mean number of patches in which blue grosbeaks was detected in between 1996 and 2000 was 36. This species is a common cowbird host in the study area.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

9. Brown-crested Flycatcher (*Myiarchus tyrannulus*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: possible spring-summer breeder

Summary

A rare species in the study area, with all birds detected in patches from RK 280 to 328 (RM 174 to 204). In all only 36 birds were counted between 1996 and 2000 at point count stations. None were found in 2000, and very few in 1998. Those patches where the species was consistently present except for 2000 included 197.6L and 198.0R.

10. Brown-headed Cowbird (*Molothrus ater*)

Minimum Breeding Criterion: observed on at least one trip
Breeding Status: spring-summer breeder

Summary

Cowbirds were most commonly detected in one of three reaches, Glen Canyon, at Cardenas Marsh, and on upper Lake Mead. They were most common in the Glen Canyon stretch. There were no significant differences between years or months in detection rates for this species.

Power To Detect Change

There is not enough power in the monitoring program to detected brown-headed cowbirds. At least 60 occupied patches would be needed to detect change after 10 years of monitoring, and the total number of patches the species was found in between 1996 and 2000 was 22. With the current monitoring program, at least 30 years would be needed to detect a decline in cowbirds if it was happening. Clearly, this species is of management concern because of its actual or potential impacts on breeding success of other species in the study area. Some form of monitoring is desired, but is likely to be one based on local population trends outside the river corridor itself, such as populations at Page and the South Rim.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

11. Bullock's Oriole (*Icterus bullockii*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: spring-summer breeder

Summary

Bullock's orioles are very rare in the study area except for Glen Canyon. Elsewhere, they were only found consistently below Diamond Creek, in 1996 and 1997. However, in the 1997 season, they were detected widely throughout the canyon above Diamond Creek, especially in the lower canyon in reach 11.

Power To Detect Change

There is currently not enough power to detect change in Bullock's orioles unless occupancy reaches 30 patches. However, they were only recorded from 21 patches between 1996 and 2000.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

12. Bushtit (*Psaltriparus minimus*)

Minimum breeding criteria: detected on two trips April-June
Breeding Status: resident breeder

Summary
Bushtit is a common winter resident along the river corridor, where it typically occurs as flocks of 10-30 birds. There is a single breeding record from tamarisk at Lee's Ferry in 1995, and a second record from the nearby Lonely Dell Ranch in 1999. During the breeding season surveys, bustits were mostly seen in Marble Canyon patches and around Lee's Ferry. However, occasional birds were detected in patches throughout the river corridor, even into June, suggesting that some local breeding may be occurring.

13. Crissal Thrasher

Minimum breeding criteria: detected on two trips April-June
Breeding Status: possible resident breeder

Summary
During the breeding bird surveys, only one crissal thrasher was detected in 5 years, a single bird at Spencer's Canyon on upper Lake Mead on 13 May 1998. Occasional reports in winter and the evidence from the Arizona Breeding Bird Atlas program suggest that the species may breed very locally in the upper Lake Mead area.

14. Cliff Swallow (*Petrochelidon pyrrhonota*)

Minimum breeding criteria: nest-building during April-June
Breeding Status: spring-summer breeder

Summary
Following completion of Glen Canyon Dam cliff swallow declined and eventually disappeared as a breeding species along the Colorado River in the study area. The only recent records were of a small colony at RM 28 in Marble Canyon in 1975 (Brown et al. 1987), and nest building at RM 2.0 and 3.5 during 1995 (Sogge et al.1998). In 1996 a small colony of 20+ nests were discovered at RM 1.7, with young being fed by June. This breeding attempt followed the 1996 controlled flood, which may have provided temporary supplies of mud for nest-building. The species is a common breeder in the lower Colorado River Valley (Rosenberg et al. 1991).

15. <u>Common Yellowthroat</u> (*Geothlypis trichas*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: spring-summer breeder

Summary

Common yellowthroat is an uncommon breeding species throughout the river corridor, and is very patchy in distribution. It tends to be an obligate breeder in marsh patches, where dense stands of *Typha* and *Phragmites* occur. The species is more commonly detected in May and June compared with April. Yellowthroats did not show significant differences between years, primarily because of large variances in detection rates.

Power To Detect Change

There is adequate power in the current program to detect a 25% change/year after 9 years, a 20% change/year after 9 years, but not at lower trends. At an alpha of 0.05, there is only adequate power to detect change after 10 years by monitoring at least 55 patches of riparian vegetation, which is unlikely for this species.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

16. Costa's Hummingbird (*Calypte costae*)

Minimum Breeding Criterion: observed on one trip
Breeding Status: possible spring breeder

Summary
Costa's hummingbird is probably breeding in the lower portions of the study area, where the bulk of the detections were. They were particularly common in 1999, when 27 birds were detected, as far upriver as patch RM 5.2R. This species appears to go through abundance cycles from year to year, as only single birds were detected in 1998 and 2000.

17. Great-tailed Grackle (*Quiscalus mexicanus*)

Minimum Breeding Criterion: detected on two consecutive trips April-June
Breeding Status: possible spring-summer breeder

Summary
In all 10 birds were counted of this recently invading species, mostly downriver from RM122.8. The majority were detected below Diamond Creek, on upper Lake Mead. A small population also occurs at Lee's Ferry, but typically does not move upstream or downstream from the area.

18. Hooded Oriole (*Icterus cucullatus*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: possible spring-summer breeder

Summary
Rare possible breeder, most commonly detected between RM190-205. There were no April detections of Hooded Oriole, with more detections in June than May. Rarely, birds were found as far upriver as RM50.0, with one bird detected in June of 1999 at RM 3.7L. A small breeding population exists in the Page area.

19. House Finch (*Carpodacus mexicanus*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: resident breeder

Summary

A common and widespread species throughout the river corridor in the breeding season. There were not any significant differnces in detections between months. Below Lee's Ferry, there were significantly fewer house finches in 1996 compared with subsequent years.

Power To Detect Change

There is adequate power in the current program to detect a 25% change/year after 4 years, a 20% change/year after 5 years, a 15% change/year after 5 years, a 10% change/year after 7 years, and a 5% change after 10 years. At an alpha of 0.05, there is adequate power to detect change after 10 years by monitoring at least 15 patches of riparian vegetation.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

20. Indigo Bunting (*Passerina cyanea*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: possible spring-summer breeder

Summary
Only three birds were detected, all at RM204.5R. One bird was seen in May of 1997, and two in June 0f 1997. This species is consistently seen in Deer Creek, where it is found along the stream in cottonwoods.

21. Lazuli Bunting (*Passerina amoena*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: possible spring-summer breeder

Summary
Relatively common in 1997 and 1998 with 30 birds detected on the May trips, suggesting these may be migrating individuals. Lazuli bunting is found in side canyons of the Grand Canyon region, where it may be breeding in riparian and other deciduous woodlands.

22. Lesser Goldfinch (*Carduelis psaltria*)

Minimum Breeding Criterion: detected on two consecutive trips April-May
Breeding Status: spring-summer breeder

Summary
An uncommon species found from middle Marble Canyon (43.1L) downstream, much more common below the Little Colorado River and especially in the lower canyon in reaches 11-12. Lesser goldfinch's are detected commonly in April and May, and become quite scarce (or silent) by June, when significantly fewer birds were found. There were no significant differences between years in detection rates.

Power To Detect Change
There is not adequate power to detect this species in the study area. Even at large trends of 25% per year, power remains <0.70 after 10 years. In order to achive reasonable power, at least 45 patches with individuals would need to be sampled, an unlikely scenario.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

23. Lucy's Warbler (*Vermivora luciae*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: spring-summer breeder

Summary

The most abundant bird along the Colorado River in riparian vegetation, Lucy's warbler also occurs in side canyon riparian zones and in upland areas where *Acacia*, *Celtis* and *Prosopis* occur. Birds typically arrive in the study area in March, but in most years were most common in June, presumably as young of year had fledged. No significant differences occurred between years or months for this warbler. The species is rare above Marble Canyon (reach 5), with few detections in the Glen Canyon stretch.

Power To Detect Change

Good power to detect a trend of 5% after 8 years, 10% after 5 years, 15% after 4 years, and 20-25% after 3 years. To detect a trend of 10% after 10 years, only 20 patches need to be sampled.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

24. Mourning Dove (*Zenaida macroura*)

Minimum Breeding Criterion: detected on two consecutive visits April-June
Breeding Status: spring-summer breeder

Summary

A sporadic but sometimes common breeder in the study area. Mourning doves show large differences in detection rates between years, and was common in 1997 and 1999 but rare in 1996, 1998 and 2000. They are distributed throughout the study area, but are especially common in Glen Canyon. They were detected equally commonly in all months.

Power To Detect Change

There is not enough power in the program to detect mourning dove. Even after 10 years at trends of 25%/year power was weak at 0.60. Relaxing alpha did not improve power. The species would have to occur at 55 patches before power improves.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

25. Northern Mockingbird (*Mimus polyglottos*)

Minimum Breeding Criterion: detected on two consecutive trips April-June
Breeding Status: spring-summer breeder

Summary
A rare sporadic breeder in the study area, with 19 birds detected over 5 years. Mockingbirds are not restricted to riparian vegetation, but can be found in the riparian zone occasionally, especially below about RM175 where mistletoe patches occur on *Acacia* and *Prosopis*. Confirmed breeding in the canyon by LaRue et al. (2001a).

26. Phainopepla (*Phainopepla nitens*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: spring-summer breeder

Summary
Fairly common on winter trips, Phainopepla's decline in number consistently between April and June. They were most commonly found below about RM170, where they associated with dense mistletoe patches. It is likely that the bulk of the breeding is over by April. In all 67 birds were detected between 1996-2000.

27. Red-winged Blackbird (*Agelaius phoeniceus*)

Minimum breeding criteria: detected on two trips April-June
Breeding status: possible spring-summer breeder

Summary
In all 22 individuals were detected, with 19 occurring below Diamond Creek, one at RM198.0R, and 2 at RM51.5L. The species probably breeds at least occasionally on upper Lake Mead, but suitable-sized patches of marshland vegetation do not apparently occur elsewhere along the river corridor.

28. Song Sparrow (*Melospiza melodia*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: resident (?) breeder

Summary

Song sparrows are abundant on upper Lake Mead, but are much less common upstream and were only consistently detected below about RM170. They were detected on all three trips, with no significant differences between trips. Because patches below Diamond Creek were not sampled after 1997, overall detections dropped off sharply.

Power To Detect Change

There is adequate power to detect trends of 20-25% after 10 years, but power drops off rapidly at shorter intervals and with smaller trends. At least 40 patches would be needed to monitor song sparrow, and this can only be done by expanding the monitoring program to upper Lake Mead, where the bulk of the population occurs.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

29. Summer Tanager (*Piranga rubra*)

Minimum Breeding Criterion: detected on two trips May-June
Breeding Status: spring-summer breeder

Summary

This species can occur anywhere in the study area, but was only detected consistently in patches below about RM190. Elsewhere, summer tanager's tend to associate with large riparian trees such as *Populus fremontii*, which are rare along the Colorado River.

30. Yellow Warbler (*Dendroica petechia*)

Minimum Breeding Criterion: detected on two trips May-June
Breeding Status: spring-summer breeder

Summary

A common breeder in willow-dominated portions of the study area. For some reason, yellow warblers seem to be rare above Lee's Ferry, and at least anecdotally seem to have declined since the 1980's. This may be the result of cowbird parasitism, which is probably common in the Glen Canyon reach. Elsewhere in the study area, there has been a steady increase, although the increase is not significant. They were significantly less likely to be detected in April compared with May and June. It is likely that many of the birds detected in May were migrants, as number of detections dropped consistently across all years in June.

Power To Detect Change

There is adequate power in the current program to detect a 25% change/year after 8 years, a 20% change/year after 8 years, a 15% change/year after 9 years, but not enough power to detect smaller trends. A 5% change can be detected after 10 years. At an alpha of 0.10, there is adequate power to detect change after 10 years by monitoring at least 50 patches of riparian vegetation.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

31. Yellow-breasted Chat (*Icteria virens*)

Minimum Breeding Criterion: detected on two trips April-June
Breeding Status: spring-summer breeder

Summary

Yellow-breasted chat is a fairly common and easily detected species in the study area because of its loud vocalizations. It is found throughout the study area, and has not shown any significant trends over the years. The species is significantly less likely to be detected in April compared with May and June.

Power To Detect Change

There is adequate power in the current program to detect a 25% change/year after 6 years, a 20% change/year after 7 years, a 15% change/year after 7 years, a 10% change/year after 9 years, but not enough power to detect smaller trends. A 5% change can be detected after 10 years. At an alpha of 0.05, there is adequate power to detect change after 10 years by monitoring at least 40 patches of riparian vegetation.

Abundance

Reach Distribution

Month Distribution

Power

Alpha

Patches

32. Willow Flycatcher (*Empidonax traillii*)

Minimum Breeding Criterion: detected on consecutive trips June-July
Breeding Status: spring-summer breeder

The status of this species in the study area since 1998 has been summarized by Tibbitts and Johnson (1998, 1999) and Johnson and Abieta (2000).

APPENDIX G

Vegetation data is presented based on sampling using the TVV method for two different data sets, 45 patches for which both complete bird data and TVV data were collected, and 62 patches for which TVV data were collected. The TVV data is broken out by species or groups in the first set, and summarized by pole meter length from 0 to 7+ meters in the second set. The third data set includes the sampling intensity for each patch. For more details see Chapter IX.

Summary based on 20 species or groups for 46 patches of riparian vegetation.

Species and group acronyms are: ACGR=*Acacia greggii*; ANNUALS=annual species; BAEM=*Baccharis emoryi*; BASAL=*Baccharis salicifolia*; BASAR=*Baccharis sarathroides*; CERE=*Celtis reticulat*a; EQFE=*Equisetum xferresii*; FAPA=*Fallugia paradoxa*; FONE=*Forestiera neomexicana*; PFORBS=perennial non-marsh forbs; PGRASS=perennial non-marsh grasses; MARSH=wetland species; PHAU=*Phragmites australis*; PHCA=*Phoradendron californicum*; PRGL=*Prosopis glandulosa*; SAEX=*Salix exigua*; SAGO=*Salix gooddingii*; TACH=*Tamarix chinensis*; TESE=*Tessaria sericea*; UPLANDS=upland shrubs.

Patch	TACH	SAEX	PRGL	ACGR	BAEM	BASAL	BASAR	TESE	CERE	FAPA	SAGO	FONE	MARSH	EQFE	PHA
(-)14.2R	5.10	0.20	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.87	0.47	0.0
(-)13.6R	9.35	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.15	0.25	0.3
(-)10.0L	4.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
(-)9.4L	8.43	0.00	0.00	0.00	0.52	0.00	0.00	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.0
(-)8.4R	7.72	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.0
(-)7.0L	10.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	2.72	0.00	0.0
(-)6.5R	3.36	0.72	0.00	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.44	0.0
(-)3.2R	10.83	0.71	0.00	0.00	0.32	0.00	0.00	0.41	0.34	0.00	0.00	0.00	0.71	0.00	0.8
(-)2.5L	6.78	0.00	0.00	0.00	0.86	0.00	0.00	2.31	0.00	0.00	0.00	0.00	0.08	0.00	0.0
1.0R	5.00	2.44	0.00	0.00	0.93	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.0
1.6R	3.11	2.20	0.00	0.00	1.41	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.34	0.86	0.0
3.7L	3.94	0.78	0.00	0.00	0.00	0.00	0.00	0.44	0.00	2.16	0.00	0.00	0.41	0.09	0.0
5.2R	2.74	0.37	0.00	0.00	1.80	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.40	0.80	0.1
43.1L	3.12	1.26	1.77	0.43	0.20	0.00	0.00	2.69	0.00	0.00	0.00	0.00	0.02	0.29	0.0
45.5L	1.87	2.21	0.00	1.00	0.71	0.00	0.00	0.00	0.00	1.41	0.00	0.00	0.16	0.23	0.0
46.7R	3.67	0.61	1.22	0.19	0.64	0.44	0.00	0.43	0.05	0.00	0.00	0.00	0.25	0.86	0.4
49.1R	1.57	0.09	0.80	0.07	0.65	0.00	0.00	0.11	0.11	0.00	0.00	0.00	0.02	0.00	0.2
50.0R	3.04	0.50	0.81	0.04	0.00	0.30	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.0
50.4L	2.87	1.59	1.84	0.25	0.27	0.22	0.00	0.79	0.07	0.00	0.00	0.00	0.07	0.43	0.2
51.5L	2.18	1.02	2.27	0.70	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	1.07	0.43	0.2
56.0R	2.44	1.34	1.79	0.00	0.74	0.00	0.00	0.15	0.03	0.00	0.00	0.00	0.08	0.72	1.0
65.3L	2.82	3.49	2.04	0.00	0.26	0.00	0.00	1.21	0.00	0.00	0.00	0.00	0.60	0.48	0.9
67.1L	1.50	0.25	4.19	0.00	0.11	0.00	0.00	1.38	0.00	0.00	0.00	0.00	0.00	0.00	0.0
71.0L	2.25	0.29	1.13	0.00	0.04	0.00	0.00	0.16	0.00	0.00	1.42	0.00	0.00	0.00	2.7
122.8L	2.82	2.00	0.00	1.22	0.00	0.10	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.32	0.2
125.5L	1.58	1.10	0.70	1.33	1.00	0.40	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.68	0.0
168.8R	3.07	0.00	2.01	0.51	0.17	0.22	0.20	0.60	0.00	0.00	0.00	0.00	0.00	0.42	0.1
171.0R	2.21	0.00	2.11	0.13	0.42	0.05	0.45	1.09	0.00	0.00	0.00	0.00	0.00	0.60	0.0
174.2L	2.22	0.00	0.89	0.67	0.00	0.16	0.24	1.45	0.00	0.00	0.00	0.00	0.00	0.42	0.0
193.8R	0.95	0.00	4.75	0.31	0.00	0.00	0.62	0.16	0.00	0.00	0.00	0.00	0.04	0.02	0.0
194.0L	2.51	1.54	3.55	0.95	0.11	0.00	0.39	0.34	0.00	0.00	0.00	0.00	2.11	0.31	0.1
196.0R	2.19	0.19	2.24	0.48	0.25	0.00	0.12	1.10	0.00	0.00	0.00	0.00	0.33	0.36	0.7
197.6L	3.07	0.00	1.97	0.26	0.00	0.00	0.84	1.00	0.81	0.00	0.00	0.00	0.00	1.64	0.0
198.0R	2.08	0.15	3.28	0.34	0.07	0.03	0.55	1.00	0.35	0.00	0.00	0.00	0.00	0.35	0.1
198.2L	1.61	0.37	2.47	0.71	0.00	0.00	0.43	0.90	0.00	0.00	0.00	0.00	0.06	0.64	1.3
200.4R	1.29	0.04	3.75	0.38	0.00	0.29	0.88	1.50	0.00	0.00	0.00	0.00	0.02	1.35	0.0
200.5R	3.22	0.00	3.20	0.50	0.42	0.00	0.08	2.89	0.00	0.00	0.00	0.00	0.00	1.98	0.0
202.5R	1.68	0.12	3.95	1.49	0.05	0.00	0.56	0.93	0.00	0.00	0.00	0.00	0.00	0.41	0.0
204.1R	1.29	0.16	2.99	0.23	0.26	0.26	0.48	0.61	0.00	0.00	0.00	0.00	0.03	0.91	0.0
204.5R	0.84	0.20	1.74	0.42	0.00	0.36	0.07	0.63	0.00	0.00	0.00	0.00	0.27	0.46	0.1
205.0L	3.43	0.00	4.17	0.13	0.06	0.00	0.12	0.71	0.00	0.00	0.00	0.00	0.00	0.23	0.0
208.7R	1.80	0.58	1.76	0.22	0.24	0.00	0.62	0.84	0.00	0.00	0.00	0.00	0.00	1.44	0.0
209.0L	0.52	0.04	1.83	0.14	0.10	0.01	0.29	0.60	0.00	0.00	0.00	0.00	0.00	0.05	0.0
213.6L	2.75	0.00	1.95	0.73	0.00	0.55	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
214.0L	6.95	0.10	2.25	0.90	0.00	0.00	0.10	1.10	0.00	0.00	0.00	0.00	0.00	1.25	0.0
214.2L	0.00	0.00	5.56	1.30	0.00	0.00	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0

Patch	PHCA	ANNUALS	P. GRASS	P. FORB	UPLAND SHRUB
(-)14.2R	0.00	2.43	0.43	3.03	0.00
(-)13.6R	0.00	2.40	0.50	0.45	0.00
(-)10.0L	0.00	1.33	0.07	0.27	0.00
(-)9.4L	0.00	1.86	0.14	0.86	0.00
(-)8.4R	0.00	1.44	0.86	1.14	0.00
(-)7.0L	0.00	1.34	0.08	0.72	0.00
(-)6.5R	0.00	0.72	0.24	0.48	0.00
(-)3.2R	0.00	0.78	0.37	2.41	0.00
(-)2.5L	0.00	1.39	0.50	0.89	0.00
1.0R	0.00	0.49	0.10	0.85	0.00
1.6R	0.00	0.14	0.77	0.61	0.00
3.7L	0.00	0.44	0.28	0.94	0.16
5.2R	0.00	0.43	0.29	0.14	0.11
43.1L	0.00	0.52	0.37	0.12	0.05
45.5L	0.00	1.87	0.13	0.36	0.81
46.7R	0.00	1.14	0.14	0.26	0.42
49.1R	0.00	1.56	0.33	0.57	1.04
50.0R	0.00	2.00	0.37	0.10	0.21
50.4L	0.00	1.57	0.10	0.50	0.18
51.5L	0.00	1.18	0.23	0.33	0.72
56.0R	0.00	1.28	0.13	0.13	0.26
65.3L	0.00	0.10	0.07	0.33	0.33
67.1L	0.00	0.25	0.22	0.03	0.73
71.0L	0.00	0.45	0.02	0.05	0.49
122.8L	0.00	0.86	0.60	0.88	1.18
125.5L	0.00	0.28	0.73	0.10	1.05
168.8R	0.00	1.37	0.36	0.23	1.40
171.0R	0.00	0.89	0.51	0.26	1.17
174.2L	0.02	0.96	0.18	1.15	1.69
193.8R	0.00	1.36	0.24	0.24	0.45
194.0L	0.01	1.34	0.61	0.11	0.69
196.0R	0.13	0.82	0.57	0.42	0.40
197.6L	0.14	1.70	0.71	0.29	0.36
198.0R	0.22	1.01	0.24	0.44	0.43
198.2L	0.00	1.84	0.30	0.00	0.83
200.4R	0.00	0.31	0.85	0.48	1.10
200.5R	0.25	0.55	0.53	0.09	0.97
202.5R	0.00	0.12	1.00	0.02	0.76
204.1R	0.30	1.00	0.53	0.18	1.16
204.5R	0.18	1.01	0.56	0.02	1.27
205.0L	0.00	0.54	0.48	0.12	0.73
208.7R	0.00	1.31	0.40	0.45	2.09
209.0L	0.05	0.61	0.22	0.14	0.21
213.6L	0.00	0.23	0.35	0.00	1.23
214.0L	0.20	0.55	0.45	0.00	0.98
214.2L	0.00	0.44	0.19	0.22	1.30

Summary of overall TVV by meter increment for 62 patches of riparian vegetation, along with overall mean TVV and one standard deviation.

PATCH	T01	T12	T23	T34	T45	T56	T67	T7	TSUM	TSUM-SD
(-)14.2R	7.73	5.68	6.89	3.33	4.00	0.00	0.00	0.00	13.97	8.72
(-)14.5L	5.00	3.41	2.23	3.17	3.78	3.00	2.75	2.50	14.05	4.78
(-)13.6R	6.63	3.00	4.20	3.73	4.44	2.13	4.00	3.33	16.25	6.25
(-)10.0L	1.80	2.20	3.29	3.83	2.25	1.00	0.00	0.00	6.20	4.90
(-)9.4L	3.11	4.40	4.71	4.50	2.14	3.00	2.00	1.00	13.48	4.92
(-)8.4R	5.53	1.89	2.03	1.65	1.94	1.37	0.15	0.06	13.81	3.23
(-)7.5L	4.44	2.80	2.80	2.88	3.43	4.00	2.00	0.00	12.90	3.72
(-)7.0L	8.88	4.30	2.44	4.50	3.77	5.25	3.88	5.75	16.80	8.04
(-)6.5R	4.50	2.77	3.33	3.00	2.75	0.00	0.00	0.00	10.11	4.16
(-)6.0R	5.22	4.33	2.13	3.67	4.88	3.14	4.00	2.50	15.46	6.21
(-)3.8L	3.50	2.60	1.70	0.40	0.13	0.11	0.04	0.00	8.48	4.80
(-)3.2R	5.05	2.34	1.73	2.02	1.76	1.85	1.85	1.07	17.68	12.96
(-)2.5L	5.93	4.59	2.90	4.08	3.29	3.50	4.40	4.25	13.17	7.20
1.0R	2.63	2.61	2.63	1.37	1.07	0.37	0.12	0.02	10.79	6.82
1.6R	4.82	2.70	1.14	0.98	0.41	0.07	0.00	0.00	10.09	9.50
3.7L	5.82	2.59	1.23	0.64	0.45	0.41	0.50	0.00	9.75	9.94
5.2R	3.36	1.68	1.20	1.92	1.04	0.68	0.08	0.00	7.63	1.70
5.8R	4.00	2.65	1.65	1.00	0.70	0.75	0.40	0.45	11.60	2.58
6.5R	3.82	1.69	1.53	0.82	0.53	0.51	0.09	0.00	9.51	4.72
6.8L	3.51	1.59	0.92	1.08	0.82	0.35	0.24	0.27	8.71	6.60
7.2R	3.35	2.57	1.39	0.74	1.04	0.78	0.04	0.00	9.78	5.55
9.2R	5.43	2.20	1.80	1.43	1.20	0.53	0.17	0.27	12.90	6.92
9.7R	5.93	3.70	1.90	0.80	0.17	0.00	0.00	0.00	14.27	14.46
38.6L	5.30	1.76	1.33	1.24	1.18	0.73	0.55	0.42	12.33	10.20
40.6R	3.70	2.40	2.63	1.55	0.83	0.55	0.25	0.10	12.13	6.39
40.8L	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.30	2.56
43.1L	4.58	4.45	2.28	0.88	0.60	0.60	0.10	0.00	10.86	2.43
45.5L	4.83	3.33	2.93	1.30	1.40	0.47	0.27	0.17	10.77	6.37
46.7L	3.70	1.70	1.40	1.10	0.80	0.50	0.20	0.00	10.73	7.73
49.1R	3.20	1.10	0.90	0.70	0.67	0.53	0.40	0.10	7.15	4.57
50.0R	3.00	0.93	0.73	0.30	0.43	0.70	0.20	0.07	7.51	4.85
50.4L	4.13	1.33	1.29	1.71	1.37	0.84	0.30	0.03	11.24	7.44
51.5L	4.40	1.30	1.70	0.90	0.50	0.70	1.00	0.97	10.60	7.33
56.R	4.69	2.54	1.83	1.29	1.06	0.54	0.11	0.11	10.15	7.58
65.3L	2.46	2.22	1.96	1.20	0.56	0.31	0.11	0.00	12.73	10.66
67.1L	1.96	2.96	1.52	1.40	0.68	0.44	0.16	0.20	8.66	6.47
71.0L	3.46	3.00	1.86	1.26	0.94	0.26	0.60	0.40	18.07	4.02
74.4L	4.40	5.09	1.86	0.43	0.11	0.00	0.00	0.00	11.83	6.98
122.8L	5.08	4.16	3.16	1.08	0.48	0.12	0.00	0.00	10.82	8.89
125.8L	5.72	2.72	0.72	0.16	0.00	0.00	0.00	0.00	9.25	5.52
168.8R	4.75	1.32	1.71	1.68	1.14	0.68	0.18	0.04	10.81	7.01
171.0R	3.82	3.09	1.03	1.24	0.64	0.52	0.03	0.00	9.88	7.19
172.2L	4.43	3.60	1.73	0.77	0.33	0.00	0.07	0.00	8.93	6.33
174.2L	4.63	3.17	1.20	0.83	0.67	0.57	0.33	0.03	10.05	4.20
174.4R	3.93	2.33	1.20	0.20	0.07	0.00	0.00	0.00	7.73	3.17
193.8R	3.88	2.48	2.28	0.28	0.24	0.20	0.00	0.00	9.22	5.96
194.0L	4.52	4.26	2.06	1.42	0.52	0.19	0.06	0.03	14.75	7.44
196.0R	4.21	2.61	1.30	0.59	0.41	0.24	0.08	0.00	9.44	8.59
197.6L	6.43	3.38	2.45	1.55	1.08	0.58	0.23	0.05	12.80	8.02
198.0R	2.06	2.27	1.52	1.19	0.51	0.23	0.01	0.00	10.67	6.40
198.2L	4.63	3.34	2.20	1.28	1.08	0.80	0.34	0.06	11.55	6.68
200.4R	6.35	2.90	1.45	0.60	0.00	0.00	0.00	0.00	12.23	6.08
200.5R	4.48	4.16	2.40	1.48	0.84	0.28	0.08	0.00	14.68	10.19
202.5R	4.60	3.05	2.20	1.50	0.60	0.35	0.05	0.00	11.09	6.53

204.1R	5.17	2.80	0.86	0.44	0.21	0.00	0.00	0.00	10.39	5.80
204.5R	2.88	1.88	0.95	0.51	0.08	0.02	0.00	0.00	8.14	5.59
205.0L	3.14	2.11	1.97	1.37	0.83	0.54	0.26	0.09	10.79	6.63
208.7R	6.83	3.57	2.20	1.03	0.13	0.00	0.00	0.00	11.74	7.05

PATCH	T01	T12	T23	T34	T45	T56	T67	T7	TSUM	TSUM-SD
209.0L	1.96	1.25	0.38	0.13	0.03	0.01	0.00	0.00	4.80	4.02
213.6L	3.05	2.20	1.60	1.20	0.25	0.10	0.05	0.00	8.00	6.47
214.0L	4.60	2.90	2.10	2.60	2.50	1.90	1.30	0.50	13.48	16.20
214.2L	4.50	2.30	0.90	0.00	0.00	0.00	0.00	0.00	9.80	7.35

Summary of TVV samples per patch, number of samples needed to reduce inter-sample dissimilarity to <5% (Sorenson’s Coefficient), and percent over-sampling.

PATCH	Samples Taken	Samples Needed	Oversampled %
(-)14.5L	20	17	18.00
(-)14.2R	30	22	36.00
(-)13.6R	20	17	18.00
(-)10.0L	15	14	7.00
(-)9.4L	21	17	24.00
(-)8.4R	36	27	33.00
(-)7.5L	10	9	11.00
(-)7.0L	25	21	19.00
(-)6.5R	25	22	14.00
(-)6.0R	13	12	8.00
(-)3.8L	10	10	0.00
(-)3.2R	41	33	24.00
(-)2.5L	36	30	20.00
1.0R	41	32	28.00
1.6R	44	33	33.00
3.7L	32	28	14.00
5.2R	29	29	0.00
5.8R	20	18	11.00
6.5R	45	37	22.00
6.8L	51	42	21.00
7.2R	23	20	15.00
9.2R	30	24	25.00
9.7R	30	23	30.00
38.6L	33	30	10.00
40.6R	40	30	33.00
40.8L	30	24	25.00
43.1L	64	44	45.00
45.5L	70	45	56.00
46.7R	211	96	20.00
49.1R	54	41	32.00
50.0R	70	49	43.00
50.4L	135	67	101.00
51.5L	60	44	36.00
56.0R	61	43	42.00
65.3L	126	72	175.00
67.1L	64	45	42.00
71.0L	55	41	34.00
74.4L	25	24	4.00
122.8L	50	36	39.00
125.5L	40	27	48.00
168.8R	82	51	61.00
171.0R	53	37	43.00
172.2L	60	39	54.00
174.2L	55	39	41.00
174.4R	15	13	15.00
193.8R	55	35	57.00
194.0L	134	59	127.00
196.0R	210	82	156.00
197.6L	70	42	67.00
198.0R	173	67	158.00
198.2L	70	42	67.00
200.4R	52	30	73.00
200.5R	64	42	52.00
202.5R	41	29	41.00

204.1R	201	69	191.00
204.5R	168	63	167.00
205.0L	83	52	60.00
208.7R	55	30	83.00

PATCH	Samples Taken	Samples Needed	Oversampled %
209.0L	160	72	122.00
213.6L	40	31	29.00
214.0L	40	32	25.00
214.2L	27	19	42.00