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MONITORING BIRD POPULATION DENSITIES ALONG THE COLORADO RIVER IN GRAND CANYON

Terrestrial Biology

of the

Glen Canyon Environmental Studies

By

Bryan T. Brown

National Park Service

30 January, 1987

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The densities of riparian breeding birds along the Colorado River between Glen Canyon Dam and Diamond Creek were documented in the spring of 1986. These densities were compared to historical information to reveal long-term population trends and to identify rates of recovery from the effects of the 1983 surplus water releases from the dam. Avian density at established study sites differed significantly between 1984 and 1986. The differences were uniform throughout the river corridor, suggesting one or more large-scale, regional influences. Mean avian density in the new-high-water-zone decreased slightly from 1984 to 1986. Bell's Vireo, Yellow Warbler, and Common Yellowthroat populations declined in abundance after 1983 due to habitat damage and nest inundation. Bell's Vireo and Yellow Warbler quickly recovered, exhibiting a recovery cycle of 2-3 years. Common Yellowthroat failed to recover by 1986 due to loss of its preferred marshy habitat. The densities of five indicator species of obligate riparian birds have increased two-fold or more from 1976 to 1986, in spite of the deleterious effects of the 1983 high water event. Obligate riparian birds have been increasing since the completion of Glen Canyon Dam in 1963 and may continue if outflow from the dam does not exceed maximum powerplant releases.

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ABSTRACT

The densities of riparian breeding birds along the Colorado River between Glen Canyon Dam and Diamond Creek were documented in the spring of 1986. These densities were compared to similar historical information to 1) reveal long-term population trends and 2) identify rates of recovery from the effects of the 1983 surplus water release from the dam.

Avian density at established study sites differed significantly between years from 1984 to 1986. The differences were uniform throughout the river corridor, suggesting one or more large-scale, regional influences over bird densities. Mean avian density in the new-high-water-zone decreased slightly from 1984 to 1986, but the decrease was not statistically significant.

Bell's Vireo, Yellow Warbler, and Common Yellowthroat populations declined in abundance after the 1983 surplus water release due to habitat damage and nest inundation caused by the high water release. Bell's Vireo and Yellow Warbler quickly recovered from the effects of the high water release, exhibiting a recovery cycle of 2 to 3 years. Common Yellowthroat had failed to recover by 1986 due to an almost complete loss of its preferred marshy habitat.

The densities of five indicator species of obligate riparian birds have increased twofold or more from 1976 to 1986, in spite of the deleterious effects of the 1983 high water event. Obligate riparian birds have been increasing in number ever since the completion of Glen Canyon Dam in 1963, and may continue to increase in the near future, especially if outflow from Glen Canyon Dam does not exceed maximum powerplant releases.

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INTRODUCTION

The density of breeding birds along the Colorado River in Grand Canyon has been changing since the completion of Glen Canyon Dam in 1963. Controlled flows from the dam allowed new riparian habitat to develop along the river below the predam scour line. This new-high-water-zone (NHWZ) was quickly colonized by riparian breeding birds (Carothers and Johnson 1975, Brown et al. 1985) which increased greatly in abundance during the next 20 years in response to the new habitat. Beginning in 1983, however, a series of large surplus water releases from the dam began to occur. These large surplus water releases resulted in the inundation of active bird nests and a loss of vegetative habitat, which in turn reduced the population densities of some species of downstream breeding birds (Brown and Johnson 1985). These changes in the riparian bird community have been directly or indirectly caused by the operation of Glen Canyon Dam.

The purpose of this study was to document the density of breeding birds in the river corridor in 1986 and to compare present avian abundance to available historical information. This comparison answers two questions. First, are avian population densities still declining from the effects of the 1983 surplus water release, or have densities stabilized or even increased? And second, how do recent changes in the bird community fit into the long-term perspective of avian succession in the river corridor? The following objectives were designed to answer these questions.

1. Document the density of indicator species (selected species of obligate riparian birds) throughout the system.

2. Document the density of all breeding birds at 10 established study sites for which historical information is available.

3. Compare this information to historical data in order to identify long-term trends in avian population densities.

Comprehensive baseline data were never gathered on the predam bird community in the old-high-water-zone (OHWZ). Very few birds nested downslope of the OHWZ prior to 1963, in what was later to become the NHWZ. This was because of the almost complete lack of vegetation in that annually-scoured environment (Turner and Karpiscak 1980). The handful of scattered bird records existing from the predam riparian zones of the river corridor only allow for the most general reconstruction of historic riparian bird communities. A conservative assumption would be that predam avian density in the OHWZ was similar to OHWZ bird densities of the present time. The basis for this assumption was the fact that percent vegetative cover in the OHWZ has remained relatively constant since the dam began operation

(Pucherelli 1987), suggesting that the density of breeding birds dependent on the OHWZ vegetation also remained relatively constant. Due to the almost complete lack of vegetation in the predam scour zone, predam avian density there (the NHWZ of the present time) was nearly zero and was probably restricted to ground-nesting birds which do not require vegetation in which to breed (i.e., Spotted Sandpiper and possily Killdeer).

Postdam investigations of the riparian bird community did not begin until 1971. In June 1971, the National Park Service and the Museum of Northern Arizona began a series of research rivertrips which provided annual information on some birds of the entire river corridor from Lees Ferry to Lake Mead (Brown et al. 1983). The Colorado River Research Program examined riparian birds from 1974 to 1976 and resulted in the first comprehensive survey of the postdam bird community (Carothers and Sharber 1976). Scattered observations on riparian birds of the river corridor were made during the period of 1977 to 1981 by Carothers, Johnson, Brown, and others. However, these observations were not designed to provide the yearly survey information found in the comprehensive annual surveys of Carothers and Sharber (1976).

Brown and Johnson (1987) carried out comprehensive yearly breeding bird surveys of the river corridor from 1982 to 1985. These surveys resulted in two levels of information on avian densities. First, downriver census information on bird density was gathered that was designed to be compatible with the previous surveys of Carothers and Sharber (1976). Second, avian density per unit area was documented for the first time at 10 paired study sites throughout the river corridor.

The information of Brown and Johnson (1987) was gathered just prior to, during, and after the series of large surplus water releases of 1983. Surplus water releases are releases in excess of maximum powerplant discharge. The word flood as used in this report is synonymous with a surplus water release. These larger surplus releases acted to reduce avian density in several ways. Water rose to unprecedented heights in the postdam NHWZ, inundating large numbers of active nests of several indicator species (Brown and Johnson 1985). This reduced the production of young birds in the 1983 breeding season, resulting in lowered recruitment to the 1984 breeding population. The 1983 surplus water release also eroded away 35% to 40% of the riparian vegetation in the NHWZ (Brian 1987, Pucherelli 1987). This loss of breeding habitat also reduced some bird densities by decreasing the availability of nesting sites in subsequent years. When the present study was initiated in April 1986, the direction that bird density was taking (continued decline, stability, or increase) was unclear.

STUDY AREA

Site Census. Ten paired study sites in ten different river reaches were established between Glen Canyon Dam and Diamond Creek in the spring of 1984. These same study sites were recensused during the present study to determine avian density per unit area. The location, elevation, and size of each of the 20 total sites are listed in Table 1. Site selection criteria were outlined by Brown and Johnson (1987).

Downriver Census. The riparian corridor between Lees Ferry and Diamond Creek, a distance of 225 river-miles, was used as the study area for the downriver census. That portion of the river between Glen Canyon Dam and Lees Ferry, a distance of 15 river-miles, was not included in the downriver census study area for several reasons. First, the comparative historical information from 1974 to 1976 and 1982 to 1985 was only gathered between Lees Ferry and Diamond Creek. And second, to conform with the downriver census methodology, rivertrips would have needed to launch at the dam. However, launching at the dam was not possible during the spring of 1986 due to high water.

METHODS

Two complementary types of breeding bird density were calculated. One type, the site census, sampled avian density per unit area for all species at 10 paired study sites. The second type of density calculation, that of the downriver census, was an indirect count of the population densities of five indicator species of obligate riparian birds throughout the river corridor. Censuses of both types were conducted during two river research trips, from 20 April to 8 May, 1986, and 29 May to 16 June, 1986.

Site Census. Breeding bird censuses at established study sites were made using the absolute count method. With this method, the observer walked slowly through the small site, stopped occasionally, and recorded each vocal or visual contact with a bird. The very small size and linear nature of the study sites, their habitat heterogeneity, and the limits of time and field work scheduling dictated the use of this method. The absolute count method in this instance was preferable to more sophisticated and time-consuming techniques such as the fixed or variable-strip census and the spot-map method (Ralph and Scott 1981).

The assumptions, details, and possible sources of error associated with the absolute count method were discussed by Brown and Johnson (1987). That report should be consulted for the complete methodology.

Table 1. Location and description of old-high-water-zone (-A) and new-high-water-zone (-B) study sites along the Colorado River in Glen and Grand canyons. River Miles are from Stevens (1983).

Site #	Location	River Mile*	Elevation (ft)	Area (ha)
01-A	Glen Canyon	7.4L**	3150	1.7
01-B	Lees Ferry	0.32**-0.0R	3100	2.9
02-A	Saddle Canyon	46.9R-47.1R	2800	1.6
02-B	Saddle Canyon	46.4R-46.7R	2800	2.8
03-A	Cardenas Creek	70.8L-70.9L	2625	1.5
03-B	Cardenas Marsh	71.0L-71.1L	2625	1.7
04-A	Lower Bass Camp	108.6R	2200	0.1
04-B	Lower Bass Camp	108.6R	2200	0.1
05-A	Forster Canyon	122.8L	2075	0.6
05-B	Forster Canyon	122.7L-122.8L	2075	0.4
06-A	National Canyon	166.5L-167.0L	1750	2.2
06-B	National Canyon	166.1L-166.5L	1750	0.4
07-A	Stairway Canyon	170.7R-171.0R	1725	1.7
07-B	Stairway Canyon	171.0R-171.1R	1725	0.7
08-A	Parashant Canyon	198.0R-198.4R	1525	1.4
08-B	Parashant Canyon	198.0R-198.1R	1525	0.5
09-A	Granite Park	208.4L-208.8L	1450	5.6
09-B	Granite Park	208.7L-208.8L	1450	1.0
10-A	220-Mile Canyon	219.8R-220.1R	1375	0.9
10-B	Granite Springs Canyon	220.3L	1375	0.1

* R and L refer to river right and river left, respectively, as one faces downstream.
** These River Miles are upstream of River Mile 0 at Lees Ferry; all remaining River Miles are downstream of River Mile 0 at Lees Ferry.

A three-way analysis of variance (ANOVA) test (fixed effects model) was used to compare annual avian density values obtained during this study and during the period 1984 to 1985. Standard square root transformations were performed on the data before analysis to comply with the normality assumption. Differences between sites, years, and zones were compared across the study period: the two-way interaction between site x year, site x zone, and year x zone were also compared. An important assumption of this test was that no significant three-way interaction occurred between site, zone, and year.

Downriver Census. The population densities of five selected species of obligate riparian birds were determined using an indirect count census (Schemnitz 1980). The indirect count, or call count (Bull 1981), was a true census of the number of all singing males heard on an 18-day, oar-powered rivertrip between Lees Ferry and Diamond Creek at the height of the breeding season. This indirect count of bird songs resulted in an index to the population densities of the five species being censused. An index is a census of some variable (in this case, bird songs) related to the true number of animals under study. Indirect counts can be inaccurate, however, because of bias and sample error.

Several assumptions must be made when using the indirect count method to census singing males in a breeding bird community (Schemnitz 1980). 1) The ratio of the resulting index to population density is the same throughout the entire study area. 2) Mortality and dispersal (including migration) during the study period are negligible, or are corrected for in the study design. 3) All members of the populations being sampled (singing males of five selected species) have an equal or known probability of being detected. 4) All singing males are mated and on territory and therefore represent a breeding pair. 5) The precision, or the ability of the census to yield consistent results, remains constant from year to year and allows for historical comparison with a high degree of fineness (ability of technique to detect change). The level of precision of these present and historical indirect counts of breeding birds in the river corridor is currently unknown. The time and expense of an 18-day downriver bird census made the repeatability of the census very difficult.

Bias and sampling error can have a strong influence on the index resulting from an indirect count census. These sources of interference include: time of year, time of day, river velocity, and weather.

Time of year is an important consideration in an indirect count of singing male birds (Best 1981). The five species of birds surveyed in the downriver census were all class-A territorial (Perrins and Birkhead 1983), summer resident insectivores. Only the male of the pair sings, and male

singing activity peaks during a certain time of the spring breeding cycle (usually when courtship, nest-building, egg-laying, and incubation occur). The peak of male singing activity in these five species lasts for approximately 30 days. The following species were censused at their indicated peaks of singing activity, as determined by comparative research over the last 5 years: Willow Flycatcher, June; Bell's Vireo, mid-April to early May; Yellow Warbler, late May to June; Common Yellowthroat, late May to June; and Yellow-breasted Chat, June. These censuses were conducted at times when migration for each species was not occurring.

Time of day is another important consideration in an indirect count of bird songs (Robbins 1981a). Singing activity reaches a peak for most species during the hour of sunrise, declines gradually as the morning progresses, reaches a lowpoint at midday, and builds again to a smaller peak at sunset. Singing activity patterns for a given species are constant from year to year, but each species may have its own specific daily cycle of singing activity (Robbins 1981a). Downriver censuses of key river reaches (reaches of known high bird density, including Buckfarm to Kwagunt and Fern Glen to Granite Park) were largely carried out in the morning to coincide with peak singing periods. Afternoon censuses of key stretches occasionally occurred, but never more than once in any given rivertrip.

The accuracy of a census of bird songs in a given river reach is ultimately related to the amount of time spent listening. Total listening time can be affected by river velocity, which may vary from an average of 4 mph at flows of 5,000 to 10,000 cubic feet per second (cfs) to an average of 6 mph at flows of 30,000 to 50,000 cfs. The slower the river velocity, the greater the probability of hearing a given male sing at a given point. Census times were supplemented during high flows to compensate for the sampling error caused by reduced listening time. This supplement consisted of rowing the census boat into eddies and remaining there for a short period of time before continuing to float downstream.

Singing activity is directly influenced by ambient weather conditions during the count period (Robbins 1981b). Singing activity is inversely correlated with wind speed, rain, and extreme temperatures. Wind and rain also reduce the ability of the observer to detect vocalizations. Cloud cover apparently has no influence on vocal activity. Downriver censuses were delayed whenever necessary to coincide with acceptable weather conditions. One day of bad weather during the census of a key stretch of river was not considered significant enough to affect the overall accuracy of a census. However, two or more days of poor weather, such as occurred during the Bell's Vireo census in late

April and early May of 1983, were cause for identifying a particular census as inaccurate and unacceptable.

The downriver census resulted in five indices to population density for the five species of obligate riparian birds chosen as indicator species. The indices, however, did not represent the total population for each species in the river corridor, but instead represented the proportion of the total population whose songs were detected during the study period. The true number of a species present in any given year could be calculated by multiplying the count data by a correction factor. The use of a correction factor accounted for nonsinging males as well as those that were overlooked due to unavoidable bias and sampling error.

Bell's Vireo was the only species for which a correction factor was calculated. This was because Bell's Vireo was the most abundant and widespread species under consideration, and because of the ease with which an adequate sample size of accuracy tests of vireo censuses could be obtained. The known number of vireos in several relatively isolated, distinct patches of habitat was compared to the number of vireos counted during a downriver census of the same patches to obtain a mean probability that any given singing male would be detected.

Accuracy tests of Bell's Vireo censuses were performed five times: one census revealed three of eight known singing male vireos (38%); a second census revealed three of seven known vireos (43%); a third revealed three of five known vireos (60%); a fourth revealed three of six known vireos (50%); and a fifth revealed one of seven known vireos (14%). All tests were performed between 1500 and 1600 hours in April and early May in optimal vireo habitat between River Miles 166 and 225.

The correction factor was calculated as the ratio of the total number of vireos known present to the number identified in the census (Marion 1974). The mean percent of vireos identified in the five tests was 41%. Therefore, an average correction factor of 2.5 was used to convert each annual Bell's Vireo index to the actual population density. This correction factor was averaged from data collected over several years, and was weighted by accuracy tests performed in the afternoon. Future monitoring should calculate a separate correction factor for each year, averaged from several tests performed at all times of day.

Each of the five species chosen as indicator species (Willow Flycatcher, Bell's Vireo, Yellow Warbler, Common Yellowthroat, and Yellow-breasted Chat) exhibited particular qualities which singled them out for special attention. First, all were obligate riparian birds limited to riparian habitat. This limitation ensured that their populations were largely responding to conditions present in the river

corridor. Second, all were highly vocal at the peak of the breeding season. This is an important consideration for species being censused by a count of singing males. And third, the five species represented a wide range of abundance, distribution, and habitat use patterns, a combination representing most of the variability exhibited by the entire riparian breeding bird community. Bell's Vireo was the most abundant obligate riparian bird in the river corridor, as well as being an extreme habitat generalist (Brown and Johnson 1987). Willow Flycatcher was the rarest regularly breeding bird, as well as having the most limited distribution. Common Yellowthroat was a habitat specialist, whose preferred habitat of marshy areas has been negatively affected by recent surplus water releases from the dam. Yellow Warbler and Yellow-breasted Chat were common to moderately abundant, and, like the other species (except Bell's Vireo), were largely limited to the NHWZ and would therefore be more sensitive to changes at the river's edge. This wide range of abundance, distribution, and haitat use patterns were the basis of an important assumption with regard to these indicator species. This assumption was that any general trend observed in this representative group was a consistent, system-wide trend applicable to the entire riparian breeding bird community.

RESULTS

Site Census. The 1986 densities of breeding birds in the river corridor are presented in Table 2. Historic densities generated in 1984 and 1985 are also presented in Table 2 for comparative purposes. The data summaries from which the 1986 densities were calculated are found in Appendices 1 and 2.

A comparison of mean annual density (Table 2) revealed several trends. The mean number of birds/40 ha in the OHWZ has remained fairly stable from 1984 through 1986 with a range of 449 to 379 pairs/40 ha. However, a moderate trend of decreasing bird density was evident in the NHWZ during the same time period, when mean density steadily declined from 611 to 395 pairs/40 ha (35% decline).

Statistical analysis (three-way ANOVA) of avian density over the period of record revealed the following differences. A highly significant difference (p=.000) in bird density existed between study sites; the difference between the OHWZ and the NHWZ was also highly significant (p=.001). However, the most important comparison was between years, for which a highly significant difference was found (p=.008).

Table 2. Breeding bird density (pairs/40 ha) in OHWZ and NHWZ sites along the Colorado River in Glen and Grand canyons, 1984-1986. Site numbers correspond to those used in Table 1.

Site Number	Location	1984		1985		1986	
		OHWZ	NHWZ	OHWZ	NHWZ	OHWZ	NHWZ
01	Glen Canyon/Lees Ferry	318	441	200	552	282	338
02	Saddle Canyon	538	486	300	571	388	371
03	Cardenas Canyon	747	941	613	824	1000	717
04	Lower Bass Camp	200	500	300	100	200	200
05	Forster Canyon	200	400	200	400	200	250
06	National Canyon	182	600	73	300	109	300
07	Stairway Canyon	565	857	529	1085	565	771
08	Parashant Wash	986	1200	943	1200	514	480
09	Granite Park	357	480	229	220	182	320
10	220-Mile Canyon/ Granite Springs Canyon	400	200	400	400	556	200
Mean Density		449	611	379	565	400	395

Additional analysis (three-way ANOVA) of bird density between sites, years, and zones indicated little interaction between those variables. Variation in bird densities between years was independent of sites (no significant difference, p=.195). Variation between years was also independent of zones (no significant difference, p=.090), which indicated that the trend of declining bird densities seen in the NHWZ was not statistically significant. Variation between zones, however, was not independent of sites (significant difference, p=.022).

Downriver Census. The yearly indices of population densities of the five indicator species included in the downriver census are indicated in Table 3. The raw data summaries by year and river reach for each species are presented in Appendices 3 through 8. Figure 1 displays selected yearly indices from Table 3 in graphic form.

Patterns of population trends were observed in the 11-year period of record (Table 3). The index to Willow Flycatcher density has been steadily, but slowly, increasing since the downriver census information was first reported in 1976. This trend was also observed in Yellow-breasted Chat density (Fig. 1). Yellow warbler density showed a similar trend of increasing numbers from 1976 to 1986, with a slight drop in 1984 (Fig. 1).

In contrast, Bell's Vireo and Common Yellowthroat showed distinctly different patterns of change (Table 3, Fig. 1). Bell's Vireo evidently doubled in numbers from 1976 to 1982, substantially declined from 1983 to 1985, and recovered to preflood densities by 1986. Common Yellowthroat density change from 1976 to 1986 was similar, except that it has not fully recovered from the decline experienced during and after the 1983 flood. However, the lack of density data for Common Yellowthroat in the key year of 1982 makes it difficult to fully understand the magnitude of the decline. Brown and Johnson (1987) discuss how the probable abundance of Common Yellowthroat in 1982 was substantially greater than its abundance in postflood conditions.

DISCUSSION

Site Census. After controlling for all other influences, there can be no doubt that avian density has changed significantly between years. This change in density over time was independent of site and zone differences, i.e., the changes over time were occurring evenly throughout all habitats and locations in the river corridor. That the changes were uniform throughout the river corridor suggested one or more large scale, regional influences over bird densities.

Table 3. Yearly index to the population densities of five indicator species of obligate riparian birds between Lees Ferry and Diamond Creek along the Colorado River in Grand Canyon, 1976 to 1986.

	Number of Singing Males Heard					
Species	1976	1982	1983	1984	1985	1986
Willow Flycatcher*	1+	2	4	4	8	11
Bell's Vireo**	67++	135	78+++	92	75	121
Yellow Warbler***	17+	32	39	33	61	80
Common Yellowthroat***	8+	-	-	21	21	29
Yellow-breasted Chat*	18+	46	53	65	62	101

*Census data from June of each year.
**Census data from mid-April to early May of each year.
***Census data from late May to June of each year.
+From Carothers and Sharber (1976). Average absolute density for April, May, and June, 1974 to 1976.
++From the April 1976 field journal of S.W. Carothers (Brown et al. 1983).
+++Census inaccurate due to poor weather and high winds.

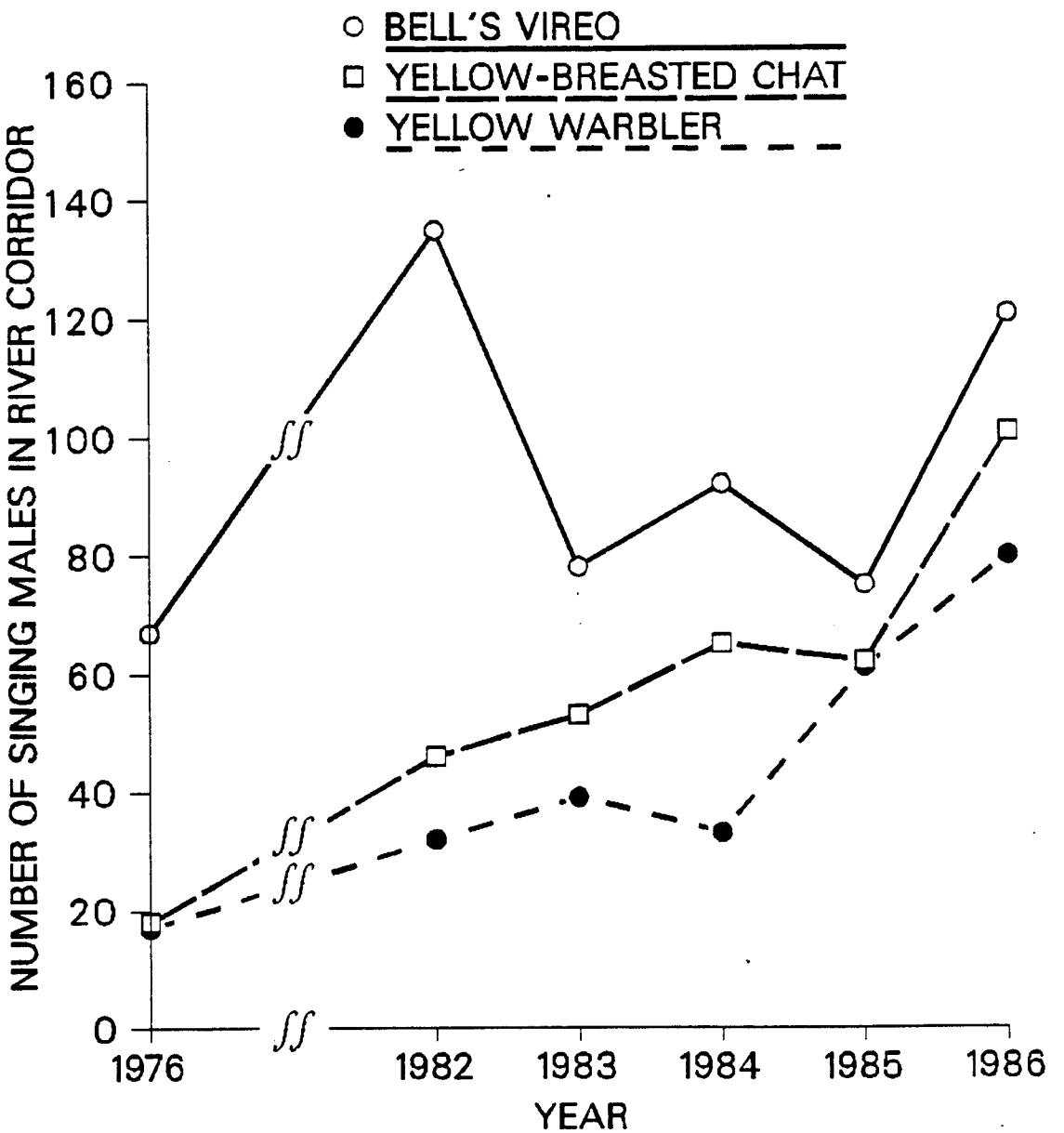

Figure 1. Population density indices of Bell's Vireo, Yellow Warbler, and Yellow-breasted Chat along the Colorado River between Lees Ferry and Diamond Creek, 1976 to 1986.

A working hypothesis was that several influences could be affecting avian density. 1) The operation of the dam could have affected bird density via water levels that controlled food or resource availability or habitat conditions in the riparian zones. 2) Regional climatic conditions could have affected food resources or other conditons influencing breeding birds from year to year. 3) Changing conditions on the wintering grounds or during migration could have affected the density of the summer resident breeding birds in the river corridor. In summary, a combination of the above factors could have been responsible. Avian densities along the Verde River of Arizona have been shown to vary as much as 50% over a 2-year period, presumably due to environmental variation of this sort (Carothers and Johnson 1973).

Significant differences between individual study sites were confirmed during the statistical analysis, but were not surprising. The study sites chosen in 1984 were established in areas that were highly variable with respect to site quality (i.e., percent cover, vegetative structure and height). That vegetation structure at well-developed sites differed from that of poorly-developed sites within the river corridor was to be expected. The significant differences that were identified between zones for the 3-year period of study agreed with the earlier findings of Brown and Johnson (1987) that the NHWZ exhibited a significantly greater density of birds than the OHWZ.

Future studies which examine avian density at estblished study sites used in this and previous studies should recalculate the size (Table 1) of each site. This is essential due to continued streambank erosion and subsequent habitat loss at several NHWZ sites, notably Stairway and Parashant, where substantial loss of habitat has occurred since 1984. Failure to correct for this factor would result in sample error reducing the calculated bird density/40 ha.

<u>Downriver Census</u>. The abundance of all five indicator species has increased since 1976 (Table 3). Caution should be exercised when comparing reported 1976 densities to those calculated from 1982 to 1986 because of the different ways in which the data were reported (except for Bell's Vireo). Carothers and Sharber (1976) reported the average absolute density of birds for April, May, and June, 1974 to 1976. Therefore, their density figures were extremely conservative. The only exception to this was the 1976 density figure used for Bell's Vireo, the data for which was gathered in a manner comparable to the 1982 to 1986 data; the data were then taken directly from the field journal of Steven W. Carothers (Brown et al. 1983). For this reason, the Bell's Vireo increase was the only instance in which the exact magnitude could be calculated. The remaining four indicator species have no doubt increased, but the exact

magnitude of those increases should be conservatively interpreted.

Bell's Vireo was the key indicator species for which the most complete historic information existed. Bell's Vireo was also the only species for which actual density (as opposed to an index) could be calculated. Using the correction factor of 2.5 (since the mean probability of hearing any given singing male was 0.4), the actual number of singing males present in the river corridor in 1986 was 121 (Table 3) times 2.5, or 302.5 singing males. The assumption was made that each singing male represented a breeding pair, indicating that 302.5 pairs of Bell's Vireos were present in 1986. The historic density indices, converted to actual densities, became: 1976, 167.5 pairs; 1982, 337.5 pairs; 1983, at least 195 pairs; 1984, 203 pairs; and 1985, 187.5 pairs. [Note: The 1983 vireo index was 78 singing males, not the 70 as incorrectly reported by Brown and Johnson (1985).]

The fact that the density of five indicator species, as shown by the downriver census, has increased since 1984 was in apparent contradiction to the finding of the site census that mean density in the NHWZ had decreased slightly since 1984. However, two important factors show this was not a contradiction, but instead was two partially overlapping perspectives on overall avian density. First, the trend of decreasing density in the NHWZ was not statistically significant. And second, bird densities in the adjacent OHWZ remained relatively constant from 1984 to 1986. These factors suggested that the indicator species (found largely in the NHWZ) increased in numbers at the same time as other NHWZ species decreased in numbers. Nevertheless, this possibility suggests that the assumption behind the acceptance of the indicator species, that any trend observed in this representative group was a system-wide trend applicable to the entire riparian bird community, was only partially appropriate. The abundance of these five indicator species may be useful as a barometer of the health of the riparian system in general and the bird community in particular, but evidently cannot be totally relied upon to identify population trends in the enire bird community.

<u>Recovery From the 1983 Flood as Related to Long-term Avian Succession</u>. Riparian bird density in the river corridor has been increasing ever since completion of Glen Canyon Dam in 1963, and has continued to increase through 1986. This long-term trend toward greater avian density (until other factors stabilize or reverse the trend) suffered a temporary setback during and after the surplus water release of 1983. Bell's Vireo, Yellow Warbler, and Common Yellowthroat densities were reduced following the flood. A quick recovery was seen in Yellow Warbler numbers (2-year recovery time), while the Bell's Vireo index only returned to approximate preflood levels in 1986 (3-year recovery time).

Common Yellowthroat density, however, has failed to recover from the effects of the flood (4-year-plus recovery time). The Common Yellowthroat is a habitat specialist in marshy areas. This water's edge habitat type was virtually eliminated by the 1983 flood and subsequent springtime flows in excess of 35,000 cfs (Brown and Johnson 1987). Even though a slight increase in Common Yellowthroat abundance was noted in 1986, the Common Yellowthroat is not anticipated to recover to preflood densities unless water levels remain below 30,000 to 35,000 cfs and marshy habitats are allowed to redevelop and increase in extent.

The Bell's Vireo recovery to approximately preflood abundance was indicated in several ways. Not only did the annual index to Bell's Vireo population density increase (Table 3), but the June abundance of vireos in River Reach 1 above the Little Colorado River increased sharply over even preflood levels (Appendix 5). That river reach was farther upstream and at a higher elevation; the known edge of the Bell's Vireo range in Arizona also occurred in this reach. For those reasons, most migrant Bell's Vireos had not yet made it that far upriver by the time the first downriver census began in mid-April. Early June appeared to be the peak vireo breeding period above the Little Colorado River, and was also the best time to do a census of that reach. This was different from the main vireo breeding population below National Canyon, where breeding birds were on territory and already paired and nesting by April (Brown and Johnson 1987). The ultimate implication of the Bell's Vireo population increase above the Little Colorado River in June 1986 was that the population increase and range expansion that had occurred prior to 1983 may still be occurring (Brown et al. 1983).

The riparian breeding bird community, as represented by five indicator species, exhibited an approximately 2 to 3-year recovery cycle from the effects of the 1983 flood. Willow Flycatcher and Yellow-breasted Chat were virtually unaffected by the flood, while Common Yellowthroat has failed to recover even after 3 years. The recovery time of the riparian bird community to future surplus water releases of a similar magnitude will almost certainly vary somewhat, their recovery rate depending on the recovery rate of their preferred habitat. However, a general knowledge of recovery times will assist in the future management of surplus water releases. This knowledge will also help to define the range of management options with regard to controlling the short-term effects of flooding.

CONCLUSIONS

The following conclusions can be drawn from the findings of this study:

1. Breeding bird densities at estblished study sites differed significantly between years during the period 1984 to 1986.

2. The densities of five indicator species of obligate riparian birds have increased at least twofold during the 11-year period from 1976 to 1986. These indicator species may continue to increase in the near future, especially if water released from the dam does not exceed maximum powerplant releases.

3. The riparian bird community, as typified by five indicator species, exhibited a 2 to 3-year recovery cycle from the population declines observed during and after the 1983 surplus water release.

4. The densities of Willow Flycatcher and Yellow-breasted Chat were not negatively affected by the 1983 event, while Common Yellowthroat has apparently failed to recover from the effects of the flood even after 3 years.

5. Bell's Vireo was the key indicator species for which the most complete historical information existed. Future monitoring should pay special attention to its abundance and distribution.

6. The operation of Glen Canyon Dam has had a substantial influence on the density of riparian breeding birds along the Colorado River in Grand Canyon.

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Appendix 1. Actual numbers of pairs of breeding or potentially breeding birds in OHWZ study sites along the Colorado River in Glen and Grand Canyons, 1986.

	OHWZ study sites									
Species	1	2	3	4	5	6	7	8	9	10
Mourning Dove	1		2					1	4	1
Black-chinned Hummingbird	2	1	10		1		2	1	3	4
Costa's Hummingbird						1				
Ash-throated Flycatcher	1	1	2		0.5	1	1	1	2	1
Bewick's Wren	1.5	2	2					2		
Blue-gray Gnatcatcher	1	2	5			1	5	1	3	1
Phainopepla	1						1		1	1
Mockingbird					0.5				1	.5
Bell's Vireo		0.5					3.5	2.5	6	1
Lucy's Warbler		2.5	5	.25	0.5	3	4	3	2	1
Yellow Warbler								1		
Yellow-breasted Chat		0.5					1	1.5	1	
Summer Tanager								0.5		
Blue Grosbeak	0.5	1						1	0.5	
Lazuli Bunting		1								
Great-tailed Grackle					0.5					
Brown-headed Cowbird	3	3	4					1	1	1
Lesser Goldfinch			3	.25			3			
House Finch	1	1	4.5				3.5	1.5	1	1
Total Density	12	15.5	37.5	.5	3	6	24	18	25.5	12.5
No. of Species	9	11	9	2	5	4	9	13	12	10

Appendix 2. Actual numbers of pairs of breeding or potentially breeding birds in NHWZ study sites along the Colorado River in Glen and Grand canyons, 1986.

	NHWZ study sites									
Species	1	2	3	4	5	6	7	8	9	10
Mourning Dove	2	1	1							
Black-chinned Hummingbird		4	4		1		3		2	
Costa's Hummingbird						0.5				
Willow Flycatcher		1	2							
Ash-throated Flycatcher	1	1	1					0.5		
Bewick's Wren	4	3	3							
Marsh Wren	1									
Blue-gray Gnatcatcher		3	3			0.5	1		0.5	
Phainopepla									0.5	
Mockingbird					0.5					
Bell's Vireo							1.5	0.5	2	.5
Lucy's Warbler	2	4	4	.25	0.5	1	1			
Yellow Warbler	1	2	1			1	1	2	1	
Common Yellowthroat	1	1	2				2	1		
Yellow-breasted Chat	4	3	1				2	0.5	0.5	
Blue Grosbeak			1				1		0.5	
Great-tailed Grackle	1	1	1		0.5					
Brown-headed Cowbird	2	2	1				1	1	1	
Hooded Oriole			1					0.5		
Oriole sp.	1									
Lesser Goldfinch			1							
House Finch	4.5		3.5	.25						
Total Density (pairs)	24.5	26	30.5	.5	2.5	3	13.5	6	8	.5
Number of Species	12	12	16	2	4	4	9	7	8	1

Appendix 3. Yearly index to Willow Flycatcher densities from Lees Ferry to Diamond Creek, 1982-1986, by river reach. Censuses made in June.

River Reach	Year 1982	1983	1984	1985	1986
River Reach 1					
Lees Ferry to Buckfarm Canyon	0	0	0	0	0
Buckfarm to Nankoweap Creek	1	4	3	7	8
Nankoweap to Little Colorado	0	0	0	0	1
(Yearly total for Reach 1)	(1)	(4)	(3)	(7)	(9)
River Reach 2					
Little Colorado to Cardenas	1	0	1	1	2
Cardenas to Phantom Ranch	0	0	0	0	0
(Yearly total for Reach 2)	(1)	(0)	(1)	(1)	(2)
River Reach 3					
Phantom Ranch to Kanab Creek	0	0	0	0	0
Kanab to National Canyon	0	0	0	0	0
(Yearly total for Reach 3)	(0)	(0)	(0)	(0)	(0)
River Reach 4					
National to Lava Falls	0	0	0	0	0
Lava Falls to Parashant Wash	0	0	0	0	0
Parashant to Granite Park	0	0	0	0	0
Granite Park to Diamond Creek	0	0	0	0	0
(Yearly total for Reach 4)	(0)	(0)	(0)	(0)	(0)
Yearly Total	2	4	4	8	11

Appendix 4. Yearly index to Bell's Vireo densities from Lees Ferry to Diamond Creek, 1982-1986, by river reach. Censuses made in April and early May.

River Reach	Year 1982	1983	1984	1985	1986
River Reach 1					
Lees Ferry to Buckfarm Canyon	0	0	0	0	0
Buckfarm to Nankoweap Creek	0	0	0	2	1
Nankoweap to Little Colorado	0	0	3	0	0
(Yearly total for Reach 1)	(0)	(0)	(3)	(2)	(1)
River Reach 2					
Little Colorado to Cardenas	3	0	3	1	2
Cardenas to Phantom Ranch	0	0	0	0	0
(Yearly total for Reach 2)	(3)	(0)	(3)	(1)	(2)
River Reach 3					
Phantom Ranch to Kanab Creek	0	0	0	1	0
Kanab to National Canyon	3	0	0	0	0
(Yearly total for Reach 3)	(3)	(0)	(0)	(1)	(0)
River Reach 4					
National to Lava Falls	36	32	28	32	34
Lava Falls to Parashant Wash	46	15	40	18	53
Parashant to Granite Park	39	24	15	16	20
Granite Park to Diamond Creek	8	7	3	5	11
(Yearly total for Reach 4)	(129)	(78)	(86)	(71)	(118)
Yearly Total	135	78*	92	75	121

* Census inaccurate due to poor weather and high winds.

Appendix 5. Yearly index to Bell's Vireo densities from Lees Ferry to Phantom Ranch, 1982-1986, by river reach. Censuses made in June.

River Reach	Year 1982	1983	1984	1985	1986
River Reach 1					
Lees Ferry to Buckfarm Canyon	0	1	0	0	0
Buckfarm to Nankoweap Creek	1	2	2	1	7
Nankoweap to Little Colorado	1	1	0	2	3
(Yearly total for Reach 1)	(2)	(4)	(2)	(3)	(10)
River Reach 2					
Little Colorado to Cardenas	1	2	3	2	2
Cardenas to Phantom Ranch	1	1	0	0	0
(Yearly total for Reach 2)	(2)	(3)	(3)	(2)	(2)
Yearly total, Reaches 1 and 2	4	7	5	5	12

Appendix 6. Yearly index to Yellow Warbler densities from Lees Ferry to Diamond Creek, 1982-1986, by river reach. Censuses made in late May and June.

River Reach	Year 1982	1983	1984	1985	1986
River Reach 1					
Lees Ferry to Buckfarm Canyon	1	3	2	1	2
Buckfarm to Nankoweap Creek	5	27	8	32	42
Nankoweap to Little Colorado	5	0	3	7	5
(Yearly total for Reach 1)	(11)	(30)	(13)	(40)	(49)
River Reach 2					
Little Colorado to Cardenas	3	1	4	2	3
Cardenas to Phantom Ranch	0	1	3	4	3
(Yearly total for Reach 2)	(3)	(2)	(7)	(6)	(6)
River Reach 3					
Phantom Ranch to Kanab Creek	1	0	1	1	1
Kanab to National Canyon	0	0	0	1	1
(Yearly total for Reach 3)	(1)	(0)	(1)	(2)	(2)
River Reach 4					
National to Lava Falls	12	5	3	7	13
Lava Falls to Parashant Wash	5	2	8	6	10
Parashant to Granite Park	0	0	1	0	0
Granite Park to Diamond Creek	0	0	0	0	0
(Yearly total for Reach 4)	(17)	(7)	(12)	(13)	(23)
Yearly Total	32	39	33	61	80

Appendix 7. Yearly index to Yellow-breasted Chat densities from Lees Ferry to Diamond Creek, 1982-1986, by river reach. Censuses made in June.

River Reach	Year 1982	1983	1984	1985	1986
River Reach 1					
Lees Ferry to Buckfarm Canyon	4	3	9	5	6
Buckfarm to Nankoweap Creek	6	21	17	20	27
Nankoweap to Little Colorado	3	2	3	1	5
(Yearly total for Reach 1)	(13)	(26)	(29)	(26)	(38)
River Reach 2					
Little Colorado to Cardenas	2	2	4	3	6
Cardenas to Phantom Ranch	0	2	0	1	3
(Yearly total for Reach 2)	(2)	(4)	(4)	(4)	(9)
River Reach 3					
Phantom Ranch to Kanab Creek	1	1	0	0	1
Kanab to National Canyon	1	0	0	0	0
(Yearly total for Reach 3)	(2)	(1)	(0)	(0)	(1)
River Reach 4					
National to Lava Falls	12	4	8	14	17
Lava Falls to Parashant Wash	13	8	21	13	24
Parashant to Granite Park	4	8	2	5	11
Granite Park to Diamond Creek	0	2	1	0	1
(Yearly total for Reach 4)	(29)	(22)	(32)	(32)	(53)
Yearly Total	46	53	65	62	101

Appendix 8. Yearly index to Common Yellowthroat densities from Lees Ferry to Diamond Creek, 1982-1986, by river reach. Censuses made in June.

River Reach	Year 1982	1983	1984	1985	1986
River Reach 1					
Lees Ferry to Buckfarm Canyon	-	-	2	2	3
Buckfarm to Nankoweap Creek	-	-	2	3	8
Nankoweap to Little Colorado	-	-	1	0	4
(Yearly total for Reach 1)	(-)	(-)	(5)	(5)	(15)
River Reach 2					
Little Colorado to Cardenas	-	-	1	1	3
Cardenas to Phantom Ranch	-	-	0	1	0
(Yearly total for Reach 2)	(-)	(-)	(1)	(2)	(3)
River Reach 3					
Phantom Ranch to Kanab Creek	-	-	1	2	3
Kanab to National Canyon	-	-	0	0	0
(Yearly total for Reach 3)	(-)	(-)	(1)	(2)	(3)
River Reach 4					
National to Lava Falls	-	-	4	5	4
Lava Falls to Parashant Wash	-	-	7	6	4
Parashant to Granite Park	-	-	0	1	0
Granite Park to Diamond Creek	-	-	3	0	0
(Yearly total for Reach 4)	(-)	(-)	(14)	(12)	(8)
Yearly Total	-	-	21	21	29