Chapter 7

Birds of the Colorado River in Grand Canyon: a Synthesis of Status, Trends, and Dam Operation Effects

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Introduction

Riparian habitats, or vegetated areas along streams and rivers, in the Western United States typically support a disproportionately large number of birds compared to adjacent nonriparian habitats, both in terms of bird abundance and the number of species present (also known as species richness). The Grand Canyon ecosystem is no exception and provides important habitat to wintering, migrant, and breeding birds (Brown and others, 1987; Carothers and Brown, 1991; Sogge and others, 1998; Kearsley and others, 2004; Spence, 2004). Importantly, the ecosystem also provides habitat for several bird species of special concern, including the southwestern willow flycatcher (*Empidonax traillii extimus*), California condor (*Gymnogyps californianus*), bald eagle (*Haliaeetus leucocephalus*), and American peregrine falcon (*Falco peregrinus anatum*).

This chapter summarizes the considerable information available from recent studies on the ecology of Grand Canyon bird species and communities. Because changes in riparian habitat undoubtedly influence the abundance and distribution of Grand Canyon birds, the chapter starts by briefly examining dam-induced habitat alterations that may affect birds. The direct and indirect effects of Glen Canyon Dam operations, including the modified low fluctuating flow (MLFF) alternative that was implemented starting in 1996, are considered for how they influence specific bird species and communities. Particular attention is given to the species of special concern listed above. The chapter concludes with a summary and a discussion of research priorities within the context of the Glen Canyon Dam Adaptive Management Program.

Background

The riparian vegetation of the Grand Canyon ecoregion is complex and dynamic, changing in response to flooding, the invasion of new nonnative species, long-term successional patterns, and climate (Turner and Karpiscak, 1980; Webb and others, 1999). The primary driving variables in the terrestrial riparian ecosystem in Grand Canyon are the flow characteristics and hydrograph of the Colorado River (Carothers and Aitchison, 1976; Stevens and others, 1995; Kearsley and Ayers, 2001). The distribution of the riparian vegetation in the


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Grand Canyon is also strongly influenced by the geography and geology of the region. The river corridor follows a 1,772-ft (540-m) elevation gradient through changing vegetation communities ranging from Great Basin desertscrub (classification per D.E. Brown, 1994) found at Lees Ferry (RM 0) with an elevation of 3,117 ft (950 m) to Sonoran desertscrub at Diamond Creek (RM 226) with an elevation of 1,345 ft (410 m). Type of bedrock geology present and the presence of major side canyons are perhaps the most important geological factors relevant to the distribution of riparian vegetation along the river (Turner and Karpiscak, 1980; Stevens and others, 1995; Spence, 2004). For example, where the bedrock consists of Precambrian schist and granite, which are hard and slow to erode, the river corridor is narrow and tends not to support much riparian vegetation except at the mouths of tributaries.

Before the construction of Glen Canyon Dam, the hydrograph of the Colorado River in Grand Canyon was driven by spring snowmelt floods and occasional large tributary inflows produced by monsoonal late-summer rains (Dolan and others, 1974; Carothers and Aitchison, 1976; Topping and others, 2003). Spring flooding controlled the abundance and distribution of riparian vegetation, producing a distinct trim line at about the 125,000 cfs level. Water-surface elevation, or stage, is typically given in terms of rate of flow (cubic feet per second (cfs)) because elevation varies over the length of the river corridor depending on local channel morphology. Above this line an extensive community of old high-water zone (OHWZ) vegetation occurred, including species such as Apache plume (*Fallugia paradoxa*), net-leaf hackberry (*Celtis laevigata* var. *reticulata*), mesquite (*Prosopis glandulosa*), and catclaw acacia (*Acacia greggii*). Because the lower zone, below 50,000 cfs, was flooded and scoured most years (Topping and others, 2003), sparse vegetation was present below the trim line and consisted of coyote willow (*Salix exigua*), tamarisk (*Tamarix ramosissima*), rushes (*Juncus* sp.), and grasses (Poaceace family) (Clover and Jotter, 1944). Most of the plant species found today in lower vegetation zones were present before the construction of the dam (Clover and Jotter, 1944; Kearsley and Ayers, 2001). Predam conditions resulted in varied riparian vegetation, producing dense riparian stands more than 164 ft (50 m) wide at some tributary mouths, but elsewhere riparian stands were patchily distributed and generally between 10 and 66 ft (3–20 m) wide (Flowers, 1959; Kearsley and Ayers, 2001).

The hydrograph of the Colorado River changed dramatically with the completion of Glen Canyon Dam (Webb and others, 1999; Topping and others, 2003). Of the many changes wrought by the dam and discussed elsewhere in this report, the most influential one in terms of riparian vegetation is the reduction of peak annual flows. In the absence of historical floods that removed lower zone vegetation, perennial plant species were able to move into and colonize these areas. These new areas of riparian vegetation are referred to as the new high-water zone (NHWZ) to distinguish them from the higher predam riparian habitats. The amount of NHWZ riparian vegetation greatly increased between 1963 and 1983 (Pucherelli, 1986), and much of the colonization of the NHWZ was by nonnative species, especially tamarisk (Turner and Karpiscak, 1980). Areas of marsh also developed in return channel-eddy complexes (Cluer, 1997), covering approximately 1% of the NHWZ of the river corridor by 1991 (Stevens and others, 1995).

The floods and subsequent high flows of 1983–85 produced considerable scour and an estimated 13% (Waring, 1995) to 39% (Pucherelli, 1986) reduction in area of the NHWZ. Following the floods, the NHWZ gradually recovered. In 1991, interim flows were established that caused further changes, primarily the stabilization of marshes and riparian colonization of the lower portion of the NHWZ between 25,000–33,000 cfs. The 1996 beach/habitat-building flow through the river corridor was designed to scour tamarisk vegetation in the lower portions of the NHWZ but had only short-term burial impacts on the vegetation, which recovered rapidly (Kearsley and Ayers, 1999; Stevens and others, 2001). Flows under the MLFF alternative have not altered the areal extent of riparian vegetation patches from that established during the period of interim flows in the early 1990s (Kearsley and Ayers, 1996, 1999).

Dam-induced changes to riparian habitat undoubtedly affected the abundance and distribution of riparian birds. These changes are not directly measurable because

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the first surveys of breeding birds along the Colorado River (Carothers and Sharber, 1976) were not conducted until after the dam was completed. Since then, surveys and studies have examined many aspects of the ecology of Grand Canyon birds, including the direct and indirect effects of the dam on specific bird species and bird communities. Riparian breeding bird studies have been conducted along the river corridor since the initiation of the Glen Canyon Environmental Studies in 1982 (Brown and others, 1987; Brown, 1987, 1989; Brown and Trosset, 1989; Spence and Pinnock, 1993; Grahame and Pinnock, 1995; Hualapai Tribe and SWCA, Inc., 1995; Petterson and Spence, 1997; Spence, 1997, 2004; Sogge and others, 1998; Kearsley and others, 2004; Yard and others, 2004). These studies collected data on the composition of bird communities; patterns of species abundance, richness, and diversity; and habitat distribution. They also provided information on habitat associations and identified riparian-dependent bird species.

Species-specific bird studies have also been conducted along the river corridor. Focus was given to bird species that were or are federally listed as endangered or threatened, including bald eagle (Brown and others, 1989, 1998; Brown and Stevens, 1992, 1997; Brown, 1993; Leibfried and Montgomery, 1993; Spence and others, 2002; van Riper and Sogge, 2004), peregrine falcon (Ellis and Monson, 1989; Brown, 1991a; Ward, 2000), and southwestern willow flycatcher (Brown, 1988; Sogge and others, 1997; Johnson, 2000; Yard, 2004a). A number of riparian bird species were also the subject of research, including the Bell's vireo (*Vireo bellii*) (Brown and others, 1983), black-chinned hummingbird (*Archilochus alexandri*) (Brown, 1992), and brown-headed cowbird (*Molothrus ater*) (Brown, B.T., 1994). Studies of the winter riparian bird community (Sogge and others, 1998; Spence, 2004; Yard, 2004b) and the aquatic bird community (Stevens and others, 1997a; Spence, 2004; Yard, 2004b) have also been conducted. These studies provide considerable information on the ecology of Grand Canyon bird communities and the direct and indirect effects of the dam on specific bird species and bird communities.

Status and Trends

Breeding Riparian Birds

The breeding bird community associated with the riparian habitat along the Colorado River is made up of bird species generally restricted to riparian habitats and species that can also be found in adjacent upland, nonriparian habitats. More than 30 species have been recorded breeding in the riparian patches along the river within the study area. Most of these are songbirds including warblers, wrens, finches, orioles, and sparrows that nest and forage for insects within the NHWZ and OHWZ vegetation. Of the 15 most common riparian breeding bird species (table 1), 10 are Neotropical migrants that breed in the study area but winter primarily south of the United States-Mexico border. The rest of the breeding birds that use the canyon are year-round residents or short-distance migrants that primarily winter in the region or in nearby southern Arizona.

Repeated research since the mid-1970s has shown that Glen Canyon Dam and its operation have few direct flow-related effects upon the riparian breeding bird community. The primary change influencing these birds has been increased habitat availability caused by the establishment of the NHWZ riparian vegetation in areas that had relatively sparse vegetation before the dam (Brown and others, 1987; Carothers and Brown, 1991; Sogge and others, 1998; Spence, 2004). Brown and Johnson (1985, 1987) also found that flows directly affected some birds that occupied this new habitat during periods of high daily change in the river level or during enormous seasonal fluctuations that occurred before 1991 and the establishment of interim flow operating criteria. For example, they found that flows as high as 31,000 cfs, approximate powerplant capacity, flooded only a few nests, including some common yellowthroat (*Geothlypis trichas*) nests; however, flows of more than 40,000 cfs began flooding nests and nest plants of some riparian breeding species, specifically the Bell's vireo

Table 1. The 15 generally most common terrestrial breeding bird species (in alphabetical order) found in riparian habitats along the Colorado River in Grand Canyon.

Common Name	Scientific Name
Ash-throated flycatcher	*Myiarchus cinerascens*
Bell's vireo	*Vireo bellii*
Bewick's wren	*Thryomanes bewickii*
Black-chinned hummingbird	*Archilochus alexandri*
Blue grosbeak	*Passerina caerulea*
Blue-gray gnatcatcher	*Polioptila caerulea*
Bullock's oriole	*Icterus bullockii*
Common yellowthroat	*Geothlypis trichas*
House finch	*Carpodacus mexicanus*
Lesser goldfinch	*Carduelis psaltria*
Lucy's warbler	*Vermivora luciae*
Mourning dove	*Zenaida macroura*
Song sparrow	*Melospiza melodia*
Yellow warbler	*Dendroica petechia*
Yellow-breasted chat	*Icteria virens*

and yellow-breasted chat (*Icteria virens*) (Brown and Johnson, 1987).

The interim operating criteria, which were in effect from 1991–96, limited maximum releases to 20,000 cfs and set minimum flows at 8,000 cfs during the day and 5,000 cfs at night. Daily fluctuations were also limited to a maximum of 8,000 cfs. This change in river flows promoted the establishment of a narrow band of vegetation near the edge of the river (Stevens and Ayers, 1994; Sogge and others, 1998). Sogge and others (1998) examined the direct impact of interim operating criteria on breeding birds in the hydrologically active zone (HAZ), the area potentially inundated by flows between 5,000 and 20,000 cfs. They found that few species nested either close to the ground or close to the river; only one common yellowthroat nest was placed low enough to be inundated at 20,000 cfs. The black phoebe (*Sayornis nigricans*), however, places its nests just 3–6 ft (1–2 m) above the water, and some phoebe nests would be inundated by any flows that raised the water level by as little as 3 ft (1 m). For other breeding bird species, Sogge and others (1998) found that nests were placed well away from the HAZ and avoided inundation under the interim operating criteria. Because the MLFF alternative is similar to interim operating criteria (Kearsley and Ayers, 1999), most nests (other than some black phoebe nests) are unlikely to be affected by changing water levels.

Sogge and others (1998) examined the potential long-term effects of dam operations on the Grand Canyon ecosystem bird community. They developed models and identified habitat features that predicted bird abundance, species richness, and diversity. They found that riparian location along the river corridor, patch size, and volume of larger woody species, especially of tamarisk, within a riparian vegetation patch were positively correlated with bird abundance, species richness, and diversity. Specifically, these models predicted the following:

1. Flow patterns that result in smaller, more isolated habitat patches would decrease bird numbers, species richness, and diversity.
2. Flow patterns that create larger and more contiguous habitat patches would increase bird abundance and richness within the constraints of local topography and geomorphology.
3. Loss of mesquite vegetation would decrease bird abundance.
4. Increases in the number of habitat patches would increase overall number of birds and bird species.
5. Changes from tamarisk shrub/tree to willow shrub/tree are not likely to greatly affect bird abundance and species richness of the Grand Canyon ecosystem bird community.

A subsequent study by Spence (2004) modeled riparian bird habitat relationships but did not examine the relationship between riparian patch size and characteristics such as total bird abundance, species richness, and species diversity. Despite the fact that data were being derived from different riparian patches, this study obtained results similar to Sogge and others (1998), concluding that higher woody-species volume and river location were the best predictors of breeding bird abundance and richness.

These two studies (Sogge and others, 1998; Spence, 2004) demonstrate that riparian patch size, the volume of woody species within a habitat patch, and the location of the patch along the river corridor are primary factors that affect the abundance and species richness of birds within a riparian patch. Also, the mix of NHWZ and OHWZ vegetation within a patch probably affects the distribution and abundance of specific bird species because certain species have ecological preferences in nesting and foraging in one or the other vegetation type (Sogge and others, 1998; Spence, 2004). Collectively, the body of research indicates that dam operations with the greatest potential to impact breeding bird species within the Grand Canyon ecoregion are those that would affect the extent and amount of riparian vegetation along the river, such as large-magnitude planned or unplanned floods.

Overall, there has been relatively little change in the distribution of riparian habitat since the initiation of canyon bird studies in the mid-1970s. Likewise, the riparian breeding bird community within the study area appears not to have changed appreciably in species composition during that 25-yr period (Spence, 2004). For the most part, the bird species that were most common in the 1980s are the most common today (Kearsley and others, 2004; Spence, 2004). Two exceptions are the Bell's vireo and the song sparrow (*Melospiza melodia*), which have apparently expanded their breeding ranges within the Grand Canyon ecoregion (Brown and others, 1983; Spence, 2004; Yard and Blake, 2004).

To track trends in riparian breeding bird populations, one long-term monitoring program was initiated in 1996 and continued through 2000 (Spence, 2004) and another from 2001 through 2004 (Kearsley and others, 2004). These studies included baseline monitoring of the breeding riparian birds, southwestern willow flycatcher, and riparian habitat in selected patches along the river corridor. Several species, mostly Neotropical migrants, showed consistent detection rates during the 1996–2000 time period (Spence, 2004). The blue-gray gnatcatcher (*Polioptila caerulea*) showed a steady decline, with detection rates dropping about 30%–50%. Two species, Bullock's oriole (*Icterus bullockii*) in Glen Canyon and yellow warbler (*Dendroica petechia*) throughout the study area, showed statistically significant increases in detection rates (Spence, 2004).

Most birds found in the study area are not year-round residents; therefore, other factors acting outside the Grand Canyon ecosystem influence bird populations, and this influence is especially true for migratory breeding birds. Outside factors—changes in winter and migratory habitat, winter weather events, and climate outside the region—can affect bird survivorship and are independent of the effects of adaptive management (Spence, 2004; Holmes and others, 2005).

Overwintering Aquatic Birds

Increases in abundance and species richness of the aquatic bird community—loons, grebes, cormorants, herons, ducks, rails, and sandpipers—in the Grand Canyon ecoregion correspond with the increased river clarity and productivity associated with the presence of Glen Canyon Dam (Stevens and others, 1997a; Spence, 2004). These aquatic bird species use the Grand Canyon ecoregion almost exclusively in the winter, nonbreeding season. Two primary foraging guilds are represented: (1) diving species that consume mostly fish and invertebrates within the water column or on the river bed and (2) dabbling species that forage in cobble bars and shallower areas where they can reach aquatic vegetation and associated invertebrates (table 2). These aquatic birds can be directly affected by dam operations that change the distribution of prey species in the water column of the river or, in the case of dabbling species, cover or expose foraging beds. Also, higher discharge rates increase river velocity and potentially increase foraging costs for species in both guilds (Spence, 2004).

Aquatic bird species are distributed fairly predictably within the study area. The upper reaches of the river, from Glen Canyon Dam to about 25 mi (40 km) downstream, tend to be relatively clear and support habitat and food, including an abundance of introduced

Table 2. The 10 generally most common overwintering aquatic bird species (in alphabetical order) encountered during surveys along the Colorado River below Glen Canyon Dam.

Common Name	Scientific Name
American coot	*Fulica americana*
American wigeon	*Anas americana*
Bufflehead	*Bucephala albeola*
Common goldeneye	*Bucephala clangula*
Common merganser	*Mergus merganser*
Gadwall	*Anas strepera*
Green-winged teal	*Anas crecca*
Lesser scaup	*Aythya affinis*
Mallard	*Anas platyrhynchos*
Ring-necked duck	*Aythya collaris*

rainbow trout (*Oncorhynchus mykiss*) for diving species. Dabblers can forage only in wider reaches with extensive shallow, low-turbidity water. Accordingly, dabblers are concentrated in wider reaches above the Little Colorado River (Stevens and others, 1997a; Spence, 2004).

Spence (2004) found that species composition and abundance of the aquatic bird communities within the study area show considerable fluctuations among years. Given similar flows, however, the resources available to waterfowl in the Grand Canyon ecoregion are relatively similar among years. Primary productivity is greatest in the clear water below the dam to approximately 25 mi (40 km) downstream and then drops rapidly as the river becomes more turbid as sediment and organic matter enter the river from tributaries. Hence, it is likely that the large year-to-year fluctuations in aquatic birds noted by Spence (2004) are due to factors outside the region. Outside factors may be numerous and potentially include conditions on the breeding grounds, recreation activities, changes in habitat availability, climate conditions, and hunting. All these factors can interact in complex ways in determining the composition and abundance of the winter aquatic community in the Grand Canyon ecoregion (Spence, 2004).

Because of the high variability in abundance for many species, the power to detect trends in overwintering aquatic birds is low. Comparing results of surveys conducted between 1973 and 1994 by Stevens and others (1997a) to data from surveys between 1998 and 2000, Spence (2004) found strong similarities in the aquatic bird communities, and the most common birds detected during both periods were similar (Spence, 2004).

Species of Concern

Southwestern Willow Flycatcher

The willow flycatcher (*Empidonax traillii*) is a small Neotropical migratory bird that breeds across much of North America and winters in portions of Central America and northern South America. The southwestern subspecies (*E. t. extimus*) breeds only in dense riparian habitats in the Western United States, including portions of Utah, Nevada, Colorado, New Mexico, Arizona, and southern California. Breeding generally occurs from late May through early August (Sogge, 2000). When the southwestern willow flycatcher was federally listed as an endangered species in 1995, fewer than 400 breeding territories for the subspecies were known throughout the Southwest; however, by 2001, that number had increased to approximately 1,000 territories distributed among more than 200 breeding sites (Sogge and others, 2003). By 2003, because of increased survey effort and a population increase in central Arizona, there were an estimated 410 territories in Arizona alone (Smith and others, 2004).

Historically, southwestern willow flycatchers were probably found within most major drainages in Arizona (Paradzick and Woodward, 2003) but were uncommon within the Grand Canyon ecoregion primarily because periodic high flows limited dense riparian habitat. The first record of a willow flycatcher in the ecoregion is from Lees Ferry in 1909, but it is not known whether it was a migrant or a breeding bird. The first nest was found in 1935. The next record was of a probable breeder collected in 1953 (summarized in Sogge and others, 1997). Flycatchers have consistently nested along the river corridor in recent years, as new riparian habitat, primarily tamarisk, has developed in response to altered river flow regimes. This expansion of riparian vegetation may have provided additional habitat for the flycatcher. Migrant willow flycatchers also occur along the river corridor, typically in late May and early June, and most of these migrants are probably of the nonendangered northern subspecies (*E. t. adastus*).

There are no direct flow-related impacts to southwestern willow flycatchers because they nest high in tamarisk vegetation, which is well above the level of normal fluctuating river flows. Indirect effects may occur as the result of flow-related changes to riparian patch size, vegetation density, and invertebrate populations that form the flycatcher prey base. The 1996 beach/habitat-building flow did not adversely affect southwestern willow flycatchers or their breeding habitat structure (Stevens and others, 2001). If future flood flows enhance riparian habitat and patch size, flycatchers may benefit. Conversely, if they substantially reduce riparian habitat at current breeding sites, the flycatcher may be impacted.

Wetland/marsh vegetation has been proposed as important flycatcher foraging habitat in the study area (Stevens and others, 2001). The necessity of wetlands to flycatchers is difficult to evaluate because the species often breeds at sites in the Southwest where extensive wetlands are absent (Sogge and Marshall, 2000).

Other potential impacts to southwestern willow flycatchers include human-related disturbance. Southwestern willow flycatchers are not apparently sensitive to disturbances such as rafts or boats floating past breeding sites; however, people moving through occupied flycatcher habitat can damage habitat, disturb the birds, or impact a nest. During the mid-1990s, visitor closures were instituted at known flycatcher breeding sites in Grand Canyon. To date, there is no evidence of direct, human-related impact to flycatchers along the river corridor. Potential and indirect human-related impacts include the eradication of tamarisk, which the flycatchers use for nesting. Its removal, particularly from known breeding sites, would adversely affect flycatchers.

Brown-headed cowbirds are nest parasites and lay their eggs in the nests of other birds, which then incubate the cowbird eggs and raise the young cowbirds as if they were their own young. B.T. Brown (1994) and Sogge and others (1997) reported that flycatchers in the Grand Canyon ecoregion experienced high rates (>25% of nests) of brown-headed cowbird parasitism, which reduced flycatcher nest success and productivity. There is no evidence, however, that dam operation or river flows affect cowbird populations or nest parasitism rates.

Because southwestern willow flycatchers migrate southward each winter, they are affected by many factors during the migration and wintering periods. Furthermore, flycatchers will regularly disperse long distances and move to different sites between years; however, the reasons behind these movements are not well known (U.S. Fish and Wildlife Service, 2002). These realities complicate interpretation of population trends in the study area and the evaluation of potential impacts of the operations of Glen Canyon Dam.

Over the last 30 yr, the population of breeding southwestern willow flycatchers in upper Grand Canyon has been very small and limited to riparian patches between approximately RM 28 and 71. From 1982 to 1991, 2 to 11 male flycatchers were detected annually, with a maximum of 4 nests in any 1 yr (Brown, 1988, 1991b). Between 1992 and 2003, only 1 to 5 territories were found in any year (Sogge and others, 1997; Johnson, 2000; Paradzick and Woodward, 2003; Yard, 2004a). Flycatchers bred only in the relatively larger patches, and breeding patch size ranged from 1.5 to 2.2 acres (0.6–0.9 ha). Breeding patches were dominated by tamarisk, and all nests had been placed in tamarisk (Sogge and others, 1997; Yard, 2004a). Overall, the southwestern willow flycatcher population in the upper river corridor continues to persist at a very low level, at only one or two sites.

In 1995, breeding flycatchers using one territory were first noted in newly developed native riparian habitat in the Lake Mead delta area, immediately downstream of the Grand Canyon-Lake Mead boundary. The following year this population reached 10 territories, but the delta was flooded during the next 2 yr by rising reservoir levels, and flycatchers were no longer present by 1998. Beginning in 1998, breeding southwestern willow flycatchers were discovered at a variety of upstream sites within lower Grand Canyon between RM 246 and 273 (Paradzick and Woodward, 2003). It is possible that birds found before 1998 breeding downstream, in what is now inundated delta habitat, moved upstream to the lower Grand Canyon reach. Between 1998 and 2001, 7–12 flycatcher territories were recorded in lower Grand Canyon; however, recent surveys in 2002 and 2003 found no breeding flycatchers in lower Grand Canyon (Smith and others, 2003, 2004) and only 2 territories in 2004 (McLeod and others, 2005; Munzer and others, 2005).

Nesting success in the upper Grand Canyon flycatcher population is generally low, and the population is probably not self-sustaining (Sogge and others, 1997). Breeding success in lower Grand Canyon is not well documented, but the lack of detections in 2002 and 2003 suggests that productivity from 1998 to 2001 was probably too low to provide for continued population persistence. Recent habitat changes along the lower river corridor caused by the changing reservoir levels in Lake Mead, however, have probably affected flycatcher site occupancy.

California Condor

The California condor is one of the rarest birds in the world and was federally listed as endangered in the United States in 1967. In Arizona, reintroduction was conducted beginning in 1996 under a special provision of the Endangered Species Act of 1973.

Condors are opportunistic scavengers that feed primarily on large, dead mammals such as deer, elk, bighorn sheep

(*Ovis canadensis*), range cattle, sheep, and horses. Condors can soar and glide up to 50 mi/h (80 km/h) and travel 100 mi (161 km) or more per day in search of food. They are long lived, living up to 60 yr, with low reproductive rates. Most nest sites have been found in caves, on rock ledges, or in tree cavities (Snyder and Schmitt, 2002; Arizona Game and Fish Department, 2004).

In prehistoric times, condors ranged from Canada to Mexico, across the Southern United States to Florida, and to the east coast in New York. Based on evidence from bones, feathers, and eggshells found in caves, condors were a resident of Grand Canyon. A dramatic range reduction occurred about 10,000 yr ago, coinciding with the late Pleistocene extinction of large mammals that condors depended on for food (Arizona Game and Fish Department, 2004). Settlement of the Western United States, shooting, poisoning from lead and DDT, egg collecting, and general habitat degradation resulted in further dramatic population reductions (Snyder and Schmitt, 2002). Between the mid-1880s and 1920s, there were scattered reports of condors in Arizona, with the last sighting near Williams, Ariz., in 1924. By the late 1930s, all remaining condors were found only in California, and by 1982 the total population had dwindled to just 22 birds (Snyder and Schmitt, 2002; Arizona Game and Fish Department, 2004).

The U.S. Fish and Wildlife Service, The Peregrine Fund, Arizona Game and Fish Department, National Park Service, and other collaborators established a condor captive-breeding and release program in Arizona. Vermilion Cliffs National Monument is the main reintroduction site, and birds released at this site frequent Grand Canyon. Since December 1996, the Arizona restoration project has released approximately 6–8 birds per year. There are now over 30 condors flying free in Arizona, and natural reproduction is occurring in the Grand Canyon region: in late 2004, 2 wild-hatched chicks stretched their wings and successfully fledged. As part of the continuing reintroduction project, individual condors will continue to be monitored daily (Arizona Game and Fish Department, 2004).

Many of the reintroduced condors have been observed within the Grand Canyon ecoregion. Although typically seen soaring overhead, condors regularly bathe and sun themselves along the banks of the Colorado River (Andi Rogers, Arizona Game and Fish Department, oral commun., 2005). It is likely that the population of condors in the region will continue to increase because of continued reintroduction efforts and natural increase. Since condors make little use of riparian habitat and are not typically found along the edge of the river, there are no likely effects of MLFF operations. The only dam management actions likely to affect this species would be those that resulted in available carrion such as dead fish along the river corridor, which could attract concentrations of feeding condors.

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Bald Eagle

Bald eagles are common breeders in Alaska and parts of Canada but are far less numerous in the contiguous United States, where they were once critically endangered. Because of extensive and successful recovery efforts since the 1960s, many bald eagle populations have increased, and in 1995 the U.S. Fish and Wildlife Service downlisted the species from endangered to threatened in the lower 48 States.

Although still somewhat rare as a breeder in Arizona, hundreds of bald eagles migrate into the State each winter; eagle numbers in Arizona increased from 225 in 1992 to 440 in 2001 (Beatty, 2001). Wintering eagles typically concentrate along rivers, lakes, and reservoirs where preferred prey, including fish, waterfowl, and carrion, is readily available (Grubb and Kennedy, 1982; Brown, 1993). The Grand Canyon ecoregion is one such concentration area, and eagles are generally present from November through March, which coincides with trout spawning and an abundance of waterfowl within the corridor. Within the study area, bald eagles are found primarily from Lees Ferry downstream to the confluence of the Little Colorado River. From 1991 to 1995, the maximum daily number of eagles detected during helicopter surveys of this reach ranged from 11 to 24 individuals (van Riper and Sogge, 2004). The Colorado River corridor in Grand Canyon hosted only 5%–10% of the wintering eagles present in Arizona on any given day during this time, but the total number of eagles using the corridor over an entire season may be substantially more (van Riper and Sogge, 2004). Systematic corridor-wide surveys were not conducted before or after the 1991–95 period.

Bald eagles often congregate at Nankoweap Creek (RM 52), a small tributary to the Colorado River in which rainbow trout sometimes spawn in large numbers.

Eagles have concentrated here since the early 1980s (Brown and others, 1989; Leibfried and Montgomery, 1993). From 1986 to 1995, maximum daily eagle counts ranged from 4 to 26, with the number of eagles varying directly with the abundance and availability of trout in the creek (Brown and Stevens, 1992; Leibfried and Montgomery, 1993; van Riper and Sogge, 2004). Neither the size of trout spawn nor eagle abundance at Nankoweap Creek was related to dam release levels (van Riper and Sogge, 2004). There is also no evidence that eagle abundance throughout the river corridor is affected by river flow, although it is likely that river turbidity affects the ability of eagles to forage for fish along the mainstem.

Human disturbance can affect bald eagles. Brown and Stevens (1997) and van Riper and Sogge (2004) documented disturbance of wintering bald eagles by humans, including flushing of eagles by hikers, rafters, anglers, and research activity. Hikers in the Nankoweap Creek delta area caused the greatest disturbance to the eagles there, but such disturbances were reduced in years when a visitor-use closure was instituted.

Evaluating the effects of the operations of Glen Canyon Dam and other management activities on bald eagles is complicated by the fact that eagle abundance in Grand Canyon is influenced by both local conditions and regional factors. Furthermore, bald eagles will travel long distances in search of abundant, easily available prey (Stalmaster, 1987) and can move readily between food concentrations at Grand Canyon, Lake Powell, and other regional lakes and rivers. Nevertheless, habitat use by foraging eagles is strongly influenced by fluctuating river flows; high flows reduce eagle foraging habitat diversity, lower foraging success in river habitat, and restrict foraging opportunities (Brown and others, 1998).

Management changes that alter prey availability could alter eagle abundance and distribution within the Grand Canyon ecosystem. For example, if the selective withdrawal of warmer water from Lake Powell increases the numbers of carp, catfish, and suckers (Hunt and others, 1992), more food resources may be available to eagles. Eagles may have more difficulty foraging along the river, however, if trout numbers decrease and/or spawning is reduced, either through water temperature/turbidity changes or through nonnative fish removal efforts.

Peregrine Falcon

Dramatic declines in peregrine falcon populations led to the addition of the peregrine to the Federal List of Endangered and Threatened Wildlife in 1970, where it was listed as endangered. Following successful recovery efforts, the peregrine falcon was delisted in 1999. The Endangered Species Act requires a minimum 5 yr of post-delisting monitoring in cooperation with State agencies to confirm recovery.


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The peregrine commonly breeds in cliffs and uses open landscapes for foraging. Nest sites are usually associated with water (White and others, 2002). In winter, some breeders stay in their nesting areas, and others may migrate.

Diet of the peregrine consists mostly of birds, from songbirds to small geese. They also occasionally eat mammals, especially bats (White and others, 2002). During the breeding season, peregrine falcons in the Grand Canyon ecoregion feed on white-throated swifts (*Aeronautes saxatalis*), swallows, and bats (Brown, 1991a). In winter, they feed mainly on waterfowl. Many of their prey items feed on invertebrate species, especially flies (Diptera), that emerge out of the Colorado River (Stevens and others, 1997b).

Given these life-history traits, any impacts to peregrine falcons from dam operations are likely to be indirect, possibly through influences on the distribution and abundance of aquatic macroinvertebrate populations, which in turn would influence the availability of the peregrine's prey items such as swifts, bats, and ducks.

The Grand Canyon peregrine population was thought to be low in the mid-1970s and apparently increased dramatically in the 1980s (U.S. Fish and Wildlife Service, 1984; Ellis and Monson, 1989; Ward, 2000). In 1981 and 1982, two nests or "eyries" were found during surveys between the Tanner and Bright Angel Trails. In 1998 and 1999, 12 eyries were found in these same areas (R.V. Ward, Grand Canyon National Park, oral commun., 2005). During the same period, the National Park Service conducted surveys throughout appropriate habitat within Grand Canyon National Park, including along the river corridor, and concluded that the peregrine population in Grand Canyon appeared stable since 1988 (Ward, 2000).

Recent Findings

Kearsley and others (2004) examined the interrelationships between vegetation and animal life, including birds, as part of a monitoring project for terrestrial riparian resources that took place from May 2001 to May 2003. Preliminary findings regarding terrestrial breeding birds showed patterns similar to those of previous studies. More breeding pairs and higher species diversity were detected at larger sites (Yard and Blake, 2004). Vegetation density was found to be an important component of habitat quality for riparian breeding birds in the Grand Canyon ecoregion, with the densities of most bird species positively correlated with the abundance of mesquite and acacia (Kearsley and Lightfoot, 2004). No difference was found in the abundance of birds over the 3 yr of the study although sample sizes were too low to analyze trends (Yard and Blake, 2004). The most commonly detected breeding species were the same as those in previous studies (Brown and others, 1987; Sogge and others, 1998; Spence, 2004).

Discussion and Future Research Needs

The construction of Glen Canyon Dam and the subsequent changes in the hydrograph of the Colorado River resulted in dramatic changes in the amount of available habitat for both the riparian breeding and the overwintering aquatic bird communities within the Colorado River ecosystem. Perennial plant species, especially tamarisk, colonized areas previously scoured by floods, creating new riparian patches in the high-water zone. These areas provide habitat for over 30 species of breeding birds, including many Neotropical migrants and the endangered southwestern willow flycatcher. Increased river clarity and productivity below the dam provide suitable habitat for many aquatic bird species such as ducks, loons, grebes, and cormorants.

Patterns of abundance and distribution of riparian breeding birds and overwintering riparian and aquatic birds within the study area are now well known. Less well known are the long-term effects of adaptive management and the management activities needed to ensure the continued conservation of riparian resources, their associated avian communities, and bird species of conservation concern. Continued monitoring would be required to address these information needs.

Monitoring riparian breeding birds to detect population changes requires considerable commitments of both time and effort to obtain sufficient data for biological and statistical significance. Data from the 1996 to 2000 breeding bird monitoring program were used by Spence (2004) to determine the adequacy of the monitoring program to detect changes in bird populations. He found that trends could not be detected for 24 of 32 (75%) riparian breeding species and that 5 to 30 yr of sampling were required to detect a 10% change in species abundance. Half of the 16 most common species included in the analysis would require over 10 yr of monitoring to detect a 10% population change, while 5 rarely detected species cannot be monitored by using the sampling protocols tested in the analyses (Spence, 2004).

An alternative approach to continued monitoring of riparian birds would be to use aerial photography, remote sensing, and geographic information systems (GIS) in order to measure habitat variables within the study areas that have been shown to predict bird numbers, richness, and diversity (Sogge and others, 1998). Key variables for monitoring would include the size and distribution of riparian patches, area of NHWZ and OHWZ woody species, and measures of total vegeta-

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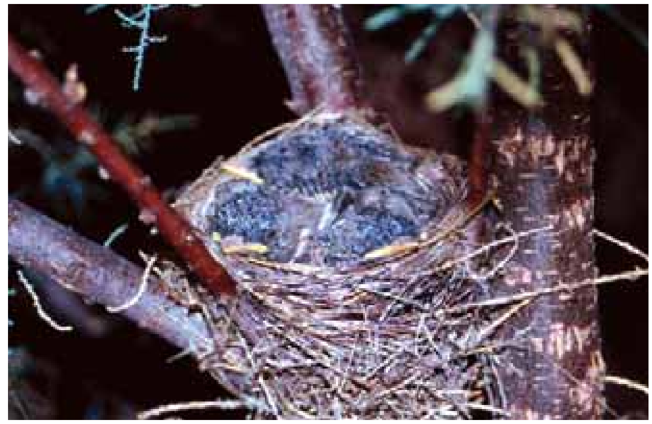
tion volume; however, simply monitoring habitat quality and extent may miss potential changes in selected bird species caused by factors within the study area other than riparian vegetation dynamics and may miss potentially profound changes in some bird species (Spence, 2004).

Existing data, collected in previous studies, could be used to better model and predict how future changes in the riparian vegetation will affect changes in terrestrial avifauna populations within the Grand Canyon ecoregion. In particular, it would be valuable to extend the current models of bird community and patch-level habitat variables (Sogge and others, 1998; Spence, 2004) to the level of individual bird species. This extension would allow the development of more useful conceptual models and more detailed predictions regarding avian resources in the Grand Canyon ecoregion. For example, models developed by Sogge and others (1998) predicted that changes from tamarisk shrub/tree to willow shrub/tree are not likely to greatly affect overall bird abundance and species richness within riparian patches in Grand Canyon, yet individual species have specific behavior, physiology, and ecology, and some may decline in response to such habitat changes. Extending models to individual species would allow identification of species that may be sensitive to future changes in the riparian vegetation.

Riparian woodlands, such as those within the Grand Canyon ecoregion, provide vital habitat for bird species of conservation concern and support the highest diversity of landbird species of all habitats in the Southwest (Rich and others, 2004). Dam operations affect birds within the ecoregion primarily through effects on breeding habitat. Under the MLFF alternative, these impacts are likely to be fairly minor compared with climate and habitat changes outside the Colorado River corridor. Thus, the Grand Canyon ecoregion is likely to continue to be an important resource for riparian birds. A well-designed monitoring program that takes into account sampling design and statistical power can be used to establish baseline values regarding the distribution and abundance of specific species from which future comparisons can be made over time. If monitoring data are linked to information regarding ecological resources and habitat requirements for specific species and the monitoring is conducted in conjunction with more regional, large-scale monitoring, insight into the causes of population changes and the effects of management actions may result (Holmes and others, 2005).

Dam operations have been shown to be directly linked to overwintering aquatic birds through effects on primary and secondary productivity; thus, they may be a useful resource to monitor. Overwintering aquatic birds can be monitored relatively easily because more than



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50% of the aquatic birds occur at or above Lees Ferry in a typical winter. Further study is necessary, however, to determine how to structure any future aquatic bird monitoring program (Spence, 2004).

Continued monitoring of species of special concern would require continuation or development of monitoring protocols specific to each species. In particular, the southwestern willow flycatcher population in Grand Canyon is extremely small relative to the current rangewide population, which encompasses approximately 1,400 territories (U.S. Geological Survey, unpub. data, 2004). Because flycatcher monitoring must follow a standard, multivisit protocol, conducting such surveys within the study area requires substantial resources. Overlaying this protocol is the challenge of relating river flows to any direct or indirect impacts to the flycatcher and its habitats. The potential impacts of tamarisk removal associated with riparian restoration projects should also be considered. Therefore, the nature and extent of future flycatcher monitoring, and the ability to interpret its results, may be worthy of discussion within the Glen Canyon Dam Adaptive Management Program. Bald eagles have not been systematically or intensively monitored along the Colorado River since 1995; nevertheless, eagles are still noted during some winter research raft trips (Yard, 2004b). van Riper and Sogge (2004) evaluated various monitoring techniques and noted that helicopter-based surveys would be the most effective method in terms of coverage and ability to detect the eagles. On the other hand, aerial surveys would have to be considered in light of potential recreation issues and current and future Grand Canyon National Park policies. Logistical difficulties associated with access make surveying for peregrine falcons in Grand Canyon National Park extremely difficult, and a thorough sample using unbiased or random methodologies has been impossible

(Ward, 2000). Despite these difficulties, the National Park Service will monitor at least five territories within the park (R.V. Ward, Grand Canyon National Park, oral commun., 2005), and Glen Canyon National Recreation Area will monitor one or more territories above Lees Ferry starting in 2005.

Many factors and processes apart from dam operations affect the structure and functioning of the Grand Canyon ecosystem, such as changes in regional climatic and atmospheric conditions, natural disturbances, adjacent land uses, the spread of invasive species, and fire suppression. These natural and human-caused events, along with adaptive management actions, have affected and will continue to affect the abundance, distribution, and composition of the Grand Canyon bird communities and their habitats.

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