Effects of Glen Canyon Dam on the Avifauna of the Grand Canyon, Arizona

By Robert A. Schell

Abstract

Glen Canyon Dam has restructured the ecology of the Colorado River through the Grand Canyon causing significant changes to native riparian habitat. The absence of scouring flood events has allowed colonization of riparian vegetation between the old and new high water lines. This has created substantial stands of riparian and marsh habitat for resident and migrant birds. While some bird species have been shown not to breed in the stands of invasive vegetation, most riparian bird species have responded positively to it. Over-wintering bald eagle populations have increased in the Grand Canyon, primarily as a result of robust non-native trout populations below Glen Canyon Dam. Other human land use practices adjacent to the canyon, such as grazing and recreation, have increased Brown-headed Cowbird populations. The Brown-headed Cowbird is a nest parasite and threatens breeding birds such as the federally endangered Southwestern Willow Flycatcher along the river corridor. Avian diversity and abundance has increased following construction of the dam. Increases in waterfowl densities, due to increased open water and marsh habitats, serve as an abundant food source for the recovering Peregrine Falcon. Invasive and highly flammable tamarisk has instilled a fire regime previously absent, which threatens individuals and breeding bird populations and further perpetuates the loss of native willow-cottonwood vegetation assemblages. Management may now be necessary to maintain stable avian communities within the Grand Canyon.

INTRODUCTION

The completion of Glen Canyon Dam in 1963 has significantly altered the ecological systems both up and down stream of the 710 ft. structure. Currently, the U.S. Bureau of Reclamation manages the flow releases and the hydroelectric power generated by the passage of water through Glen Canyon Dam. The repression of the natural flood events, coupled with the blockage of sediment at Lake Powell, has dramatically altered the character of the Colorado River below the dam. Once identified as a turbid system with extremely variable thermal and flow fluctuations including periodic, large-scale flood events, Glen Canyon has produced a flat line hydrograph of clear, cold water with near zero long-term flow variability (Stevens et al. 1995).

Alteration of hydrological and geological processes has changed the ecology of the Grand Canyon. Although the Grand Canyon avifauna has not directly suffered from the changes in the natural flow regime, environmental transformation associated with the flows have caused a shift in the occupying avian communities.

Erosion of channel banks, sediment deposition along the channel bottom, and the hydrological stability (which are consequences of Glen Canyon Dam) has resulted in both the construction and destruction of riparian habitat, altering its availability and structure.

Prior to the congressional authorization of Glen Canyon Dam in 1956, fewer than 500 people had navigated the Colorado River through the Grand Canyon (Lavender 1985). Various exotic species, both plant and animal were introduced to the Grand Canyon in the late 19th and early 20th centuries. Following dam completion, the area experienced a recreational boom, leading to an increased demand for protection of the exotic trout fishery, rafting flows and other miscellaneous human entertainments. Factors such as these have altered bird communities throughout the Grand Canyon.

I chose several specific umbrella species to illustrate avian trends in response to the altered flow regime caused by Glen Canyon Dam. The Bell's Vireo (*Vireo bellii*) is a good example of the response seen in many species of riparian-breeding passerine generalists. In contrast the Southwestern Willow Flycatcher, Western Yellow-billed Cuckoo, and Yuma Clapper Rail are all endangered ecological specialists that require very specific habitat types to breed. Peregrines, Bald Eagles, California Condors and Spotted Owls are all charismatic mega-fauna on the upswing of their respective extinction trajectories that have found refuge in Grand Canyon National Park. Peregrine Falcons and Bald Eagles have increased via a shift in trophic levels attributed to the operation of Glen Canyon Dam. While California Condors and Mexican Spotted Owls were once extirpated from the Grand Canyon, they have now recolonized the region.

HISTORICAL CHANGES (PRE GLEN CANYON DAM)

The climactic history of the Southwest is filled with extremes. Once characterized by cooler temperatures and considerably higher rainfall, it is now one of the hottest, driest regions in the worlds. Since the beginning of the Holocene (approx. 10,000 years ago), the Southwest has experienced a permanent drought that has transformed the landscape into a mostly arid region (Thompson and Anderson 1997). This era of climate warming has resulted in the shrinkage of the vast woodland/forest habitat that once dominated the region and the simultaneous expansion of deserts and scrubland. This caused shifts in bird communities. For example, formally low altitude dwelling Wood-pewees (*Contopus* spp.) have moved to higher elevations. Subsequently lowlands have been colonized by species adapted to arid environments such as Greater Road-runners (*Geococcyx californianus*), Cactus Wrens (*Campylorhynchus brunneicapillus*) and Black-throated Sparrows (*Amphispiza bilineata*) (Brown et al. 1987). The shift in avian communities is illustrated Figure 1.

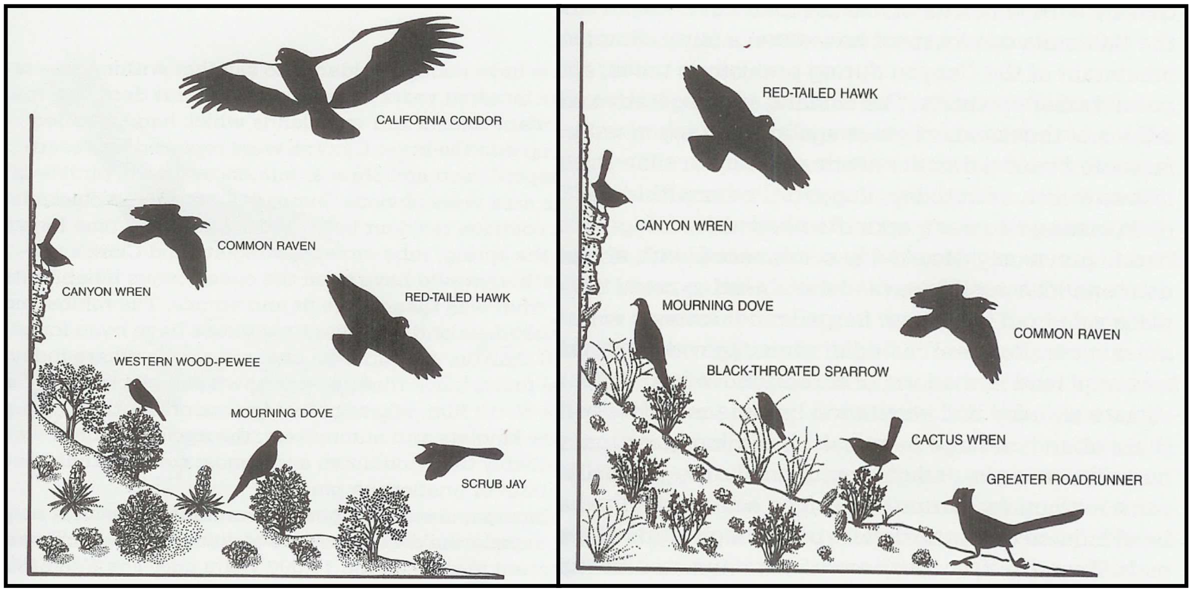


Figure 1. These generalized habitat sections (above) show typical avifauna and vegetation of past and present. The left figure shows the plant communities of 10,000 years ago, dominated by juniper, banana yucca, single-leaf ash and skunkbrush. The right represents present-day communities comprised of desert scrub, ocotillo and creosote bush (Brown et al. 1987).

A complete, chronologically accurate, fossil record of past Grand Canyon bird communities has been developed from remains found in very large, isolated caves and provides evidence of giant birds that once inhabited the canyon (Brown et al. 1987). These caves were protected from predators and thus were ideal nest sites for three large carrion-eating raptors called Teratorns. These species weighed upwards of fifty pounds and stood in excess of four feet at the shoulder (Brown et al. 1987).

Climate changes likely caused the extinction of birds such as Merriam's Teratorn, and the extirpation of another, the California Condor (*Gymnogyps californianus*), which has since been reintroduced by humans. The extinction of large North American mammals, as a result of the warming trend and the Pleistocene overkill, which were the birds' primary food source, is largely responsible for the disappearance of this avian taxa.

The most recent of the large birds to vanish from the Grand Canyon is the California Condor. The decline of this species came largely before European settlement. The last confirmed account came from a publication in The Auk in 1899. When Herbert Brown was crossing the Colorado River in March of 1881, one of Brown's compatriots, Miles Noyes, shot one of presumably the last pairs of condors, out of curiosity.

The settlement of the southwestern United Stated had little further direct effect on the avifauna of the Grand Canyon, although indirect ecological affects of humans in the Canyon have had large and significant impacts. The implementation of cattle grazing brought the simultaneous introduction of the Brown-headed Cowbird (*Molothrus ater*) to the Southwest.

Possibly the single most dramatic and unsurpassed transformation of the Southwest landscape came during the age of engineering, marked by the closure of Hoover dam in 1938. Harnessing water to provide irrigation and power to the inhabitants of this thirsty region became widespread. One of the most notable of all the super-dams is Glen Canyon Dam. Behind it lies Lake Powell, a nine trillion gallon reservoir that extends 186 miles upstream. The political decisions that have dictated the allocation of water have also governed the flow rate and volume released from Glen Canyon Dam through the Grand Canyon.

The minimally variable system below Glen Canyon Dam has provided a stable environment allowing riparian vegetation to flourish and the establishment of many productive marshes. Both of these resulting habitat types serve as viable bird habitat.

RIPARIAN COMMUNITIES (POST GLEN CANYON DAM)

Prior to the closure of the dam in 1963, scouring floods were a regular and critical component of the Grand Canyon system. These floods removed nearly all riparian vegetation below the old-high water mark and repetition of high flows excluded germination of seeds and recruitment below this zone (Figure 2). Flood events maintained sandbars and channel banks as largely unvegetated corridors. The simultaneous recession of the ground water table due to lack of replenishing flood events resulted in the isolation of native riparian vegetation from its water source (Busch et al. 1992).

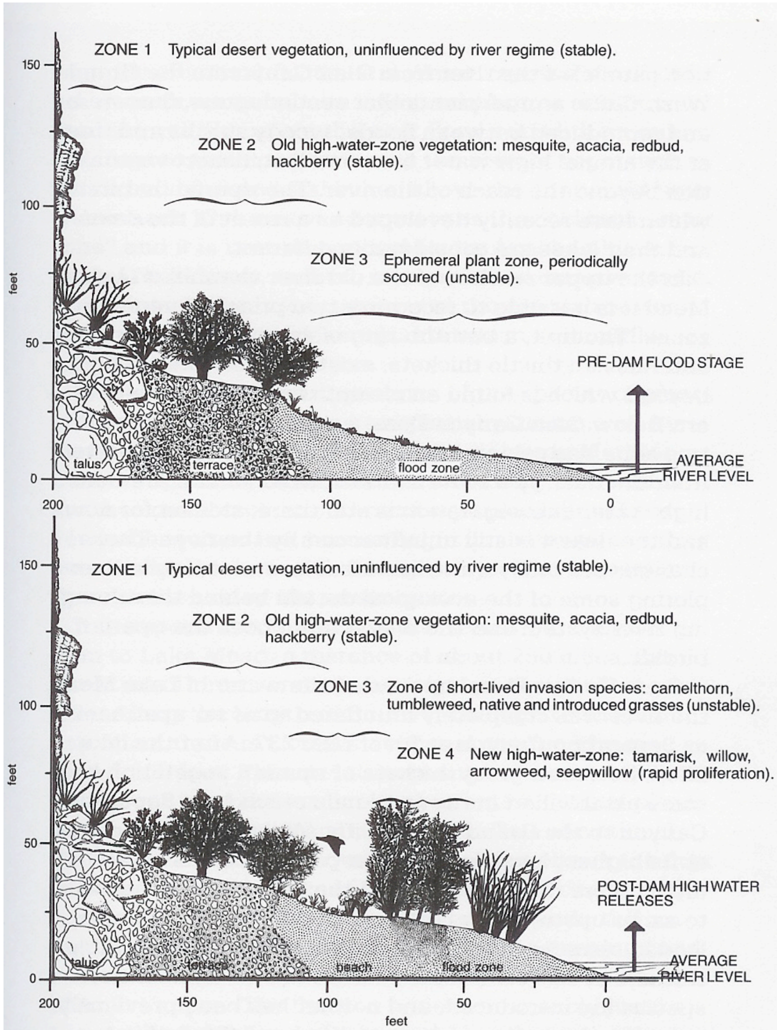


Figure 2. (top) This schematic shows the riparian distribution prior to Glen Canyon Dam when natural flood scour was frequent and only annual grasses and forbs could colonize channel banks. (bottom) Post Glen Canyon Dam flow regime prevents flood scour, creating a new zone of riparian vegetation is dominated by exotic species (Brown et al. 1987).

The river below Glen Canyon Dam experiences lower flows than historical (pre-dam) records indicate, while the system upstream of both Glen Canyon and Hoover Dams became inundated with water. As Lakes Mead and Powell filled, all the river-bank vegetation extending upstream was flooded and drowned. In its stead, sediment deposits at the upper end of the reservoirs have forged massive delta systems which now support some of the largest continuous stands of riparian vegetation in these dammed systems.

The persistent lack of floods and continuous deposition of sediment has created a large canvas below the historic high water mark for colonization by new riparian vegetation.

Elimination of flood events is correlated with the decline of cottonwood and willow stands and the consequential increase of the highly invasive tamarisk. Tamarisk (*Tamarix chinensis*) was introduced in the Grand Canyon around the turn of the century; however, it wasn't until 1938 that the tamarisk was noted by E. Clover in sparse quantities (Webb et al. 2002). Establishment of tamarisk results in a self-perpetuating regime of fire (Marshal and Stoleson, 2000). Riparian habitats are neither fire-adapted nor fire-generated, therefore when fire occurs in a riparian system, the results are usually catastrophic (Marshal and Stoleson 2000). This cycle threatens any remaining cottonwood-willow stands, along with subsequent mortality of any current avian occupants, and/or their progeny (see M. King this volume).

TRENDS IN RIPARIAN AVIFAUNA

To date, there have been 373 bird species recorded from the greater Grand Canyon area (NPS 2004), 250 of which have been found along the river itself. 48 species in particular nest in the riparian vegetation adjacent to the river.

Of 69 avian species that breed and/or reside along the river corridor and are likely affected by Glen Canyon Dam 49 species (71%) are or may be benefiting. Six Species (9%) are being negatively affected. The remaining 13 species are probably responding but at present, there is insufficient information to make a judgment as to how. For information on all perceived species responses, see Appendix 1.

To riparian generalist passerines, the increase in riparian vegetation, as a result of Glen Canyon Dam, has afforded opportunities for species to increase their numbers, breeding effort and range. Summer birds largely forage on insects while winter birds feed mainly on seeds. Both seeds and arthropods have become more abundant as a result of increased riparian vegetation (primarily tamarisk).

Piscivorous birds have also done well in Glen Canyon Dam's wake. Exotic trout in the tail-waters and tributaries support populations of avian fish predators

Below I discuss further each of the aforementioned trends in greater detail and use different species to exemplify each response pattern. Figure 3 illustrates the general responses seen in Grand Canyon birds.

Birds rely heavily on the canyon as a stop-over point during migration. Waterfowl and shore-birds utilize the lakes and river in large abundance (Brown et. al. 1987). They stop to forage temporarily in both spring and autumn while on their cross-continental passage. Specifically Western Grebes and Black-crowned Night-Herons, once migrants, now breed in this region since the formation of Lakes Powell and Mead (Brown et al. 1987).

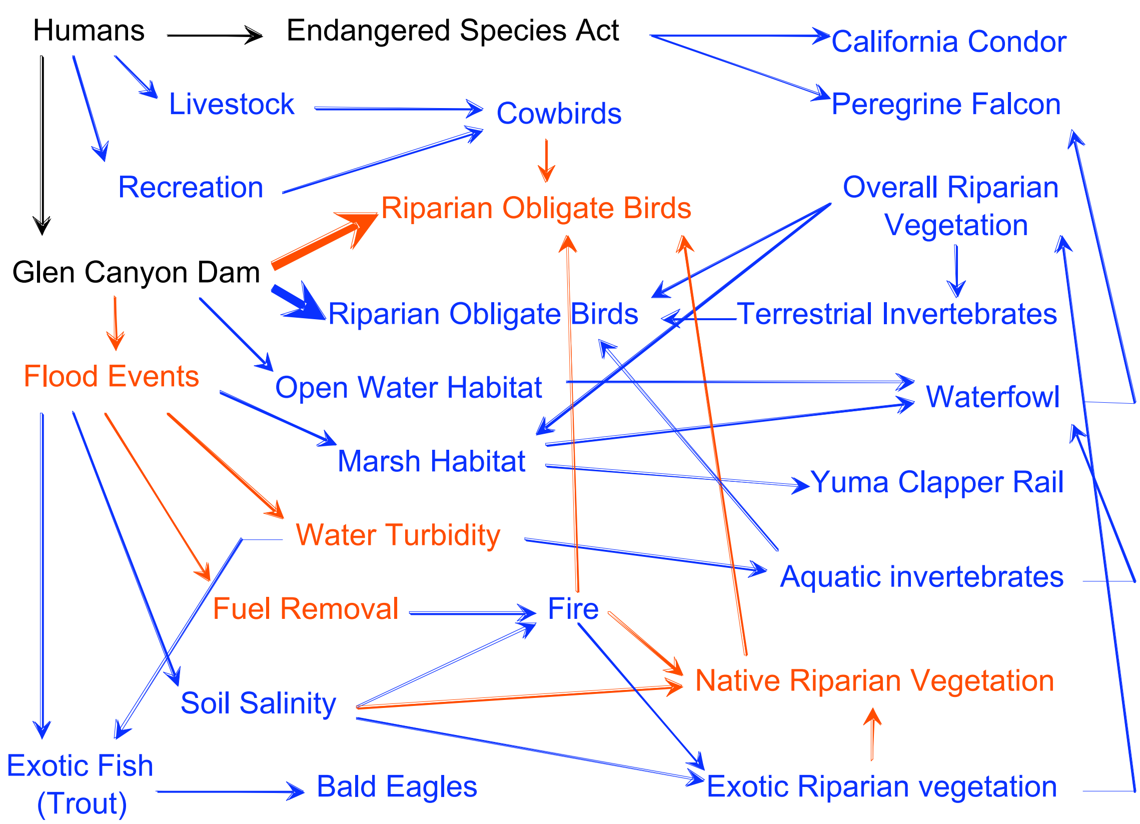


Figure 3. This original flow diagram illustrates the general patterns seen in Grand Canyon avifauna and outlines general mechanisms for response. Items in blue are increasing, while items in red are decreasing. Likewise blue arrows indicate a positive influence while red arrows indicate a negative influence.

TAXA SPECIFIC RESPONSES

Brown-headed Cowbird

The Brown-Headed Cowbird has seen a positive response in their population, not as a direct result of the dam, but from the increase in human recreation since the dam's construction.

The Cowbird is native to the midwestern plain states. Its ecological requirements require close association with herds of large ruminants, originally American Bison, where the Cowbirds forage on insects displaced by their movements. However, as bison became scarce, transition to their bovine counterparts occurred.

The picture above depicts a large speckled Brown-headed Cowbird egg (upper right) among a clutch of four smaller vireo eggs in a parasitized Bell's Vireo nest (www-personal.ksu.edu/~kosciuch/research.htm).

Cowbirds are notorious for their reproductive strategy. They do not nest; instead, they find viable nests of other species and lay their egg(s) among the host's clutch. The Cowbird's egg(s) generally hatch first and the nestlings usually kill the host's offspring, burdening the host who raise and feed the hatchlings (Shaffer, et al. 2003). The picture to the right shows a Cowbird egg amongst a clutch of Bell's Vireo eggs.

Many bird species that occur within the Cowbird's native range possess evolutionarily-instilled defensive mechanisms against the Cowbird's brood parasitism; however, species excluded from this evolutionary arms race are particularly vulnerable to nest parasitism, making the Cowbird an especially threatening adversary to native Grand Canyon birds. Cowbird parasitism significantly compromises its host's ability to successfully fledge young (Uyehara et al. 2000). I will discuss this further with specific reference to the Southwestern Willow Flycatcher.

Within the canyon itself, human recreation, particularly, commercial pack-stock has led to increasing Cowbird populations in the same method that they are attracted to cows. Likewise cattle-grazing along the rim and increased trash production in this region are responsible to inflating Cowbird numbers.

Bell's Vireo *(Vireo Bellii)*

Above is a picture of Bell's Vireo in hand. Image courtesy of Jim Hilabeck (www.mobirds.org/ WarblerShow/Vireo.htm).

Perhaps the most notable of species that has benefited from the new vegetation, and therefore the dam, is Bell's Vireo (*Vireo bellii*).

Facing declines throughout most of its range due to habitat loss (Phillips et al. 1964, Rea 1977, Goldwasser et al. 1980, Rosenberg et al. 1982), Bell's Vireo has seized the opportunity to rebound in the Canyon with vigor. Prior to 1963, the breeding range of Bell's Vireo extended slightly beyond Lake Mead with a few pockets of breeding individuals in the western Grand Canyon (Phillips et al. 1964). As soon as Glen Canyon Dam was completed, riparian woodland began to expand, and with it the range and numbers of the Bell's Vireo (Brown et al. 1983). Between 1963 and 1983, the breeding range of Bell's Vireo expanded 145 miles through the Grand Canyon (Figure 4). Range expansion has likely continued to and beyond Lees Ferry in the last 22 years.

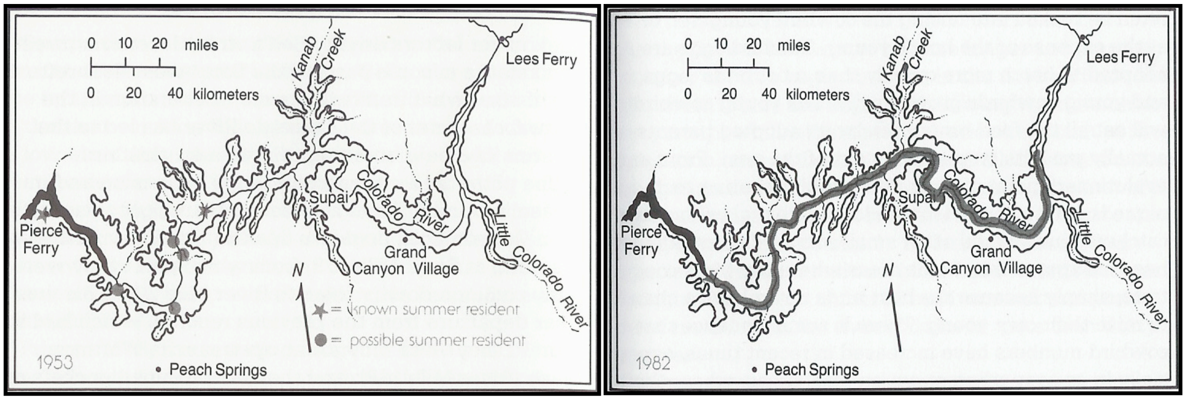


Figure 4. These two maps show the breeding range of the Bell's Vireo in the Grand Canyon. Above left is from 1953. Above right is from 1982, thirty years later, twenty years after the completion of Glen Canyon Dam, showing the range expansion of 145 miles (Brown et al. 1987)

This same trend applies to a variety of other Grand Canyon breeders. Yellow-breasted Chat (*Icteria virens*), Lucy's (*Vermivora luciae*) and Yellow Warbler (*Dendroica petechia*), Summer Tanager (*Piranga rubra*), House Finch (*Carpodacus mexicanus*), Indigo (*Passerina cyanea*) and Lazuli Buntings (*Passerina amoena*), and Blue Grosbeak (*Guiraca caerulea*) have all experienced a positive response to the increase in riparian habitat (Brown et al. 1987.)

Southwestern Willow Flycatcher (*Empidonax trailii extimus)*

The Southwestern Willow Flycatcher, a federally endangered songbird, appears to have benefited from the changed flow regime caused by the increased amount of riparian vegetation. However sustainability in the Grand Canyon is questionable.

Above is a picture of the Southwestern Willow Flycatcher. Image courtesy of Doug Wechsler (http://www.backfromthebrink.org/pop_up_slideshow.cfm?animalid=5)

The response of the Southwestern Willow Flycatcher (SWWF) to Glen Canyon Dam is one that is extremely difficult to categorize into discrete response variables. To some extent, their response is still unknown. The determining factor responsible for the initial declines of the Flycatcher was probably habitat loss and modification (USFWS 2002).

The Southwestern Willow Flycatcher is one of four Willow Flycatcher subspecies found in the United States and, as its name implies, breeds in the southwestern Unites States and northern Mexico (Figure 5). Unlike the other subspp., *E.t. extimus* is a riparian obligate, breeding in dense riparian vegetation with a nearby source of water.

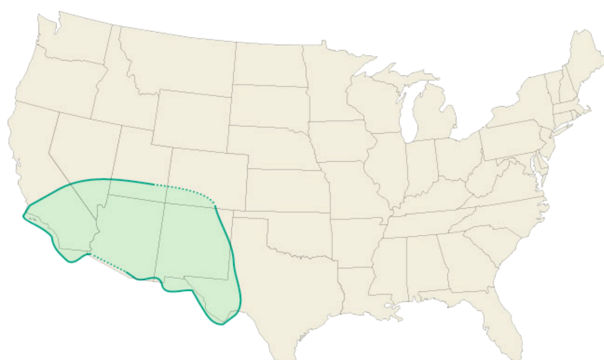


Figure 5. Southwestern Willow Flycatcher breeding range within the United States (Sogge N/D).

They arrive on their breeding grounds throughout May and early June, eggs are generally laid beginning in May and fledging occurs between mid June and August (Sogge et al. 1997).

The SWWF was federally listed as endangered species in March of 1995 (USFWS 1995); the petition to list was submitted in 1993 and organized survey efforts have been conducted since then. While range-wide population increases have likely occurred, most of the variation over time (Figure 6) is probably attributed to increase in survey efforts (Sogge et al. 2003).

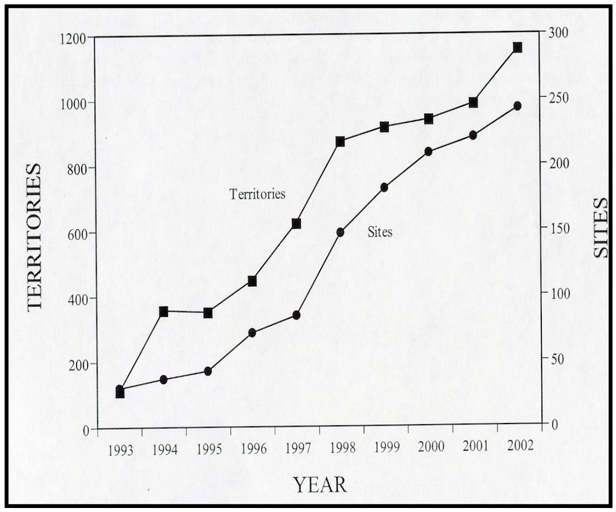


Figure 6. Change in SWWF sites (areas with SWWF) and territories (SWWF pairs) since 1993, the year when the SWWF was proposed to be listed. Much of the increase seen is likely due to increased survey effort (Sogge et al. 2003).

Populations of SWWF and along the Grand Canyon are surprisingly sparse. When breeding activity recorded by the Arizona Department of Game and Fish in 2000-2003 is plotted an Arizona map, it appears that relatively few SWWF nest along the Colorado River above Lake Mead (Willow Flycatcher 2000-2003 Survey and Nest Monitoring, ADGF). The USGS in determined that there 38 sites and 29 territories along the Colorado River in 2002 (Sogge et al. 2002).

A study conducted by the Arizona Department of Game and Fish quantified SWWF habitat in Arizona using GIS-based satellite imagery. They discovered that while the drainage of the Colorado River and major associated tributaries, less the Little Colorado River, between Glen Canyon Dam and Lake Mead represents an area of 10,232 square miles, there is only 420 acres of high probability SWWF habitat (Dockens and Paradzick 2004). Compared to Arizona as a whole, this represents 11% of the drainage area but only 1.3% of the state's high probability habitat. 330 of the 420 acres (78%) of high probability habitat occur at the inflow to Lake Mead. This delta region supports the largest continuous stands of mixed native-exotic riparian habitat along the Colorado River between Glen Canyon and Hoover Dams. The Gila River is the stronghold for SWWF in Arizona, supporting over 17,300 acres of high probability habitat (Dockens and Paradzick 2004).

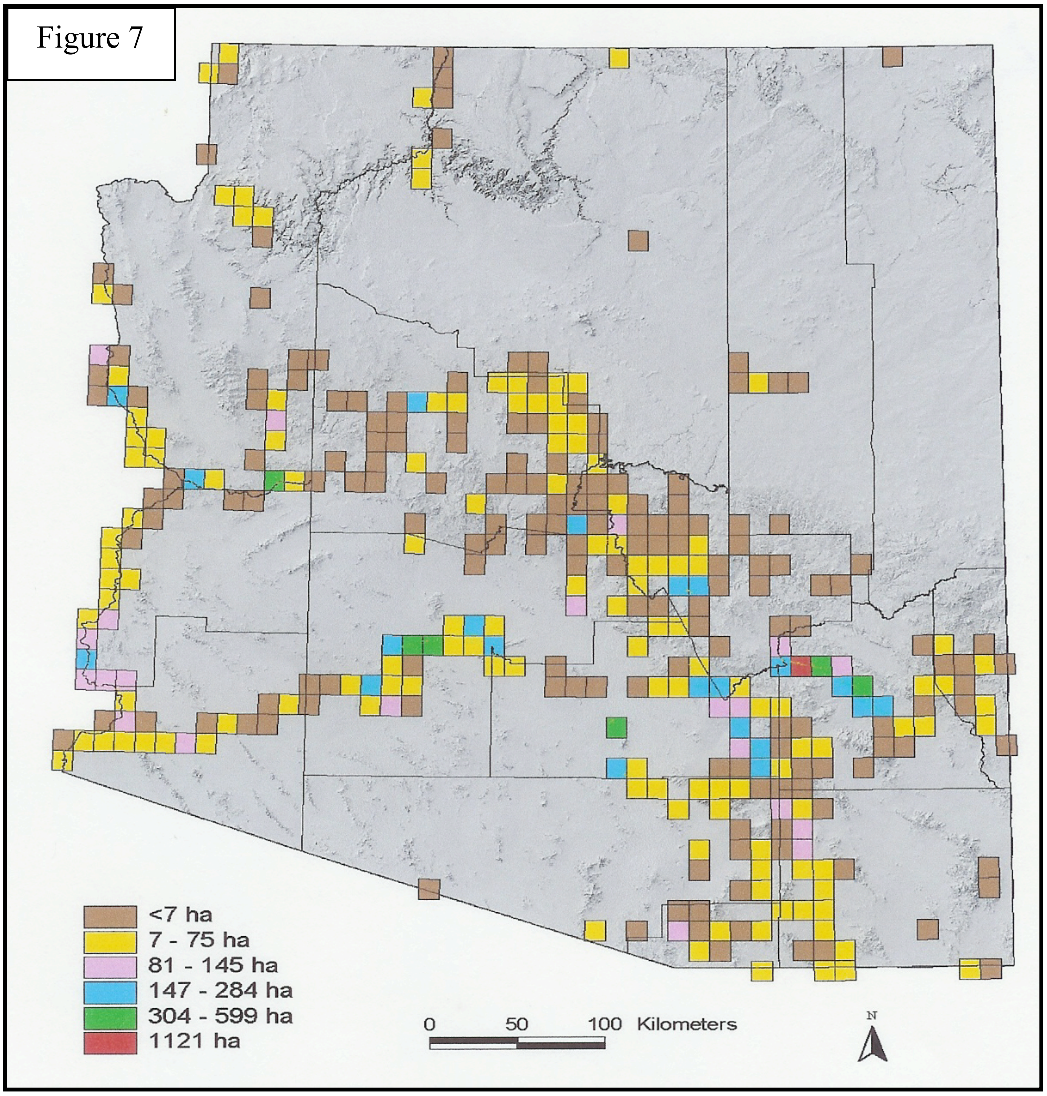


Figure 7. The distribution of high probability SWWF habitat in Arizona (Dockens and Paradzick 2004).

Notice the few parcels of habitat along the Grand Canyon in Figure 7. There are no stands greater than 75ha anywhere along the Colorado River and no high probability habitat between Glen Canyon Dam almost until Kanab Creek. The largest continuous habitat patches occur along Kanab and Havasu creeks and at the inflow to Lake Mead. Also notice how little habitat exists along the Colorado River, relative to the abundance of habitat found in the southern part of the state. This does not mean that SWWFs do not breed elsewhere along the river; however, the map simply denotes stands of habitat that is currently believed to support high concentrations of SWWF.

Historic declines have been attributed to the loss of native riparian willow-cottonwood stands and that the saltcedar stands replacing them are unsuitable nesting habitat.

Monotypic stands of tamarisk lack the broad leafed structure of native willow-cottonwood habitats and therefore may not provide adequate thermal refugia for nesting birds (Rossenberg et al. 1991) (Figure 8). In a system that often experiences temperatures in excess of 108 degrees Fahrenheit, the upper lethal temperature for many avian embryos (Walsberg and Voss-Roberts 1983), it seems likely that temperature may pose a problem.

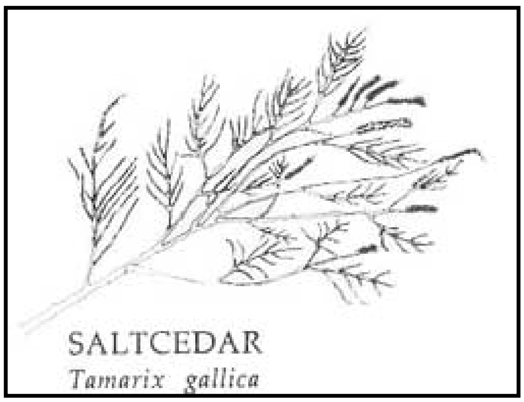


Figure 8. Pictures above show the dichotomy in structure between native willow and tamarisk foliage. It is easy to see how tamarisk would not provide sufficient shade to nesting Southwestern Willow Flycatchers.

Since SWWFs are one of the latest nesting birds in Southwestern arid riparian systems, they may require substantial buffering against extreme environmental conditions (Hunter 1988). Dense riparian vegetation within the interior of heterogeneous vegetation creates a mosaic that is not uniform. Surface water may be necessary to create the proper microclimatic conditions needed for breeding (Sogge and Marshal, 2000). Therefore, in regions where extensive monotypic stands of saltcedar and particularly high temperatures persist (for example on the lower Colorado River) SWWF may suffer permanent breeding impairment (Owen and Sogge, 2002).

When saltcedar is paired with russian olive, another exotic species, resulting structure may sufficiently mimic that of native cottonwood-willow stands, providing suitable habitat for SWWF. Figure 9 suggests that tamarisk may actually provide better nesting substrate when adequate structure is achieved.

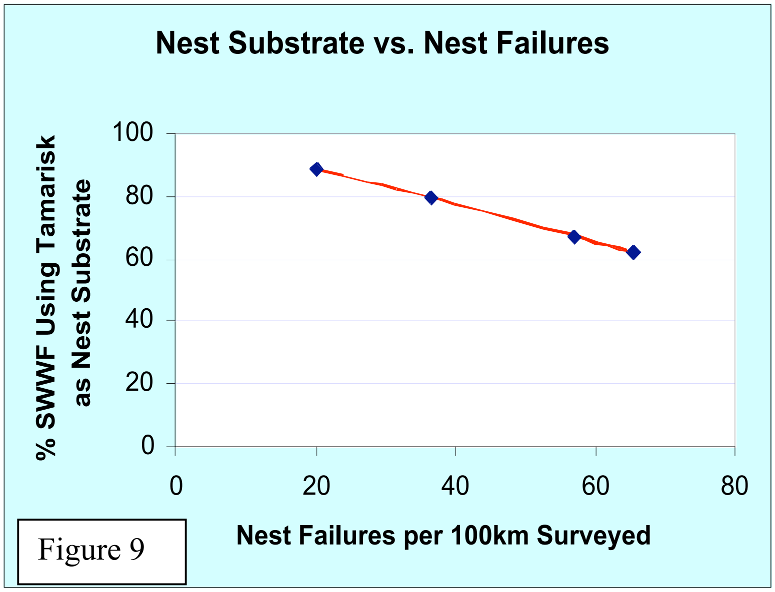


Figure 9. Original graph adapted from Arizona Department of Game and Fish Survey and Nest Monitoring reports from 2000- 2003. This shows a decrease in nest failures as use of tamarisk as nesting substrate increases, suggesting tamarisk may function as better nesting substrate when sufficient habitat heterogeneity exists.

A recent study, using radio telemetry at Roosevelt Lake, AZ, compared available habitat with habitat usage by SWWF giving an index of habitat preference. It shows that mixed (native-exotic) mature riparian habitat was used more often than any other habitat (53%) despite it comprising only 28% of available habitat. Moreover, it shows that mature habitat, comprised exclusively of either native or exotic species was not preferentially used (Cardinal and Paxton, 2005). This suggests that habitat heterogeneity may be more important than vegetation species composition (Figure 10).

Other studies claim tamarisk support a less diverse and abundant community of associated arthropods (DeLoach et. al 2000). However, an in-depth analysis was conducted by the USGS comparing 12 physiological parameters of SWWF in native and tamarisk dominated habitats. Nine of the 12 parameters showed no significant difference between the two habitats (Owen and Sogge 2002). Triglyceride and glycerol levels exhibited significant differences suggesting that tamarisk dominated habitats may provide better energetic conditions than native habitats (Owen and Sogge 2002). They also noted that tamarisk flowers bloom during much of the SWWF breeding season, subsequently attracting large bodied insect pollinators which may compensate for reduced taxonomic diversity.

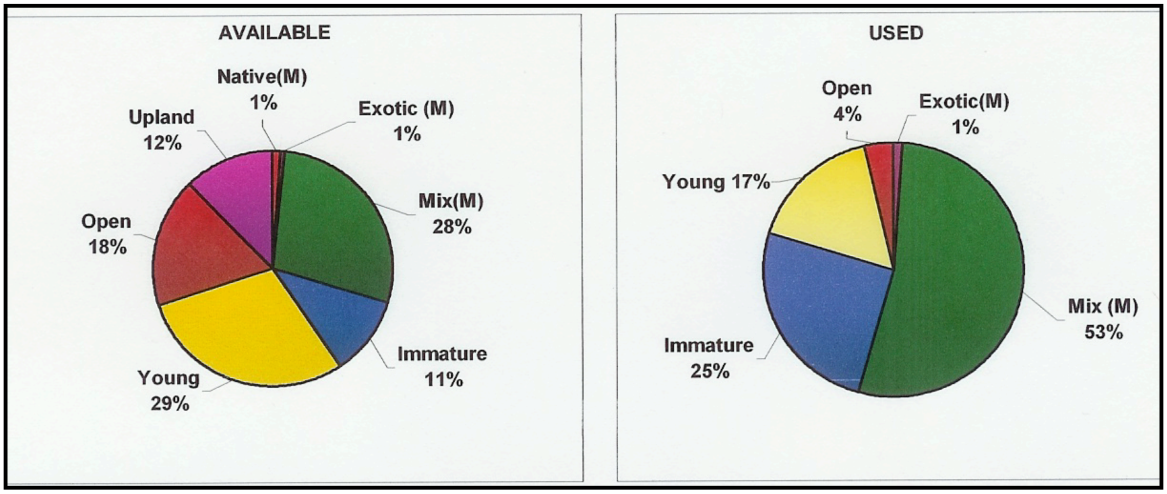


Figure 10. % vegetation types available vs. % vegetation used as SWWF breeding Substrate (M) = Mature (Cardinal and Paxton 2005).

Other threats to SWWF include toxicants and cowbird parasitism. Glen Canyon Dam disrupts natural contaminant dissemination, including selenium. Selenium like salt is accruing in the Colorado River. Aquatic insects accumulate selenium in the benthos, and when they are subsequently eaten, SWWFs are exposed. Little work has been done on effects of pollutants on SWWF; however, high selenium levels have been noted in birds along the lower Colorado River (King and Andrews 1996) and in Colorado, where a Willow Flycatcher nestling was found with skull and bill deformities (Marshal and Stoleson 2000). Like selenium, Cowbird concentrations have been artificially inflated as human land use has increased. As one of the 220 species known to host Cowbirds, the SWWF experiences particularly high rates of parasitism - one study, in the Grand Canyon, showed 50% of SWWF nests contained Cowbird eggs (Brown 1994). Cowbird eggs significantly reduce SWWF success (Uyehara et al. 2000). Cowbirds lay their eggs from May 6th to July 18th which coincides with the breeding season of SWWF. Therefore Cowbird parasitism could be largely responsible for the absence of SWWF in otherwise suitable habitat (Unitt 1987). Relative success between parasitized vs. unparasitized nests can be seen in Figure 11.

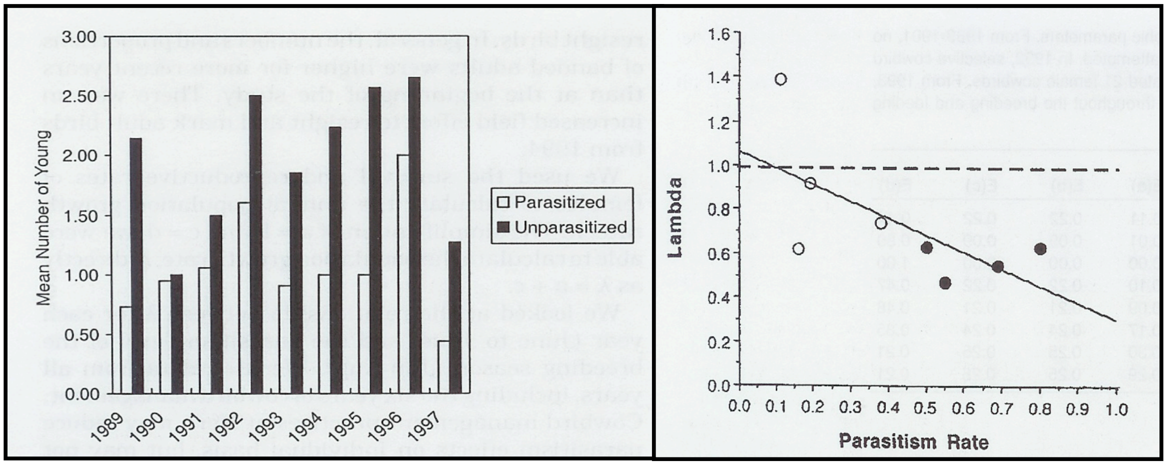
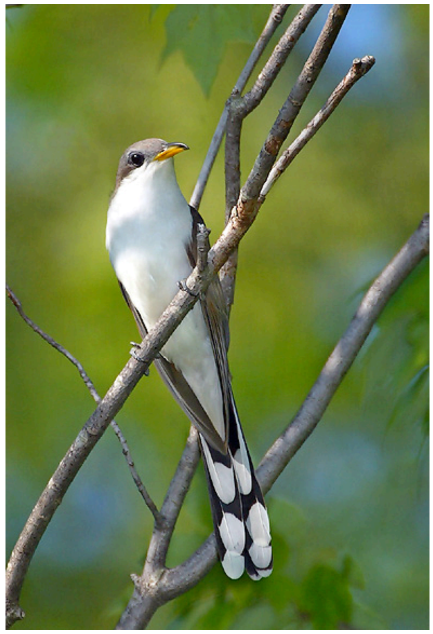


Figure 11. (Left) graph shows the contrasting difference between number of birds fledged in parasitized Southwestern Willow Flycatcher nests versus unparasitized nests. (Right) Population growth rates of the Kern River Population are significantly associated with parasitism rates. Lambda above 1.0 represents increasing populations, below 1.0 denotes declining population Solid circles represent years with no Cowbird management (1989-1991) and open circles represent years with Cowbird management (1993-1996) (Uyehara et al. 2000).

The fate of the Southwestern Willow Flycatcher is still unknown; however, of all the mechanisms of decline that face SWWF, the invasion of saltcedar and subsequent replacement of native willow-cottonwood habitat is likely not a major problem because since suitable habitat structure is needed, not species composition . The secondary fire regime instilled by tamarisk is a much larger concern. If native or mixed habitat stands burn, monotypic tamarisk will likely recolonize, eliminating the crucial structure necessary for SWWF. The insufficient thermal buffering of nests is a problem in monotypic stands and is further exacerbated by warming climate trends. Restoration to provide maximum heterogeneity in riparian habitats should be of utmost importance, preferably using native species and natural processes. It is possible that sufficient suitable habitat structure to maintain SWWF populations, within the Grand Canyon, may never be attainable short of human intervention.

Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)



Above Picture is of a Western Yellow-billed Cuckoo. Image courtesy of AJ Hand (www.ctbirding.org/ raptors_to_cuckoos.htm).

The Western Yellow-billed Cuckoo (WYBC) was extirpated from the Grand Canyon less than a decade after Glen Canyon Dam was built. However, though planned restoration efforts, the WYBC may find refuge along the Lower Colorado River below the canyon.

The WYBC, a subspecies of the Yellow-billed Cuckoo, shares many natural history similarities with those of the SWWF. The SWWF and the WYBC both require riparian habitats to breed. WYBC have not been seen in the Grand Canyon since late July, 1971 (Brown et al. 1987).

While the breeding range of the Cuckoo originally extended from northern Mexico all the way to the southwestern corner of British Colombia, it has suffered an extreme range contraction in the past 70 years (Suckling and Greenwald 1998).

The Cuckoo was last known to breed in Canada in the 1920s, Washington in the 1930s, Oregon in the 1940s and Northern California in the 1950s (Lymon and Halterman 1987). It now breeds in very fragmented, small, isolated patches (Figure 11).

Figure 12. This map shows the historic range of the Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*) in light red. The dark red represents extant breeding populations of the Cuckoo. This extreme example of range contraction is attributable to the widespread loss of riparian vegetation in the west in the last 70 years (Halterman 1991)

Cuckoo densities, local ranges, annual breeding and migration cycles are highly variable and are based largely on insect abundance and fluctuations (Clay 1929, Nolan and Thompson 1975). They are highly specialized species equipped to forage on anti-predator-adapted caterpillars, for example, caterpillars equipped with both toxins and hairy spines, specifically the Tent caterpillar, which is regularly taken by the WYBC in Arizona (Phillips et al. 1964).

However, unlike the SWWF, the WYBC requires extensive, continuous stands of mature willow-cottonwood habitat for breeding. While it was largely disproved that the SWWF nests only in native vegetation, the WYBC has been documented to nest in tamarisk a mere 2.5% of the time in an area now dominated by invasive tamarisk (Hunter et al. 1988). In addition, while the SWWF requires only 1.5-2.25 acre patches along the Colorado River to breed (Sogge et al. 1995), the WYBC requires 100-200 acres of willow-cottonwood habitat in excess of 600 feet wide to be considered “suitable” breeding habitat (Layman and Halterman 1989).

Due to the habitat requirements of the WYBC, it may be unreasonable to expect that the Grand Canyon to serve as functional WYBC breeding habitat due to canyon’s physical constriction of the riparian vegetation. The Lower Colorado River below Hoover Dam once represented the stronghold of the WYBC in this part of its range (Layman and Halterman 1987) and therefore provides an opportunity for successful restoration and recovery. In order for these efforts to be successful, poor management practices, such as flooding out 1400 acres of native willow habitat along Lake Mead to increase capacity (Suckling and Greenwald 1998), must be avoided in the future to prevent further loss of native riparian habitat. Likewise, delta inflows also represent points of possible colonization for the WYBC.

In December, 2004, the Lower Colorado River Multi-Species Conservation Plan was finalized, which calls for the restoration of 4,050 acres of native willow-cottonwood habitat (LCRMSCP 2004). If completed, this restoration should allow for the reestablishment of a modest breeding population of WYBC, not to mention benefiting a suite of other species including the SWWF.

Yuma Clapper Rail (*Rallus longirostris yumanensis*)

Above picture of two rails in typical marsh habitat. Image courtesy of Jim Zipp (www.ctbirding.org/ raptors_to_cuckoos.htm).

The Yuma Clapper Rail currently does not occur in the Grand Canyon. The critically endangered species is rarely seen, but heard in the marshes along the Lower Colorado River below Hoover Dam, north through Lake Havasu to Needles (Anderson and Ohmart 1985). In time, this species is likely to expand its range into the Grand Canyon

The Yuma Clapper Rail is unique in that it is the only Clapper Rail subspecies of twelve that utilizes freshwater habitats to breed (Anderson and Ohmart 1985). Therefore, unlike the others, it is the only one found inland from the coast.

One of the results of the altered flow regime caused by both Glen Canyon and Hoover Dams is the subsequent formation of marsh habitat. Such habitat is caused by the filling of backwater eddies with sediment and the subsequent colonization of vegetation. Not only is it probable that Yuma Clapper Rail numbers have improved as a result of more habitat, but it has been hypothesized that they are expanding their range northward (Anderson and Ohmart 1985). It is therefore conceivable that if marsh habitat is maintained along the Colorado River within the Grand Canyon and if Yuma Clapper Rails continue Expanding its range, populations will be able to colonize the marsh habitat west of Lake Mead and into the Grand Canyon. However, the Yuma Clapper Rail's expansion is limited by its fragmented habitat. Lake Mead currently represents an enormous obstacle in the course of range expansion and it may be worthwhile to artificially reintroduce Clapper Rails into the canyon.

Bald Eagle (*Haliaeetus leucocephalus*)

Above is a picture of a mature Bald Eagle with a fish in its talons, not unlike what can be seen in the Grand Canyon during winter. Image courtesy of Carol Simko and David Goodnow. (www.snew.freeuk.com/ goodnow1.htm).

As Bald Eagles rebounded from a severe population bottleneck, they began using the Grand Canyon as over-wintering habitat. Before the early 1980s Bald Eagles were rare transient visitors to the Canyon. They have since colonized the canyon exploiting a niche which wasn't available before the dam was built. The Bald Eagle was taken to the brink of extinction by organochloride (DDT) poisoning, reaching an all-time low in 1963 at an estimated 417 pairs. As one of the first species placed on the Endangered Species list in 1976, these birds faced a difficult path of recovery. DDT was banned shortly thereafter and the species has slowly been able to convalesce. The species was declared fully recovered in 2000, with approximately 7,678 pairs (www.baldeagleinfo.com).

Bald Eagles migrate south from their breeding grounds in Canada and Alaska to the contiguous United States and Northern Mexico (McClelland et al. 1994). Large aggregations of eagles have been measured and continued to rise in the state of Arizona, increasing from 225 individuals in 1992 to 440 in 2001 (Beatty 2001). Being primarily a piscivorous species, populations tend to gather along rivers where their preferred prey (fish) are in highest abundance (Grubb and Kennedy 1982). Bald Eagles were first observed along Nankoweap Creek, a Grand Canyon tributary, in the early 1980s, although it wasn't until 1987, when six birds were noticed, that they received any real attention (Brown et al. 1989, Leibfried and Montgomery 1993). In the Grand Canyon, Bald Eagle monitoring began in 1988 (Brown 1989).

Prior to the construction of Glen Canyon Dam, native fishes were abundant. Large fish were available; however, due to high sediment loads and turbidity, these fish were a difficult resource for eagles to exploit. Since the closure of the dam in 1963, clear, cold water is taken from the hypolimnetic zone and discharged via the penstocks. The water remains clear until, at tributary confluences, sediment enters the main-stem. This clear, cold water supports a prolific, tail-water, exotic rainbow trout population that Eagles are fully capable of exploiting. The slow, shallow water if the tributaries make fish even easier to catch (Stalmaster 1987). It, therefore, is a combination of the exotic fish and reduced sediment load which allows for one of the highest concentrations of over-wintering Bald Eagles in the southwestern United States (Brown 1989). It is only within this completely altered system that resource utilization by Bald Eagles is possible. Without the human manipulation of the river, the now productive over-wintering Bald Eagle habitat would not have been created. Figure 13 shows the relationship between trout and eagle numbers in Nankoweap Creek between 1990 and 1994.

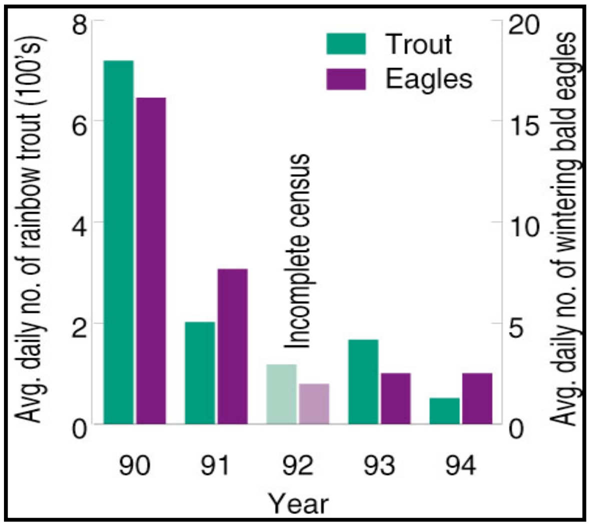


Figure 13. Average daily numbers of Rainbow Trout and Bald Eagles at Nankoweap Creek 1990-1994, showing direct correlation between trout and eagle numbers (Van Riper et al. N/D).

Osprey (*Pandion haliaetus*) and Belted Kingfishers (*Ceryle alcyon*) also benefit from the exotic trout, however Osprey are not residents of the Grand Canyon, so I will not mention them further.

Peregrine Falcon (*Falco peregrinus*)

Above is a picture of a Peregrine Falcon feeding its chicks on a cliff-side nest. Peregrines nest regularly in Marble Canyon between Lee's Ferry and the Little Colorado River confluence where cliffs in excess of 150 feet are abundant (www.hancockhouse.com/products/fasfal_pics.htm).

The Peregrine Falcon is another species that, like the Bald Eagle, is recovering following a very long stint on the Endangered Species List. Also, like the eagle, it has experienced a positive response since Glen Canyon Dam. Officially listed in 1970 to the Endangered Species Conservation Act of 1969, declines were attributed to DDT poisoning and eggshell thinning in the 1950s and 1960s. Since the banning of DDT in the 1970s and the release of over 6,000 reared falcons by The Peregrine Fund's captive breeding program, populations have been climbing see figure 14. The Peregrine was taken off the Endangered Species List on August 25th, 1999 (Mesta 1999). Since delisting, population numbers have continued to grow (USFWS unpublished data).

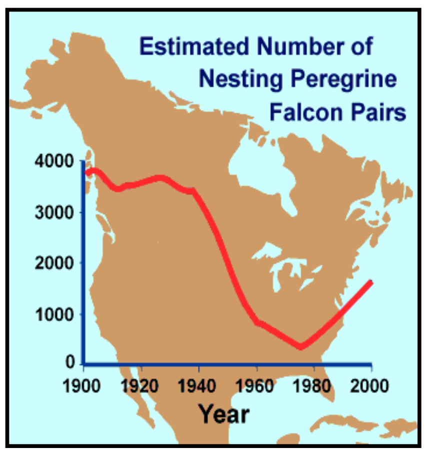


Figure 13. This graph shows the decline and recovery of the Peregrine Falcon (Connecticut Department of Environmental Protection).

While many Peregrines have recently begun nesting on high buildings and bridges, historically they require tall cliffs in excess of 50 meters as habitat. A source of water is also necessary, which likely correlates to adequate prey availability (Johnsgard 1990). Both these habitat requirements are met along the Colorado River in the Grand Canyon and therefore support one of the largest populations of Peregrines in the lower 48 states (Brown et al. 1991, Brown et al. 1992).

In the Grand Canyon, Peregrines take avian prey almost exclusively (96%) (Sherrod 1978). White-throated Swifts (*Aeronautes saxatalis*) and various waterfowl make up the majority of the Peregrines' diet (Brown 1991). Waterfowl have always been present in the Grand Canyon but, since 1963, there has been an observed increase in waterfowl populations (Brown and Stevens 1997). Therefore waterfowl may provide greater resource availability for Peregrines in one of the falcons already most reproductive areas.

California Condor (*Gymnogyps californianus*)

Above is a picture of a California Condor. There are no condors without patagial tags. These individualized tags affix to the wing and allow for easy identification and monitoring with minimal disturbance to the bird. Image courtesy of the Peregrine Fund.

Although unrelated to the construction or operation of Glen Canyon Dam, it is difficult to discuss Grand Canyon avifauna, without briefly mentioning the California Condor.

The California Condor became rare elsewhere in their range after their extirpation from the Grand Canyon at the turn of the 20th century. Competition for an increasingly scarce resource of large mammalian carcasses, coupled with being shot and poisoned are the causes for declines from historic numbers. As a result the California Condor became one of the first species listed under the Endangered Species Act.

Population declines continued throughout the 1970s and reached a critical level in 1982 with only 22 individuals. Frustrated, biologists enacted a desperate plan to save the species by capturing every single animal in the wild by 1987 and establishing a captive breeding program to release the resultant progeny into the wild. For five years, there was not a single condor in the wild. Finally, in 1992, captive-bred birds began to be released.

In December, 1996 a second "nonessential" population was established in the Grand Canyon National Park. At present, 45 Condors exist in the Grand Canyon with 14 more awaiting release (The Peregrine Fund 2005). The first chick hatched in the wild fledged in 2003 and two more in 2004 (The Peregrine Fund 2003 & 2004). This project will surely continue until multiple sustainable populations are established.

DISCUSSION

Glen Canyon Dam, under its current operation has benefited the canyon's avian occupants beyond expectations (see Appendix 1). Moreover, the potential for further colonization is very high. In order to maintain the best habitat for the greatest number of bird species maximum vegetation abundance and diversity should be preserved.

. From an avian habitat standpoint, the formation of new riparian vegetation along the floodplain and at the inflows of reservoirs has naturally mitigated for the loss of vegetation upstream as the dam filled. While the majority of this new habitat is non-native tamarisk, for many generalist riparian bird species, vegetative species composition is not significant. In fact, most riparian avian species that inhabit the Grand Canyon have extended both their range and populations.

Riparian specialists such as the Southwestern Willow Flycatcher and the Western Yellow-billed Cuckoo, may face future declines if riparian stands become monocultures of tamarisk. Management and restoration of structurally diverse, riparian habitat may allow for sustainable populations of both species to exist.

. I believe that the Grand Canyon has potential to serve as SWWF habitat, however, only after significant restoration effort, which may be costly. I do not believe that the current SWWFs in the Grand Canyon represent a stable population and therefore is not a justifiable restoration priority In Arizona, priority for conservation and SWWF protection should be placed on the Gila, Lower Colorado, Verde and Salt Rivers where substantial habitat exists and where, according to breeding surveys, SWWF preferentially breed.

The probability of catastrophic fire, in localized riparian stands, has been greatly increased by the tamarisk invasion. Timing of fire events could cause reproductive failure for any birds currently nesting in affected areas and a subsequent loss of future breeding habitat until vegetation is reestablished.

Restoration of the native flow regime may not be the answer either. Returning to the natural regime of scouring floods or large scale pulse-flow releases do not selectively remove tamarisk - it scours and/or buries all vegetation, causing an overall loss of habitat. Scouring flows should therefore be minimized. The restoration of tamarisk stands to native cottonwood-willow and/or supplementing existing stands with large woody species to maximize structural diversity is key to restoring habitat for riparian species.

Pollution accumulation is a wild-card factor that has been overlooked in a system where contaminants are concentrated due to the altered flow regime. Studies should be conducted to examine toxicant inflow from the Colorado River's tributaries. Contaminant levels should also be sampled in aquatic macro-invertebrates, the probable route of uptake by insectivorous birds.

Cowbirds are one of the biggest afflictions in riparian passerine birds, therefore trapping programs should be initiated to reduce parasitism rates. Furthermore, restriction of heavy grazing and human disturbance near known riparian breeding habitats needs to be implemented to reduce Cowbird presence. They represent a significant threat along the river corridor which negatively affects riparian breeding birds. Parasitism rates need to be lowered substantially to maintain healthy populations. However, creating habitat structure should remain the top priority.

If geologic processes, such as sediment transportation and interannual variability, were restored, there would likely be a negative response by waterfowl and trout, which could reduce resource availability for bird species dependant upon them. Subsequently, overall habitat quality would be reduced and we could see reductions in Bald Eagle and Peregrine Falcon numbers.

The result is a balancing act of management decisions regarding what to preserve and how to restore what has been, and is currently being, lost. Managing for biodiversity focus must be emphasized on endemic (first priority) and rare species (second priority).

Because humans have interfered to the point where action is required to manage the ecosystem, decisions must be made relative to where focus and funds should be placed. In the case of the Grand Canyon ecosystem, the diverse species and processes are all represented by their own constituency, but many actions are mutually exclusive. Therefore, we must decide whether to preserve the native biodiversity in the Grand Canyon or continue with the current, economically profitable resource usage and face further ecosystem homogenization.. Either way, it is impossible to satisfy every constituency.

Appendix 1: Response of Grand Canyon Birds to Glen Canyon Dam

Species not listed here:

a) likely not affected by dam construction/operation

b) do not reside in Grand Canyon longer than for migratory stop over

Common Name	Response				Reason for Response
	Positive	May be Increasing	Negative	Unknown	
Acorn Woodpecker				x	Decrease in cottonwoods
American Coot	x				Increased marsh habitat
American Dipper		x			Increased riparian habitat
American Kestrel		x			Increased prey availability
Ash-throated Flycatcher			x		Decrase in OHWL* veg
Bald Eagle	x				Increased prey availability
Bell's Vireo	x				Increased riparian habitat
Belted Kingfisher	x				Increased prey availability
Bewicks Wren	x				Increased riparian habitat
Black Phoebe	x				Increased riparian habitat
Black-chinned Hummingbird	x				Increased riparian habitat
Black-chinned Sparrow				x	More information needed
Black-crowned Night Heron	x				Increased marsh habitat
Black-throated Blue Warbler				x	May be colonizing
Blue-gray Gnatcatcher	x				Increased riparian habitat
Blue Grosbeak	x				Increased riparian habitat
Brown-headed Cowbird	x				Increased human disturbance
Bullock's Oriole	x				Increased marsh habitat
Bushtit	x				Increased riparian habitat
California Condor	x				Human reintroduction
Cliff Swallow			x		Decreased nesting substrate
Common Moorhen	x				Increased marsh habitat
Common Yellowthroat	x				Increased riparian habitat
Coopers Hawk				x	Decrease in cottonwoods
Costa's Hummingbird			x		Decrease in desert vegetation
Crissal Thrasher				x	More information needed
Downey Woodpecker				x	Decrease in cottonwoods
European Starlings	x				Increased human disturbance
Flammulated Owl				x	May occur along river corridor
Great Blue Heron			x		Unknown (Webb et al. 2002)
Great -tailed Grackle	x				Increased riparian habitat

Common Name	Response				Reason for Response
	Positive	May be Increasing	Negative	Unknown	
Green Heron	x				Increased marsh habitat
Hairy Woodpecker				x	Decrease in cottonwoods
Hooded Oriole	x				Increased riparian habitat
House Finch	x				Increased human disturbance
House Sparrow	x				Increased human disturbance
House Wren	x				Increased riparian habitat
Indigo Bunting	x				Increased riparian habitat
Ladder-backed Woodpecker				x	Decrease in cottonwoods
Lazuli Bunting	x				Increased riparian habitat
Lesser Goldfinch	x				Increased riparian habitat
Lesser Nighthawk	x				Increased prey availability
Lesser Yellowlegs				x	May be colonizing
Lucy's Warbler	x				Increased riparian habitat
Magnificent Hummingbird	x				Increased riparian habitat
Marsh Wren	x				Increased riparian habitat
Northern Mockingbird		x			Increased riparian habitat
Peregrine Falcon	x				Increased prey availability
Phainopepla	x				Increased riparian habitat
Prairie Falcon	x				Increased prey availability
Red-winged Blackbird	x				Increased marsh habitat
Rose-breasted Grosbeak				x	May be colonizing
Ruby-crowned Kinglet	x				Increased riparian habitat
Say's Phoebe	x				Increased riparian habitat
Song Sparrow	x				Increased riparian habitat
Spotted Sandpiper	x				Increased marsh habitat
Vermillion Flycatcher				x	May be colonizing
Western Grebe	x				Increased open-water habitat
Western Kingbird		x			Increased riparian habitat
Western Sandpiper		x			Increased marsh habitat
Western Screech-Owl	x				Increased riparian habitat
White-breasted Nuthatch				x	Increased riparian habitat Decrease in cottonwoods
White-throated Swift		x			increased prey availability

Willow Flycatcher	x				Increased riparian habitat
Common Name	Response				Reason for Response
	Positive	May be Increasing	Negative	Unknown	
Yellow Warbler	x				Increased riparian habitat
Yellow-billed Cuckoo			x		Decrease native riparian habitat
Yellow-breasted Chat	x				Increased riparian habitat
TOTALS	43	6	5	13	

* OHWL - Old High Water Line, or zone 1 vegetation types, refer to figure 2

Primarily derived from (Brown et al. 1987)

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