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Bird Conservation Along the Lower Colorado River

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ABSTRACT
Riparian corridors in the southwestern deserts are among the most threatened bird habitat types in the United States of America. In the early 1900s, dams were built along the length of the lower Colorado River, the primary water source for the Southwest, to meet the increasing water needs of a rapidly growing human population. These changes altered annual flood regimes and disconnected the river from its historic floodplain, which dramatically reduced riparian corridors and affected the organisms that inhabit them. In this case study, we present an overview of efforts to conserve riparian birds, restore their habitat, and monitor their populations along the Colorado River. Our goal is to prepare students to think like a professional conservation practitioner who makes decisions that maximize conservation outcomes in light of limitations in local opportunities, budget, and political will for conservation. We also discuss how to determine effectiveness of conservation action, and manage adaptively to further optimize conservation outcomes as new data become available. We use the example of avian population data to describe the role of monitoring in assessing conservation needs, assessing the effectiveness of conservation actions, and the unique opportunity bird monitoring lends for citizen science by the birding public in conservation science.

LEARNING OBJECTIVES

By the end of this case study and its accompanying exercises, students will be able to:

1. Discuss the direct and indirect impacts of anthropogenic changes on bird habitats along the lower Colorado River.
2. Distinguish among different conservation actions, including habitat preservation, restoration, and creation, and debate the relative costs, limitations, and benefits of each in the context of the lower Colorado River.
3. Describe the role of long-term bird population monitoring in the context of conservation action and adaptive management.
4. Use long-term monitoring data to prioritize conservation actions and apply monitoring to adaptive management (Exercise 3).

INTRODUCTION

In the desert landscape of the southwestern United States and northwestern Mexico, the Colorado River forms a ribbon of life-sustaining water flanked by forests, scrubland, marshes, agriculture, and cities thriving on the use of this water. The forests and other natural communities dependent upon the river once stretched along the length of the lower Colorado River, from the end of the Grand Canyon to the river's terminus in the Gulf of California. Among the diverse flora and fauna in this region were large breeding populations of many species of birds (Grinnell 1914). Over the years, however, the lower Colorado River ecosystem has changed enormously as advancements in technology have allowed humans to store, control, and use the river's water. Logging, conversion of land for housing and agriculture, and unintentional introduction of non-native species have also contributed to the degradation of the native ecosystems of the region. Breeding populations of many native species of birds have declined in turn (Rosenberg et al. 1991). A number of initiatives have worked to preserve the river's ecosystems and its wildlife, including bird populations, and in recent years, research, funding, and action for bird conservation in this region has increased (e.g., see Figure 1). In order for these actions to be as effective as possible, research and monitoring are ongoing to understand the impacts of past and current conservation actions and inform future plans. Such long-term monitoring[1] ensures that planners and land managers have the best possible results in restoring habitat[2] for bird populations on the lower Colorado River.

This case study focuses on the nature of anthropogenic[3] changes to this river system, the measures being taken for species conservation, and how one can determine whether or not these conservation measures are effective.

*Figure 1. The Vermilion Flycatcher (*Pyrocephalus rubinus*) is a species covered under the Lower Colorado River Multi-Species Conservation Program. Concern for this species is largely due to a significant reduction in population numbers from current estimates to those calculated over 100 years ago. Photo credit: D. Fletcher.*

CONFLICT BETWEEN WILDLIFE AND HUMAN NEEDS

Limited water availability and a growing human population in the deserts of the southwestern United States have resulted in a conflict between the conservation of native species and urban and agricultural water needs. Historically, the Colorado River and its tributaries consisted of meandering rivers with a saturated floodplain[4] that often gave way to extensive wetlands. These wetlands were covered with muggy thickets of willows[5] and marsh vegetation, interspersed with majestic cottonwood[6] forests that depended on the river's very high water tables[7] and frequent flooding for survival and recruitment. In a desert environment, sensitive riparian wildlife depend upon these shady, cool oases. In fact, many riparian[8] bird species occur exclusively in these oasis environments (riparian-obligate[9] species).

Metropolitan areas, ranches, and agricultural fields also depend on water from the river, which provides the only large-scale supply of this limited commodity in the entire southwestern region. To accommodate water needs for development, several large dams were built in the early 1900s (including the famous Hoover Dam), which served to store river water for irrigation and municipal uses. The river was also deepened, straightened, and rip-rapped[10] (lined with rock to prevent erosion; Figure 2) to prevent flooding of settlements along the river and of the agricultural fields that had sprung up on the rich soils of the river's former floodplain. Riparian vegetation and wetlands were removed to make room for graded fields and housing. Together, these activities made much of the lower Colorado River ecosystem unsuitable for native riparian vegetation: the groundwater table became too low for their roots to reach, wetlands were cut off from the river, and regular annual flooding no longer occurred to provide its critical function in sprouting seeds of riparian plants.

Humans also introduced exotic plant species. For example, the invasive saltcedar[11] (*Tamarix* spp.) was brought from Asia as a windbreak tree in the 1900s, but soon spread throughout the rivers and riparian vegetation of the Southwest (Friedman et al. 2005). It now dominates large portions of all southwestern rivers, replacing native riparian vegetation in many places. This disrupted the nesting of riparian birds that previously depended on the cottonwood-willow woodlands growing in active floodplains. Saltcedar took hold in deforested areas, and turned out to be particularly tolerant of changing hydrologic conditions, as it can survive in locations where the groundwater table has dropped. However, many riparian birds, such as the endangered[12] Southwestern Willow Flycatcher (*Empidonax traillii extimus*), only find suitable nesting habitat in those stands that retain similar hydrologic conditions as intact cottonwood-willow forest, i.e., a high groundwater table that allows the soils to be

Figure 2. Rip-rap along the banks of the Colorado River. Photo credit: L. Harter.

saturated through most of their breeding season (Sogge and Marshall 2000, Hinojosa-Huerta 2006). Therefore, while saltcedar woodlands are abundant in many previously intact floodplain areas, many stands are unsuitable for most obligate riparian and wetland birds (Figure 3).

EFFORTS TOWARDS SOLUTIONS

Riparian bird communities have dramatically changed in the southwestern United States following the channelization and impoundment of the Colorado River for water, energy development, and flood control, all of which have caused widespread loss of riparian habitat[2]. In order to address such losses, the lower Colorado River region has become the focus of intense conservation efforts in recent years. The US Bureau of Reclamation (USBR), US Fish and Wildlife Service (USFWS), state agencies, and tribal governments are managing most of the remaining high-quality riparian areas in the region. Consequently, government agencies are leading conservation actions to mitigate habitat loss, create new habitat for threatened[13] and endangered species, and prevent new species from becoming threatened enough to be considered for protection under the Endangered Species Act.

The Lower Colorado River Multi-Species Conservation Program (or LCR MSCP) launched in 2005 with the goal of offsetting, or compensating, these losses in wildlife habitat through riparian habitat restoration and creation along the river. The LCR MSCP spans about 400 miles from Lake Mead, Nevada, to the Southern International Border between Mexico and the United States (Figure 4). The program is a multi-stakeholder partnership involving 57 different federal, state, and local government agencies; water and power users, and other interested parties. It is expected to cost over one billion dollars to complete over its 50-year lifespan (2005–2055). Thousands of hectares of cottonwood-

Figure 3. A dense thicket of saltcedar growing along the lower Colorado River. Photo credit: L. Harter.

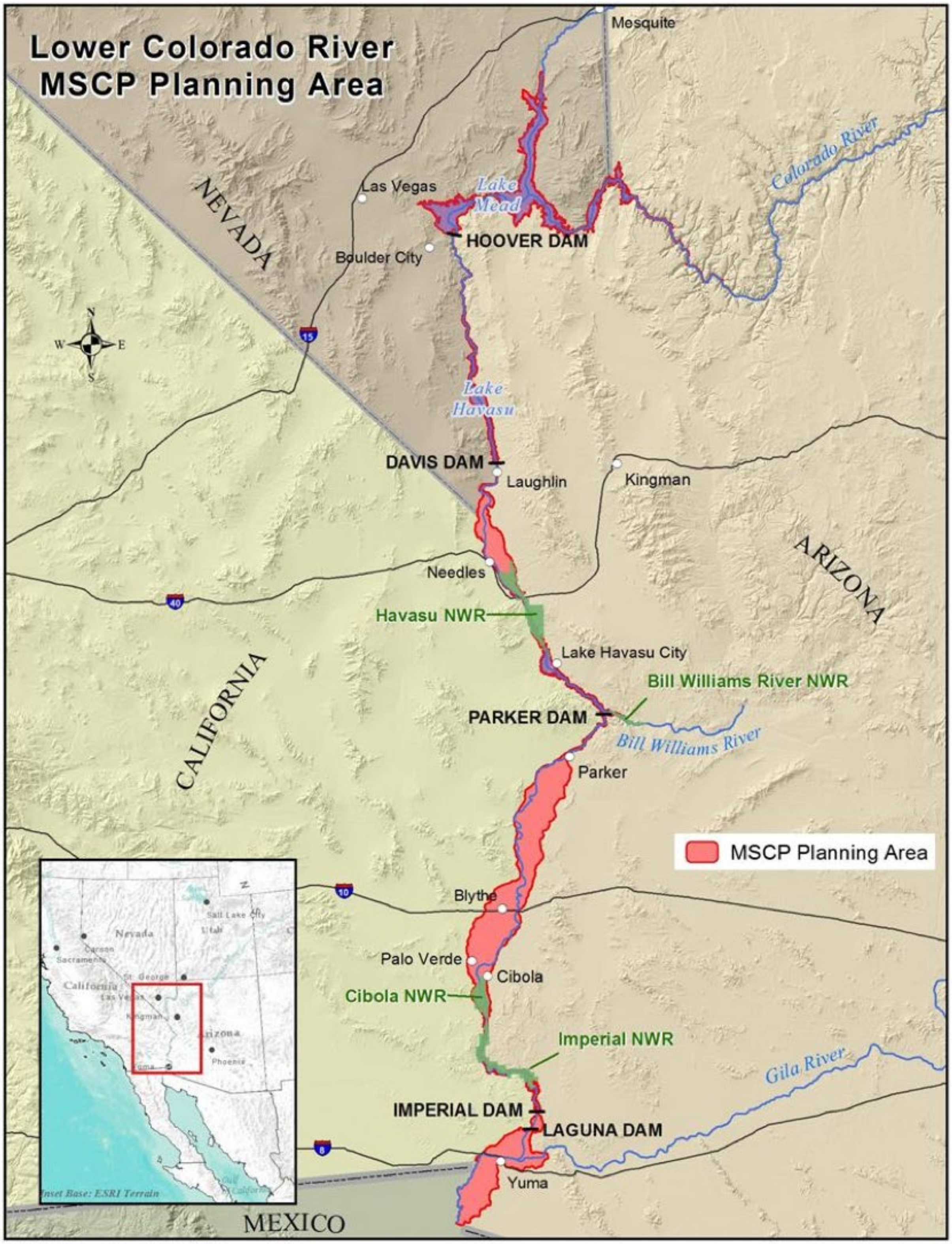


Figure 4. Map of the lower Colorado River Valley showing the LCR MSCP planning area. (NWR=National Wildlife Refuge). Image credit: Bureau of Reclamation / US government work.

willow and mesquite[14] plantings have been installed in retired agricultural fields, and existing wetlands and backwaters[15] have been enhanced to mitigate losses of fish and wildlife habitats to channelization and impoundments (LCR MSCP 2004). The participating stakeholders work together to implement this program through a steering committee to ensure that research is shared and that the program is making the best conservation choices based on the needs and goals of each group.

As part of the LCR MSCP program, riparian birds have been comprehensively inventoried and monitored since 2007 to determine the effectiveness of the program and to refine conservation actions taken. In this case study, we summarize some of these findings, their implications for local conservation action, and how large-scale bird survey data inform habitat management.

CONSERVATION PLANNING AND ACTIONS

Conservation planning under the LCR MSCP covers around 27 species, including insects, plants, fish, amphibians, reptiles, mammals, and birds (for details, see https://lcrmscp.gov/). The program works toward habitat conservation for covered species to balance human uses of water from the Colorado River with the conservation needs of species that are listed under the Endangered Species Act and other covered species that may be at risk of being listed. In this case study, we focus on the program's conservation efforts for birds.

The lower Colorado River is used by over 400 bird species during at least part of their life cycle (Rosenberg et al. 1991). The river forms a migratory corridor for birds moving between breeding and wintering areas, where these birds use riparian environments as stopover habitat to rest and refuel. At least 74 bird species use the area for breeding (GBBO 2018), 12 of which are targeted by the LCR MSCP because they are recognized under the Endangered Species Act as threatened or endangered, or else were determined by program scientists and other entities as species of concern[16], or sensitive[17], due to declining populations or loss of habitat based on information available at that time (LCR MSCP 2004). These 12 species are:

- Arizona Bell's Vireo (*Vireo bellii arizonae*),
- California Black Rail (*Laterallus jamaicensis coturniculus*),
- Elf Owl (*Micrathene whitneyi*),
- Gila Woodpecker (*Melanerpes uropygialis*),
- Gilded Flicker (*Colaptes chrysoides*),
- Least Bittern (*Ixobrychus exilis*),
- Sonoran Yellow Warbler (*Setophaga petechia sonorana*),
- Summer Tanager (*Piranga rubra*),
- Vermilion Flycatcher (*Pyrocephalus rubinus*),
- Yuma Ridgway's rail (*Rallus obsoletus yumanensis*),
- Western Yellow-billed Cuckoo (*Coccyzus americanus*), and
- Southwestern Willow Flycatcher (*Empidonax traillii extimus*).

In this case study, we focus on conservation efforts surrounding the sensitive landbirds Arizona Bell's Vireo, Gila Woodpecker, Gilded Flicker, Sonoran Yellow Warbler, Summer Tanager, and Vermilion Flycatcher.

Overview of Conservation Actions

All conservation actions come with different sets of opportunities, challenges, and limitations. The three basic forms of conservation action for this system are: 1) preservation, which involves protecting remaining functional riparian areas; 2) restoration, which involves improving existing riparian areas, so they can function better as wildlife habitat; and 3) creation, which is to create and maintain new patches of wildlife habitat. Most often, land managers decide which of these options to pursue on a given piece of land based on which lands are actually available for conservation action and what condition, in terms of habitat quality, they are in for the species targeted for conservation. Further, conservation practitioners are tasked with deciding a) how to spend a limited budget on different conservation opportunities available in a project area, and b) how to optimize their chances of a net benefit for wildlife across a landscape.

Habitat Preservation

In a few places along the Colorado River, patches of native riparian vegetation have survived and even thrived. Many of these patches are on protected land managed as riparian habitats by entities such as National

Wildlife Refuges, Tribes, state agencies, the Bureau of Reclamation, or state and county parks. Others, however, are still subject to commercial or agricultural development, or to degradation from a variety of factors. There are obvious benefits to protecting these places: it's usually the least expensive option for conservation action, and it prevents additional losses of wildlife habitat. These patches are typically characterized by high microhabitat[18] complexity. Different species might require decadent[19] trees and snags[20], large patches of riparian shrubs, marsh vegetation, or barren spots created by overbank flooding of the river. Microhabitat complexity is a critical concept in the conservation of riparian areas, because it allows for maximum species diversity.

Preservation may also be a good conservation strategy for some wildlife in areas with reduced microhabitat complexity, because such complexity may develop over time if a site is undisturbed. Preservation may sometimes be all that is needed to improve wildlife habitat quality, if certain land uses such as livestock grazing or off-road vehicle use are the primary source of habitat degradation. In addition, preservation may be used as a way to reserve the area for additional conservation actions in the future, such as restoration (see next section).

The main constraint on habitat preservation in this region is the limited amount of land that still functions optimally, or close to optimally, as riparian wildlife habitat; in other words, there is only so much land left to preserve. In other regions, preservation can also be accomplished through conservation easements in working landscapes, where agriculture, such as livestock production, can persist while minimizing livestock damage to the most sensitive wildlife habitats, and many examples of successful marriages of wildlife conservation in working landscapes exist (e.g., Charnley et al. 2014). Most historic riparian areas of the lower Colorado River, however, now consist of dry uplands that have minimal value to riparian wildlife, and landscapes on the former floodplain consist primarily of high-intensity agricultural fields. Remaining intact riparian stands (i.e., those that are dominated by wet soils and complex native vegetation) are relatively scarce and tend to be small in size (often less than 30 hectares). While even the smallest patch of native riparian vegetation is sufficient for some riparian bird species (such as the Western Kingbird and Black-chinned Hummingbird), larger patches tend to provide habitat to more species. For instance, a single pair of the threatened Western Yellow-billed Cuckoo requires patches of at least 20–40 hectares to breed (USFWS 2013). Larger preserved areas also generally have greater microhabitat complexity, since increasing microhabitat complexity requires increasingly large areas. Finally, another limitation on preserving high-quality habitat areas is that these areas are often located immediately adjacent to lakes, backwaters, or other reliable water sources, areas that are often the most valuable to developers, driving up the political and financial costs of protecting them.

An Example of Preservation Within the Lower Colorado River Region

There are four National Wildlife Refuges within the lower Colorado River region (Figure 4). Imperial National Wildlife Refuge is one example of habitat preservation on the lower Colorado River (Figure 5). While the riparian ecosystem of this site has been altered by human activity such as upstream dams and invasive species, the river bank in this 30-mile reach has not been rip-rapped. This means that water is free to flow into side channels and backwaters, supporting large stands of complex microhabitats. Among saltcedar stands, the refuge also includes healthy stands of cottonwood-willow, arrowweed[21] and mesquite-dominated desert washes, and extensive marshes. These stands support a high abundance and diversity of breeding and migrant birds, making it a success story of habitat preservation.

Habitat Restoration

Another possible conservation strategy is to restore riparian habitat in places where it is degraded, with the goal of improving its suitability for birds or other wildlife. Habitat restoration activities include managing water flows to simulate natural flow regimes, manually or chemically removing invasive species, and seeding or planting native vegetation. The costs of these interventions range from relatively inexpensive (e.g., hand-planting native trees by volunteers) to expensive (e.g., inundation with water through channel restoration).

Figure 5. Imperial National Wildlife Refuge. Photo credit: L. Harter.

Once restored, sites are usually preserved for long-term conservation, so restoration can ultimately have the same benefits as preservation of intact sites. In many cases, restoration is necessary to make a site valuable enough to be preserved for conservation, and it has the ultimate benefit of increasing the net area of habitat for many species that were previously not able to use the site.

Generally, restoration aims to achieve at least a simulation of the historic environments present at the site, even when it may take years for the newly restored conditions to take effect in terms of benefits for wildlife. Aside from trying to simulate historic ecosystem processes and conditions, restoration planners often adjust their project around the needs of a particular sensitive species. In these cases, it is important to begin a project with quantitative objectives and plans for how to measure success. Success is then measured with quantitative monitoring of bird populations or vegetation metrics[22] that describe habitat suitability for targeted birds, before and after restoration.

An Example of Restoration Within the Lower Colorado River Region: Managed Flooding

In a natural system, periodic flooding events are necessary for the seeding and growth of riparian plant species such as cottonwood and willow. Flooding scours areas where seeds of trees can sprout without competition and keeps the soils moist long enough for these seedlings to grow roots deep enough to reach the groundwater (Rood et al. 2003). Regular flooding also raises the groundwater table high enough to support the continued growth of healthy stands of trees (Molles et al. 1998, Merritt and Bateman 2012). Surface water also increases arthropod abundance, which is critical to the breeding success of many bird species (Gray 1993, Duguay et al. 2000, Iwata et al. 2003).

Considering the benefits to periodic flooding events, managers on the Colorado River actively manage for flooding, especially (and most effectively) in tributaries that are not rigidly managed for water delivery to meet human needs. For example, at Havasu National Wildlife Refuge, native willows are sprouting anew with additional water that is used to flood parts of the landscape. Also, when water is available, the US Army Corps of Engineers, in coordination with the Bill Williams River Corridor Steering Committee, strategically releases water from Alamo Dam upstream of the Bill Williams River National Wildlife Refuge timed to coincide with a natural flood cycle and the seeding of cottonwood and willow trees. This method has helped native trees to outcompete

Figure 6. Riparian forest on the Bill Williams River National Wildlife Refuge. Photo credit: A. Leist.

invasive saltcedar and maintain 58 kilometers of riparian forest, the largest stretch of mostly intact native riparian habitat along the lower Colorado River corridor (Figure 6; Shafroth and Beauchamp 2006). However, dams and river channelization permanently prevent flooding on much of the mainstem of the Colorado River and, thus, flood events have been all but eliminated along its lower reaches (Rosenberg et al. 1991), making this strategy of riparian habitat restoration, which is popular in other parts of the West, impractical along other parts of the lower Colorado River.

Habitat Creation

Habitat creation involves converting one landscape cover type into another, in such a way that continued human maintenance is required. Because many alterations to the Colorado River and its historic floodplain are permanent and irreversible, habitat creation can be used to mitigate for the loss of riparian areas elsewhere along the river. For example, as part of the LCR MSCP, over 1,800 hectares of different riparian habitat types[2] were created along the lower Colorado River as of 2015 (LCR MSCP 2016).

Habitat creation allows a site to be extensively redesigned and managed, from topography, water delivery, and other abiotic factors, to plant species composition. Moreover, because habitat creation sites may be located well above the groundwater table and may not be subject to seasonal flooding, a long-term plan for irrigation is often necessary. Therefore, long-term maintenance needs to be planned, and its costs may far exceed those of habitat preservation or restoration projects. On the other hand, because habitat creation sites can be established on relatively inexpensive landscapes (such as former agricultural fields or desertified[23] floodplain areas), large swaths of land can be secured for habitat creation for a lower per-hectare cost. For example, over 500 hectares of the Palo Verde Ecological Reserve were planted between 2006 and 2013 for habitat creation (LCR MSCP 2015), and this site is large enough to support a population of the threatened Western Yellow-billed Cuckoo with 49 breeding territories confirmed in 2014 (Parametrix Inc. and Southern Sierra Research Station 2015).

An Example of Habitat Creation Within the Lower Colorado River Region

A recent habitat conservation area of the LCR MSCP, called the Laguna Division Conservation Area, pioneers a new habitat creation design that was derived from an adaptive management[24] approach (see sections below). Based on the lessons learned from earlier habitat creation sites comprised of row plantings of native species, this newer approach attempts to provide additional microhabitat complexity, which some species may require. This large area (nearly 450 hectares!) was covered by dry upland saltcedar as recently as 2011, but is now being transformed into a patch-mosaic of native vegetation planted appropriately for the landscape contours, including transition zones of native vegetation that ties the riparian zone to the upland desert, mimicking naturally occurring riparian systems. An extensive marsh and open waterway, checked by artificial control structures that allow overbank flooding to mimic historic flood regimes, stretches through the area, flanked by cottonwood-willow patches of varying sizes surrounded by mesquite bosque[25] and other native upland cover types (LCR MSCP 2012). This area is still maturing, but very well may represent the latest improvement in maximizing a site's suitability for riparian birds through habitat creation.

The Job of a Conservation Practitioner

The job of a conservation practitioner requires integrating a complex set of issues into decision making in order to achieve conservation outcomes. When planning and managing a conservation project, the project manager must consider the biology and ecological needs of the targeted species, the ecological conditions and physical limitations of the site, the financial and political framework that overlays the project, and how to measure success, so that management is adapted based on new findings from effectiveness monitoring[26]. While daunting, it is also one of the most exciting and challenging careers for applying scientific knowledge to real-world problems.

Each of the three strategies described in this case study—habitat preservation, restoration, and creation—are chosen based on the project site's attributes and resources available for conservation action. It is the job of the conservation practitioner to determine which action is most likely to be successful in a given project. Ornithologists, such as those working for governmental agencies, bird observatories, or other non-profit conservation organizations, can provide scientific data on birds from monitoring. This allows conservation practitioners to evaluate how successful their conservation actions were after enough time has passed for the ecosystem to respond (see below). These scientific data provide the basis for adaptive management, which allows conservation practitioners to refine their plans as needed based on results; for instance, to increase habitat suitability even further for the species targeted by the program.

On the lower Colorado River, conservation practitioners working under the LCR MSCP, have put into practice a number of conservation actions in order to preserve, restore, and create habitat for riparian birds and other wildlife dependent upon this ecosystem. Long-term bird monitoring in these areas is an example of how conservation projects can be evaluated in order to inform future projects and improve adaptive management decisions going forward.

Adaptive Management and Summary of Steps in Conservation Planning

All well-designed conservation strategies have an adaptive management plan, which takes advantage of data collected on earlier phases in the conservation project and new research. For instance, as part of their management program, the LCR MSCP conducted intensive research on the Elf Owl, Western Yellow-billed Cuckoo, and Southwestern Willow Flycatcher to learn more about each species and its habitats. The results of this research were then used to improve habitat creation designs and management, and to determine the most effective methods for species monitoring. Early phases of conservation action are monitored quantitatively in terms of achieving initial goals (e.g., particular plant densities and vigor) and in terms of target species colonization (e.g., number of Willow Flycatcher territories after conservation action compared to before). Research on what environmental factors allow a bird to nest successfully in a given habitat patch and what methods will allow researchers to quantify its occupancy and abundance in different sites are critical to achieving conservation success in the long term.

The key to successful adaptive management is the use of quantifiable data collected to determine effectiveness of particular strategies, for example, what age-class distribution of trees is most suitable for nesting of a bird species, or how far from saturated soils we can expect a particular bird species to nest. As these habitat suitability criteria become known in greater detail and in a quantifiable way, adaptive management allows a conservation program to become more and more biologically- and cost-effective over time. But, the continual refinement of adaptive management requires ongoing monitoring to capture and incorporate new information from the dynamic and changing system. In summary, Figure 7 displays the basic steps in habitat conservation planning for bird species in the lower Colorado River.

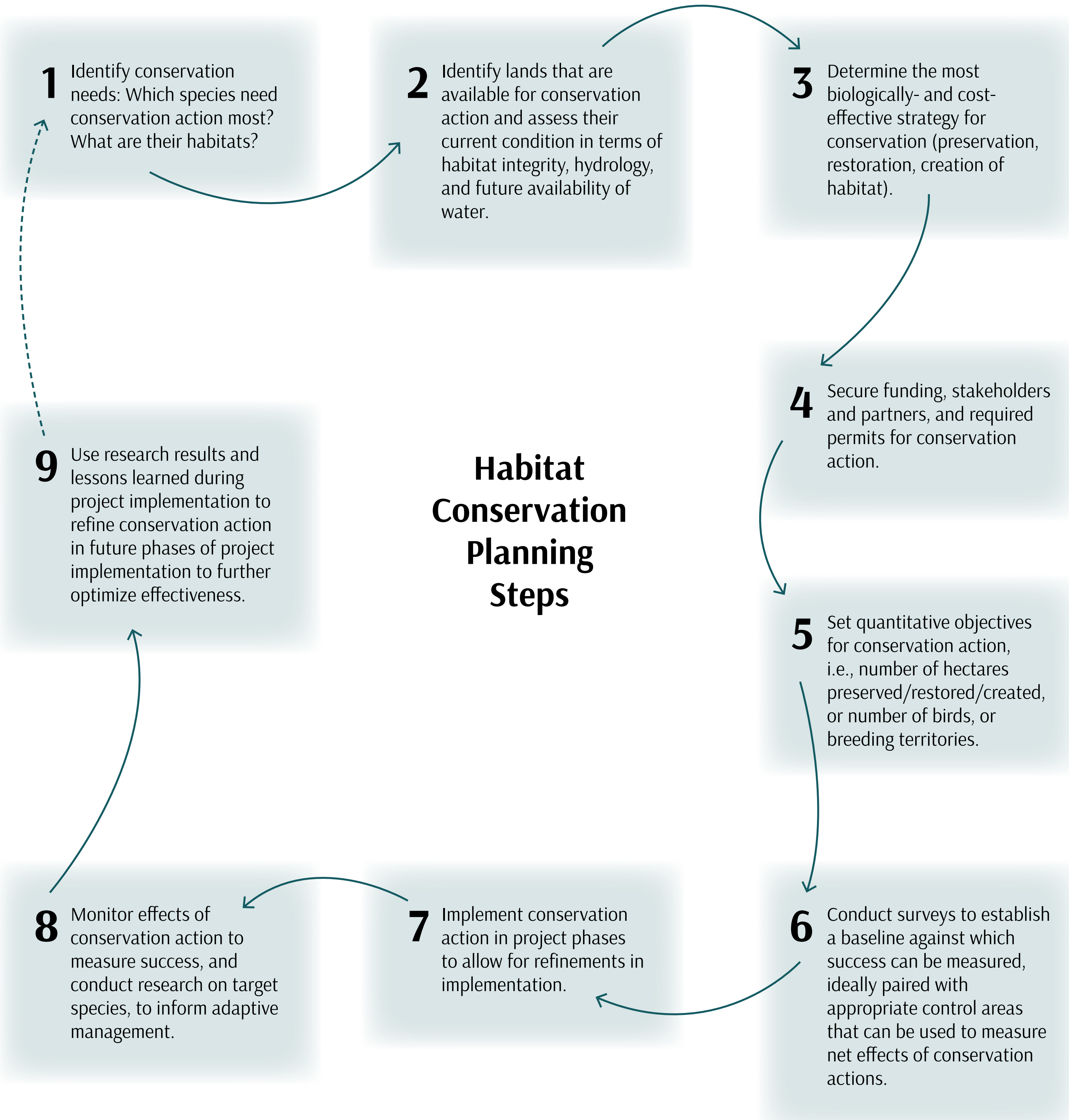


Figure 7. Habitat conservation planning steps for bird species in the lower Colorado River.

LONG-TERM BIRD MONITORING IN CONSERVATION

With millions of dollars being spent on conservation actions along the river, it is essential to document whether or not these programs are effective in meeting their goals and quantitative objectives. Monitoring serves the function of evaluating the initial "best shot" implementation plan and then continues to provide real time feedback on the effectiveness of specific conservation actions. As part of this, it is also important to monitor control sites where no conservation actions have been taken, in order to account for regional population dynamics that are independent of local conservation programs when evaluating their effectiveness.

The avifauna of the Colorado River was documented in the scientific literature during the 1860s by various explorers (e.g., Coues 1878); however, the first semi-comprehensive inventory did not take place until 1910, with Joseph Grinnell's Colorado River expedition. The Colorado River was still in a relatively undisturbed state then, prior to most dam construction (Grinnell 1914). Grinnell floated the river from Needles, California to Yuma, Arizona, and reported abundant sightings of riparian and wetland birds such as Bell's Vireo, Yellow Warbler, Vermilion Flycatcher, Yellow-breasted Chat, and Summer Tanager. This section of river was not surveyed again extensively for bird species until the mid-1970s, when researchers from Arizona State University found that the species that had experienced the most dramatic changes since Grinnell's time were those that depend on cottonwood-willow forests (Anderson and Ohmart 1984; summarized in Rosenberg et al. 1991). Species such as the Willow Flycatcher, Bell's Vireo, Summer Tanager, and Yellow Warbler had all but disappeared in many places, particularly where native vegetation was lost or replaced by saltcedar (but see Box 1).

Today, birds are often used as a tool for measuring ecosystem response to conservation action because: 1) they are comparatively easy to monitor and bird monitoring techniques are already well-studied (e.g., Sutherland et al. 2004); 2) they are considered excellent indicators of overall environmental health because, as a community, they rely on a large variety of ecosystem features and services (e.g., Wiens 1989); and 3) they are often conservation targets themselves due to population declines (Rosenberg et al. 2016). Because birding is among the most popular outdoor activities in the United States (USDA 2002), bird monitoring also provides an excellent opportunity for the public to participate as citizen scientists in collecting bird population data (Dickinson et al. 2012, Tulloch et al. 2013).

*Figure 8. Costa's Hummingbird (*Calypte costae*) recorded during surveys. Photo credit: D. Fletcher.*

Box 1: The Yellow Warbler: A Story of Resilience

*Figure 9. Yellow warbler (*Setophaga petechia*), a species that has recovered on the lower Colorado River in recent years. Photo credit: A. Leist.*

Of all the songbirds nesting in riparian areas along the lower Colorado River, Yellow Warblers experienced the most dramatic changes in population densities. In the early 1900s, Grinnell found Yellow Warblers to be abundant and estimated that approximately four males occupied every 0.4 ha of cottonwood-willow habitat in some areas (Grinnell 1914). By the late 1970s, however, only one single successful breeding attempt was documented, and only a handful of singing male Yellow Warblers were found throughout the study area from Davis Dam in southern Nevada to the Mexican border (Rosenberg et al. 1991).

It is unclear why Yellow Warblers declined so sharply while other riparian species with similar habitat requirements declined less. Most notably, these birds disappeared even from large tracts of continually intact forest along a tributary of the Colorado River, the Bill Williams River. In addition to the loss of cottonwood and willow habitats elsewhere, Yellow Warbler populations also likely experienced increased brood parasitism from Brown-headed Cowbirds, which increased regionally with the expansion of agricultural lands. Perhaps the invasion of saltcedar was the last straw for already fragile populations of Yellow Warblers. Even within relatively intact riparian forests, saltcedar was able to get a foothold and filled in gaps in the canopy and the understory layer.

Since the 1970s, Yellow Warblers have rebounded significantly; current population estimates are around 1,786 pairs for the Great Basin Bird Observatory study area. This species has returned to areas it historically occupied, and even uses breeding sites with a significant saltcedar component if there are moist soils and at least a few native trees. This rebound in numbers since the 1970s, and prior to widespread conservation action, may be an indication of the species' capacity for adaptation to habitats dominated by a newly introduced tree species.

Population monitoring takes time. Conservation practitioners need to be aware of both the length of time it takes for the conservation action to take effect (e.g., maturation of vegetation) and the time it takes for species to be able to respond. For instance, a freshly excavated wetland may only take one or two years to be colonized by invertebrates and marsh vegetation that provide habitat for wildlife; riparian woodlands, however, may take up to 15 years to mature. Some species also take time to colonize the site even after it becomes suitable. Therefore, the definition of long-term monitoring varies greatly depending on the project and the organisms involved. Strayer et al. (1986) define a study as long-term if it continues at least as long as one generation time as the longest lived organism within the study system or at least "long enough to include examples of the important processes that structure the ecosystem under study."

In the case of bird conservation on the Colorado River, the breeding cycles of most riparian songbirds are roughly annual so birds may respond to changes in available habitat within the course of a few years. Planted trees, however, require years to mature, thin out, intermix, recruit, and become decadent—all important factors in creating microhabitat complexity. Therefore, a tree planting project may attract far fewer breeding birds after two years than it would after 30 years of growth.

To account for this factor, the LCR MSCP is designed as a 50-year program.

Status of Riparian Birds of the Lower Colorado River

Beginning in 2007, the Great Basin Bird Observatory (GBBO) was contracted by the US Bureau of Reclamation to conduct surveys along the entire lower Colorado River. The purpose of this initial study was to estimate population densities and develop a program to monitor long-term population trends for riparian-obligate birds. Though all species present were recorded on datasheets, emphasis was placed on six species covered by the LCR MSCP: the Arizona Bell's Vireo, Sonoran Yellow Warbler, Summer Tanager, Vermilion Flycatcher, Gilded Flicker, and Gila Woodpecker. These were among the species that had experienced the most dramatic declines between the time of Grinnell's surveys and the mid-1970–80s.

Methods of the Monitoring Study

Between 2007 and 2015, GBBO monitored lower Colorado River riparian birds annually in both conservation areas undergoing habitat preservation, restoration, or creation, as well as in random plots throughout the lower Colorado River that can serve as control sites (Figure 10). The plots were also classified by vegetation type and, in the case of conservation sites, by amount of time since conservation action was taken. This information helps conservation planners to determine which vegetation types support which species and how long it takes those species to colonize sites after successful conservation action. Using these monitoring data, it is possible to estimate territory density for breeding birds in conservation sites and control sites throughout the project area by habitat type as a metric for bird population responses to conservation action.

Results of the Monitoring Study

The data collected since 2007 show dramatic increases in several bird species along the lower Colorado River since the 1970s, even when taking into account that different monitoring methods were used in different decades (Table 1). For example, the Yellow Warbler and Bell's Vireo, which were almost absent during the 1970s, had already begun to return to many places along the river prior to conservation action from the LCR MSCP. These rebounds can be attributed to many factors, as illustrated in Box 1. Other species appear to have

Figure 10. Trail clearing and data collection by GBBO staff. Photo credits: A. Arcidiacono, left; A. Leist, right.

*Figure 11. Cactus Wren (*Campylorhynchus brunneicapillus*) with nesting material. Photo credit: A. Leist.*

*Figure 12. Gila Woodpecker (*Melanerpes uropygialis*), a species covered under the LCR MSCP. Photo credit: A. Leist.*

approximately the same population levels today as in the 1970s—for example the Gila Woodpecker, which relies on trees big enough for excavating nesting cavities. Still other species that were present in the 1970s have now dropped to near zero. These include the Gilded Flicker, which was historically common in parts of the study area and is now nearly extirpated[12] in riparian habitats in the region. It is unclear why some species are resilient to major environmental change, while others are not, and only continued conservation research can illuminate possible underlying causes.

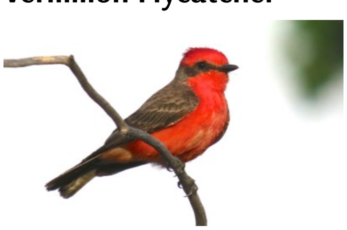
Many of the LCR MSCP target species are now using newly restored and created riparian habitat, as found in recent surveys of conservation areas (Table 1). Habitat creation sites have provided several species, including the Sonoran Yellow Warbler, Summer Tanager, Arizona Bell's Vireo, and Vermilion Flycatcher, with new habitat hectares that would otherwise have been unsuitable. Many species, however, still occur in lower numbers in habitat creation than in habitat preservation sites, while other species are still absent. Long-term monitoring is needed to determine what can be done to further improve habitat suitability, whether conservation actions simply need more time to become effective, or whether other factors not related to habitat needs may prevent the species from establishing territories in these areas.

Adaptive Management in Practice

The results of monitoring have contributed to adaptive management. For instance, starting in 2005, some of the first habitat creation sites were planted using the most cost-effective and efficient methods to achieve what was then known to be basic habitat requirements of the species covered by the program. This involved row plantings of one or two native species of trees (such as cottonwood, willow, mesquite, and Baccharis[27]) resulting in evenly spaced and evenly aged stands, which was easiest to implement and irrigate, while also having the advantage of shading out invasive species such as saltcedar. Even though this approach was effective in attracting some riparian bird species (e.g., Western Yellow-billed Cuckoo, Blue Grosbeak, Western Kingbird), other riparian bird species have not yet colonized these created patches.

Habitat models derived from monitoring data later indicated that refining the plantings would improve habitat quality. This finding resulted in new techniques for habitat creation and habitat management that result

Table 1. Historic and current population size estimates (by mated pair) for target species throughout the study area. Note that survey methods differed among studies, thus only major shifts in abundance are meaningful. Photo credits: A. Leist- Arizona Bell's Vireo, Gila Woodpecker, Sonoran Yellow Warbler, and Gilded Flicker and A. Arcidiacono- Vermilion Flycatcher.

SPECIES	GRINNELL (1910)	BIRDS OF THE LOWER COLORADO RIVER VALLEY (1974–1984)	CURRENT RESEARCH (POPULATION SIZE ESTIMATE 2011–2015)
Arizona Bell's Vireo 	Abundant	57% population decline during the period covered (100 pairs and declining)	Rebounding; 1,365 pairs estimated to be present
Gila Woodpecker 	Common and widespread	500 pairs estimated to be present in study area	Apparently stable; 573 pairs estimated to be present
Sonoran Yellow Warbler 	Numerous in cottonwood-willow	Considered to be almost extirpated from the Lower Colorado River Valley	Rebounding; 1,786 pairs estimated to be present
Gilded Flicker 	Common where saguaros[28] present	Fairly common in saguaros along the Bill Williams River, but rare elsewhere	Further declines; 22 pairs estimated to be present, only recorded nesting along the upper Bill Williams River
Summer Tanager 	Characteristic species of cottonwood-willow	Considered rare to uncommon; 69 pairs estimated to be present	Possibly rebounding; 262 pairs estimated to be present
Vermilion Flycatcher 	Numerous from Ehrenberg to Yuma	Drastically reduced; < 10 pairs found in the lower Colorado River Valley	Possibly rebounding; Very local, and very few in native vegetation; 112 individuals estimated to be present

in a "messier" and more complex mosaic of riparian tree plantings with mixed sizes and species composition, which studies have shown to be associated with higher bird diversity through resource partitioning than more uniform tree stands (e.g., Wiens 1989).

These considerations have informed the planting approaches used in newly created habitat sites, such as the Laguna Division Conservation Area, though monitoring will need to continue in order to evaluate the success of these "messy" habitats. It will take time for the woodland stands to mature and better reflect the habitat where targeted species naturally occur. For example, cavity-nesting species, such as the Gila Woodpecker and Elf Owl, rely on snags that occur in senescent[29] tree stands, and they are therefore expected to be among the last species that will be found nesting in created habitat on the lower Colorado River. Additionally, the system is dynamic in other ways (e.g., changing water demands and availability, climate change) and continued monitoring can help identify and address changing conditions.

Future Directions in Bird Conservation Science

Large conservation programs such as the LCR MSCP will always depend on government programs, often with many stakeholders who share both program costs and regional conservation benefits. Much like municipal and county planners seek to provide sufficient water and land for their residents, resource management agencies seek to secure and sustain natural resources including birds and bird habitats, particularly in the West, where public lands are abundant. To make conservation programs as effective as possible, government agencies and their partners focus much of their applied research effort on monitoring programs such as the one outlined here. Many times, birds and their habitats become rare before their conservation needs are fully understood, and large-scale monitoring that is paired with applied research often fills major knowledge gaps in our understanding of bird conservation.

Because of the complexity of conservation programs, as well as the ecosystems and species targeted by them, professional scientists and experienced conservation planners are needed to provide the best conservation strategies and actions for these programs. However, much has changed in recent years that opens up the possibilities of exciting and cost-efficient ways to empower programs with more and better data than was previously possible. For instance, many monitoring and conservation planning efforts now rely on drones that collect high-resolution geo-referenced photography of conservation sites or biological hotspots (Zahawi et al. 2015). Also, methods continually improve for surveyors to collect spatially explicit data by entering these directly on a tablet or smartphone into a geodatabase while surveying in the field.

Because of these technological advances, more opportunities have also opened up for citizen scientists to get involved in collecting critical data for advancing bird conservation science by recording bird observations, often through smartphones, into global databases that can be accessed and used by the public and researchers alike. The data collected have already been used in many important aspects of bird conservation including identifying the impacts of habitat loss, pollution, diseases, and climate change on bird populations; determining bird migration paths; documenting long-term changes in the numbers of bird species; identifying geographic variation in bird behavior; generating management guidelines for birds; identifying habitats that should be conserved; and advocating for the protection of declining species (Sullivan et al. 2017).

GLOSSARY

1. **Long-term monitoring** refers to standardized measurements of ecological metrics that allow us to determine population level responses of organisms to environmental change over an extended period of time.
2. **Habitat** refers to a species' required physical and biological environment. It can be measured through physical environmental variables, such as humidity, soil type, elevation, ambient temperature, average snowfall and rain, and many others, as well as vegetation, predators, food resources, and competitors present in the areas occupied by the species. Low-quality and high-quality habitat are often distinguished by land managers to identify areas that are associated

with low productivity and survivorship of the species with those associated with high population performance. **Habitat type** is a term often used by wildlife managers to describe the basic land cover (or vegetation) type in which the species can be expected to be found. The term **riparian habitat** has become standard usage by wildlife managers to describe the idealized environment for a group of wildlife species, such as those that require a riparian setting or other easily classified habitat type.

3. **Anthropogenic** describes the influence of humans on nature.
4. **Floodplains** are the areas within a river valley that may become inundated during flood events.
5. **Willow**: *Salix gooddingii* (Goodding's willow). large, dominant tree found in southwestern riparian forests. *Salix exigua* (coyote, or sandbar, willow): understory to midstory, shrubby tree often growing in dense stands in southwestern riparian forests.
6. **Cottonwood**: *Populus fremontii*. Large, dominant tree found in southwestern riparian forests.
7. **Water table** is the level of underground water, which in riparian and wetland areas is usually a function of the river and associated water bodies.
8. **Riparian** refers to vegetation types (or wildlife associated with that vegetation) and physical environments that are directly dependent on the conditions provided by a stream or river, including their high water tables and floodplain areas.
9. **Riparian-obligate** are organisms that occur exclusively in riparian ecosystems.
10. **Rip-rap** is material used to permanently stabilize a river channel, usually rock or concrete blocks.
11. **Saltcedar**: *Tamarix* spp. Non-native, invasive tree often dominating degraded riparian areas in the Southwest.
12. **Endangered** species are listed by a federal or state agency as being in danger of extinction or **extirpation** (local extinction).
13. **Threatened** species are listed by federal or state agencies as being vulnerable to endangerment in the near future based on population trends and/or habitat disturbances.
14. **Mesquite**: *Prosopis glandulosa/pubescens*. Native, common tree often associated with more xeric edges of riparian corridors in the Southwest. Dense, spreading growth form.
15. **Backwaters** are ponding water in still areas of a stream or river, which provide important habitat for sensitive life stages of various aquatic and terrestrial animals.
16. **Species of concern** are those species listed by various federal or state agencies or groups as being of conservation concern. These are not necessarily in danger of extinction or local extinction, but may have negative population trends or be rare and/or very locally distributed.
17. **Sensitive species** may be rare, locally distributed, and/or dependent upon a specific habitat type and thus are considered sensitive to anthropogenic influences and development.
18. **Microhabitat** describes the immediate physical and biological environment of a species' life stage (measured at a finer geographic scale than a species' overall habitat requirements, see #2).
19. **Decadent** refers to senescent (see #29) plants, often featuring dead branches and dying wood.
20. **Snag** refers to a dead standing tree, which provides important nesting opportunities for cavity-nesting wildlife.
21. **Arrowweed**: *Pluchea sericea*. Understory shrub, native and common in southwestern riparian areas. Occurs as an early successional plant, often dominating disturbed areas.
22. **Metric** is defined as a standard of measurement. For instance, one may use as a metric for breeding bird abundance the number of breeding territories (as opposed to the number of individual birds) to most accurately describe breeding bird response to conservation action in breeding habitat.
23. **Desertified** areas are those that have become more arid than they previously were.
24. **Adaptive management** is a structured, iterative process of robust decision making in conservation and land management in the face of uncertainty, aiming to reduce this uncertainty over time via system monitoring.
25. **Bosque** is a deciduous woodland associated with streams, rivers, or other sources of near-surface water tables. Sometimes used synonymously with riparian gallery forest.
26. **Effectiveness monitoring** is a specific type of monitoring in which an area is monitored following

a conservation action with the particular goal of assessing the effectiveness of that conservation action.

27. **Baccharis**: *Baccharis salicifolia/salicina/sarothroides*. Understory shrub found in southwestern riparian areas, often associated with wetlands and cottonwood-willow forest associations in riparian areas.
28. **Saguaro**: *Carnegiea gigantea*. Tall, columnar cactus with a single trunk and several arms, similar to a tree.
29. **Senescent** here refers to plants that are growing old or aging.

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