On the Wings of the Lower Colorado River:

Birds of Concern of the LCR MSCP

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Abstract

The riparian ecosystems of the lower Colorado River, an area spanning from Lake Mead to the border with Mexico, are used by over 400 bird species at some point in their life cycle and serve as a corridor for birds migrating between breeding and wintering grounds (Alder 2007). The LCR MSCP (Lower Colorado River Multi-Species Program) is a 50 year-plan involving 57 different agencies that covers 24 species listed under the Endangered Species Act (ESA) or that may be at risk for listing (Fletcher et al. 2019). The LCR MSCP works towards a collaborative goal to conserve native species and their habit along the river, recover ESA-listed species, and reduce the chance of future listings for other declining species. The use of digital platforms such as websites can further conservation education through images, video, sound, and interactive components. I created a website, www.OntheWingsoftheLCR.com, to serve as an interactive educational experience and tool focused on avian conservation to complement the "Bird Conservation Along the Lower Colorado River," a case study for undergraduate-level classrooms, featured on the Great Basin Bird Observatory (GBBO) website. Biologists and GBBO assessed the website content and interactive focus to provide feedback for users navigating the site. With this additional interactive educational website, a case study for classroom use has a complementary educational tool, providing a robust learning experience.

Introduction

The Colorado River, once an untamed ribbon of life, flows from the Rocky Mountains in western Colorado through the Grand Canyon and then meanders south, passing into Mexico and finally reaching the Gulf of California. The sign over the Hoover Dam reads "a vision of

lonely lands made fruitful," signaling the bounty of water created by taming the river into one of the most regulated rivers in the world.

Damming of the Colorado River began in the early 1900s; the famous Hoover Dam was created in 1935 and formed Lake Mead in the lower basin, and then Glen Canyon Dam formed Lake Powell in the upper basin. Both dams account for 85% of the entire basin's storage capacity and provide water for 25 million people and two million acres of irrigated farmland (Conway et al., 2010). Nine dams exist in the lower basin, which helps provide water to 40 million people.

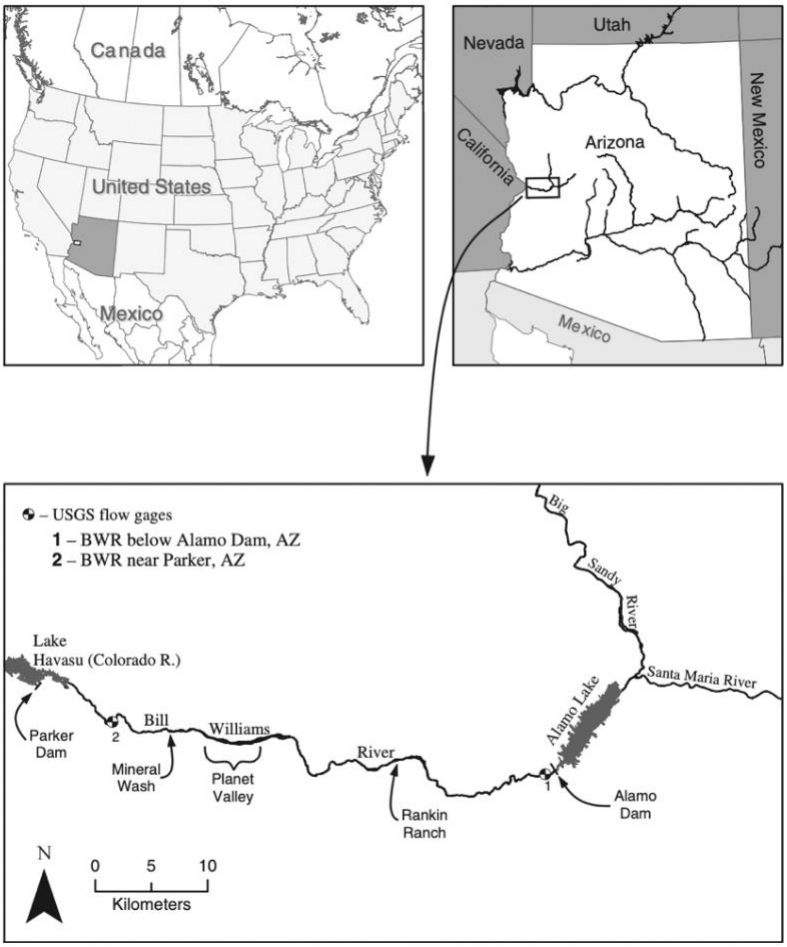

Figure 1: Map of the Bill Williams River (Credit: Shafroth et al., 2010)

The Colorado River offers a corridor of life for hundreds of wildlife species by creating critical wetland and riparian forest habitats. This outreach project provides information about the natural history of the lower Colorado River basin and one of its tributaries, the Bill Williams River, one of the last sections with extensive stands of native Fremont cottonwood (*Populus fremontii*) and Gooding willow (*Salix gooddingii*).

About the Will Williams NWR (National Wildlife Refuge)

The Bill Williams River flows through the Sonoran Desert in western Arizona (Figure 1). At 65 kilometers long, this tributary flows westward from the Colorado River. In 1993, an almost 2,500-hectare area, about 14.5 kilometers of the river, was selected to become the Bill Williams National Wildlife Refuge. The NWR is actively managed for wildlife through invasive species control, restoration and creation of riparian habitat, prescribed fire, and monitoring of plants and wildlife (Harshman & Maddock, 1993). A diverse array of wildlife calls the Bill Williams home, including 34 reptile species, 57 mammals, including bighorn sheep (*Ovis canadensis*) and cougars (*Puma concolor*), seven amphibians, 40 species of butterflies, 192 aquatic species, and over 355 bird species. Along with being one of the last remaining stands of native cottonwoods along the lower Colorado River, this NWR serves as an IBA (Important Bird Area) and as a stopover for migratory Neotropical birds as well as a breeding grounds for many birds, including endangered species such as the western DPS (distinct population segment) yellow-billed cuckoo (*Cuculidae americanus*), Yuma Ridgway's rail (*Rallus obsoletus yumanensis*), and southwestern willow flycatcher (*Empidonax traillii extimus*) (Alder, 2007).

Hydrology of the River

The Bill Williams River is a sand-bed river that begins its journey at the confluence of the Santa Maria and Big Sandy rivers and flows through red canyons and alluvial valleys to its confluence with the Colorado River in Lake Havasu. Since the construction of the Alamo Dam in 1968, the river has seen a 90% reduction in the magnitude of high flows. Prior to damming, the river had high flows due to flooding in the spring and later summer during the monsoon season. In the post-dam era, the high discharge flooding has been almost eliminated, as demonstrated in the streamflow data below (Shafroth et al., 2010)(Figure 2).

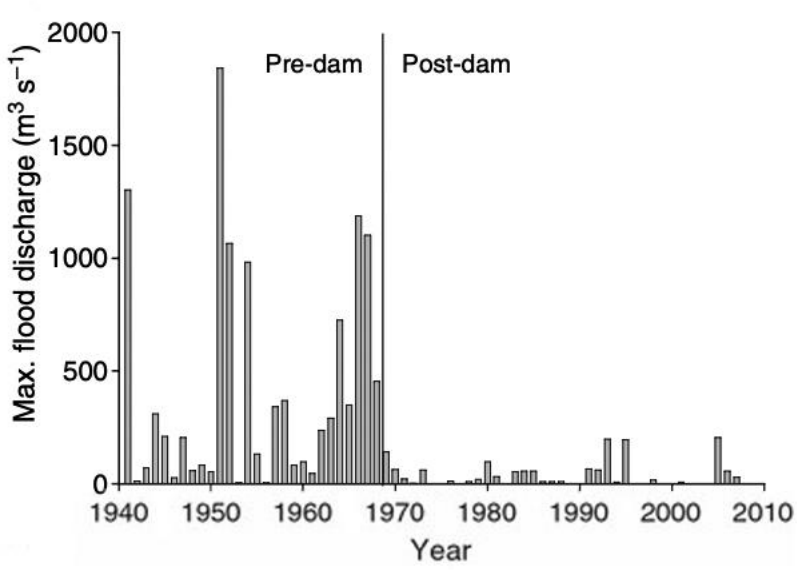

Figure 2: Pre-dam and post-dam streamflow data for the Bill Williams River (1940-2007), as measured at the "Bill Williams River below Alamo Dam" stream gaging station. Annual flood series. (Credit: Shafroth et al., 2010)

The impact of the Alamo Dam has decreased the channel width, increased the river sinuosity, and decreased the braiding index, all impacts to the river morphology by regulating the flows of the river (Figure 3). These changes led to a strong link between saltcedar (*Tamarix* spp.), an invasive plant, expanding on less-inundated land (with flow regulation) and saltcedar

lining the banks, thus simplifying the channel more. This biotic and abiotic feedback system has created a feedback loop in which the river channel's change is accelerated, leading to a more favorable river system for invasive species (i.e., saltcedar) and difficulty restoring a river to a pre-dam state (Kui et al., 2017).

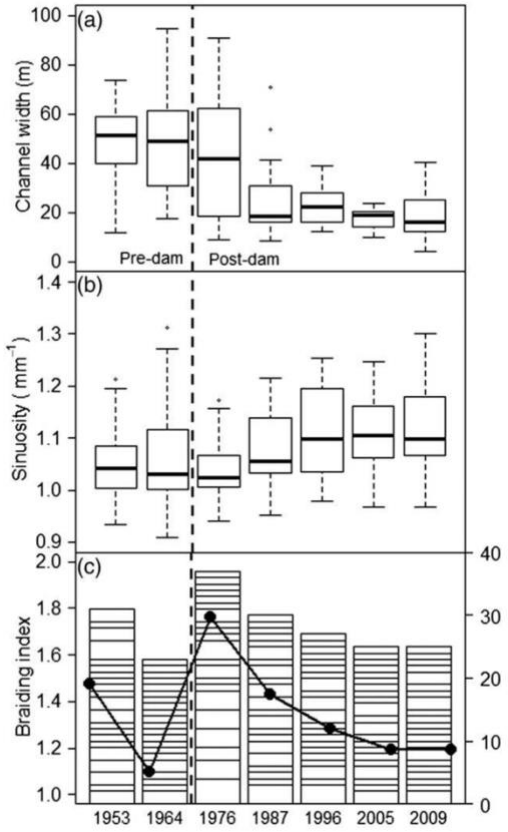

Figure 3: Changes in river channel (a) width, (b) sinuosity, and (c) braiding index pre -dam and post-dam. (Credit: Kui et al., 2017)

In the 1990s, stakeholders with interest in how the Bill Williams River is managed met and created an adaptive management plan. By using experimental flood releases, they aimed to define flows required to sustain desired riparian conditions within the river corridor to create habitat for native species. Adaptive flow management sets flow regimes using information about the relationships between hydrology and ecology. It then monitors river systems to

collect information used to adjust future flow prescriptions to achieve management goals (Shafroth et al., 2010). At this time, the Bill Williams River is deemed one of the eight rivers in the U.S. that are part of the Sustainable Rivers Project (SRP), a collaboration between the U.S. Army Corps of Engineers and The Nature Conservancy. The SRP aims to restore and sustain critical ecological functions of rivers that create habitat for native species while continuing to use dams as a resource for human needs.

In 2006 and 2007, experimental flood pulses intended to mimic pre-dam floods facilitated a reduction in saltcedar as measured during vegetation studies conducted by Shafroth et al. (2010) before and after the flood pulses. The results suggest that flood pulses could create conditions that are advantageous to native species. These results indicate that floods could support regeneration of native plants and facilitate habitat restoration. Currently, water is released through the Alamo Dam in the spring before cottonwoods release seeds and drawing down the flow, which allows for sufficient soil moisture for seed establishment without inundation (Shafroth et al., 2010).

Threats to the Lower Colorado River

Although the Colorado River provides the ability for agriculture, allocates water to cities of the Southwest, and hydropower, it has not been without a cost to the environment and organisms that inhabit and use the river. Anthropogenic impacts to the Southwest intensified with Anglo-American settlement in the 1870s and have continued to escalate as a limited water source has been overallocated in attempts to meet the needs of a growing population (Alder, 2007).

One of the biggest threats to the riparian system is habitat loss through the regulation of the river with dams and impoundments and the removal of vegetation and wetlands to make room for agriculture and housing. The alterations have made much of the lower Colorado river unsuitable for native vegetation. Wetlands were cut off from the river, and the groundwater tables became too low for trees to reach. Pre-dam flooding had once provided the necessary dispersal, moisture, and mineral substrates for seed germination and recruitment of native trees. Without regular flooding, native trees lacked the necessary dispersal, moisture, and mineral substrates for seed germination and recruitment (Fletcher et al., 2019).

Since the damming of the Colorado River, saltcedar (*Tamarix* spp.) has established and replaced native riparian plant species. Saltcedar was introduced from Eurasia as an ornamental and for erosion control in the 1800s. As the name suggests, it is salt-resistant and can tap into deeper groundwater than the native plants. Reduced inundation frequency resulting from altered flow regimes favors saltcedar as it can exist in high salinity and low moisture soils. The continual spread and domination of saltcedar can increase wildfire potential (Hinojosa-Huerta et al., 2013). Prior to dam construction, almost 450,000 acres of native riparian vegetation existed. Now, only 126,000 acres remain, with only 23,000 acres consisting of native vegetation (Alder, 2007).

The removal of saltcedar started in the 1950s with the goal of recovering water as saltcedar was assumed to take more of the native trees' water. When wildlife policies were established, saltcedar was thought to negatively impact bird populations and directly cause a quantifiable decline (Van Riper et al., 2008). In 2004, non-native tamarisk beetles (*Diorhabda carinulata*)

were introduced to the upper Colorado River as a biocontrol to reduce saltcedar through defoliation. As the tamarisk beetles spread much faster than predicted, many stands of saltcedar stood defoliated without a replacement resulting in reduced canopy, bare ground, and noxious weeds (Nagler et al., 2018). In studies in Utah and Colorado, 91% of the plants growing beneath defoliated saltcedar were highly invasive cheatgrass *(Bromus tectorum)* and Russian knapweed *(Rhaponticum repens).* (Hultine et al., 2010; Kennard et al., 2016; Nagler et al., 2018)

As the biocontrol unpredictably spread, numerous studies revealed that many bird species breed in saltcedar. The southwestern willow flycatcher, a federally endangered subspecies, often nests in saltcedar. There is a concern about their populations suffering as the beetles push into their habitat. Data collected for other avian species indicated no reduction in survivorship, productivity, or food base, suggesting that removal of saltcedar could result in a net decrease of the riparian habitat value for birds (Sogge et al., 2008, Van Riper et al., 2008).

A third threat is the impact of pesticides and agriculture on wildlife and humans. The agricultural industry along the Lower Colorado River basin relies on pesticide applications for high-yield crops. Of the little research done on contaminant impacts on the fish population, organochlorine pesticides such as DDT were present in some fish, which could impact the reproductive health of fish. Selenium leached from irrigated soils along the upper Colorado basin has been detected in high concentrations in fish which could decrease taxa richness in the aquatic community and bioaccumulate within the food web, ultimately negatively affecting humans (Hinck et al., 2007).

The last threat is the convergence of three factors that threaten the Colorado River's water supply: meeting the delivery burden of expected population growth, the plausibility of multiyear droughts, and probable flow reductions due to climate change. One model reveals that with a 20% flow reduction, which follows current trends, there is over a 50% chance of the river's reserves drying (Rajagopalan et al., 2009). A second model echoing that with predicted trends and an average rise of less than one degree Celsius will likely deplete reservoirs (McCabe & Wolock, 2007).

LCR MSCP

There is a distinct conflict between the conservation of the riparian ecosystem and its inhabitants and the urban and agricultural water needs. With the collaboration of numerous agencies in the face of unavoidable truths, management strategies have been put into place through conservation strategies such as habitat preservation, restoration, and habitat creation.

Habitat preservation can occur when a selected area may recover on its own if left untouched. Restoration occurs by managing water to mimic natural patterns, removing invasive species, and planting native vegetation. Quantifiable objectives are created and then can be assessed by monitoring bird populations or vegetative metrics. Habitat creation is the process of converting a landscape into a more desirable one, such as the creation of the Laguna Division Conservation area, which relies on planting a more complex mosaic of riparian habitat that is structurally staggered to promote more biodiversity. This newer adaptive management

contrasts with earlier programs of the 1990s that planted uniform rows of cottonwood and willow trees (Fletcher et al., 2019).

In 2005, a program was launched to achieve habitat restoration and creation, the Lower Colorado River Multi-Species Conservation Program (LCR MSCP). This 50 year-plan works with 57 different agencies and covers 27 species listed under the Endangered Species Act or may be at risk for listing. The LCR MSCP works towards a collaborative goal to conserve native species and their habit along the river, recover listed and threatened species under the ESA, and reduce the chance of future species listings. Many native species of the region's breeding bird populations have declined in the past century, with the most impacted being those reliant on cottonwood-willow forests (Rosenberg et al., 1991). Bird species of concern included on the LCR MSCP are the Arizona Bell's vireo (*Vireo bellii arizonae)*, Gila woodpecker (*Melanerpes uropygialis*)*,* gilded flicker *(Colaptes chrysoides*), Sonoran yellow warbler (*Setophaga petechia sonorana*), southwestern willow flycatcher, summer tanager (*Piranga rubra*), western yellow-billed cuckoo, California black rail (*Laterallus jamaicensis coturniculus*), western least bittern (*Ixobrychus exilis*), Yuma Ridgway's rail, vermilion flycatcher (*Pyrocephalus* obscurus) and elf owl (*Micrathene whitneyi)* (Fletcher et al., 2019).

Table 1: Federally Listed Species that Occur in the Bill Williams Wildlife Refuge

Common Name	Scientific Name	ESA Listing Status
Birds		
Southwestern willow flycatcher	*Empidonax traillii extimus*	Federally Endangered
Western yellow-billed cuckoo	*Coccyzus americanus*	Federally threatened
Yuma Ridgway's rail	*Rallus longirostris yumanensis*	Federally Endangered
Reptiles		
Sonoran desert tortoise	*Gopherus morafkai*	Candidate for listing
Northern Mexican garter snake	*Thamnophis eques megalops*	Federally threatened
Fish		
Bonytail	*Gila elegans*	Federally Endangered
Razorback sucker	*Xyrauchen texanus*	Federally Endangered
Humpback chub	*Gila cypha*	Federally Endangered

Birds reach every corner of our planet and can serve as indicators of ecosystem health because they show population-level responses to environmental changes (Fraixedas et al., 2020). Since birds are relatively easy to monitor and extensively studied, they often are focal species to research for ecological conservation (Sutherland et al., 2004). Aside from tangible benefits to humans, birds serve as cultural symbols and human inspiration. When I mention that I study birds, people tell me about their personal experiences with birds. It is always a positive experience, from watching a bird feed its nestling to feeling the presence of a bird signifies good fortune.

Since 2007, birds have been monitored along the riparian corridor of the Lower Colorado River as part of the LCR MSCP. The federally listed western yellow-billed cuckoo, southwestern willow flycatcher, and marsh birds are monitored in single-species programs. The Great Basin Bird Observatory monitors the remaining species. The Great Basin Bird Observatory is a non-profit organization of scientists with the mission "to further bird conservation in the

Great Basin and adjoining regions through applied research, partnerships, and education." Riparian birds are monitored along the LCR MSCP stretch of river from Lake Mead down to Yuma, Arizona, in conservation areas (i.e., the habitat preservation, restoration, or creation sites) and random plots to act as control sites. Long-term monitoring goals include defining habitat characteristics for target species, tracking populations statuses over time, and understanding response to created habitats to recommend adaptive management strategies for habitat creation and restoration (Fletcher et al., 2019).

The data that the Great Basin Bird Observatory has collected showed increases in some species from prior research by Grinnel (1910) and research conducted from 1974 to 1984 along the LCR (Rosenberg, 1991). The Sonoran yellow warbler and Arizona Bell's vireo appear to be rebounding; however, the gilded flicker is nearly extirpated from most of its historical range. Some target species such as the Sonoran yellow warbler, summer tanager, Arizona Bell's vireo, and Vermilion Flycatcher are using restored and created habitat sites. However, the use of created habitat sites is less than that of restoration sites. Further research will help address if more time is necessary for conservation or if other variables are the cause (Fletcher et al., 2019).

Conservation Education

The case study for a classroom lesson, "Bird Conservation Along the Lower Colorado River," created by Great Basin Bird Observatory, is a fundamental piece of conservation education. As we continue into a world deeply impacted by climate change, scarcity with dwindling natural resources and disappearing species, the need for education and outreach for the environment becomes increasingly important. While working with PRETOMA, a non-profit

organization focused on sea turtle restoration and outreach in Costa Rica, we connected with the community on the decline of sea turtles due in part to the poaching of eggs, used as traditional cultural food. A previous local poacher gained interest in our conservation and began working within the sea turtle conservation program after learning the impacts of poaching. Without public support, environmental conservation management plans are not feasible. Conservation education can help agencies create plans that integrate environmental concerns and public concerns and strengthen community involvement and support (Jacobson et al., 2015).

Often, outreach cannot be done with direct experiences and must be presented via scientific literature, workshops, or story-telling. I invite you to take a walk with me. Imagine we've trekked through the stark upland desert for hours. The sun burns so fiercely that your bones feel as if they are radiating beneath your skin. Sweat evaporates the moment it peeks out of your pores. We see the occasional glimmer of life, such as the evidence of a loggerhead shrike (*Lanius ludovicianusI*) in the form of a skewed lizard. In the cooler part of the day, the shrike eviscerated a side-blotched lizard by impaling it on a teddybear cholla (*Cylindropuntia bigeloviil*), a fuzzy-looking cactus armed with vicious spines. He was trying to impress a mate with this bold display of hunting aptitude. Another merciless crag of volcanic rock to conquer. You yearn for water. And then, as you deliriously crest the peak, the image of a lush, forested river paints the muted landscape with verdant hues. It is the Bill Williams River, a magnificent riparian corridor tucked between the Buckskin and Rawhide Mountains. If you were the early Anglo-Saxon explorers or a bird migrating north searching for breeding grounds, this would stop you in your tracks. Paradise.

What I just described illustrates a scene that I scientifically explained earlier. This likely created a visual experience in your brain as you read it. Although there is nothing quite like the actual experience of stepping foot into the tangles of willows, cottonwoods, and mesquite at the Bill Williams River, creating a visual reference creates a deeper connection to what is being learned (Bobek & Tversky, 2016).

What is learning? It is the process of understanding a concept where the learner can access already learned information, add to it, and synthesize it to create connections. The more this information is assessed and built upon with further information and experience, the more likely it is to retain in long-term memory and be available for future problem-solving. Jacobson et al. (2015) break the process down further to learning as a function of mental activity, experience and reflection, and social and environmental interactions.

Although scientific literature is the cornerstone of information and education, especially with undergrad and professional education, it is not the only means of conservation education. Immersive and interactive education can engage students in active learning, complement literature, and re-enforce their learning through multiple channels (Rau, 2017). Beyond offering a different perspective for scientific teaching, experiential education can create an emotional connection and inspire environmental protection. Years after teaching as a naturalist at an outdoor science school, I received a letter from a prior student that chose their college major of environmental conservation based on their time at outdoor school.

Visual digital art combined with technology such as the internet allows for the creation of websites that can carry with them text, images, maps, videos, sounds, and allow the user to be linked to other resources. The Monterey Bay Aquarium in California dazzles its users with

live webcams of their sea otters, kelp forest, and jellyfish for an immersive experience (https://www.montereybayaquarium.org). Like direct experiential learning, web-based learning invites learners to explore a nature-based scene that can mimic that immersion. By using digital content creation as a mode to expand literature-based education, conservation education can be more powerful. I have partnered with Great Basin Bird Observatory to create a website that will serve as an interactive educational experience focused on avian conservation. It will complement their case study, "Bird Conservation Along the Lower Colorado River," designed for undergraduate-level classrooms.

Methods

I researched primary literature for the two distinct aspects of my capstone, the Lower Colorado River and LCR MSCP birds and conservation education with Oregon State University library 1-Search and Google Scholar. Keywords ranged from "lower Colorado river conservation" to specific bird species being researched to "visual learning," "conservation education," and "environmental education." I already had papers from Great Basin Bird Observatory and fellow organizations I have worked with through the years on the Lower Colorado River and referenced them.

In addition, I searched Google for educational, interactive websites and was intrigued by The Monterey Bay Aquarium's use of interactive learning through live webcams of their exhibits (https://www.montereybayaquarium.org). CNN had a profound interactive page about the "ticking time bomb" of what ecosystems are being impacted by climate change (https://edition.cnn.com/interactive/2020/12/world/ticking-time-bomb/). This was the original

website Lauren Harter and Dawn Fletcher sent to me upon bringing up my initial idea to them over a year ago.

My first line of action for the website development was establishing a web and domain host with DreamHost and purchasing the domain "OnTheWingsoftheLCR.com." I used WordPress 5.9.3 coupled with Elementor Pro 3.6.4 as the framework for creating the web page. I have used both previously, and they offer the ability to integrate plugins that would be vital for the interactive landscape. WP Draw Attention was purchased as the plugin to create the interactive landscape as I had used it prior, and its interface is relatively simple to work with. I then made the layout after a mock sketch on paper of my site, including a home page, birds page, about page, references page, and interactive map page. My goal was to keep the website simple enough for not only undergrads to access or for the public to interrupt if they visit the site. By creating five pages, each page can serve its dedicated purpose, Home as a starting point, Birds for more information on each LCR MSCP bird, About for general LCR information, Reference to relay where to seek more detailed information, and Interact to host the interactive landscape.

Upon starting the semester, I had already reached out to Mel Preston, a biologist and scientific illustrator and former colleague. We set bi-monthly sessions to work out the details of the landscape together. After they created a final line drawing, we photographed it and imported it on the iPad to the illustration app called Procreate. We overlayed block colors for each drawing element and then layered a final sketch on top to convey depth and detail. The image was imported into WordPress and then into WP Draw Attention to create the backdrop for the interactive map. Each of the 12 LCR MSCP birds is woven into the drawing in its

respective habitat. When users locate the bird, they can hover over it to learn more information on that bird and link to the page dedicated to that species.

Each of GBBO's six target birds was photographed by a colleague or me and imported into Procreate on the iPad. Using an Apple Pencil, I referenced each photo to sketch each bird. I aimed for colorful images with fine pen strokes to define details to create a visually bold and compelling website theme.

Results

Home Page

The home page sits as the front face and landing page for the project. It features the project's title, "On the Wings of the Lower Colorado River," along with a header and footer. The header is on each page and displays a simple way to navigate the website. There are two calls to action, the About "Learn More" section, which takes the user to the About page and the "Come Meet The Birds" section, which leads users to the bird gallery.

About Page

The about page will discuss the background of the Colorado and Bill Williams River, identify what the LCR MSCP is, and address bird conservation. All website content is pulled from this paper's introduction.

References

This page lists all references used for the website and credits contributions from Lauren Harter and Dawn Fletcher of GBBO, Mel Preston for the landscape illustration, Keith Brennan for the drone Bill Williams River coverage, Bobby Wilcox for photos, Jarrod Swackhamer.

Interactive Landscape

The Interactive Landscape is the core interactive learning experience of this project. The backdrop is an illustration of the Lower Colorado riparian habitat based on a composite of the Bill Williams River. Using the WP Draw Attention plugin, a polygon overlays each of the 12 LCR MSCP birds in the scene. There are five habitats depicted where the birds nest. The upland desert features saguaros with the elf owl, gilded flicker, and Gila woodpecker. The mesquite bosque ecotone hosts the Bell's vireo and vermilion flycatcher. The cottonwood riparian forest hides the yellow-billed cuckoo, Sonoran yellow warbler, and summer tanager. The willow forest fittingly hosts the southwestern willow flycatcher. And the black rail, Ridgway's rail, and western least bittern secretively slink through the marsh cattails. When a user hovers over the area each bird lives, the polygon pops up, and they can click. A lightbox pops up with an illustration or photo of the bird and a few facts with the option to click and "Learn More," which redirects to the sole web page for the listed species. At the bottom of the lightbox is my interpretation of their song and an embedded mp3 file with their song, sourced from the website, Xeno-Canto.org, a site dedicated to sharing bird songs.

Birds

Vermilion Flycatcher

Habitat: The Vermilion Flycatcher, a flame-red bird, stands out as it perches atop desert riparian vegetation such as honey mesquite. Generally, a resident in the Southwest, Vermilion Flycatchers breed from South to Central America and Mexico.

About: Flycatchers are known for perching and then flying out to catch an insect and bring it back to their perch. This maneuver is called "sallying." During the breeding season, the male will puff his fiery plumage while singing and propel himself into the air, rising higher and higher over his territory.

Species of Concern: Considered a species of concern in California and placed on the LCR MSCP Multi-Species Conservation Program for its dwindling populations in the Lower Colorado River Valley, these stunning birds are impacted by loss of habitat and water management practices that have reduced annual flooding leading to the loss of native habitat (i.e., cottonwoods and willows).

Populations (along the LCR): One numerous along the Lower Colorado River, by the 1980s, less than 10 pairs were found. GBBO estimated just over 100 pairs in their 2015 analysis showing some recovers. They aren't often in native habit and seem to be pushing out of the Sonoran Desert into the Mojave with the creation of artificial habitats such as golf courses and suburban parks.

References: (Rosenberg, 1991) (Fletcher et al., 2019)

Sonoran Yellow Warbler

Habitat: The Yellow Warbler is found across the Americas, with breeding occurring in the United States and Mexico. The Sonoran Yellow Warbler is only found along the Lower Colorado River Valley into Mexico. It nests primarily in native cottonwood and willow trees lining the river.

About: Yellow Warblers build cup nests higher in the trees and encounter brood parasitism from Brown-headed Cowbirds. The cowbirds will lay their eggs in the nests of other birds and let their young be cared for by them! The Yellow Warbler will notice the new eggs and begin to build another nest on top of it. This is one of the threats that continues to threaten riparian nesting birds.

Species of Concern: Both a species of concern in California and part of the LCR MSCP Multi-Species Conservation Program, this dazzling bird was almost extirpated due to the loss of flooding along the Colorado River after damming. The habitat structure has changed from the river's extensive alteration through the loss of native trees due to invasive species and lack of natural flooding.

Populations (along the LCR): In the early 1900s, during Grinnel's exploration of the river, he recorded an abundance of Yellow Warbler. By the 1970s, only one breeding pair was recorded in the study area from Davis Dam to the Mexican border. However, by 2015, GBBO had estimated over 1700 pairs in the study area, a significant comeback. Yellow Warblers have seemingly adapted to the altered habitat, particularly by using the invasive saltcedar.

References: (Rosenberg et al., 1991) (Fletcher et al., 2019) (Shuford & Gardali, 2008)

Gila Woodpecker

Habitat: The charismatic and noisy Gila Woodpecker is found in the Southwest in southern Arizona, parts of California, Nevada, and into northeastern Mexico. They often nest in saguaro cactus but will use trees such as cottonwoods and willows.

About: They drill cavities to create their nesting site, which serves as a home for a secondary cavity nester such as an Elf Owl in future seasons. Exceptionally aggressive, they will defend a large territory around their nest.

Species of Concern: Listed as endangered in California, the Gila Woodpecker is a species of concern on the LCR MSCP (Lower Colorado River Multi-Species Program). Due to the loss of larger trees and large intact swaths of habitat along with competition from the introduced European Starling, the Gila Woodpecker has declined in California.

Populations (along the LCR): Once common and widespread, the estimated pairs in the 1970s were down to 500. GBBO estimates a similar number today, showing a population that remains stable. Gila Woodpeckers will likely be the last of the focal species to move into created conservation sites as they need aged, more extensive tree stands.

References: (Rosenberg et al., 1991) (Fletcher et al., 2019) (Hunter, 1984)

Arizona Bell's Vireo

Habitat: Their loud song can often be heard from the clumps of mesquite bosque (woodlands) and prefer early successional scrub and brushlands along riparian edges. The Arizona Bell's Vireo is a subspecies found along the Lower Colorado River and east throughout the Chihuahua.

About: These Neotropical birds migrate from Central America and Mexico by the stars in the night sky (as most migrating birds do). If you look closely, you can see a small hook on the vireo's bill, which they use to pummel their food, such as insects, before consuming. Yum!

Species of Concern: Listed in California as endangered, on the LCR MSCP (Lower Colorado River Multi-Species Program) and Audubon's Society's "Red Watchlist." Degradation of riparian habitat from agriculture and waterway modification is the cause of concern.

Populations (along the LCR): In 1936, this was a common breeding bird on the California side of the river. Based on Rosenberg's accounts, there was a 57% population decline from 1974 to 1984 with an estimated 100 pairs. Brown-headed Cowbirds increased due to agriculture along the river. These brood parasites lowered the breeding success of many birds, such as the Bell's Vireo, by laying eggs in their nests. The Arizona Bell's Vireo populations are rebounding with habitat protection and cowbird control.

References: (Rosenberg et al., 1991) (Fletcher et al., 2019) (Phillips, 1964)

Summer Tanager

Habitat: The Summer Tanager is a neotropical migrant that flies north from South and Central America and Mexico to breed across the southern and eastern United States. Along the Colorado River, they breed in cottonwood and willow forests and often in created conservation areas. Although so bright, they can be hard to see in the forest's canopy.

About: The male of this species is the only all-red bird in North America. He will sing a sweet robin-like song from his territory. When they eat bees (which they love), they will swipe them across a branch to remove their stinger.

Species of Concern: Listed as a Species of Special Concern in California and on the LCS MSCP (Lower Colorado River Multi-Species Conservation Program). The loss of riparian cottonwood-willow forests and the increase of Brown-headed Cowbirds are likely causes of the recent decline.

Populations (along the LCR): Grinnell's surveys in the early 1900s showed Summer Tanagers as common in the cottonwood-willow forests along the river. By 1983, 69 pairs were located along the Lower Colorado River Valley. GBBO estimated 262 pairs with analysis in 2015, an increase, although still a species in peril.

References: (Rosenberg et al., 1991) (Fletcher et al., 2019) (Hunter, 1984)

Gilded Flicker

Habitat: This desert-dwelling woodpecker breeds in southern Arizona, southern Nevada, southeastern California, and into Sonora, Mexico, and Baja California. They excavate their nesting cavities in giant cactus (i.e., saguaro and Mexican giant cardon).

About: This woodpecker is related to the common widespread Northern Flicker and shares similar behaviors such as the famous "wicka wicka" call and dance move. Two rivals or a pair will swing their head back and forth while facing each other and call "wicka wicka wicka" to each other. It's a popular dance move sweeping the west coast right now.

Species of Concern: Loss of riparian forests and saguaro cactus in the Lower Colorado River are the main reasons the Gilded Flicker is nearly extirpated from the Valley. It is also evident Gilded Flickers will not reside near human settlements, which are common along the Lower Colorado River since the introduction of agriculture. Wildfires also present further habitat loss as the

saguaro cactus, where they nest, can be killed. This flicker is endangered in California, on the Yellow Watch List for Partners in Flight, and included in the LCR MSCP (Lower Colorado River Multi-Species Conservation Program).

Populations (along the LCR): There was a 50% population decline in the United States from 1950 to 2014. As of 2015, only 22 estimated pairs remain on the upper reaches of the Bill Williams River. Future programs with the LCR MSCP involve the creation of artificial snags for nesting.

References: (Rosenberg et al., 1991) (Fletcher et al., 2019) (Rosenberg et al., 2016) (Corman & Wise-Gervais, 2005)

Evaluation

Evaluating websites and visual media can have many facets, and there are many styles of websites, just as there are many styles of writing scientific reviews. In "Conservation Education and Outreach Techniques," Jacobson states that the key is to make a site easy to navigate and read. Text should be concise with simple vocabulary and headings. Pages should be available through one click. Visuals should provide clarifying information (Jacobson, 2015). I aimed to follow these rules and keep the information contained in the website broad and easy to navigate. A website can go beyond clear design and ease-of-use by offering something innovative and different while building a relationship with the user. Beyond just telling the user about the Lower Colorado River, I invited the user to interact with the landscape and birds and created a deeper connection and investment.

After a draft creation of the page, I invited fellow biologists and colleagues to navigate around the page and provide feedback. Users reported design issues on different screens, so I re-evaluated my website from a mobile and tablet experience and removed elements that cluttered those screens. Users also suggested color-coding the interactive map with the five habitats of the river to make it clear where each bird(s) was. I addressed each issue or suggestion and provided a tweak to resolve it.

Discussion

From the initial settlement by European Americans in the 1800s to the creation of the dams in the 1900s to the beginning of conservation practices in the 1980s to adaptive management practices in the 2000s, knowledge or lack thereof, has profoundly impacted two centuries of the lower Colorado River's history and the life that it supports.

The future of the lower Colorado River and anthropogenic impacts will hinge on adaptive management efforts and the collaboration of agencies and public education. Addressing smaller scale dammed tributaries such as the Bill Williams River as a whole watershed within the lower Colorado River is necessary to restore a system in imminent danger.

Suggestions for Future Work Along the LCR

An immense consequence of human practices on the river has resulted in habitat loss which directly impacts birds. Thus, the need for adaptive management that can be adjusted as

critical research and monitoring is accomplished. A priority is to shift the initial focus of saltcedar removal to planting 20-40% native vegetation within homogeneous stands, thus increasing avian abundance in diversity, which is decidedly lower in pure saltcedar habitats (Van Riper et al., 2008). Prescribed fire is another suggested management practice that has shown a promising impact on increasing endemic marsh birds, especially Yuma Ridgway's rail, in wetland marshes. Fire mimics disturbance by removing built-up vegetation and functioning as a disturbance event that historically occurred with seasonal flooding (Conway et al., 2010).

Along with fire, simulated pulse floods could mimic natural floods and have begun implementation along stretches such as the Bill Williams River. In a study along the Mexican portion of the Colorado River, which undergoes unplanned flood pulses from agricultural spillage and overflow from the United States, researchers found despite the presence of saltcedar; there existed a higher abundance of native trees (Nagler et al., 2005) and bird densities that were ten times higher than the United States portion of the river (Hinojosa-Huerta et al., 2008). The last management strategy that has been proposed is managing regulated floods for beavers, as they can benefit the ecosystem by creating impoundments that increase water quality and invertebrate abundance (Andersen & Shafroth, 2010).

As drought and climate change become a new normal based on models, flexibility in current water management practices could mitigate some of the risks to reduced flows and reservoir capacities. These measures need to be implemented before significant signs of local climate change (Rajagopalan et al., 2009). In some areas, water recycling from wastewater

treatment plants is already being implemented, which will become more common in the water-scarce future.

Suggestions for Conservation Education about the LCR

A last vital requirement of future management along the lower Colorado River is the outreach and education of conservation strategies between all the river stakeholders, from agencies to the public. Web-based interactive learning experiences are crucial to the future of learning as distance education becomes more prominent in a post-Covid world. And education and outreach can extend beyond the classroom and act as a catalyst for change by igniting interest in the community.

In 2014, after decades of the Colorado River's surface flow rarely reaching Mexico's delta due to the United States diversions, the river was allowed to meet the ocean for three days in the one-day release of the Minute 319 project. Through social media, videos, and the locals' direct experiences, a deep interest in conserving the river rippled through the public (Bark et al., 2016). The lack of disconnect to the what, how, and who of the Lower Colorado River conservation and management crystalized this experience, demonstrating the need for conservation education beyond literature. With tools such as social media and web-based learning, education can reach farther and propel interest and involvement to shape the future life-force of the Lower Colorado River.

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