RESEARCH ARTICLE

Importance of Native Understory for Bird and Butterfly Communities in a Riparian and Marsh Restoration Project on the Lower Colorado River, Arizona

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ABSTRACT

The riparian and marsh habitats of the lower Colorado River, Yuma, Arizona have been degraded by flow regulation, agricultural development, and non-native species invasion. Degradation has caused a decline in birds and butterfly communities. To improve habitat, restoration efforts have occurred at the Yuma East Wetlands (YEW), Arizona. In this study, we evaluated the effect of on-going riparian and marsh restoration on the community characteristics of breeding birds, butterflies, and vegetation, including cover, nectar resources, and host plant abundance at the YEW. Results indicated that restored riparian sites had four-fold higher total resident bird density than control habitats; however no difference was detected in riparian bird richness. Restored marsh habitats had two-fold higher total resident bird richness than the control habitats and three-fold higher marsh bird abundance than control habitats. Butterfly species richness and abundance were higher in restored riparian sites. Butterfly richness was correlated with flowering plant richness and abundance, vegetation species diversity, and percent herbaceous plant cover. Restored riparian sites had four times more total forb richness and abundance and five times higher host plant abundance than control riparian sites. Restored marshes had higher percent herbaceous plant cover and lower percent open water than control sites. This study indicates the importance of planting diverse native grasses and herbaceous plants and shrubs in restoration projects to benefit wildlife species.

Key Words: desert riparian, Lepidoptera, wetland, wildlife recovery.

Restoration Recap

- Flow regulation and water development projects on the lower Colorado River have caused marsh filling, exotic species invasion, high soil salinities, and declining wildlife populations.
- Riparian and marsh restoration was conducted at 142 hectares in the Yuma East Wetlands, Yuma, Arizona, and included exotic plant removal, construction of backwater channels, and planting native trees, shrubs, forbs, and graminoid species.
- Planting native understory comprised of graminoids, forbs, and shrubs provides habitat for butterflies, birds, and other wildlife communities and competition for recolonizing exotic plant species.
- Flood irrigation mimics historic flood events, provides water to restored native vegetation, and is a water source for butterflies, birds, and other wildlife.

Flow regulation and water development projects along major river systems have dramatically altered the hydrologic regime, causing detrimental effects to the riparian and marsh habitats, particularly in the southwestern United States. Riparian and marsh plant communities, such as cottonwood (*Populus* spp.), willow (*Salix* spp.), and native bulrushes (*Schoenoplectus* spp.), that are dependent on pulse floods for irrigation, seedling recruitment (Rood and Mahoney 1990, Braatne et al. 1996), and germination (Brattne et al. 1996) have declined (Rood et al. 1990, Poff et al. 1997, Stromberg 2001). This coupled with agricultural development, timber harvesting, and non-native species invasion has altered habitats, allowing vast expanses of exotic species such as: saltcedar (*Tamarix* spp.), giant reed

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(*Arundo donax* L.) and other non-native reeds (*Phragmites* spp.) to dominate. Drying and filling of marshes, a lack of sediment flushing from flood events, and increased agricultural input have added to native species decline and non-native, salt-tolerant species dominance. These habitat changes have compromised ecological function and caused wildlife communities to decline (Power et al. 1996, Poff et al. 1997, Postel and Richter 2003).

Historically, the lower Colorado River once supported more than 400,000 ha of native riparian, marsh, aquatic, and intertidal habitat from what is now Hoover Dam to the Sea of Cortez (Phillips et al. 2009). In the past century, the habitats along the lower Colorado River have been greatly modified due to the construction of more than nine dams, timber harvesting, clearing for development and agriculture, and non-native species invasion. The disturbed and desiccated riparian and marsh habitats resulting from dams and development projects provided a competitive advantage for non-native vegetation, such as saltcedar and the non-native common reed (*Phragmites australis* ssp. *berlandieri*). Saltcedar was introduced around 1920 for windbreaks, to stabilize river banks, and as an ornamental plant. Currently, this highly invasive species dominates much of the riparian area along the lower Colorado River (Saltonstall et al. 2010). The sub-tropical common reed, has expanded to form a monoculture along the bank lines and marshes due to infilling and disturbance (Chambers et al. 1999, Saltonstall et al. 2010). These drastic changes to the riparian and marsh habitats on the lower Colorado River have reduced habitat for several resident and migrating wildlife species.

The effects caused by development projects and non-native species invasion have prompted large-scale efforts to restore native habitats. Riparian and marsh habitat restoration is burgeoning on the lower Colorado River with the primary goal of recovering wildlife species (LCR MSCP 2004; Phillips et al. 2009). To evaluate restoration success, researchers often measure structural habitat components and single species or class recovery, with few studies evaluating wildlife community recovery (Noss 1990, Golet et al. 2008). Evaluating the effects of habitat restoration on the recovery of wildlife communities can help establish success criteria for riparian and marsh restoration, determine if restoration techniques sufficiently address the needs of the wildlife community, and redefine restoration strategies.

Butterflies can serve as a good indicator of ecological health because larvae often have specific host plants (Nelson 2007), adults are nectar generalists, some species can quickly respond to environmental change (Erhardt 1985, Erhardt and Thomas 1991, Scoble 1992), and they occupy a broad range of ecological niches (Scoble 1992, Waltz and Covington 2004). Butterflies provide essential ecosystem functions, including pollination and energy transfer (Tallamy 2004). Studies have used them as ecological indicators for ponderosa pine forests (Waltz and Covington 2004) and riparian areas (Nelson 2007); however few restoration studies monitor the recovery of butterfly communities (Nelson and Wydoski 2008, 2013). Studies have shown that to restore a healthy riparian butterfly assemblage, restoration projects need to control exotic species and incorporate restoration of hydrologic processes, habitat complexity, host plants, and nectar sources (Nelson and Andersen 1999, Nelson and Wydoski 2013). However, restoration projects, particularly on the lower Colorado River, have not supported historic butterfly assemblages because compositional (presence of host plants), structural (closed canopies), and functional (hydrology, flowering phenology) diversity is lacking (Nelson and Andersen 1999).

Bird communities may quickly re-colonize areas that have experienced improvements in habitat quality, particularly in restored habitats (Passell 2000, Gardali et al. 2006). The structure and composition of vegetation often strongly influences the distribution of birds (Rotenberry 1985, MacNally 1990) and successful breeding strategies. As migratory and residential bird communities have declined on the lower Colorado River due to loss of habitat and invasion of exotic saltcedar (Anderson and Ohmart 1984, Hunter et al. 1988), restoration projects have prioritized bird community recovery within the region (LCR MSCP 2004, Phillips et al. 2009). Also, birds provide important ecological functions in riparian and marsh ecosystems, including pollination and predation. The relatively rapid positive response to habitat restoration and specific habitat requirements for many bird species makes this taxon ideal for evaluating ecosystem health and function.

The broad life history traits and important ecological functions that bird and butterfly communities have in riparian and marsh habitats make them good ecological indicators of vegetation community health. Therefore, the recovery of bird and butterfly communities is an important metric to evaluate restoration project success. In order to evaluate the success of riparian and marsh restoration along the lower Colorado River in the Yuma East Wetlands (YEW), Yuma County, Arizona, we evaluated the effect of habitat restoration on the richness and abundance of bird and butterfly communities. We also evaluated habitat structure and diversity and availability of nectar resources and host plants for butterfly species at restored versus control sites. We hypothesized that bird and butterfly richness and abundance would be greater in restored versus control sites. Also, we hypothesized that habitat structure and diversity and availability of nectar resources and host plants for butterfly species would be greater in restored versus control sites.

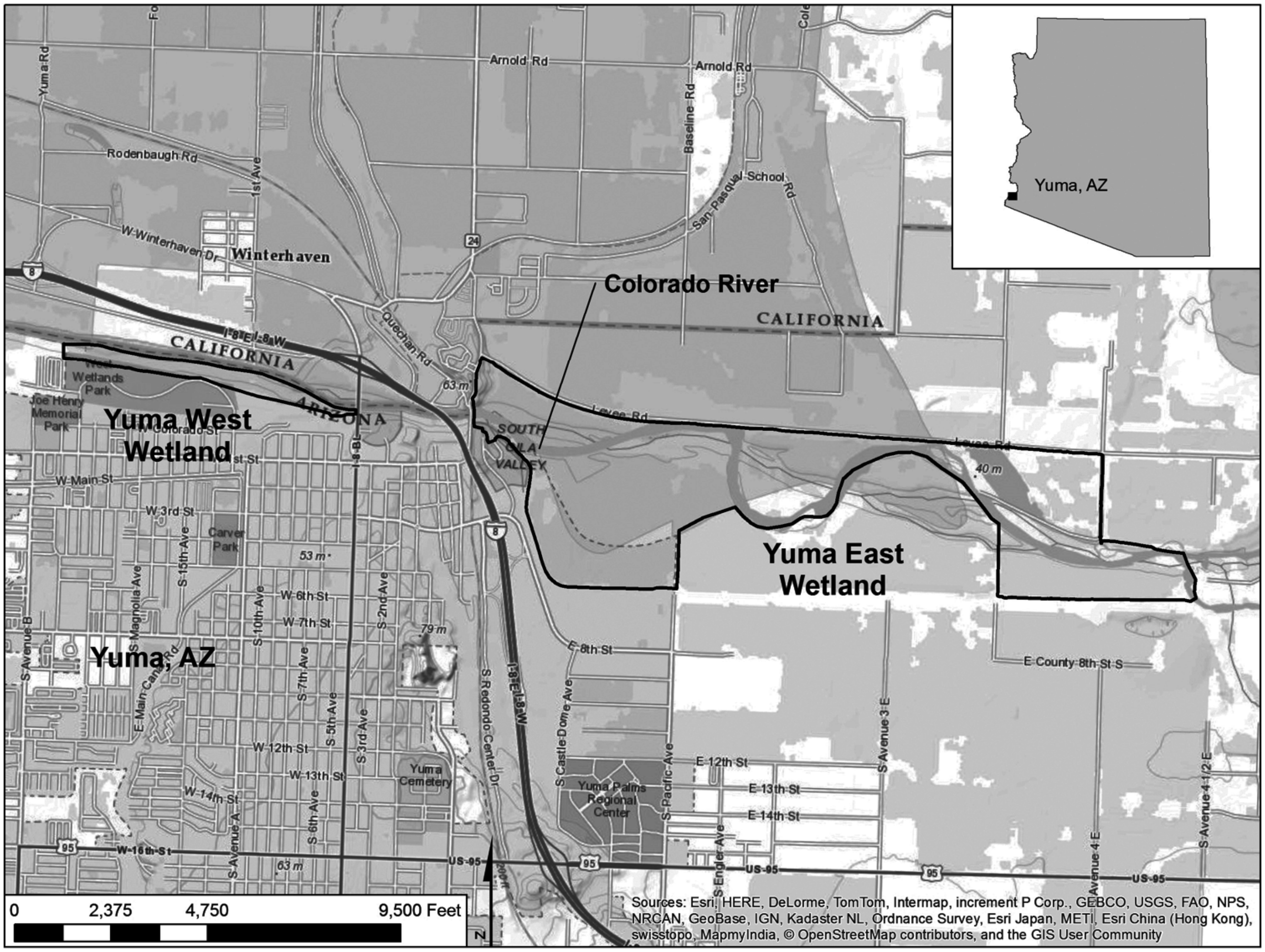

Figure 1. Location of the Yuma East Wetlands and Yuma West Wetlands in Yuma, AZ, US.

Methods

Study Site

The 566 ha YEW lies on the lower Colorado River, in Yuma County, Arizona (Figure 1). Almost a century of flow control activities, channelization, agricultural manipulation, timber harvesting, non-native species invasion, and unregulated dumping extensively modified the site. As a result, historic native cottonwood and willow riparian areas at the YEW have converted to monotypic stands of exotic saltcedar and invasive reeds. Increased sedimentation, a lack of water, and invasive plants also threatened the remaining native marsh habitat.

In 2001, the Yuma Crossing National Heritage Area (YCNHA) initiated the YEW Restoration Project as a multi-stakeholder effort to restore native riparian and marsh habitats (Phillips et al. 2009). A diverse group currently owns and manages the land, including: the Quechan Indian Tribe, City of Yuma, State of Arizona, U.S. Bureau of Land Management, and private landowners. The YCNHA used a collaborative process to secure funding, develop a project design, and implement projects. They have currently restored over 142 hectares of native riparian and marsh habitats.

Restoration activities included excavating a series of backwater channels (a total of 2.4 km) along contours of historic channels connected to the Colorado River. A series of stop-log structures, mimicking historic pulse flows, flood the channels and allow for flood irrigation to surrounding riparian and marsh habitats. Site alterations created approximately 60.7 ha of native marshes dominated by California bulrush (*Schoenoplectus californicus*), chairmaker's bulrush (*Schoenoplectus americanus*), and cattail (*Typha* sp.) connected to the backwater channels. In areas where salinity exceeded the tolerance of other native riparian species, the YCNHA planted salt-tolerant species such as: inland saltgrass (*Distichlis spicata*), alkali sacaton (*Sporobolus airoides*), western sea purslane (*Sesuvium verrucosum*), and salt heliotrope (*Heliotropium curassavicum*). Finally, the YCNHA planted riparian areas dominated by cottonwood, willow, and mesquite (*Prosopis* spp.) with an understory of native graminoids and forbs.

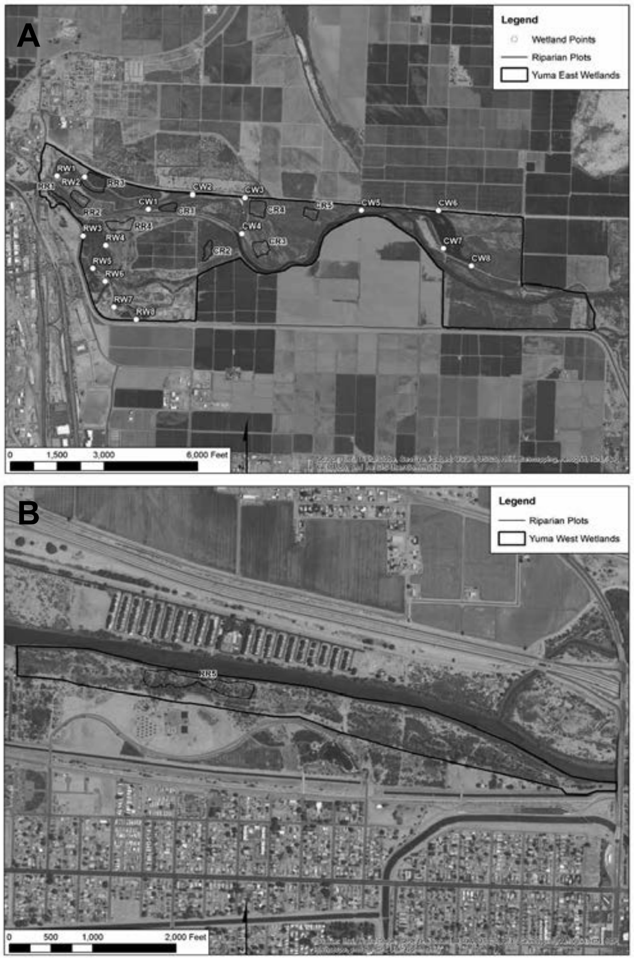

Figure 2. Map of restored and control monitoring locations for riparian and marsh sites. (A) In the Yuma East Wetlands in Yuma, AZ, there are four restored riparian (RR), five control riparian (CR), eight control marsh (CW) and eight restored marsh (RW) monitoring locations. (B) In the Yuma West Wetlands in Yuma, Arizona, there is one RR monitoring location.

Butterfly Sampling

We sampled butterflies during May, June, July, and September 2011 in restored and control riparian habitats for a total of 22 days (Figures 2A and 2B). We established one transect, 100 m in length, in each of the control and restored riparian plots discussed above. However if the vegetation was too dense to penetrate, the transects followed the perimeter of the site. Diurnal butterflies are very sensitive to cool and windy conditions, which reduces the chance of observation (Waltz and Covington 2004). Therefore, we sampled butterflies between 0700 and 1400 hrs, on days warmer than 17°C with winds less than 10 mph (Pollard 1977).

We identified butterfly species encountered along each transect and recorded their location along the transect (in meters) during timed searches. One minute per every 20m was spent searching for butterflies. This time did not include the time in pursuit of a butterfly. In addition to the location, we recorded behavior for the butterfly, including basking, flying, nectaring, etc. If a butterfly was nectaring, we identified the plant species. If we detected multiple individuals of one species in the same location conducting the same behavior, we recorded the number of individuals on the datasheet. If we could not identify a butterfly by sight, we captured the individual with a sweep net, identified it in the field, and released it.

Riparian Bird Surveys

We surveyed riparian birds using the intensive area search method (Bart et al. 2010,Great Basin Bird Observatory 2010) in ten plots systematically located in restored and control riparian habitats (Figures 2A and 2B). We placed five restored plots in areas dominated by cottonwood and willow with an understory of forbs and graminoid species, including salt heliotrope, western sea purslan, alkali sacaton, and inland saltgrass. We then placed five control plots in saltcedar and arrowweed (*Pluchea sericea*) areas. Plots ranged in size from 1–3 ha to include several breeding territories of land birds. We conducted area searches during the highest breeding activity for most riparian birds: early April–June 2011. Six bird surveys were conducted over four days with at least five days in between surveys. We considered birds detected in the plot three times or with observed nesting evidence as residents.

Marsh Bird Surveys

We conducted marsh bird surveys three times for three days each over the typical marsh bird breeding season: March 15–May 31, 2011 in eight restored and eight control marsh areas (Figure 2). Points were located 200 m apart to prevent double counting. We used a combination of methods to detect nesting activities of birds that breed in marshes, which included: 1) the National Marsh Bird Monitoring Program protocol developed by USFWS (Conway 2011); and 2) variable circular plots to detect other nesting birds. We initiated variable circular plot surveys after completing the marsh bird protocol. We measured birds in 10 m increment bands around the center of the plot up to 100 m for a total of 5 minutes (Reynolds et al. 1980). We only counted the avifaunal species actively utilizing the habitat. We considered birds residents if they were known breeders in marsh habitats along the lower Colorado River (Conway 2011).

Habitat, Host Plant, and Nectar Resource Distribution

To determine if habitat characteristics and host plant frequency differed between restored and control plots, we measured total vegetation volume (TVV) at 30 randomly selected points in the riparian habitats and 20 points in the marsh habitats after completing the breeding bird surveys. TVV measures the number of 10 cm radius cylinders with vegetation in them and is a useful measure of habitat quality for breeding birds (Mills et al 1991). We measured

TVV for vegetation at each randomly selected location by extending an 8 m pole vertically through the vegetation. We recorded all vegetation touching the pole and within 0.1 m radius for each decimeter section (Rotenberry 1985, Mills et al. 1991). We calculated TVV for each sampling location as: $\frac{h}{10p}$; where h = the total number of hits summed over all sections at all points measured, and p = the number of points at which vegetation volumes were measured (Mills et al. 1991).

At each TVV point, we measured a three-meter radius circle for riparian areas and two-meter radius circle for marsh areas around each point to estimate vegetation species cover. We used the Daubenmire Cover Scale to estimate percent cover for each vegetation species in the plot using the following vegetation strata classes, including: herb (< 0.5 m), shrub (woody stems, 0–4 m), medium canopy (4–6 m), and tall canopy (> 6 m) (Daubenmire 1959). We used this method to determine butterfly host plant abundance for the butterfly species detected to provide a broader area for host plant detections.

Abundance of nectar plants and blooms has shown to directly affect butterfly distribution (Steffan-Dewenter and Tscharntke 1997). To estimate the availability of nectar plants and blooms for butterflies, we established 3 m diameter plots every 10 m along the butterfly transects. At each plot, we tallied the plants with blooming flowers by species and the number of inflorescence counted four times after each butterfly sampling period.

Statistical Analyses

We used the independent sample t-test to examine the differences in bird, butterfly, and vegetation species richness, abundance, and density in restored and control riparian and marsh habitats. Levene's test for equal variances assessed the equality of variances for the variables calculated for the two groups. We used the Pearson Product Moment Correlation (PPMC) coefficient to measure the linear correlation between butterfly richness and flowering plant species richness and abundance, vegetation species diversity, and percent herbaceous vegetation to assess dependence between the two variables, using an $\alpha = 0.10$. We performed statistical analyses using IBM SPSS Statistics (IBM SPSS v. 22, IBM Corporation and others).

We assessed bird and butterfly community compositions in restored and control riparian and marsh habitats with non-metric multidimensional scaling (NMDS), using Bray-Curtis dissimilarity measure (Faith et al. 1987, Minchin 1987) to place multidimensional data in ordination space. We analyzed ordination results with a multi-response permutation procedure (MRPP) to test the hypothesis of no differences between restored and control units, where $\alpha = 0.10$. The A (Agreement) statistic in the MRPP analysis described within group similarity, with A = 1 when all items within a group are identical (McCune and Grace 2002). We used PC-ORD Version 5 software to perform ordination and MRPP (PC-ORD v. 5, MjM Software, Gleneden Beach, OR, McCune and Mefford 2006).

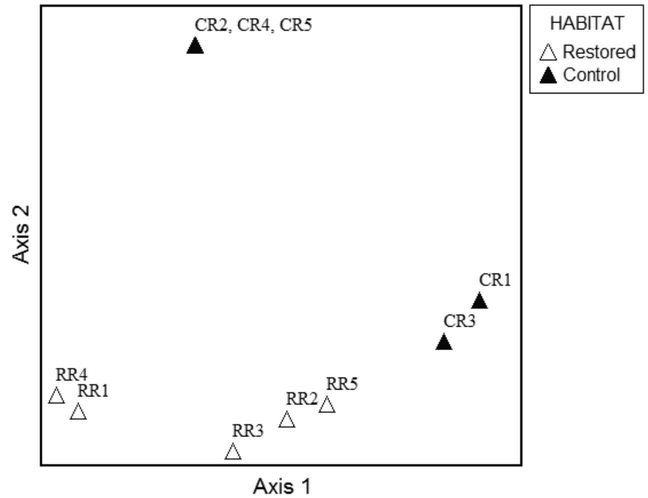

Figure 3. Non-metric multidimensional scaling ordination of butterfly assemblages in restored and control riparian habitats, n = 5 per habitat, for 2011 at the YEW, Yuma County, AZ. A significant difference was detected between restored versus control marsh sites (MRPP test, T = –2.527, *p* = 0.0234, A = 0.17).

Results

Butterflies

Spatial ordination of butterfly assemblages by nonmetric multidimensional scaling (NMDS) 3-dimensional plot showed a distinction between restored and control riparian habitats (Final Stress = 0.001, Figure 3). The NMDS selected 3 axes, which accounted for 93% of variance observed in butterfly assemblages (Axis 1 = 42%; Axis 2 = 33%; and Axis 3 = 18%). The MRPP analysis supports a statistically significant difference between restored and control butterfly communities: t-statistic = –2.527, $p = 0.0234$. We interpreted A = 0.17, which is relatively high value for ecological data, to indicate the butterfly assemblages within treatment units were similar and ecologically significant.

We found butterfly richness ($t = 5.837$, $p \leq 0.0001$) and abundance ($t = 2.194$, $p = 0.034$) significantly higher in the restored versus control riparian habitats (Figure 4). We detected eight species using the restored riparian habitats, while only detecting two species in the control riparian habitats. Western pygmy blue (*Brephidium exile*) was the most abundant butterfly using the restored habitats (Table 1).

Riparian Birds

Spatial ordination of resident riparian bird assemblages by NMDS 5-dimensional distance plot showed a slight distinction between restored and control riparian habitats (Final Stress = 0.00033, Figure 5A). The NMDS selected 3 axes,

Table 1. Total cumulative observations for butterfly species detected in the restored and control riparian sites in the YEW, Yuma County, AZ.

Family	Scientific Name	Common Name	Host plant family	Restored observations	Control Observations
Hesperiidae	*Pyrgus communis*	Common Checkered-skipper	Malvaceae	1	0
Lycaenidae	*Brephidium exile*	Western Pygmy-Blue	Chenopodiaceae	245	0
Lycaenidae	*Hemiargus ceraunus*	Ceraunus Blue	Fabaceae	26	0
Lycaenidae	*Leptotes marina*	Marine Blue	Fabaceae	1	0
Lycaenidae	*Strymon melinus*	Gray Hairstreak	Fabaceae and Malvaceae	1	0
Pieridae	*Pieris rapae*	Cabbage White	Brassicaceae	1	1
Pieridae	*Nathalis iole*	Dainty Sulphur	Asteraceae (Tagetes)	5	0
Pieridae	*Colias eurytheme*	Orange Sulphur	Fabaceae	6	5

Table 2. Total number of resident birds detected and density (#/hectare) in the restored and control riparian habitats in the YEW, Yuma County, AZ. * indicates detected as a migrant in the site.

		Total Number Detected		Density (#/hectare)	
Genus species	Common Name	Restored Riparian	Control Riparian	Restored Riparian	Control Riparian
Pipilo aberti	Abert's Towhee	10	0*	1.03	0.00
Calypte anna	Anna's hummingbird	2	0*	0.21	0.00
Myiarchus cinerascens	Ash-throated flycatcher	0*	2	0.00	0.26
Vireo bellii	Bell's vireo	1	0	0.10	0.00
Polioptila melanura	Black-tailed gnatcatcher	2	3	0.21	0.39
Geothlypis trichas	Common yellowthroat	1	0*	0.10	0.00
Toxostoma crissale	Crissal thrasher	1	0*	0.10	0.00
Callipepla gambelii	Gambel's quail	9	0*	0.93	0.00
Melanerpes uropygialis	Gila woodpecker	3	0*	0.31	0.00
Quiscalus mexicanus	Great-tailed grackle	2	0	0.21	0.00
Carpodacus mexicanus	House finch	11	2	1.14	0.26
Picoides scalaris	Ladder-backed woodpecker	2	0*	0.21	0.00
Chordeiles acutipennis	Lesser nighthawk	0*	2	0.00	0.26
Zenaida macroura	Mourning Dove	26	6	2.69	0.78
Mimus polyglottos	Northern mockingbird	3	0	0.31	0.00
Melospiza melodia	Song sparrow	0*	1	0.00	0.13
Auriparus flaviceps	Verdin	36	6	3.72	0.78
Tyrannus verticalis	Western kingbird	0*	2	0.00	0.26
Zenaida asiatica	White winged dove	4	5	0.41	0.65

which accounted for 34% of variance observed in resident riparian bird assemblages (Axis 1 = 25%; Axis 2 = 4%; and Axis 3 = 5%). CR1 and CR2 showed significant spatial separation from the other locations, which was likely due to the presence of only one resident bird species. Despite the perceived spatial difference between habitats, the MRPP analysis supported the hypothesis that no difference existed between restored and control resident bird communities: A = 0.0004, t-statistic = −0.1545, $p = 0.389$. The A = 0.004, which indicates that bird assemblages within restored units had low similarity, is likely due to minimal differences detected between restored verses control sites. The restored riparian habitats had a four-fold higher total resident bird density than the control riparian habitats (Independent sample t-test; t = 1.729, $p = 0.018$, Figure 6A). Mourning doves (3 individuals/hectare) and verdins (4 individuals/hectare) had the highest densities in the restored riparian habitats (Table 2). We identified a total of 15 species as residents in the restored habitats and only 9 species as resident species in the control habitats; however this difference was not significant (t = 1.283, $p = 0.386$, Figure 6B).

Marsh Birds

Spatial ordination of the resident marsh bird assemblage by NMDS 1–dimensional plot showed significant spatial separation between restored and control marsh habitats (Final Stress = 26.9, Figure 5B. The NMDS selected 2 axes, which accounted for 67% of variance observed in marsh bird assemblages (Axis 1 = 19% and Axis 2 = 48%).The MRPP analysis did not support the hypothesis that no differences existed between restored and control resident avian communities: t-statistic = −6.0701, $p = 0.0001$. The

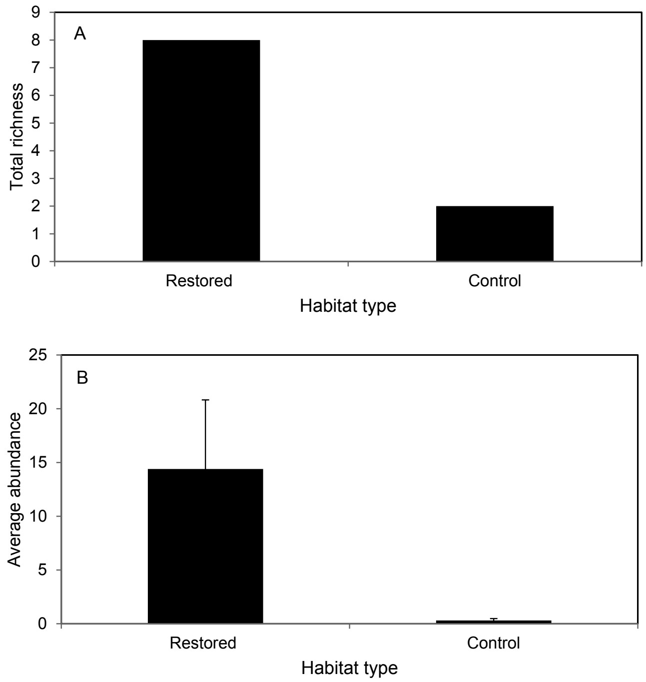

Figure 4. (A) Total butterfly richness in restored versus control riparian habitats in the YEW, Yuma County, AZ (t = 5.837, *p* ≤ 0.0001). (B) Average butterfly abundance in restored versus control riparian habitats in the YEW, Yuma County, AZ (t = 2.194, *p* = 0.034).

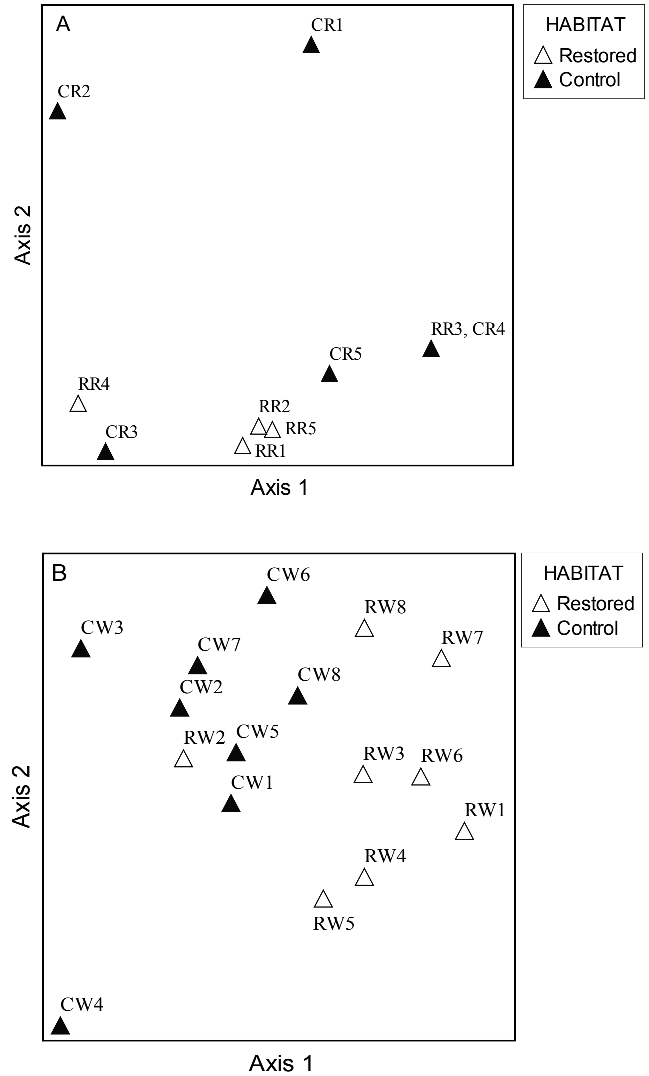

Figure 5. (A) Non-metric multidimensional scaling ordination of resident riparian bird assemblages in restored and control habitats, n = 5 per habitat, for 2011 at the YEW, Yuma County, AZ. No significant difference was detected between restored (RR) versus control riparian (CR) sites (MRPP test, T-statistic = –0.1545, *p* = 0.389, A = 0.004). (B) Non-metric multidimensional scaling ordination of resident marsh bird assemblages in restored and control habitats, n = 8 per habitat, for 2011 at the YEW, Yuma County, AZ. A significant difference was detected between restored (RW) versus control marsh (CW) sites (MRPP test, T = –6.0701, *p* = 0.0001, A = 0.045).

value of A = 0.045 while fairly low but common for ecological data, may indicate that within treatment units were fairly similar.

Restored marsh habitats had two-fold higher total resident bird richness than the control marsh habitats (t = 3.073, *p* = 0.004; Figure 6C), and three-fold higher marsh bird abundance than control sites (t = 3.496, *p* = 0.001; Figure 6D, Table 3). The high abundance detected in the restored sites resulted from the high abundance of yellow-headed blackbirds and marsh wrens. American coots had high abundances at one site in the control marsh habitats.

Vegetation Characteristics

Riparian Vegetation Characteristics. Restored riparian habitats had significantly higher species diversity than the control riparian sites (Table 4). We detected no herbaceous cover at the control sites; which was likely due to the dense saltcedar populations. We detected 14 species in the restored riparian sites and six species in the control riparian sites during the TVV surveys, and an additional 14 species in the restored sites and one species in the control site when vegetation cover was measured (Table 5).

Marsh Vegetation. We detected significant differences in percent herbaceous plant cover and open water between the restored and control sites (Table 6). Restored marsh sites had higher percent herbaceous plant cover when compared to the control sites; however control marsh sites had higher open water when compared to restored marshes. We only detected seven native species in restored marsh sites, including: Olney's three-square (*Schoenoplectus americanus*), inland saltgrass, yerba mansa (*Anemopsis californica*), alkali sacaton, salt heliotrope, alkali bulrush (*Schoenoplectus maritimus*), and Canadian horseweed (*Conyza canadensis*). No statistical differences occurred in species diversity and percent shrub cover between the two habitats (Table 6).

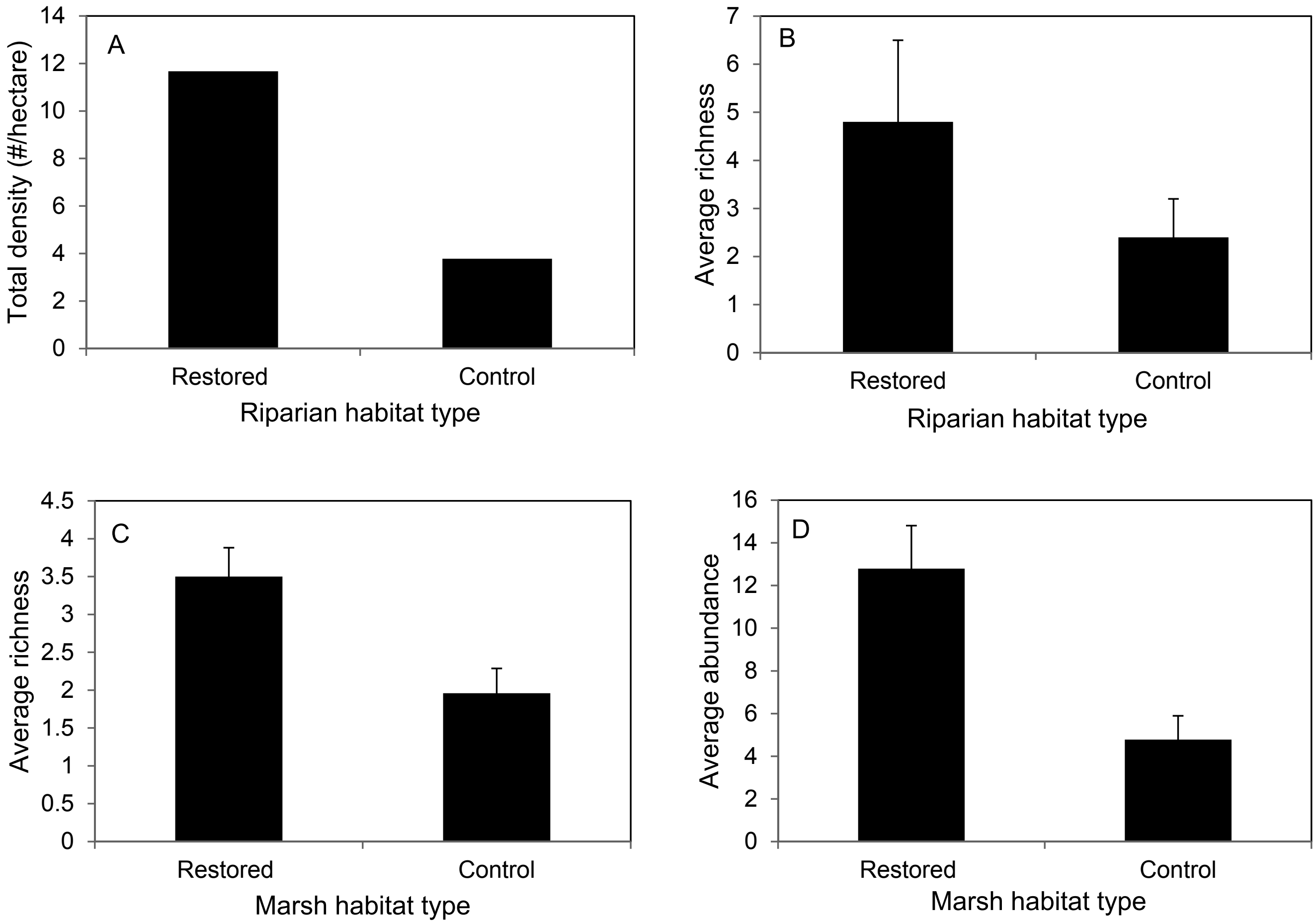

Figure 6. (A) Total resident bird density (#/hectare) in restored versus control riparian habitats in the YEW, Yuma County, AZ (t = 1.729, *p* = 0.018, n = 5) for 2011. (B) Average riparian bird richness in restored versus control riparian sites within the YEW, Yuma County, AZ (t = 1.283, p = 0.386). (C) Average marsh bird richness in restored versus control marsh sites within the YEW, Yuma County, AZ (t = 3.073, *p* = 0.004). (D) Average marsh bird abundance in restored versus control marsh sites within the YEW, Yuma County, AZ (t = 3.496, *p* = 0.001). Error bars indicate standard error.

Table 3. Total number of resident birds detected in the restored and control marsh habitats in the YEW, Yuma County, AZ.

Genus species	Common Name	Total Number Detected	
		Restored Marsh	Control Marsh
Fulica americana	American coot	6	39
Himantopus mexicanus	Black-necked Stilt	4	0
Aythya valisineria	Canvasback	0	1
Anas cyanoptera	Cinnamon teal	12	0
Rallus longirostris	Clapper rail	6	0
Gallinula chloropus	Common Moorhen	0	6
Geothlypis trichas	Common yellowthroat	12	8
Ardea herodias	Great blue heron	1	1
Charadrius vociferus	Killdeer	10	0
Ixobrychus exilis	Least bittern	1	1
Cistothorus palustris	Marsh wren	22	4
Podilymbus podiceps	Pied-billed grebe	0	2
Agelaius phoeniceus	Red-winged blackbird	1	0
Egretta thula	Snowy egret	3	0
Melospiza melodia	Song Sparrow	10	0
Porzana carolina	Sora	1	3
Xanthocephalus xanthocephalus	Yellow-headed blackbird	54	19

Host Plant and Nectar Resources Abundance. We observed four times more total flowering species richness (t = 5.386, $p = 0.002$) and abundance (t = 1.334, $p = 0.065$, $\alpha = 0.10$) in the restored versus control riparian sites. Control riparian sites had a significantly higher number of inflorescences than detected at the restored riparian sites (t = –1.040, $p = 0.019$, Table 7). The high number of inflorescences was primarily from saltcedar. In restored riparian sites, planted native species, including pinkladies (*Oenothera speciosa*) and salt heliotrope, had the highest abundances of blooming individuals. However, we also detected many recruiting native and invasive weeds blooming in the restored areas, including Canadian horseweed, white sweet clover (*Melilotus alba*), yellow sweet clover (*Melilotus officinalis*), saltmarsh fleabane (*Pluchea odorata*), silverleaf nightshade (*Solanum elaeagnifolium*), common sowthistle (*Sonchus oleraceus*), arrowweed, and saltcedar. We observed arrowweed and saltcedar as the two most abundant flowering individuals in the control riparian habitat (Table 7). Butterflies primarily used the following species for nectar sources in the restored riparian habitats: western sea purslane, screwbean mesquite (*Prosopis pubescens*), and salt heliotrope. We observed only one individual butterfly nectaring

Table 4. Average Total Vegetation Volume (TVV), species diversity (Shannon diversity index), percent herbaceous cover, percent shrub cover, and percent mid-canopy cover for restored versus control riparian sites in the YEW, Yuma County, AZ. * indicates significance at $p < 0.05$.

Average Values	Restored	Control	t	*p*-value
TVV	0.183	0.200	–0.239	0.817
Species Diversity (H’)	1.383	0.658	2.822	0.022*
% Herb Cover	18.00	0	2.500	0.293
% Shrub Cover	14.00	16.00	12.00	0.744
% Mid-canopy	18.00	32.00	12.00	0.429

Table 5. Vegetation species detected during the TVV and vegetation species cover (Cover) surveys in the restored and control riparian habitats at the YEW, Yuma County, Arizona (1 = presence, — = not detected).

Plant Species Information				Riparian Habitat		Survey Type	
Common Name	**Scientific Name**	**Growth Habit**	**Status**	**Restored**	**Control**	**TVV**	**Cover**
Mule-fat	*Baccharis salicifolia*	Shrub	Native	1	—	1	1
Willow baccharis	*Baccharis salicina*	Shrub	Native	1	—	1	1
Emory’s baccharis	*Baccharis emoryi*	Shrub	Native	1	—	1	1
Bermuda grass	*Cynodon dactylon*	Graminoid	Introduced	1	—	1	1
Saltgrass	*Distichlis spicata*	Graminoid	Introduced	1	—	1	1
Arrowweed	*Pluchea sericea*	Shrub	Native	1	1	1	1
Honey mesquite	*Prosopis glandulosa*	Tree	Native	1	1	1	1
Screwbean mesquite	*Prosopis pubescens*	Tree	Native	1	1	1	1
Saltcedar	*Tamarix* spp	Tree	Introduced	1	1	1	1
Common Reed	*Phragmites australis* var. *berlandieri*	Graminoid/shrub	Introduced	—	1	1	1
Fremont cottonwood	*Populus fremontii*	Tree	Native	1	1	1	1
Western sea-purslane	*Sesuvium verrucosum*	Herb	Native	1	—	1	1
Alkali sacaton	*Sporobolus airoides*	Graminoid	Native	1	—	1	1
Coyote willow	*Salix exigua*	Tree	Native	1	—	1	1
Goodding’s willow	*Salix gooddingii*	Tree	Native	1	1	1	1
Blue palo verde	*Parkinsonia florida*	Tree	Native	1	—	1	1
Mexican evening primrose	*Oenothera mexicana*	Herb	Native	1	—	1	1
Salt heliotrope	*Heliotropium curassavicum*	Herb	Native	1	—	—	1
Sweet clover	*Melilotus alba*	Herb	Introduced	1	—	—	1
Common sowthistle	*Sonchus oleraceus*	Herb	Introduced	1	—	—	1
Chairmaker’s bulrush	*Schoenoplectus americanus*	Graminoid	Native	1	—	—	1
Blue palo verde	*Parkinsonia florida*	Tree	Native	1	—	—	1
Four-wing saltbush	*Atriplex canescens*	Shrub	Native	1	—	—	1
Big saltbush	*Atriplex lentiformis*	Shrub	Native	1	—	—	1
Canadian horseweed	*Conyza canadensis*	Herb	Native	1	—	—	1
Desert marigold	*Baileya multiradiata*	Herb	Native	1	—	—	1
Johnsongrass	*Sorghum halepense*	Graminoid	Introduced	1	—	—	1
Mexican sprangletop	*Leptochloa fusca* ssp. *uninervia*	Graminoid	Native	1	—	—	1
Sweetscent	*Pluchea odorata*	Herb	Native	1	—	—	1
Pinkladies	*Oenothera speciosa*	Herb	Native	1	—	—	1
Desert globemallow	*Sphaeralcea ambigua*	Herb	Native	1	—	—	1

on saltcedar in control riparian sites; we observed all other detected individuals in the control sites flying.

We found a five times higher host plant family abundance in the restored versus control riparian sites (t = 2.515, $p = 0.036$). The host plant families detected during the vegetation surveys in both restored and control sites, included Asteraceae, Fabaceae, Malvaceae, and Chenopodiaceae. The primary species detected in the Asteraceae family included mule-fat (*Baccharis salicifolia*), willow baccharis (*Baccharis salicina*), Emory's baccharis (*Baccharis emoryi*), desert marigold (*Baileya multiradiata*), and pinkladies (Table 5). The primary species detected in the Fabaceae family included screwbean and honey mesquite (*Prosopis glandulosa*), sweet clover (*Melilotus spp*), and blue palo verde (*Parkinsonia florida*). Species in the Malvaceae and Chenopodiaceae families included desert globemallow (*Sphaeralcea ambigua*), four-wing saltbush (*Atriplex canescens*), and quailbush (*Atriplex lentiformis*).

Table 6. Average species diversity (Shannon diversity index), percent herbaceous cover, percent shrub cover, and percent open water for restored versus control marsh sites in the YEW, Yuma County, AZ. * indicates significance at $p < 0.05$.

Average Values	Restored	Control	t	*p*-value
Species Diversity (H')	1.521	1.231	1.151	0.269
% Herb Cover	28	4	4.59	0.001*
% Shrub Cover	42	60	–1.489	0.159
% Open Water	2	10	–2.292	0.038*

The statistical analysis correlated ($\alpha = 0.10$) butterfly species richness with flowering species richness (PPMC = 0.611, $p = 0.061$), flowering species abundance (PPMC = 0.639, $p = 0.047$), vegetation species diversity (PPMC = 0.581, $p = 0.078$), and percent herbaceous vegetation (PPMC = 0.621, $p = 0.055$). This indicates that butterfly species prefer a diversity of flowering herbaceous species for nectaring. The habitat characteristics discussed under riparian birds indicated that restored riparian habitats had higher vegetation species diversity and percent herbaceous vegetation than control riparian sites. The analysis did not find butterfly species abundance correlated with any environmental variables.

Discussion

The results of this study indicate that restoring structural complexity to native plant communities in riparian and marsh habitats on the lower Colorado River can have a positive and significant effect on bird and butterfly density, richness, and abundance. A diverse native understory comprised of graminoids, forbs, and shrubs was a particularly important component to structural and species diversity in restored riparian and marsh sites. The understory contributed to the higher plant species diversity and percent herbaceous cover detected in restored riparian sites and percent herbaceous cover in restored marsh sites than their control equivalents. No herbaceous cover was detected at control riparian sites because saltcedar and arrrowweed were so dense they prevented herbaceous plant growth. A

Table 7. Total blooming plant abundance (TBPA) and total inflorescences (TI) for restored versus control riparian sites during 2011 at the YEW, Yuma County, Arizona.

		Restored Riparian		Control Riparian	
Common Name	Scientific Name	TBPA	TI	TBPA	TI
Desert marigold	*Baileya multiradiata*	3	3	—	—
Lambsquarters	*Chenopodium album*	6	2	—	—
Canadian horseweed	*Conyza canadensis*	12	78	—	—
Salt heliotrope	*Heliotropium curassavicum*	160	1399	—	—
White sweetclover	*Melilotus alba*	56	464	—	—
Yellow sweetclover	*Melilotus officinalis*	19	144	—	—
Pinkladies	*Oenothera speciosa*	690	1529	—	—
Saltmarsh fleabane	*Pluchea odorata*	5	120	—	—
Western sea-purslane	*Sesuvium verrucosum*	34	2710	—	—
Silverleaf nightshade	*Solanum elaeagnifolium*	1	2	—	—
Common sowthistle	*Sonchus oleraceus*	12	105	—	—
Violet	*Viola* sp.	1	7	—	—
Baccharis	*Baccharis spp.*	14	569	—	—
Arrowweed	*Pluchea sericea*	82	552	190	1972
Sandbar willow	*Salix exigua*	101	226	—	—
Saltcedar	*Tamarix* spp.	11	834	178	13636
Honey mesquite	*Prosopis glandulosa*	35	336	1	10
Screwbean mesquite	*Propsopis pubescens*	44	403	5	39
Goodding willow	*Salix gooddingii*	1	10	—	—
Total		1287	9493	374	15657

diverse native understory has shown to provide competition to recolonizing invasive species (Fargione and Tilman 2005, Maron and Marler 2007), beneficial nectar resources and host plants for butterflies (Nelson and Andersen 1999, Fleishman et al. 2005, and Nelson and Wydoski 2008), and habitat complexity for bird and other wildlife species (Tewksbury et al. 2002, Krueper et al. 2003, Golet et al. 2008, Dickson et al. 2009). Also, one study suggested that bird habitat may be less dependent on woody vegetation then on understory characteristics like forb and graminoid richness (Shanahan et al. 2011).

The study also found butterfly richness correlated to percent herbaceous vegetation and flowering species richness and abundance. Studies have shown the importance of understory nectar plants in structuring butterfly assemblages (Nelson and Andersen 1999, Fleishman et al. 2005, and Nelson and Wydoski 2008). However, many riparian restoration projects, particularly on the lower Colorado River, do not plant native understory forbs (Nelson and Andersen 1999). Although not tested, regular flood irrigation in the riparian sites at the YEW may provide other required resources for butterflies, including: increased nectar production (Zimmerman and Pyke 1988, Boose 1997, Carroll et al. 2001), increased host plant production (Ripple and Beschta 2006), and a drinking water source (Nelson 2003). While control riparian sites in the YEW showed a significantly higher number of inflorescences, primarily from saltcedar, than the restored sites, the lack of soil moisture likely reduced nectar production. The dearth of butterfly richness and abundance supports this hypothesis.

Despite greater butterfly richness and abundance in restored riparian sites versus control sites, we did not find the indicative native riparian obligate butterfly assemblage of Fatal metalmark (*Calephelis nemesis*), Viceroy (*Limenitis archippus*), and Mourning cloak (*Nymphalis antiopa*) (Nelson and Andersen 1999). The difficulty of occupying habitat from distant source populations may explain the absence of these species. Studies have shown that butterfly colonization of habitat patches decreased as the distance between patches increased without habitat corridors (Haddad 2000). Some taxa may take several years to colonize patches even from nearby source populations (300–700 m) (Thomas et al. 1992). Riparian obligate butterflies, including the Fatal metalmark, Viceroy, and Mourning cloak do occur on the Yuma County species list (www.butterfliesandmoths.org), but suitable habitat corridors from the distant source populations may not connect to the YEW. However, the presence of suitable nectar resources, functioning hydrology, and sufficient host plants may support these if introduced. Also, this limited study may not have captured all the species utilizing the restored and control sites.

We detected four resident riparian obligate bird species unique to the restored riparian habitats: Gila woodpecker (*Melanerpes uropygialis*), Bell's vireo (*Vireo bellii*), Abert's towhee (*Melozone aberti*), and Crissal thrasher (*Toxostoma crissale*) (Hunter et al. 1987). In riparian areas, Gila woodpeckers require broad-leafed trees for cavity nests (Hunter et al. 1987), Abert's towhees occur in areas with dense understory and moist soils (Corman and Wise-Gervais 2005), and Crissal thrashers utilize tall, dense brush and shrub thickets (Corman and Wise-Gervais 2005). The presence of these species at restored sites attests to the structural complexity of the diverse native plants present, including the mature native species that were retained on site during restoration construction. Despite the presence of these species, we did not observe other riparian obligate species that occur in mature, natural riparian habitats of the lower Colorado River in restored habitats (Hunter et al. 1987, Rosenberg et al. 1991). We identified some of these birds as migrants at the restored sites, including yellow warbler (*Setophaga petechial*), hooded oriole (*Icterus cucullatus*), Lucy's warbler (*Oreothlypis luciae*), willow flycatcher (*Empidonax traillii*), and blue grosbeak (*Passerina caerulea*). However, the absence of the complete community at the YEW may result from the immature status of the restored habitats at the time of the study. Species such as brown-crested flycatchers (*Myiarchus tyrannulus*), yellow warbler, yellow-breasted chat (*Icteria virens*), and summer tanager (*Piranga rubra*) prefer tall and dense stands of cottonwood and willow when nesting in riparian habitats (Rosenberg et al. 1991, Corman and Wise-Gervais 2005). Whereas yellow-billed cuckoo (*Coccyzus americanus*), Lucy's warbler, Baltimore oriole (*Icterus galbula*), and blue grosbeaks prefer mixed-age stands, mesquite bosques, or can be more habitat generalists. These species may occupy the site as the habitat matures. During surveys conducted during 2013, surveyors detected blue grosbeak territories (H. Trathnigg, Fred Phillips Consulting, unpub. data) and yellow-billed cuckoo (LCR MSCP 2013). Finally, some species have high site fidelity (including the willow flycatcher) and do not tend to disperse great distances from their breeding sites to occupy new habitats (Sedgwick 2004).

In marsh sites, we found bird richness and abundance significantly higher in restored sites compared to control sites. We detected six endangered Yuma clapper rails (*Rallus longirostris yumanensis*) in the restored marshes with evidence of breeding. We observed other marsh birds, such as least bitterns (*Ixobrychus exilis*) and soras (*Porzana Carolina*) in both the restored and control marsh habitats. The restored marshes, including a mile long backwater channel, provide potential habitat for marsh bird species of concern such as the Yuma clapper rail and the black rail (*Laterallus jamaicensis*). Yuma clapper rails prefer tall marsh vegetation such as California bulrush and cattail, and water levels fluctuating to a maximum of approximately 30 cm (1ft) (Eddleman 1989). Black rails prefer shallow marshes (< 5 cm) dominated by threesquare bulrush (*Scirpus americanus*) and saltgrass adjacent to California bulrush (Repking and Ohmart 1977). We did not detect black rails in the restored marshes. While rare along the lower Colorado River, stable populations do exist within 20 miles of the YEW. Since, black rails have high juvenile dispersal rates (Corman and Wise-Gervais 2005), they may colonize the restored YEW marshes in the future.

Management Implications

This study shows that planting a diverse native understory to enhance structural complexity in riparian and marsh habitat restoration projects will benefit a diversity of butterfly and bird species. The environmental variables and plant associations that occur at the YEW would support and enhance reintroduced riparian obligate butterfly assemblages. Also, as the riparian habitat matures, more riparian obligate bird species may breed at the site, as indicated by the breeding evidence of blue grosbeak and yellow-billed cuckoo in 2013. Finally, marsh birds do benefit from contiguous shallow marsh (< 1m).

Restoring the native understory also provides competition for invasive weeds and attracts invertebrates, which serve as a food source for birds and other wildlife. The understory has implications for other wildlife species, including the Yuma hispid cotton rat (*Sigmodon hispidus eremicus*), a regionally rare and isolated small mammal. The YEW has the largest known population of this species currently found on the lower Colorado River (C. Dodge, Bureau of Reclamation, Lower Colorado River Multi-Species Conservation Program, pers. comm.). These preliminary results indicate that butterfly and bird species, and other wildlife, monitoring should continue to reveal the changes in community composition as the habitats mature.

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