Using prey availability to evaluate Lower Colorado River riparian restoration

Running Title: Prey availability in lower Colorado restoration

Zan Rubin[1,*] zankrubin@gmail.com;

Blanca Rios-Touma[1,2];

G. Mathias Kondolf[1,3];

Mary E. Power[4];

Parsa Saffarinia[5,†];

Jennifer Natali[1]

Authors:

***Zan Rubin**

University of California Berkeley, Landscape Architecture and Environmental Planning, 202 Wurster Hall, Berkeley, CA, 94720, USA. zankrubin@gmail.com

Blanca Rios-Touma

University of California Berkeley, Landscape Architecture and Environmental Planning, 202 Wurster Hall, Berkeley, CA, 94720, USA;

Grupo de Investigación en Biodiversidad, Medio Ambiente y Salud –BIOMAS- Facultad de Ingenierías y Ciencias Agropecuarias. Ingeniería Ambiental. Universidad de las Américas, Quito-Ecuador. Calle Queri y Av. Granados, Quito, Ecuador EC170137

G. Mathias Kondolf

University of California Berkeley, Landscape Architecture and Environmental Planning, 202 Wurster Hall, Berkeley, CA, 94720, USA

Collegium - Lyon Institut d'Etudes Avancées, Université de Lyon, 24 rue Jean Baldassini allée A, 2me étage, 69007 Lyon FR.

Mary E. Power

University of California Berkeley, 3060 Valley Life Sciences Building #3140, Department of Integrative Biology, Berkeley, CA, 94720, USA

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Parsa Saffarinia
University of California Berkeley, 3060 Valley Life Sciences Building #3140, Department of Integrative Biology, Berkeley, CA 94720.
Current affiliation: University of California Riverside, Department of Biology, Riverside, CA 92521, USA

Jennifer Natali
University of California Berkeley, Landscape Architecture and Environmental Planning, 202 Wurster Hall, Berkeley, CA, 94720, USA.

Author Contributions: ZR, BRT, GMK, MEP conceived and designed the research; ZR, BRT, PS, JN performed the fieldwork; BRT, PS performed insect identification, ZR, BRT, GMK, MEP, PS, JN analyzed the data; ZR, BRT, GMK, MEP, JN wrote and edited the manuscript

Abstract

The Lower Colorado River Multi-Species Conservation Program (MSCP) is charged with restoring habitat for 26 species such as the southwestern willow flycatcher (*Empidonax traillii extimus*) impacted by water development projects on the river. As of 2015, the MSCP had spent $200 million to create 1,200 hectares of habitat at nine sites, but the benefits to these insectivorous birds and other target species have not been quantified. Many MSCP projects emphasized riparian plantings of willow (*Salix exigua, S. gooddingii*) and cottonwood (*Populus fremontii*) on high terraces disconnected from the river. We documented prey availability for insectivores in constructed habitats as an indicator of restoration effectiveness. Using sticky traps as a proxy to estimate aerial insect flux, we found the number of aquatic insects, proportion of aquatic insects, total number of insects, and number of insect orders were all significantly lower in MSCP plantation sites than at the river's edge. Riparian restoration sites over 100 m from the river had only 4% of the aquatic

insects, 20% of the total insects, and only half as many insect orders as sites adjacent to the river. Thus, food availability and overall habitat quality for insectivores are likely low in restoration sites that are distant from the river.

Keywords

Ecological assessment, Effectiveness monitoring, Desert rivers, Aquatic-terrestrial subsidies, Southwestern willow flycatcher, Lower Colorado River Multi-Species Conservation Program.

Implications for Practice

In arid rivers where flow and disturbance regimes have been muted by demands for water resources, planners should prioritize riparian restoration adjacent to valuable aquatic food sources.

Restoration of flow regimes could increase extent and complexity of arid river floodplains with potential to increase aquatic insect abundance and sustain food webs for riparian insectivores.

Large-scale, long-term conservation programs can use intermediate measures of ecological interactions (such as prey availability) to understand limitations of current practices and adjust restoration strategy.

Introduction

Restoration projects often emphasize physical habitat, but few studies evaluate the quality of food availability in engineered habitats. Functional restoration requires food resources for target species, yet evaluations typically monitor habitat or populations of target species. In dryland rivers, more energy and nutrients typically flow from rivers to the riparian zone than from riparian zones to rivers (Marti et al. 2000). For example, in two Nevada sites, insect biomass decreased 70% within 30 m of the river (Theimer & Pellegrini 2011). Insect numbers also decreased exponentially with distance from the Eel River in California, and various insectivores were more common closer to the river (Power et al. 2004, Hagen and Sabo 2011). The reliance of terrestrial biota on stream productivity implies that restoring habitat for insectivores requires restoring the linkages between rivers and terrestrial habitats. In this study, we evaluated insect abundance (as prey for insectivores) in riparian restoration along the lower Colorado River.

The Lower Colorado River Multi-Species Conservation Program

The Lower Colorado River Multi-Species Conservation Program (MSCP) is a $600 million program to create habitat for 26 species along the lower Colorado River, including at least 2,404 ha of riparian (cottonwood-willow) habitat. Some cottonwood-willow plantations sit on terraces disconnected from the river by levees. Because groundwater pumping and channel incision have lowered the water table, these plantations will require irrigation in perpetuity (Nagler et al. 2007). Further, these plantations do not provide the habitats and functions of self-formed riparian ecosystems (Nelson 2003). Accordingly, the MSCP restoration strategy has been questioned for emphasizing static habitats, rather than restoring channel dynamics, which could create self-sustaining ecosystems (Adler 2007; Graham 2007). Although riparian vegetation has increased over the past century in most of the Colorado basin (Webb et el 2007), populations of several native species that depend on these habitats have declined, suggesting that habitat functions may be impacted by more than the extent of vegetation.

The southwestern willow flycatcher (*Empidonax traillii extimus*) is an emblematic example. It was federally listed as endangered in 1995 when the total population declined to less than 1,000 (U.S. Fish and Wildlife Service 2002). The flycatcher nests from May to September in dense riparian thickets adjacent to slow or ponded water in secondary channels, backwaters, marshes, and sloughs along the river- the types of habitats that were common when Southwestern rivers were unregulated (Webb et al. 2007). Nest sites typically have dense foliage from ground to ~4 m high (U.S. Fish and Wildlife Service 2002). The southwestern willow flycatcher is considered a generalist insectivore, with a diet that varies considerably between sites and years, suggesting that overall insect availability is more important for flycatcher populations than abundance of specific prey taxa (Wiesenborn and Heydon 2007; Durst et al. 2008).

The MSCP seeks to recreate riparian habitats, but MSCP restoration sites have not yet supported breeding by southwestern willow flycatchers (Lower Colorado River Multi-Species Conservation Program 2017). Colonization of the plantations may be limited by the small remnant population, site fidelity, or insufficient insect availability due to remoteness from the river, because some plantations are thousands of meters from the riverbank. The MSCP monitoring program has emphasized metrics such as acres planted, and presence of target species (Lower Colorado River Multi-Species Conservation Program 2017). Despite its ecological importance to the species, insect availability had not been measured. We used sticky traps to estimate insect fluxes in MSCP plantations in comparison to reference (best current ecological condition), control (altered, unrestored), and agricultural locations along the lower Colorado River.

Hypothesis

We hypothesized that there would be more insect abundance and diversity at the river's edge than at MSCP plantations distant from the Colorado River. To test this hypothesis and assess the potential for prey availability to limit southwestern willow flycatcher recovery in MSCP sites, we evaluated aquatic insect activity-abundance (captures per 48h-m^2 sticky trap area), the percentage of insects of aquatic origin, the total activity-abundance of insects, and richness at the ordinal level.

Methods

Study Sites

We selected three sites in Arizona for comparison (Fig. 1), which include two contrasting styles of restoration (Ahakhav Tribal Preserve near Parker (Ahakhav) and Cibola National Wildlife Refuge near Cibola, (Cibola)) and a reference ecosystem with successfully breeding southwestern willow flycatchers (Bill Williams River National Wildlife Refuge near Lake Havasu (Bill Williams)). The Ahakhav restoration site, implemented by the Colorado River Indian Tribes between 1995 and 2000, is adjacent to a backwater channel of the Colorado, with low-density plantings of willow, cottonwood, and mesquite. Ahakhav lies in the broad Parker Valley, where the incised Colorado River flows between constructed levees. Air photos from 1938 show a dynamic channel with little vegetation (Fig. S1). Now, much of the valley is planted with alfalfa, and the channel has been narrowed and straightened. Cibola (Fig. S2) was planted in 2008 and 2009 and represents the large, densely-planted, flood irrigated, restoration typical of several MSCP sites. At Cibola, we sampled in MSCP plantations over 500 m from the riverbank, separated from the river by a levee, irrigation and drainage canals, and alfalfa fields. Other MSCP sites are considerably farther from the river, including willow-cottonwood plantings at Cibola more than 2 km from the river. The Bill Williams River National Wildlife Refuge site (Fig. S3), maintains riparian forests through extensive restoration efforts and an environmental flow release program at Alamo Dam. Floods, although limited by upstream dams, still occur and facilitate recruitment of willow, cottonwood, and *Tamarix*. Southwestern willow flycatchers have reliably nested along the lower Bill Williams, suggesting insect densities are sufficient (LCRMSCP 2015a).

Insect Sampling and Analyses

At Ahakhav, Cibola and Bill Williams sites, we sampled along transects, collecting insects at 0 m, 30 m, and 100 m from the river. At Ahakhav, the 0, 30 and 100-m samples were inside the restoration area. We also sampled an abandoned agricultural field 620 m from the river at Ahakhav. At Cibola, the first 100 m from the river were unrestored; we also sampled in the MSCP willow-cottonwood plantation 550 m and 590 m from the riverbank, and in an alfalfa field 505 m from the river. In all, we established 13 sampling stations at the three sites (Table 1). At each site, we surveyed topography, measured canopy cover with a spherical densiometer, and identified each plant with stem diameter greater than 1cm within 10 m diameter plots around each sampling location (Table 1).

We sampled insects three times during the southwestern willow flycatcher breeding season: May, July, and September 2013. We used sticky traps to collect adult insects by coating a non-toxic sticky resin (Tree Tanglefoot®) onto both sides of 8 ½ by 11-inch biodegradable acetate sheets (Encalada & Peckarsky 2007). We set the traps at each of our study sites for 48 hours to sample two daily cycles. Night sampling may introduce error for daytime feeders, but nighttime feeders such as insectivorous bats are also target species under the MSCP, so we sampled both day and night to include all available insect food. The traps, clipped by clothespins onto nylon rope, were set along cross-valley transects oriented perpendicular to the river (Fig. S4). We set eight traps at each location, with four acetate sheets in each of two rows set 1 m and 2 m above the ground.

We identified most non-Dipteran insects to family, genus or species level, differentiating aquatic from terrestrially originated insects. The identification process was incomplete when individuals were damaged. Also, Dipterans can be either aquatic or terrestrial, and some are both (e.g. Stratiomyiids or Chironomids that dwell in algal mats or leaf litter along shorelines). We identified some aquatic Diptera (e.g. Phoridae, Psychodidae) to family or genus level and attempted to differentiate aquatic from terrestrial taxa. If an insect was not identified as aquatic or terrestrial we included it in the count of insect abundance and richness, but did not include it in our count or proportion of aquatic insects. Therefore, our estimates of aquatic insects and proportions were conservative.

Sticky traps measure activity-abundance, which we assumed would be correlated with insect availability to insectivores. Due to limited sample size and loss of some acetate sheets, we did not investigate pseudoreplication (i.e. variability between the 8 acetate sheets at each sampling location during each sampling period). Instead, we treated those 8 (or less, if some sheets were lost) sheets as a single sample and analyzed results averaged per m^2 of acetate sheet. We compared the river's edge (0-m sites at Ahakhav, Cibola, and Bill Williams) with the two MSCP plantation sites (collected more than 500 meters from the river in Cibola MSCP plantation sites). For each sampling period (May, July, September), we compared the average abundance at river's edge sites to average abundance at Cibola plantation sites. To illustrate the variability within each group we calculated standard error for each group for each sampling period. To test differences in insect abundance at the river's edge sites (Ahakhav-0, Bill Williams-0, and Cibola-0) with abundance in MSCP plantation sites (Cibola Plantation 550 and Cibola Plantation 590) we conducted repeated measures ANOVA (R version 3.2.0) analyses to test for differences between group means and temporal trends within each group. Because we sampled each site three times (May, July, September) we also tested for trends over that period. We transformed data when necessary to meet expectations of normality and homogeneity of variances. Nineteen of the 312 deployed acetate sheets were lost to wind (Table 1). To account for lost sheets, we used the average number of insects trapped after 48 hours per square meter of trap to estimate activity-abundance. We measured richness by counting orders trapped at each location, which may under-estimate richness where more sheets were lost (A-Control, C-alfalfa, and C-Plant 550).

A large monsoonal rainstorm occurred during our September sampling; approximately 2.5 cm of rain fell at Cibola and approximately 5 cm fell at the Bill Williams River. That single day's rain was approximately 25% of the total precipitation in 2013. In response, two species of terrestrial insects showed large population increases: Homoptera: Aleyrodidae and Hemiptera: *cf.* Diaspididae. We excluded these insects from our analyses because both were too small (<1 mm) to be fed upon by the insectivores of interest, and we expect they were present only in response to the rare rain event.

Results

Total insect activity-abundance, aquatic insect activity-abundance, percentage of aquatic insects, and ordinal richness were all significantly lower ($p<0.1$ from repeated measures ANOVA tests) in MSCP plantation sites than at the river's edge.

Aquatic insects (Fig. 2a) decreased from an average of 381 per 48h-m^2 of sticky trap at river's edge sites to only 12 per 48h-m^2 at sites 100 m from the river, and 11 per 48h-m^2 in MSCP Cibola plantation sites (a decrease of 97% from the river's edge). Aquatic insect activity-abundance was less in MSCP plantations than the river's edge (p= 0.032; repeated measures ANOVA, log-transformed data, Fig. 3a). There was also a significant decrease in aquatic insect activity-abundance over the summer (p=0.065).

The percentage of aquatic insects decreased from an average of 60% at river's edge sites to only 12% at sites 100 m from the river, and 16% in the MSCP Cibola plantation sites (Fig. 2b). The percentage of aquatic insects was lower in MSCP plantations than at the river's edge (p = 0.063; repeated measures ANOVA, arcsine transformed data, Fig. 3b). There was no significant trend in the proportion of aquatic insects trapped over the summer (p=0.15).

Total insect activity-abundance decreased from an average of 472 per 48h-m^2 at river's edge sites to only 90 at sites 100 m from the river, and 71 (a decrease of 85% from the river's edge sites) in MSCP Cibola plantation sites (Fig. 2c). Total insect activity-abundance was significantly less in MSCP plantations than at the river's edge (p = 0.055; repeated measures ANOVA, Fig. 3c). There was no significant seasonal trend in the total activity-abundance of insects trapped over the summer (p=0.12).

Ordinal richness decreased with distance from the river (Fig. 2d), from an average of 10 orders at river's edge sites to 7 at sites 100 m from the river, and 5 in the Cibola plantation sites. Ordinal richness was less in MSCP plantation sites than at the river's edge (p = 0.011; repeated measures ANOVA, log-transformed data, Fig. 3d). Aquatic orders and families were only consistently present in the first 30-100 m from the river. Farther than 100 m from the river, aquatic insects appeared sporadically and were mainly tiny Chironomidae that can be easily transported by the wind. Interestingly, at Cibola, there was a high density of terrestrial insects and high terrestrial ordinal richness found in the alfalfa field. Unlike other sites, there was a significant trend in ordinal richness over time at Cibola, with a decrease in richness in both river and plantation sites over the summer (p=0.014).

Discussion

Our finding that MSCP plantation sites more than 100 m from the river had only 4% of the aquatic insects, 20% of the total insects, and only half as many insect orders as sites adjacent to the river indicates that food availability is lower in the plantations than along the river, even in its degraded state. This finding calls into question the effectiveness of riparian plantations on terraces distant from the river as a restoration strategy. The patterns of total insects, aquatic insects, percent aquatic, and ordinal richness was consistent during each period, decreasing with distance from the river. The only exceptions to the decreasing trend was observed with the count of total insects, where high numbers were trapped in May at the Ahakhav fallow field and in all sampling periods at the Cibola alfalfa field. We attribute these findings to lack of cover at these sites (i.e. insects being blown into sticky traps) and to insect production/attraction in the irrigated alfalfa field. Despite the significant difference in mean values between river's edge and plantation sites, our statistical power was limited by having only sampled three transects and by substantial variability in catches at the river's edge sites.

Productivity at the River

The decrease in both total and aquatic insects of approximately an order of magnitude within the first 100 meters from the river's edge is consistent with results from other aquatic-to-terrestrial insect subsidy studies. Muehlbauer et al. (2014) found that insect flux on 109 streams decreased 90% an average of 330 m from the river's edge and insectivore abundance decreased 90% at 570 m from the river's edge. Similarly, Hinojosa-Huerta (2008) found that the presence of surface water was the greatest predictor of avian density and richness along the lower Colorado River in Mexico. Thus, the overall habitat quality of restoration sites that are distant from the river appears to be considerably lower for riparian insectivores such as southwestern willow flycatcher. Our findings suggest that despite a history of impacts to the Colorado, the river channel itself is still the most productive habitat for insects, and restoration along the riverbank may have greater potential to support insectivores. The MSCP experimented with fertilizing plantations to increase insect production (Lower Colorado River Multi-Species Conservation Program 2010) and amending soils to improve water retention and extend the duration of moist or ponded conditions during irrigation (Lower Colorado River Multi-Species Conservation Program 2015b), but these approaches were deemed technically infeasible. Even if feasible, such approaches would probably not support riparian insectivores in restoration sites distant from the river.

Regional Variability

Although there are many differences between the Ahahkav, Bill Williams, and Cibola sites that might influence insect production (e.g. water quality, channel morphology, substrate, flow depth and velocity,) the consistent trend at all sites suggests that such variability is less significant than distance from the river. Other studies that could inform restoration planning include Glenn's (2008) finding that the less-managed and more heterogeneous US-Mexico border (limitrophe) reach of the Colorado River had higher habitat complexity and supported richer avian populations than the more canalized reaches upstream. Similarly, a longitudinal study along the Colorado River in Grand Canyon demonstrated that sites below tributary junctions had food webs more supportive of native species, attributable to the more natural flow and sediment regimes of the tributaries and the resulting intact populations of native biota (Cross et al. 2013). One implication of these studies is that restoration potential varies across the landscape, so regional restoration planning on the lower Colorado would benefit from a basin-wide analysis of insect communities and habitat potential along the Colorado River and its tributaries.

Restoring Connected Floodplains and a Dynamic River

Our results support a restoration approach that creates a dynamic and connected river-floodplain system of features such as side channels, backwaters, and seasonally inundated floodplain to provide a prey base for riparian insectivores. A connected and hydrologically complex floodplain would likely increase insect abundance and diversity throughout the riparian corridor by expanding aquatic insect production and increasing the extent of riparian areas adjacent to aquatic insect sources. Further, a more natural flow regime can create new meander cutoffs, activate existing backwaters and oxbow lakes, and maintain early successional habitat features (Golet et al. 2013).

In a promising restoration approach towards these goals, the 2014 Colorado River Delta pulse flow experiment implemented under the Minute 319 binational agreement temporarily inundated ~1,600 ha of river channel and terraces. Preliminary observations documented numerous benefits including increased abundance and diversity of birds, as well as groundwater recharge, and increased vegetation establishment (International Boundary and Water Commission 2016). Future pulse flows and long-term monitoring of both MSCP and Minute 319 reaches will allow for more thorough evaluation of restoration effectiveness for avian populations.

MSCP monitoring results also highlight the importance of dynamic river systems for supporting focal species. Whereas riparian vegetation along the historical lower Colorado River existed in short-lived patches between episodes of disturbance, willows and cottonwoods planted by the MSCP are expected to be long lived. MSCP plantations are typically planted in dense rows, and they retain little understory foliage after the first few years. The MSCP Palo Verde Ecological Reserve hosts a growing population of yellow-billed cuckoo (*Coccyzus americanus occidentalis*), which nest almost exclusively in 2-3-year-old willow and cottonwood trees (Lower Colorado River Multi-Species Conservation Program 2013). However, as the plantations age, the trees get uniformly larger and the young trees favored by cuckoos disappear (Fig. 4). There is evidently no plan to artificially maintain the nesting habitat provided by young trees in these plantations, habitat that would naturally be sustained by the dynamic river disturbance-succession processes of erosion, deposition, and vegetation recruitment.

Our results call into question the suitability of MSCP cottonwood-willow plantations as habitat for insectivores. Along with studies done elsewhere, our study highlights the importance restoring the processes that can sustain food webs and quality habitat in heavily-modified ecosystems. In highly modified areas such as the lower Colorado River, restoration planners must ensure that all components for a functioning ecosystem (e.g. prey availability, habitat structure, maintenance of suitable seral stages, and edges between terrestrial and aquatic habitats) are established and sustained.

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Table 1. Site descriptions

Figure 1. The MSCP program area extends along the Colorado River from Lake Mead to the Mexican border. We sampled at the Ahakhav Tribal Preserve, (34° 7'57" N, 114°20'21" W), Bill Williams River (34°17'14" N, 114° 4'25" W), and Cibola National Wildlife Refuge (33°21'38.96" N, 114°41'56" W).

Figure 2. Insect numbers and orders plotted against distance from the river for each of the three sample areas, Ahakhav, Bill Williams River, and Cibola. Mean values from the three sampling periods (May, July, September) are shown for each site.

Figure 3. Repeated measures ANOVA tests for aquatic insect abundance and total insect abundance were performed on transformed data, but presented on real units in graphs as insects per 48h-m^2. The number of aquatic insects and the number of orders were significant at the 0.05 level (**) all tests were significant at the 0.10 level (*). Error bars are ± 1 SE showing the variation within each group for each sampling period.

Figure 4. MSCP restoration plots are typically planted in dense rows, and after the first years of growth, there is little understory foliage.

Supplementary Figures

Figure S1. The wide (~1000 m) and dynamic channel of 1938 (a) was greatly simplified and narrowed (~200 m) by 2013 (b), though it was still complex relative to other reaches of the lower Colorado (a side channel is present). The control site was a fallow alfalfa farm that hadn't been cultivated for several years. Due to restoration activities and the elimination of scouring flows, substantially more vegetation was present in 2013 than in 1938. Sources: 1938 [*Norman et al.*, 2006]; 2013 [http://goto.arcgisonline.com/maps/World_Imagery]

Figure S2. In 1938 (a) the Colorado River at Cibola was ~500 m wide including a large mid-channel bar, and large patches of both vegetated and unvegetated portions of the floodplain. The channel in 2013 (b) at Cibola was fixed in place with "J dykes" and a levee (just east of point C-100) and narrowed to ~100 m wide. The alfalfa field and MSCP plantation sites were disconnected from the river by the levee. Sources: 1938 [*Norman et al.*, 2006]; 2013 [http://goto.arcgisonline.com/maps/World_Imagery]

Figure S3. The lower Bill Williams River in the Bill Williams River National Wildlife Refuge is an extremely dense forest of willow, cottonwood and tamarisk, as visible in 2013 (b). Oblique imagery from 1947 shows the same area as an actively prograding delta as the Bill Williams River flows (left) into the backwater of the Colorado River at Lake Havasu. Lake Havasu was formed in 1938 by Parker Dam. Thus, even though the flow of the Bill Williams River is regulated by Alamo Dam upstream, the downstream Bill Williams maintains an active channel and has had several episodes of vegetation recruitment and erosion over the past eight decades.

Sources: 1947 [ARB000384820057 from USGS Earth Explorer]; 2013[http://goto.arcgisonline.com/maps/World_Imagery].

Figure S4. Cross sections (looking upstream) of A) Ahakhav Tribal Preserve, B) Bill Williams River National Wildlife Refuge, and C) Cibola National Wildlife Refuge.

Table 1. Site descriptions and vegetation characteristics at insect sampling locations

					Vegetation Species Count											
SITE	**Station**	**Distance from River (m)**	**Type**	**% *Canopy Cover***	**Alfalfa**	**Herbaceous Perennial**	**Pluchea sericea**	**Tule**	**Phragmites australis**	**Tamarix ramosissima**	**Prosopis glandulosa**	**Salix spp.**	**Populus fremontii**	**Unknown**	**Total Plants per 10 m circle**	**Acetate sheets lost (%)**
Ahakhav	A-0	0	Restored	*54*	0	0	15	0	280	1	1	0	0	0	594	3%
	A-30	30	Restored	*5*	0	0	72	0	0	0	1	0	0	0	73	0%
	A-100	100	Restored	*14*	0	0	100	0	0	0	2	0	1	0	103	0%
	A-CTRL	620	Fallow ag	*0*	0	0	0	0	0	0	0	0	0	0	0	10%
Bill Williams	B-0	0	Reference	*80*	0	110	0	0	0	1	0	3	0	0	228	1%
	B-30	30	Reference	*68*	0	0	0	0	0	5	0	5	0	0	10	0%
	B-100	100	Reference	*97*	0	0	0	0	0	9	0	0	0	0	9	0%
Cibola	C-0	0	Unrestored	*7*	0	0	36	50	40	3	0	0	0	0	258	1%
	C-30	30	Unrestored	*0*	0	0	200	0	0	3	0	0	0	0	203	0%
	C-100	100	Unrestored	*0*	0	0	75	0	0	8	4	0	0	5	87	1%
	C-ALF	505	Ag	*0*	100s	0	0	0	0	0	0	0	0	0	100s	7%
	C-PLANT 550	550	Restored	*93*	0	0	0	0	0	1	0	280	4	0	285	7%
	C-PLANT 590	590	Restored	*82*	0	0	0	0	0	8	0	250	7	0	265	0%

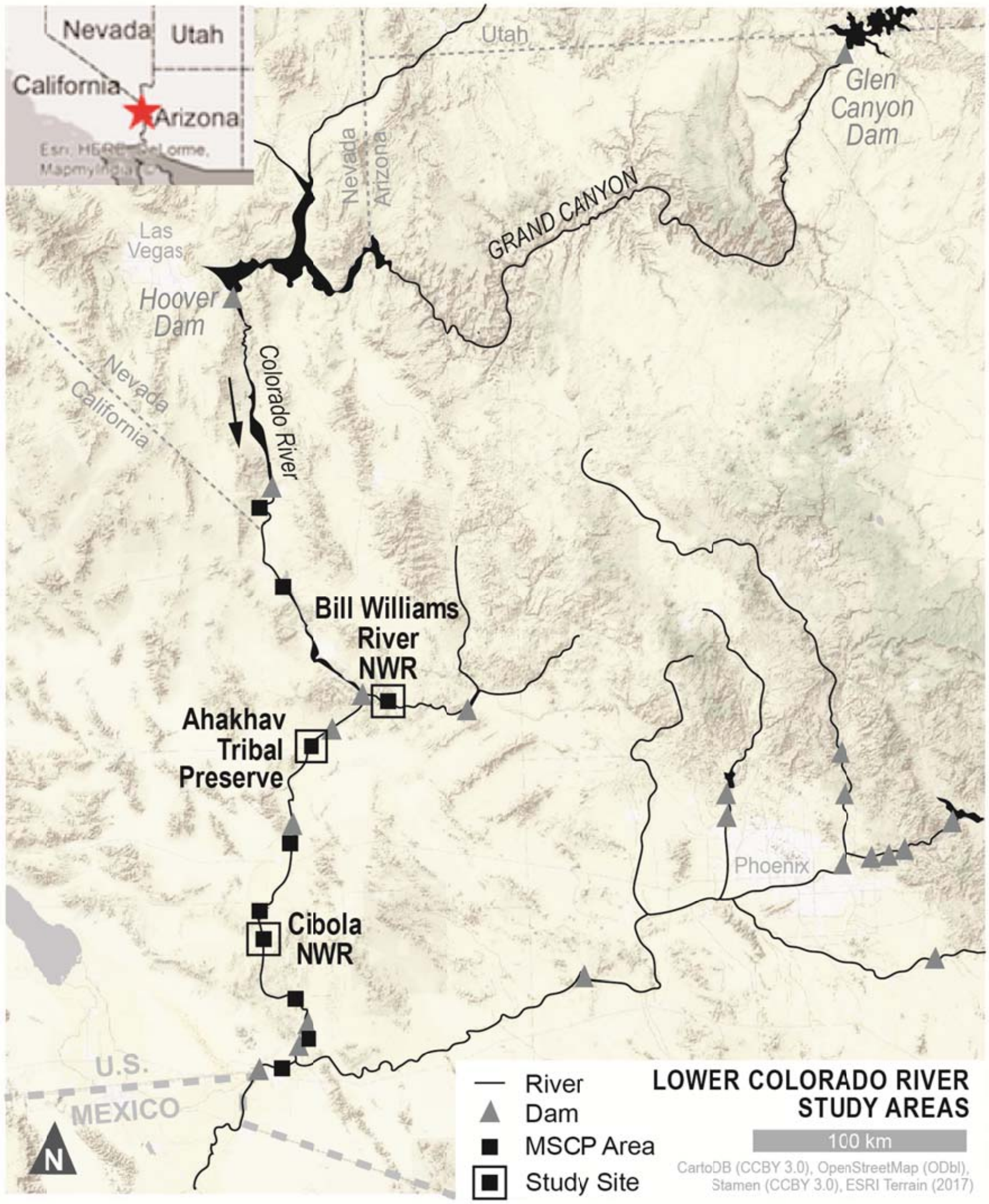
Nevada
Utah
California
Arizona
Utah
Nevada
Arizona
Glen
Canyon
Dam
GRAND CANYON
Las
Vegas
Hoover
Dam
Colorado River
Nevada
California
Bill Williams
River
NWR
Ahakhav
Tribal
Preserve
Phoenix
Cibola
NWR
U.S.
MEXICO
N
River
Dam
MSCP Area
Study Site
LOWER COLORADO RIVER
STUDY AREAS
100 km
CartoDB (CCBY 3.0), OpenStreetMap (ODbl),
Stamen (CCBY 3.0), ESRI Terrain (2017)

Figure 1.

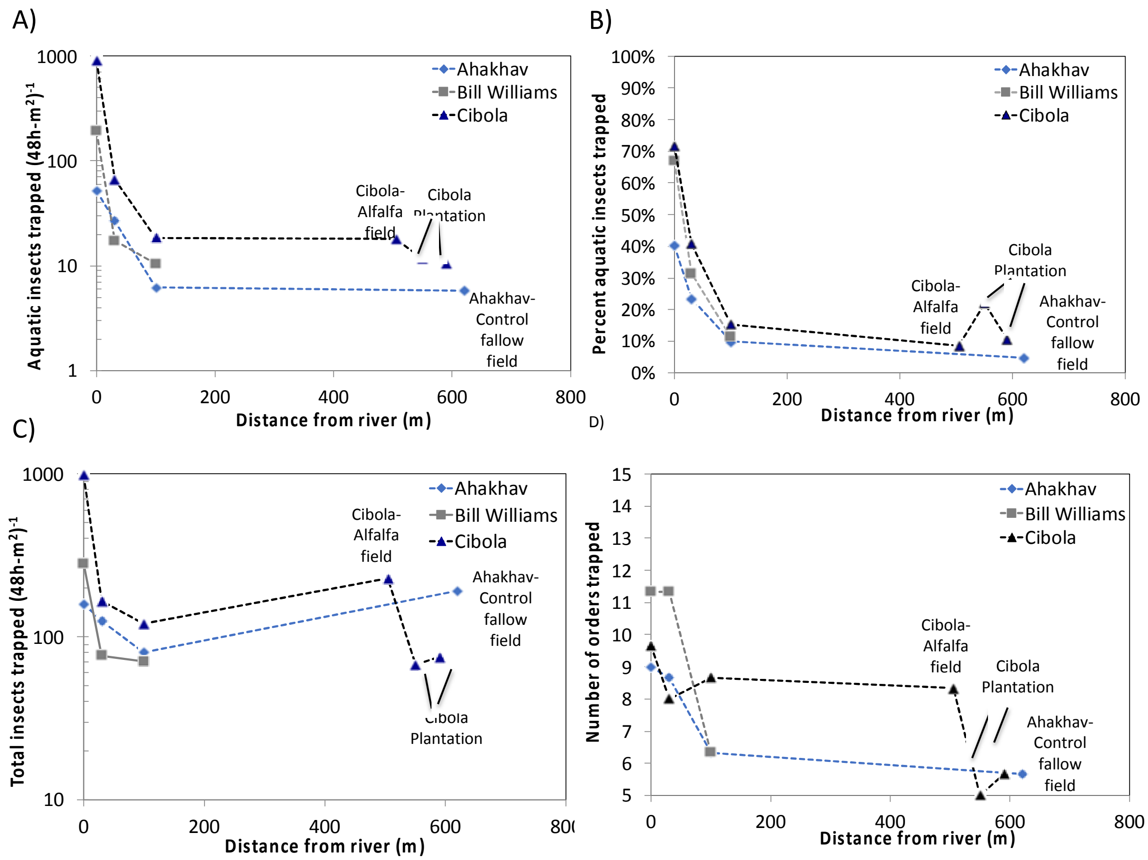
A)
Aquatic insects trapped (48h-m²)-1
Distance from river (m)
Ahakhav
Bill Williams
Cibola
Cibola-Alfalfa field
Cibola Plantation
Ahakhav-Control fallow field
B)
Percent aquatic insects trapped
Distance from river (m)
Ahakhav
Bill Williams
Cibola
Cibola-Alfalfa field
Cibola Plantation
Ahakhav-Control fallow field
C)
Total insects trapped (48h-m²)-1
Distance from river (m)
Ahakhav
Bill Williams
Cibola
Cibola-Alfalfa field
Ahakhav-Control fallow field
Plantation
D)
Number of orders trapped
Distance from river (m)
Ahakhav
Bill Williams
Cibola
Cibola-Alfalfa field
Cibola Plantation
Ahakhav-Control fallow field

Figure 2.

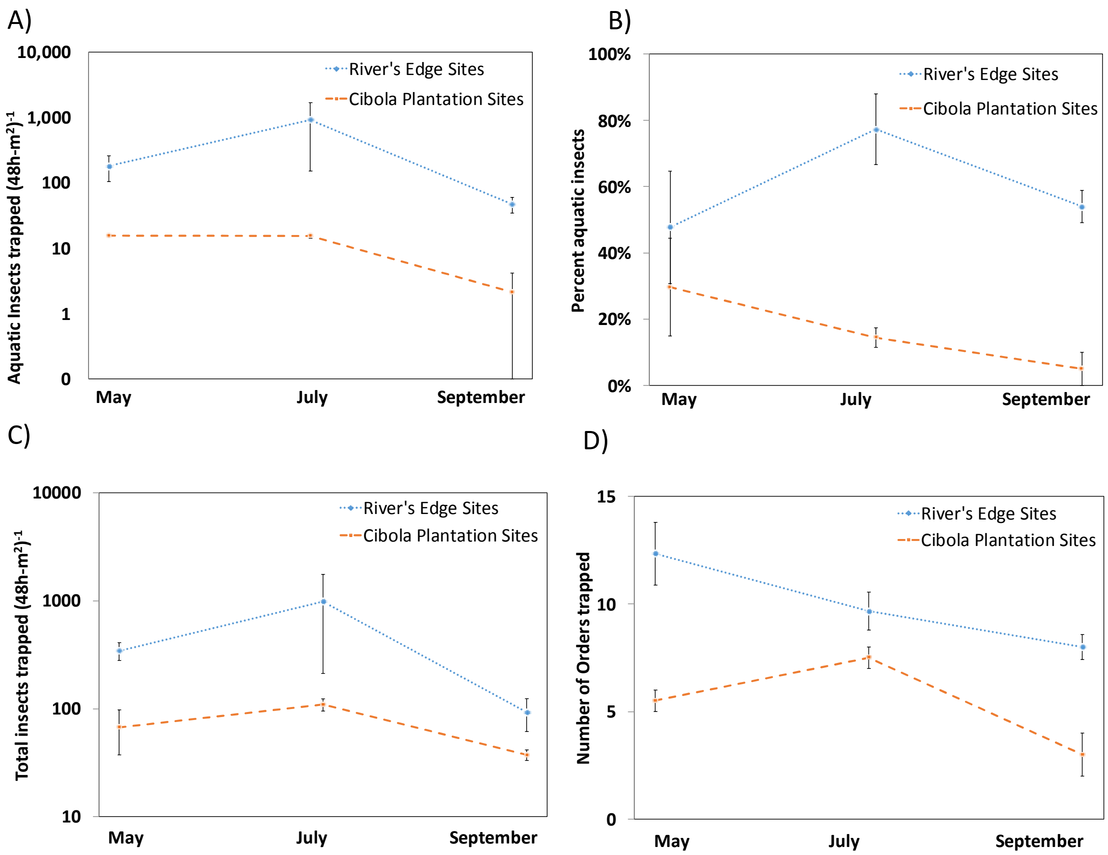
A)
10,000
1,000
100
10
1
0
Aquatic Insects trapped (48h-m²)-1
River's Edge Sites
Cibola Plantation Sites
May
July
September
B)
100%
80%
60%
40%
20%
0%
Percent aquatic insects
River's Edge Sites
Cibola Plantation Sites
May
July
September
C)
10000
1000
100
10
Total insects trapped (48h-m²)-1
River's Edge Sites
Cibola Plantation Sites
May
July
September
D)
15
10
5
0
Number of Orders trapped
River's Edge Sites
Cibola Plantation Sites
May
July
September

Figure 3.

Figure 4.