

# **Invasive Plant Encroachment, Wildlife, and Riparian Restoration in the Southwest**



Photos are credited to Andy Dean USFWS (southwestern desert and riparian zone), Victoria Wrubel (saltcedar), Joanna Gilkeson USFWS (Monarch Butterfly), the United States Fish and Wildlife Service (Southwestern willow flycatcher) and Larry Palmer USFWS (American beaver).

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## Executive Summary

Invasive species are considered one of the world's top conservation and restoration challenges for ecosystem conservation and restoration. Invasive riparian plants are particularly a problem in the southwestern United States where freshwater tributaries are rapidly transitioning from native plant communities to invasive plant communities. It remains unclear how wildlife communities are responding to invasive plant encroachment. In this review I address the following two questions: 1) When native vegetation is displaced by non-natives, how do native wildlife species adapt? 2) When managers remove non-native plants from riparian corridors during restoration efforts, how will wildlife be affected? The scope of this review is focused specifically on the top invasive riparian tree species in the southwest US, with special attention to New Mexico, although I expanded the review to incorporate relevant examples from throughout the US and the world where necessary. I specifically focused on four invasive plants, the tree of heaven *Ailanthus altissima*, Siberian elm *Ulmus parvifolia*, tamarix or saltcedar *Tamarix ramosissima*, and Russian olive *Elaeagnus angustifolia* because those are considered the most prevalent and problematic invasive trees in the focal study region. This review encompasses information available on vertebrates and invertebrates in the southwest, but given the lack of studies focused on invertebrate groups, the information presented here is biased towards vertebrate taxa.

## **Acknowledgements**

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## **Introduction**

Invasive species are considered one of the world's greatest threats to biodiversity and one of the most difficult challenges to contend with for ecosystem conservation and restoration. In the United States alone, thousands of invasive species have been recorded, many of which are rapidly expanding their geographic distributions and outcompeting native species. Invasive plants spread especially fast and scientists are actively working to understand the ramifications of spread for wildlife.

Around 5,000 nonnative plants have been introduced and successfully established themselves in the United States. However, not all of those species are considered invasive, which is defined as a nonnative plant that also causes ecological or economic harm. Some states in the US have had especially difficult challenges with invasive plants. Hawaii, for example, has around 1,200 nonnative plants distributed across the archipelago, and 18 of those have been labelled as highly impactful invasive terrestrial plants (Vitousek et al. 1987). Many western US states have seen a wide expansion of invasive grasses like cheat grass, which have proliferated in recent decades. Cheat grass is considered one of the greatest threats to Great Basin sagebrush communities and ultimately has had a variety of impacts on native wildlife like sage grouse. The southwestern US is dealing with similar challenges. 37 species of plants have been categorized as noxious weeds in New Mexico by the Bureau of Land Management (BLM) and a variety of invasive species are negatively impacting riparian ecosystems specifically.

Despite awareness that many nonnative plants negatively impact ecosystems, there are also well documented benefits provided by many of those species (Chiba 2010, Bartomeus et al. 2016). Nonnative plants have been shown to provide shelter and food for native wildlife species and can serve as substitutes for extinct native plant taxa (Shlaepfer et al. 2011). However,

whether nonnative plant encroachment has a net benefit or cost for wildlife is completely context dependent. The extent that native plants are replaced, the species of animals that interact with native versus nonnative plants, and whether any animal species were already threatened with extinction prior to nonnative plant encroachment, are a few examples of important variables to consider.

In the southwestern United States, for example, trees like Russian olive, Siberian elm, salt cedar and tree of heaven, have encroached upon native plants across several watersheds. Managers are actively working to slow or reverse those changes but are forced to make economically and ecologically costly decisions with incomplete scientific literature on invasive plant encroachment, native plant restoration and the extent that wildlife are impacted before and after native plant restoration efforts. These challenges are particularly important to unravel considering the uniqueness of many southwestern wildlife species, many of which are endemic to only that region. Furthermore, the treatments used to eliminate invasive plants for restoration can sometimes have a cascade of impacts on wildlife themselves. Herbicides have traditionally been one of the most successful tactics used to eliminate invasive plants, which include treatments of auxin mimics, mitosis inhibitors, photosynthesis inhibitors, lipid biosynthesis inhibitors, and amino acid synthesis inhibitors (Wieting et al. 2022). Mechanical methods have also been used, but with less success in many cases because many invasive tree species survive cutting if entire root systems are not also removed from the soil (Wieting et al. 2022). Because invasive plant encroachment and methods used to remove invasive plants can both result in negative impacts on wildlife, it is important to consider how wildlife respond to invasive plant communities initially.

There are many riparian reliant wildlife species native to the southwestern United States, several of which are currently listed as species at risk. Many other riparian reliant wildlife species have unknown conservation statuses because they have either not been species of conservation focus to date or are simply difficult for biologists to study. Among wildlife species in the southwest, large vertebrates tend to receive the most attention for conservation and restoration efforts. This is partially done because species that represent that classification provide much of the economic value to states and communities via hunting, trapping, and wildlife viewing. Those species are also often times considered the most charismatic by the general public. The impacts of riparian encroachment by invasive plant species on many charismatic wildlife species have been partially examined, and examples of possible behavioral changes include shifts in: 1) foraging, 2) anti-predator behavior (i.e. access to specific cover, 3) movement patterns, 4) communication and reproduction, 5) plant-animal communication, and 6) construction behavior (Stewart et al. 2021). However, there are still many aspects of vertebrate responses to invasive plant encroachment that are yet to be studied, and several vertebrates and invertebrates have received little attention as the focal species in such studies. Considering the major restoration efforts that are taking place across the southwestern US, some of the missing intricacies of wildlife responses to nonnative plant encroachment need to be further investigated.

Here, I focused on four species of invasive southwestern trees that are rapidly encroaching throughout riparian corridors and replacing native vegetation. I reviewed the literature to determine the extent that these four species are known to be positively or negatively impacting native wildlife species and discuss the ramifications for riparian restoration efforts. When data was absent on these specific species and naïve southwestern wildlife, I expanded the search further to capture broadly applicable examples from other geographic regions.

## Focal Invasive Species

I considered the impacts of Russian olive, salt cedar, tree of heaven and Siberian elm on wildlife throughout this review because they are regarded as some of the most invasive species in the southwestern United States (Figure 1A-D). However, these species are not restricted to the southwest and the conclusions drawn in this review are broadly applicable to other geographic regions. I reviewed the GBIF biodiversity database (<https://www.gbif.org/>) to understand the extent that these focal species have spread across North America since their introduction, then mapped their known geographic locations (Figures 2-5). The following maps should be viewed as a general guideline to the distributional patterns of these species across North America and the southwest, not as an exhaustive list of every location these species occur. This was done to aid in understanding the geographic scope of potential impacts of these species on nonnative wildlife and to understand which wildlife species may be impacted in the future.



Figure 1. The focal invasive plant species that were the focus of this review. A) Russian olive (photo: Janice Tucker), B) Saltcedar (photo: Jean Yamamura), C) Tree of heaven (photo: Joseph DiTomaso), D) Siberian elm (photo: Daniela Castim).

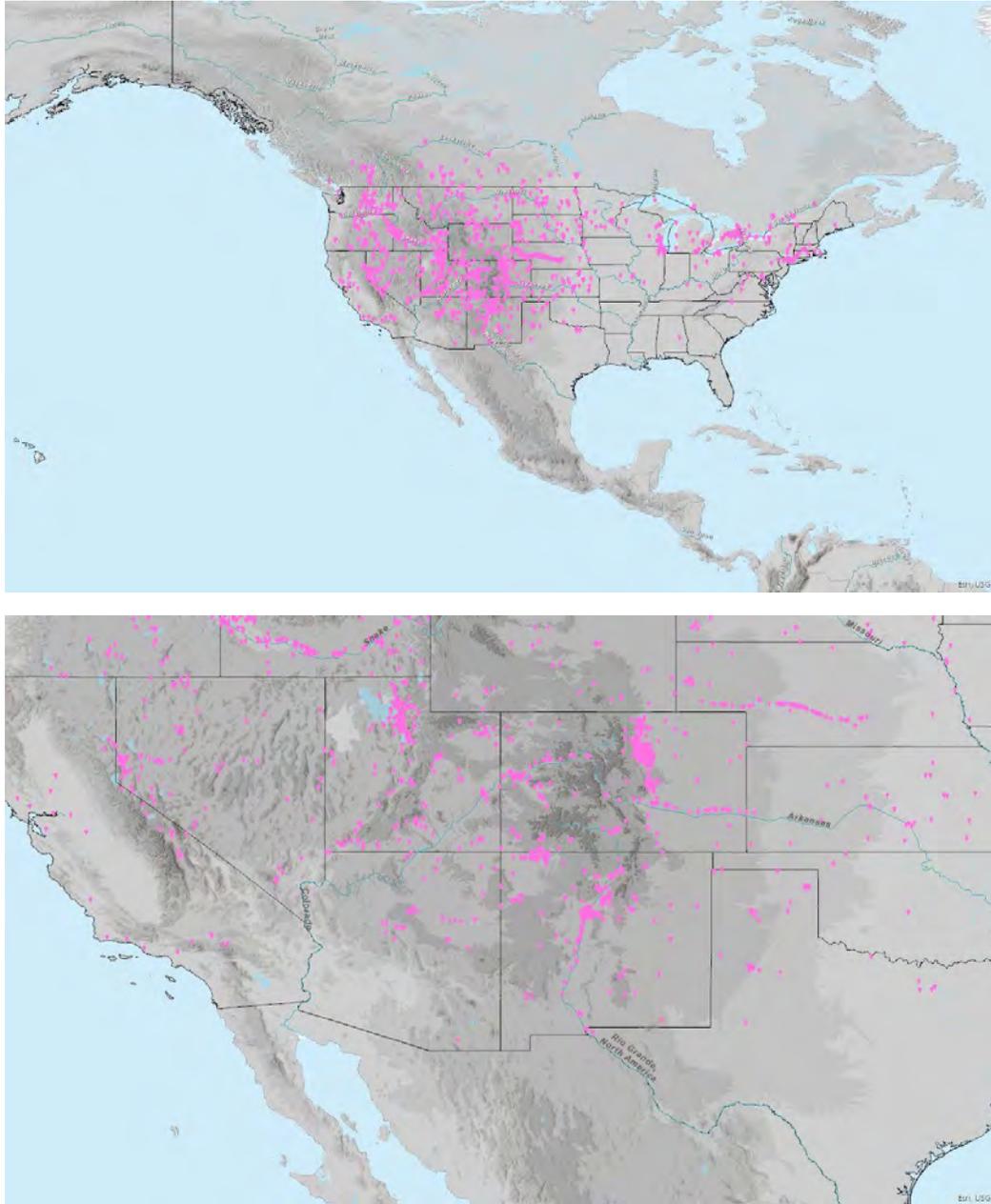


Figure 2. Russian olive records from North America. An initial search of the Gbif database yielded 21,918 records from North America. After screening the data, 4,333 records with specific location data were available for mapping. The top panel shows the approximate distribution of

Russian olive across North America and the bottom panel shows the approximate distribution in the southwest.

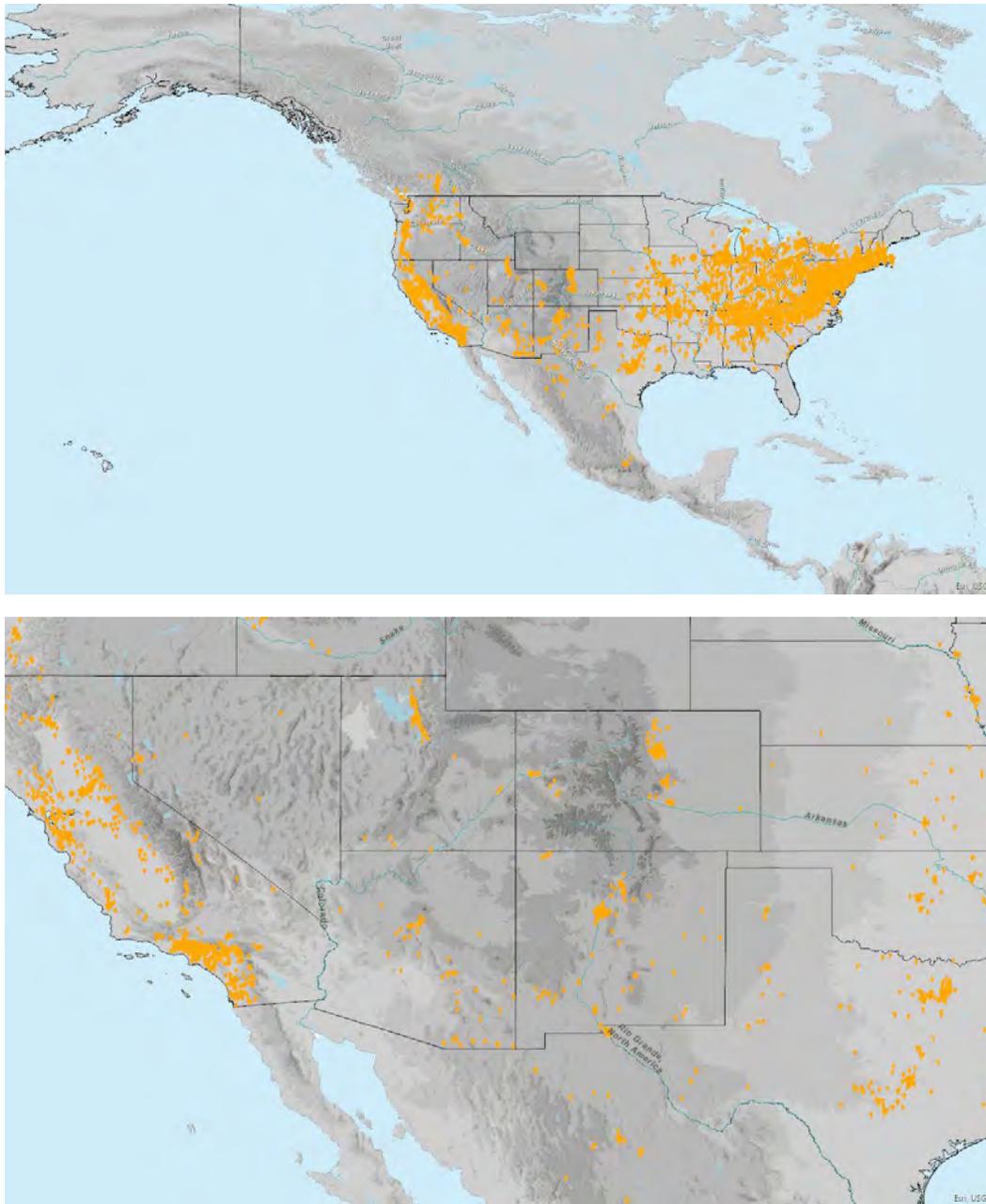


Figure 3. Tree of heaven records from North America. An initial search of the Gbif database yielded 108,353 records from North America. After screening the data, 28,725 records with specific location data were available for mapping. The top panel shows the approximate

distribution of the tree of heaven across North America and the bottom panel shows the approximate distribution in the southwest.

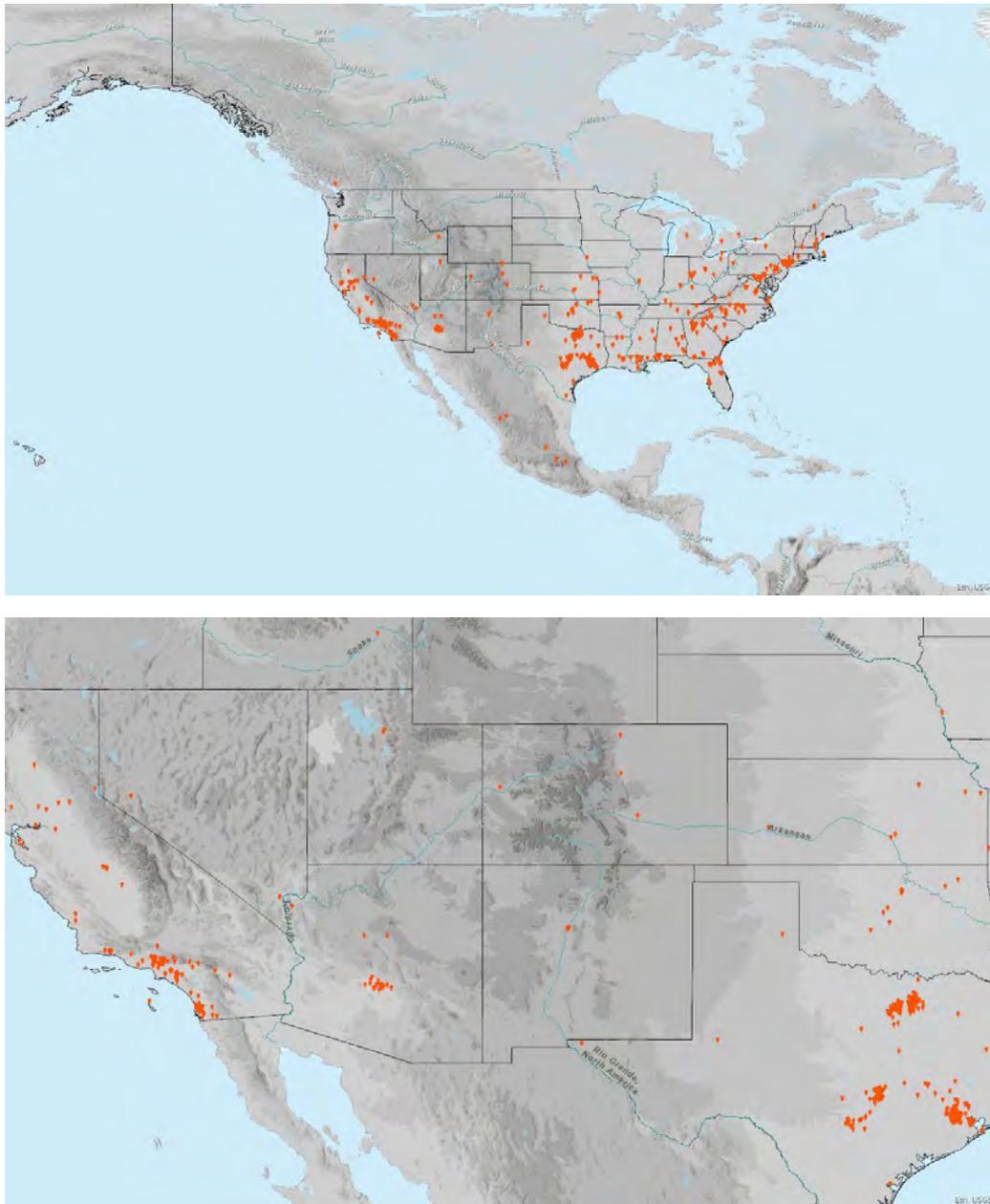


Figure 4. Siberian elm records from North America. An initial search of the Gbif database yielded 11,688 records from North America. After screening the data 8,187 records with specific location data were available for mapping. The top panel shows the approximate distribution of

the Siberian elm across North America and the bottom panel shows the approximate distribution in the southwest.

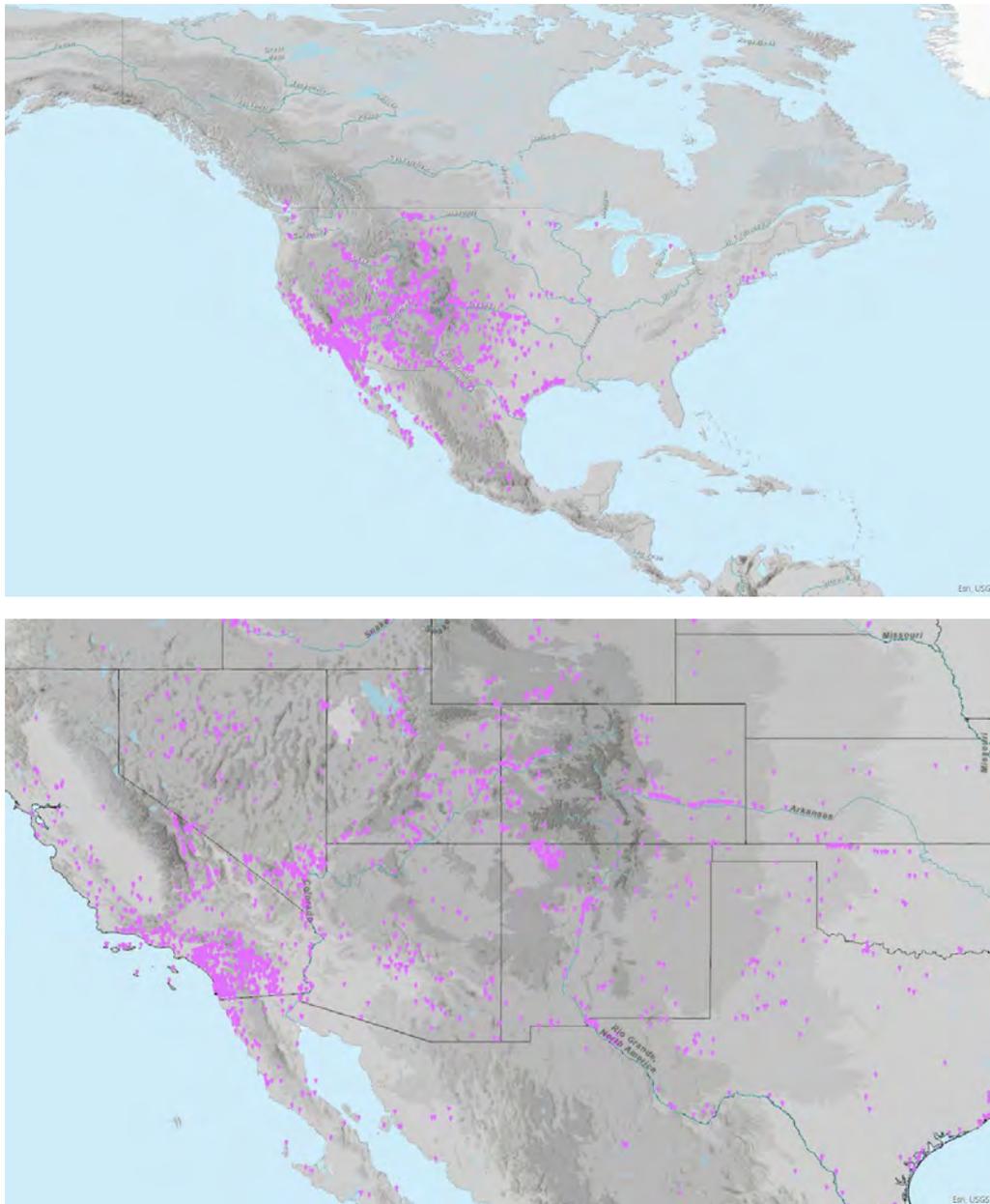


Figure 5. Salt cedar records from North America. An initial search of the Gbif database yielded 6,400 records from North America. After screening the data 4,632 records with specific location data were available for mapping. The top panel shows the approximate distribution of the salt

cedar across North America and the bottom panel shows the approximate distribution in the southwest.

### **Responses of Wildlife to Invasive Plant Encroachment**

**Arthropods**—Arthropods include arachnids, crustaceans and insects and collectively these groups represent most of the animal diversity in riparian corridors. Like all animal communities, arthropod populations fluctuate in response to a myriad of environmental factors and especially in response to ecosystem disturbance. However, the responses of arthropod communities specifically to invasive plants in the Southwest remain largely unstudied (Anderson 1994, Ellis et al. 2000).

The few studies conducted on responses of arthropod communities to invasive plant encroachment suggest that arthropod diversity can be negatively impacted overall, but some species may benefit from the presence of nonnative plants (Nelson and Anderson 1999). Katz and Shafroth 2003 found that arthropod diversity and density declined in patches of Russian olive. Andersen (1994) found that cicadas commonly used and survived well in salt cedar but emerged later in the year in those stands than would normally occur in native cottonwood-willow stands. Bateman and Paxton (2009) noted that these shifts in emergence times could impact birds that feed on cicadas because resource pulses were delayed to different time periods. Furthermore, Albrecht et al. (2016) documented the changes in pollination patterns which take place following replacement of native plants by invasive plants, which has the potential for long-term impacts on riparian corridor ecosystems.

Although some of these hypotheses have been formulated, there has only been one study that investigated whole insect community responses to any of the focal invasive tree species targeted in this review. Collette et al. (2014) investigated whether insect diversity was lower on

invasive plants than on native riparian plants in British Columbia (BC), Canada. However, she only focused on Russian olive for the nonnative portion of the experiment and used two other native species, wood's rose and saskatoon, for focusing the work. She found no difference in insect diversity on Russian olive versus native shrubs. There were no specific discussions of specific specialist species in that thesis though, aside from a general discussion mentioning that specialist species may have had time to adjust their preferences in the last ~100 years since the introduction of Russian olive to that region of BC. There is no evidence to support specialist insects making a switch to new nonnative plant species so quickly though and a encourage caution while interpreting that discussion.

*Positive benefits*—Saltcedar has been found to flower throughout several summer months after the initial flower onset of native riparian plants, which could lengthen periods of time where pollen and nectar resources are available to arthropods (Drost et al. 2001, Yard et al. 2004, McGrath and van Riper 2005). However, if saltcedar completely replaces native riparian plants along long stretches of stream, the benefits are likely to be negated because spring bloom from native plants will not be available along large sections of water networks. Therefore, small patches of nonnatives mixed with the native plants could theoretically provide an overall net benefit to riparian arthropod communities, but the invasive nature of the plants in question may preclude this possibility without constant management.

*Butterflies and Moths*—Several species of sphinx moths are known to commonly feed and develop on riparian plant species like cottonwood and willow in the southwest (Figure 6). However, sphinx moths are not considered to specialize on those plants and have been commonly found on a variety of other plant species. It is possible that other moth and butterfly specialist species could be negatively impacted if there is evidence that nonnatives are replacing

their preferred foraging sources. Examples from other students have shown that native lupine flowers have been completely replaced by nonnative plant invasions in other regions, something that would theoretically impact any insect species that preferred or specialized on those lupine flowers (Dangremond et al. 2010). Severns et al. (2008) showed that invasive plants threatened the survival of an endangered prairie butterfly by altering prairie plant community structure and foraging landscapes. Similarly, Valtonen et al. (2006) found that multiple Lepidoptera species were adversely affected by the encroachment of a nonnative *Lupinus* species along roadways. Specifically in the southwest, it remains unknown which moth and butterfly species can utilize invasive trees to the same extent they might use native riparian species.



Figure 6. White-lined sphynx moth *Hyles lineata*. Photo taken by Tom Koerner, USFWS, Seedskaatee. National Wildlife Refuge.

### **Responses of Bird communities—**

More than 900 species of birds are native to North America and hundreds of species rely on riparian habitats in the western and southwestern United States. Many of those species are migratory and some are neotropical migrants that spend portions of the year wintering in Latin American countries. Although it is generally believed that many birds will be negatively affected by the encroachment of nonnative trees, Corman and Wise-Gervais (2005) showed that 76% of low and mid-elevation riparian breeding birds would nest in saltcedar. Smith and Finch (2014) showed variable impacts on birds in areas where invasive trees had started to invade riparian systems. Studies on the lower Colorado River in the southwest US showed that bird diversity was overall lower in saltcedar than native riparian plant communities, even though some species chose to use nonnative tree habitat (Ellis 1995). Anderson et al. (1977) also showed that some bird species would use nonnative tamarix in a variety of different contexts, but it depended on the species.

Bateman and Paxton (2009) suggest that generalist birds tend to respond better to the encroachment of nonnative plants than specialist birds. For example, several species of woodpeckers that engineer their nesting cavities seem to prefer native riparian trees. If that is the case, birds that utilize woodpecker holes would also be affected, including species like saw-whet owls and northern pygmy owls that commonly use old woodpecker cavities. Russian olive produces fruit that many bird species will eat; however, studies in New Mexico have shown that of all the birds typically found to nest in riparian native trees, more than 50% avoided nesting Russian olive. Of the bird species that do decide to nest in nonnative trees, there is no evidence that nest success and productivity rates are different than native plants (Stoleson and Finch, 2001).

Raptors are expected to be negatively affected by nonnative tree encroachment because the structure and height of saltcedar, Russian olive and other nonnatives is not conducive to the nesting ecology of most riparian nesting raptors. When native vegetation is present, many raptors will select the highest trees with long horizontal branches for nesting and perching to hunt (Bateman and Paxton 2009). Because waterfowl and shorebirds don't commonly utilize riparian trees for nesting, it is suspected that these groups will be less impacted by nonnative plant encroachment (Bateman and Paxton 2009). However, it is possible bird species in these groups could be affected in other ways such as water loss, changes in arthropod diversity, or encroachment of invasive trees in shoreline nesting habitat. The Southwestern willow flycatcher and yellow-billed cuckoo are two southwestern riparian dwelling species that are listed as federally endangered and have been mentioned as species that could be at risk of invasive plant encroachment. However, studies to date have shown no or limited data to support negative impacts of invasive trees on these two species (Drost et al. 2001, Durst 2004).

### **Responses of Mammals—**

There are surprisingly few studies on the impacts of the focal invasive plant species on mammals (Ellis et al. 1997). Raccoons have been shown to benefit from Russian olive trees because they will consume the fruits of the tree, and raccoons may even aid in dispersing seeds of the tree after consumption, positively benefiting its expansion. Lesica-Miles (2004) found that American beavers selected native cottonwood trees for food, which they hypothesized was opening space for invasive Russian olive and tamarisk to take over larger expanses of ground on riparian corridors. Juhász et al. (2022) compared the foraging preferences of beavers and determined that beavers actively avoided two different species of nonnative trees and overwhelmingly preferred

native trees in the *salix* and *populus* genera (willow spp. and poplar spp.). Albert and Trimble (2000) suggest beavers are a keystone species to consider in riparian restoration efforts based on work that was carried out on the Zuni Indian Reservation. It can be concluded from these various studies that beavers are likely being negatively impacted by invasive tree encroachment in the southwest, although the majority of research is being carried out in other regions. Invasive saltcedar, Siberian elm, tree of heaven, and Russian olive have different wood densities and characteristics than native cottonwoods and willows, which suggests those invasives will not be an equal foraging source regardless of the geographic focus of study.

A few studies have tested whether the removal of saltcedar and Russian olive had positive impacts on small rodents. Anderson (1994) tested whether the removal of nonnative tree species in riparian zones along the Colorado river positively benefitted 15 different focal mammal species. The study included information on white-throated woodrat (*Neotoma albigula*), cactus mouse (*Peromyscus eremicus*), Merriam's kangaroo rat (*Dipodomys merriami*), Arizona cotton rat (*Sigmodon arizonae*), the southern grasshopper mouse (*Onychomys torridus*), and the deer mouse (*Peromyscus maniculatus*). However, the work was not conducted long enough to determine whether the treatment truly had an impact on the focal small mammal species. Given the natural stochasticity of wildlife populations of any species, the research wasn't robust enough to test whether any changes in biomass could be attributed to the nonnative removal treatment or to other environmental pressures. In other studies, capture rates of Crawford's gray shrews were evaluated in areas where saltcedar and Russian olive had been removed, but no significant effect of removal could be determined (Chung-MacCoubrey et al. 2009). Chung-MacCoubrey and Batemen (2006) found positive effects of nonnative tree removal on various bat species along the

middle Rio Grande River. However, there is little other information to determine how bat communities respond to nonnative plant encroachment in the southwest.

Based on the ecology of many bat species, it is possible that some could be impacted by loss of roosting sites, which may be more suitable in some native tree species. Other bat species may be more negatively impacted by a loss of preferred insect species that could be negatively impacted by nonnative plant encroachment. From another perspective, some native mammals can aid in discouraging the establishment of invasive plants. Pocket gophers, for example, have been shown to negatively impact root systems of nonnative trees (Manning et al. 1996), positively contributing to restoration targets.

**Responses of Reptiles and Amphibians**— Herpetofaunal species are some of the most underrepresented taxa when considering the impacts of nonnative trees on wildlife. This is surprising given the roles that many reptiles and amphibians play in ecosystems, their high diversity in many parts of the southwest, and the variety of endemic species that are unique to different desert ecosystems or specific watersheds. The Chihuahuan desert is home to more than 170 species of amphibians and reptiles, while the greater Chihuahuan desert ecoregion is home to approximately 217 species. 18 of the 170 desert-specific species are considered endemic to the region <https://www.nps.gov/articles/amphibians-reptiles-chihuahuan-desert.htm>. In the Sonoran Desert there are approximately 100 reptile and 20 amphibian species <https://www.nps.gov/im/sodn/ecosystems.htm>, highlighting the unique diversity associated with the different desert ecosystems in the southwest. Not all of the species in those totals are found along riparian corridors, but many of them are.

Collectively, the few studies that have attempted to compare how reptile species respond to removal of nonnative plants have obtained little information that can be used for big picture management schemes. Studies that estimated the impacts of nonnative plant removal on abundance of prairie lizards, New Mexico whiptails, Chihuahan spotted lizards, desert grassland whiptails, and side-blotched lizards found benefits of invasive plant removal in some cases, and no effect in other cases (Batemen et al. 2008a). No effects were found on amphibians. However, these short-term studies lack the nuance and length of study necessary to truly compare and contrast herpetofaunal communities between native and nonnative plant zones.

Among amphibians, there is also relatively little data specific to the southwest. However, studies from other regions provide some evidence that the impacts of nonnative plants could be serious for native amphibians depending on the context. Watling et al. (2011) found evidence in laboratory studies that water with extracts of nonnative shrub species could prove lethal to amphibian larvae. Therefore, it is possible that amphibians laying eggs in riparian corridors, particularly along the root systems of nonnative plants, could be more susceptible to such impacts than may be readily apparent. Ecological studies of *Bufo* species in the US shows that some species may depend on periods of flooding to create proper breeding habitat (Bateman et al. 2008b). Although not yet tested, this suggests that areas choked out by invasive trees might not provide the proper breeding habitat, especially if the trees soak up excess amounts of water.

**Responses of Fish**—Few studies have been conducted on fish responses to nonnative plant encroachment. Some studies found evidence that crane fly larvae had higher growth rates when fed saltcedar than those fed native vegetation; however, native vegetation stays longer in streams than saltcedar. Bateman and Paxton (2009) mentioned that it is possible the less nutrient rich

native vegetation might still provide more benefit overall by holding longer in streams, benefitting invertebrates like crane-flies and eventually benefitting fish.

Stromberg et al. (2007) showed that stream flow can be significantly altered by invasive tree encroachment, and although impacts on fish were not specifically addressed, it can be expected that fish populations can be negatively impacted by such changes. Kennedy et al. (2005) showed that eradication of tamarix can positively benefit native fish densities in riparian streams. Valley and Bremigan (2002) provide some of the best evidence that invasive macrophytes can alter structure which largemouth bass used for hunting prey such as bluegill, which could have a long-term impact on foraging success and, ultimately, survival rates. Although that study was not conducted in southwestern riparian corridors, the same line of thinking could be applied to riparian specialist species in the southwest and eventually tested in that system.

### **New Mexico's At Risk Riparian Species**

The New Mexico Department of Game and Fish (NMDGF) publishes an annual list of Threatened and Endangered species (collectively considered "At Risk") which includes mostly vertebrates, but also some invertebrate species. The 2022 report included 40 species that were considered to be require riparian habitat, or at least commonly use riparian habitat. The species that use riparian habitat and qualify as At Risk are summarized here because they are some of the first species that could be most directly impacted by invasive plant encroachment in riparian zones (Table 1).

Table 1. List of At Risk species in New Mexico as defined by the New Mexico Department of Game and Fish (NMDGF) in 2022. Species are divided by major taxonomic group with specific At Risk statuses provided. Some species are currently unprotected but considered species to watch closely. A single species, the Gould’s turkey, is listed as Endangered, but has been proposed for delisting by the NMDGF.

<b>Species Common Name</b>	<b>Scientific Name</b>	<b>Status in New Mexico</b>
<b>Mammals</b>		
North American least shrew	<i>Cryptotis parvus</i>	Threatened
Spotted bat	<i>Euderma maculatum</i>	Threatened
Western yellow bat	<i>Lasiurus xanthinus</i>	Threatened
Arizona shrew	<i>Sorex arizonae</i>	Endangered
(Peñasco) least chipmunk	<i>Neotamias minimus atristriatus</i>	Endangered
Meadow jumping mouse	<i>Zapus hudsonius</i>	Endangered
(Arizona) montane vole	<i>Microtus montanus arizonensis</i>	Endangered
Colorado chipmunk	<i>Neotamias quadrivittatus australis</i>	Threatened
<b>Birds</b>		
Common Ground Dove	<i>Columbina passerina</i>	Endangered
Elegant Trogon	<i>Trogon elegans</i>	Endangered
Northern Beardless-Tyrannulet	<i>Camptostoma imberbe</i>	
Thick-billed Kingbird	<i>Tyrannus crassirostris</i>	
Common Black-Hawk	<i>Buteogallus anthracinus</i>	
(Gould’s) Wild Turkey	<i>Meleagris gallopavo mexicana</i>	Endangered
Whiskered Screech-Owl	<i>Megascops trichopsis</i>	Threatened
Broad-billed Hummingbird	<i>Cynanthus latirostris</i>	Threatened
Varied Bunting	<i>Passerina versicolor</i>	Threatened
Abert’s Towhee	<i>Melospiza aberti</i>	At Risk
Bell’s Vireo	<i>Vireo bellii</i>	Threatened
Gila Woodpecker	<i>Melanerpes uropygialis</i>	Endangered
Costa’s Hummingbird	<i>Calypte costae</i>	Threatened
Violet-crowned Hummingbird	<i>Amazilia violiceps</i>	Threatened
Broad-billed Hummingbird	<i>Cynanthus latirostris</i>	Threatened
<b>Fish</b>		
Roundtail chub	<i>Gila robusta</i>	Threatened

Chihuahua chub	<i>Gila nigrescens</i>	Threatened
<b>Reptiles</b>		
Green Ratsnake	<i>Senticolis triaspis</i>	Unprotected
Mountain Skink	<i>Plestiodon callicephalus</i>	Unprotected
Giant Spotted Whiptail	<i>Aspidoscelis stictogramma</i>	Unprotected
Western River Cooter	<i>Pseudemys gorzugi</i>	Unprotected
Mexican Gartersnake	<i>Thamnophis eques</i>	Unprotected
<b>Amphibians</b>		
Sonoran Desert Toad	<i>Incilius alvarius</i>	Unprotected
<b>Molluscs and Arthropods</b>		
Ovate vertigo	<i>Vertigo ovata</i>	Threatened
Shortneck snaggletooth	<i>Gastrocopta dalliana dalliana</i>	Endangered
Gila springsnail	<i>Pyrgulopsis gilae</i>	Threatened
Pecos assiminea	<i>Assiminea pecos</i>	Endangered
Roswell springsnail	<i>Pyrgulopsis roswellensis</i>	Endangered
Socorro springsnail	<i>Pyrgulopsis neomexicana</i>	Endangered
Chupadera springsnail	<i>Pyrgulopsis chupadera</i>	Endangered
Texas hornshell	<i>Popenaias popeii</i>	Endangered
Noel's amphipod	<i>Gammarus desperatus</i>	Endangered

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## Future Directions

Collectively, there is still a great deal of information lacking about how wildlife species respond to nonnative plant encroachment in the southwestern US, and therefore it remains unclear how riparian restoration may or may not impact wildlife communities as well. Both negative and positive impacts of invasive trees have been reported for southwestern wildlife species. Several vertebrate groups are especially neglected when it comes to studies focused on the impacts of invasive plants on their persistence (Figure 7). Some evidence suggests that once compromised, it may not be possible to restore some ecosystems to pre-invasion levels, and some studies show evidence that small vertebrates might be heavily impacted by restoration efforts themselves

(Wolf et al. 2018). This means that careful consideration should be given to the context prior to extensive restoration efforts being made.

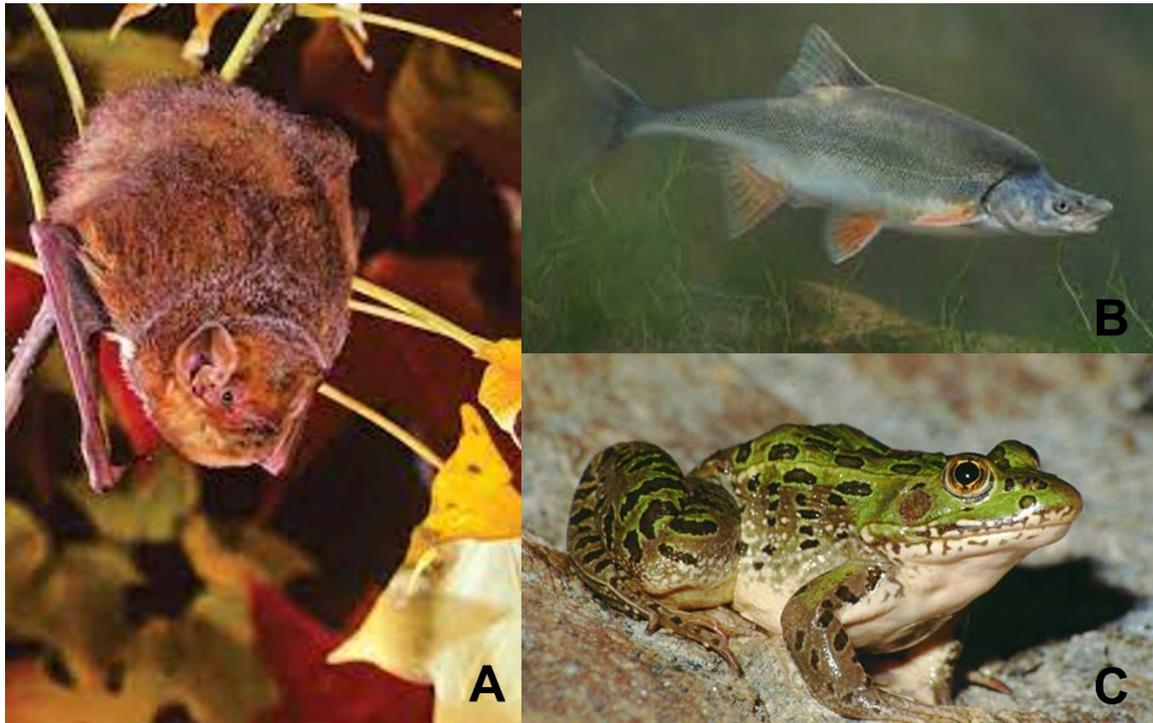


Figure 7. Examples of neglected groups in studies focused on invasive riparian plants and wildlife in the southwestern US. A) Eastern red bat pictured to represent all native bats to the southwest (photo credit: Merlin D. Tuttle), B) humpback chub pictured to represent all endemic fish to the southwest (photo credit: George Andrejko, Arizona Department of Fish and Game), and C) Chiricahua leopard frog picture to represent all endemic amphibians to the southwest (photo credit: Erik Enderson, Center for Biological Diversity).

In general, it seems that generalist animal species are likely to respond better to invasive plants than specialist species, which may be one key consideration prior to considering costly

restoration efforts. Any species that is dependent on riparian plants like willow or cottonwood will likely not respond well to replacement by nonnative plants like those included in this review. If the goal is to store native specialist wildlife species, removal of invasive plants may be the only option in some cases. This is only a generalization though, and some generalist species can also be negatively impacted by invasive tree encroachment.

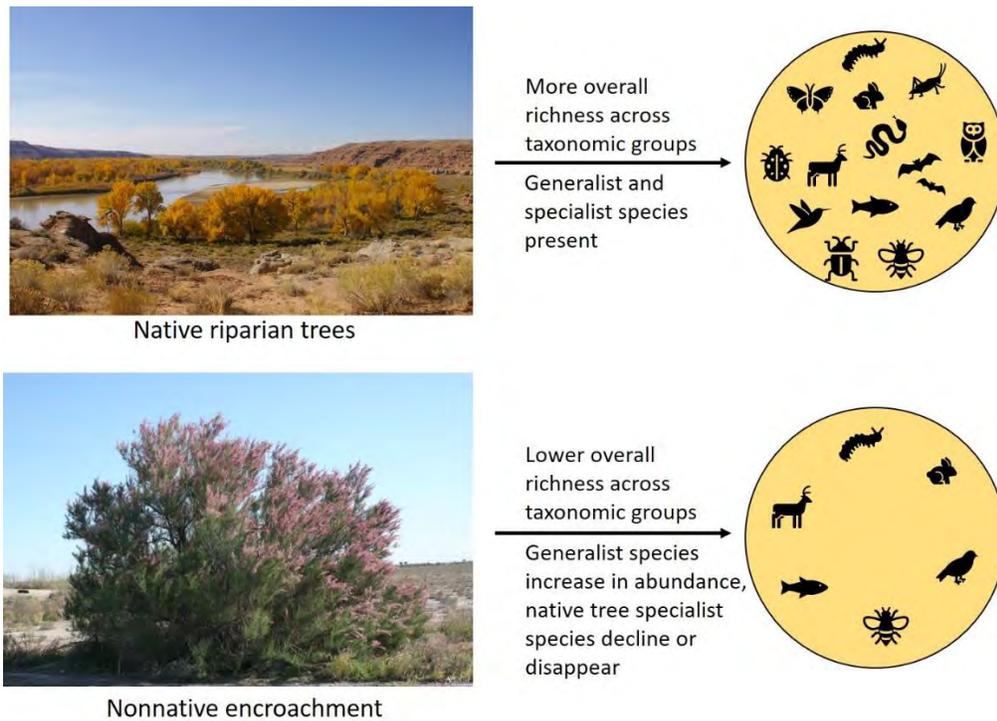


Figure 8. Predicted generalizable pattern for determining which species will be the most quickly and most severely impacted by invasive plant encroachment. The photo for the native riparian trees is credited to Ryan Mollnow (USFWS) and the nonnative encroachment photo is credited to the Texas A&M Agrilife Extension center.

In the future, there are several lines of study that require additional research before the impacts of riparian encroachment on wildlife can be more completely understood. I have posed these as potential questions that could be pursued by undergraduate or graduate students.

### **Unanswered Questions**

#### **Question 1: Are there other broadly identifiable characteristics that make it possible to predict how a given species of wildlife will respond to nonnative encroachment?**

One generalizable pattern that I found based on the limited work that has been done suggests that specialist species are the most likely to respond poorly to invasive plant encroachment, while generalists will tend to adapt for easily to such change. However, there may be other traits that could be broadly applied to a variety of wildlife species, regardless of taxonomic grouping, which could be used to predict how negatively a given species might be impacted.

#### **Question 2: What are the impacts of invasive trees on riparian invertebrate diversity?**

This whole area of focus should be considered an urgent need for conservation and restoration efforts in the southwest. Invertebrates make up a disproportionate piece of the biodiversity in the Southwest and yet have received less research attention. Considering the linkages between large vertebrates and invertebrates, this topic could yield important information in the future.

**Question 3: What are the impacts of invasive trees on semiaquatic mammals like beavers and otters?** Some work has looked at the impacts of invasive trees on beavers, but this question could be further expanded to included multiple semi-aquatic species and to further address the ramifications for beavers. Because beavers are regarded as an ecosystem engineer with well

quantified positive impacts on other riparian dwelling species, this question could address ecological cascades in southwestern riparian zones.

**Question 4: What are the impacts of invasive riparian trees on neglected southwestern vertebrates?** A study like this focused specifically on bats, endemic fish and amphibians would be especially interesting for conservation initiatives across the southwest and would potentially inform restoration efforts in the future.

**Question 5: Can we predict a biogeographic pattern associated with invasive plants and negative consequences for wildlife?**

Southwest stream networks are unique because many drainages and associated native plants are completely isolated from one another. Isolation over time allows unique species to evolve and there are examples of many micro endemics across the southwestern US

## **Conclusions**

Ultimately, invasive plant impacts on wildlife are only partially understood, which means the extent that invasive plant removal will benefit wildlife restoration remains largely unclear.

Although there are a variety of examples that suggest restoration will positively benefit many native wildlife species, more research needs to be done. There is data to suggest that some wildlife species are heavily impacted by invasive tree species in the southwest, particularly specialist wildlife species that rely on native plants like willow or cottonwood. Beavers are one of the few examples of mammals that have been studied in enough detail to understand some of the negative impacts of invasive trees on their populations. Some insects, such as cicada spp.,

have shown a shift in seasonal emergence times in areas where salt cedar has taken over sections along riparian corridors. There are many remaining questions about the effects of invasive plant encroachment on wildlife species in the southwest. Given the economic value of biodiversity for a variety of ecosystem services that benefit humans, it seems to be a worthwhile area of investigation that researchers should continue to pursue. Before a decision is made to restore a riparian corridor by removing invasive trees, it is essential to consider what the restoration goals are. Examples of targets include aiming for max historical species richness, returning key ecological functions, max abundance of valuable game species, aesthetic value, erosion control and stability, or cultural value. Because invasive trees do not necessarily negatively impact all native wildlife, the kinds of restoration goals will dictate the extent that restoration measures need to be taken. I recommend future investigations specifically focus on two groups of wildlife species when testing for effects of invasive trees, 1) riparian specialist wildlife, 2) At Risk wildlife, or 3) previously neglected endemic wildlife. I suspect that targeted studies on these groups, particularly those that could be considered a true specialist on plants like willows or cottonwoods, will yield more informative information for future restoration efforts. Appendix 1 provides a list of riparian dwelling species with species divided into specific kinds of riparian habitat types. This list is based on the New Mexico Department of Game and Fish riparian woodlands and wetlands associated species definitions <https://nmswap.org/vegetation-types/6>.

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Appendix 1. List of riparian species partitioned by distinct habitat types as defined by the New Mexico Department of Fish and Game.

<b>Common Species Name and Habitat Type</b>	<b>Scientific Name</b>
<b>Montane-subalpine wet shrubland &amp; wet meadow</b>	
Boreal toad	<i>Anaxyrus boreas</i>
Chiricahua leopard frog	<i>Lithobates chiricahuensis</i>
Northern leopard frog	<i>Lithobates pipiens</i>
boreal owl	<i>Aegolius funereus</i>
American bittern	<i>Botaurus lentiginosus</i>
Lewis's woodpecker	<i>Melanerpes lewis</i>
long-billed curlew	<i>Numenius americanus</i>
Virginia's warbler	<i>Oreothlypis virginiae</i>
white-tailed ptarmigan	<i>Lagopus leucura</i>
spotted bat	<i>Euderma maculatum</i>
American mink	<i>Neovison vison</i>
Western bluebird	<i>Sialia mexicana</i>
flamulated owl	<i>Psiloscops flammeolus</i>
black-throated gray warbler	<i>Setophaga nigrescens</i>
Mexican spotted owl	<i>Strix occidentalis lucida</i>
boreal chorus frog	<i>Pseudacris maculata</i>
<b>Great plains floodplain forest</b>	
Northern leopard frog	<i>Lithobates pipiens</i>
plains leopard frog	<i>Lithobates blairi</i>
Bendire's thrasher	<i>Toxostoma bendirei</i>
American bittern	<i>Botaurus lentiginosus</i>
pinyon jay	<i>Gymnorhinus cyanocephalus</i>
bald eagle	<i>Haliaeetus leucocephalus</i>
loggerhead shrike	<i>Lanius ludovicianus</i>
red-headed woodpecker	<i>Melanerpes erythrocephalus</i>
Lewis's woodpecker	<i>Melanerpes lewis</i>
Virginia's warbler	<i>Oreothlypis virginiae</i>
bank swallow	<i>Riparia riparia</i>
least shrew	<i>Cryptotis parva</i>
Southwestern willow flycatcher	<i>Empidonax traillii extimus</i>
common black hawk	<i>Buteogallus anthracinus</i>
yellow-billed cuckoo	<i>Coccyzus americanus</i>
least tern	<i>Sternula antillarum</i>
Bell's vireo	<i>Vireo bellii</i>
gray vireo	<i>Vireo vicinior</i>

New Mexico meadow jumping mouse  
black-tailed prairie dog  
Pecos assiminea  
big bend slider  
California kingsnake  
boreal chorus frog  
Rio Grande leopard frog

**Southwest riparian forest**

Chiricahua leopard frog  
Arizona toad  
plains leopard frog  
violet-crowned hummingbird  
juniper titmouse  
common black hawk  
lucifer hummingbird  
Costa's hummingbird  
Northern beardless tyrannulet  
yellow-billed cuckoo  
common ground dove  
broad-billed hummingbird  
bald eagle  
loggerhead shrike  
whiskered screech owl  
red-headed woodpecker  
Lewis's woodpecker  
Gila woodpecker  
Abert's towhee  
Virginia's warbler  
flamulated owl  
bank swallow  
Grace's warbler  
black-throated gray warbler  
elegant trogon  
thick-billed kingbird  
gray vireo  
red-faced warbler  
elf owl  
painted redstart  
Lucy's warbler  
Mexican long-nosed bat  
spotted bat  
western yellow bat

*Zapus hudsonius luteus*  
*Cynomys ludovicianus*  
*Assiminea pecos*  
*Trachemys gaigeae*  
*Lampropeltis getula californiae*  
*Pseudacris maculata*  
*Lithobates berlandieri*

*Lithobates chiricahuensis*  
*Anaxyrus microscaphus*  
*Lithobates blairi*  
*Amazilia violiceps*  
*Baeolophus ridgwayi*  
*Buteogallus anthracinus*  
*Calothorax lucifer*  
*Calypte costae*  
*Camptostoma imberbe*  
*Coccyzus americanus*  
*Columbina passerina*  
*Cyananthus latirostris*  
*Haliaeetus leucocephalus*  
*Lanius ludovicianus*  
*Megascops trichopsis*  
*Melanerpes erythrocephalus*  
*Melanerpes lewis*  
*Melanerpes uropygialis*  
*Melospiza aberti*  
*Oreothlypis virginiae*  
*Psiloscops flammeolus*  
*Riparia riparia*  
*Setophaga graciae*  
*Setophaga nigrescens*  
*Trogon elegans*  
*Tyrannus crassirostris*  
*Vireo vicinior*  
*Cardellina rubrifrons*  
*Micrathene whitneyi*  
*Myioborus pictus*  
*Oreothlypis luciae*  
*Leptonycteris nivalis*  
*Euderma maculatum*  
*Lasiurus xanthinus*

jaguar  
Mexican gartersnake  
narrow-headed gartersnake  
Giant spotted whiptail  
Arizona black rattlesnake  
reticulate gila monster  
mountain skink  
green rat snake  
arid land ribbonsnake  
big bend slider  
vesper sparrow  
western bluebird  
pygmy nuthatch  
Southwestern willow flycatcher  
burrowing owl  
snowy plover  
peregrine falcon  
varied bunting  
least tern  
Mexican spotted owl  
Bell's vireo  
Gould's wild turkey  
New Mexico meadow jumping mouse  
American mink  
Dona Ana talussnail  
Western river cooter  
plain-bellied water snake  
neotropic cormorant  
lowland leopard frog  
Rio Grande leopard frog  
Sonoran desert toad

#### **Warm Desert Lowland Riparian Shrubland**

Chiricahua leopard frog  
Arizona toad  
Western narrow-mouthed toad  
plains leopard frog  
Bendire's thrasher  
lucifer hummingbird  
Costa's hummingbird  
Northern beardless tyrannulet  
yellow-billed cuckoo  
common ground dove

*Panthera onca*  
*Thamnophis eques*  
*Thamnophis rufipunctatus*  
*Aspidoscelis stictogramma*  
*Crotalus cerberus*  
*Heloderma suspectum suspectum*  
*Plestiodon callicephalus*  
*Senticolis triaspis*  
*Thamnophis proximus*  
*Trachemys gaigeae*  
*Pooecetes gramineus*  
*Sialia mexicana*  
*Sitta pygmaea*  
*Empidonax traillii extimus*  
*Athene cunicularia*  
*Charadrius nivosus*  
*Falco peregrinus*  
*Passerina versicolor*  
*Sternula antillarum*  
*Strix occidentalis lucida*  
*Vireo bellii*  
*Meleagris gallopavo mexicana*  
*Zapus hudsonius luteus*  
*Neovison vison*  
*Sonorella todsoni*  
*Pseudemys gorzugi*  
*Nerodia erythrogaster*  
*Phalacrocorax brasilianus*  
*Lithobates yavapaiensis*  
*Lithobates berlandieri*  
*Incilius alvarius*

*Lithobates chiricahuensis*  
*Anaxyrus microscaphus*  
*Gastrophryne olivacea*  
*Lithobates blairi*  
*Toxostoma bendirei*  
*Calothorax lucifer*  
*Calypte costae*  
*Camptostoma imberbe*  
*Coccyzus americanus*  
*Columbina passerina*

Aplomado falcon  
loggerhead shrike  
red-headed woodpecker  
Lewis's woodpecker  
gila woodpecker  
Abert's towhee  
Virginia's warbler  
varied bunting  
bank swallow  
black-throated gray warbler  
Bell's vireo  
Lucy's warbler  
spotted bat  
Mexican gartersnake  
Narrow-headed gartersnake  
giant spotted whiptail  
Arizona black rattlesnake  
reticulate gila monster  
green rat snake  
arid land ribbonsnake  
gray-banded kingsnake  
Cassin's sparrow  
Western bluebird  
lowland leopard frog  
Sonoran desert toad  
Rio Grande leopard frog

*Falco femoralis*  
*Lanius ludovicianus*  
*Melanerpes erythrocephalus*  
*Melanerpes lewis*  
*Melanerpes uropygialis*  
*Melospiza aberti*  
*Oreothlypis virginiae*  
*Passerina versicolor*  
*Riparia riparia*  
*Setophaga nigrescens*  
*Vireo bellii*  
*Oreothlypis luciae*  
*Euderma maculatum*  
*Thamnophis eques*  
*Thamnophis rufipunctatus*  
*Aspidoscelis stictogramma*  
*Crotalus cerberus*  
*Heloderma suspectum suspectum*  
*Senticolis triaspis*  
*Thamnophis proximus*  
*Lampropeltis alterna*  
*Peucaea cassinii*  
*Sialia mexicana*  
*Lithobates yavapaiensis*  
*Incilius alvarius*  
*Lithobates berlandieri*

#### **Rocky Mountain Montane Riparian Forest**

boreal toad  
Chiricahua leopard frog  
Jemez Mountains salamander  
Sacramento mountains salamander  
Arizona treefrog  
Northern leopard frog  
sagebrush sparrow  
juniper titmouse  
common black hawk  
Costa's hummingbird  
evening grosbeak  
yellow-billed cuckoo  
common ground dove  
olive-sided flycatcher  
broad-billed hummingbird

*Anaxyrus boreas*  
*Lithobates chiricahuensis*  
*Plethodon neomexicanus*  
*Aneides hardii*  
*Hyla wrightorum*  
*Lithobates pipiens*  
*Artemisiospiza nevadensis*  
*Baeolophus ridgwayi*  
*Buteogallus anthracinus*  
*Calypte costae*  
*Coccythraustes vespertinus*  
*Coccyzus americanus*  
*Columbina passerina*  
*Contopus cooperi*  
*Cyananthus latirostris*

black swift  
pinyon jay  
Cassin's finch  
bald eagle  
yellow-eyed junco  
loggerhead shrike  
Lewis's woodpecker  
Gila woodpecker  
long-billed curlew  
Virginia's warbler  
flammulated owl  
bank swallow  
Grace's warbler  
black-throated warbler  
Bell's vireo  
red-faced warbler  
painted redstart  
Lucy's warbler  
williamson's sapsucker  
Mexican long-nosed bat  
pale Townsend's big-eared bat  
spotted bat  
Pacific marten  
American mink  
mineral creek mountain snail  
Jemez woodlandsnail  
Sangre de Cristo woodlandsnail  
false marsh snail  
narrow-headed gartersnake  
Clark's nutcracker  
mountain bluebird  
Western bluebird  
pygmy nuthatch  
Arizona toad  
southwestern willow flycatcher  
Mexican spotted owl  
gray vireo  
New Mexico meadow jumping mouse  
California kingsnake  
Penasco least chipmunk  
Mexican whip-poor-will  
boreal chorus frog  
Arizona montane vole

*Cypseloides niger*  
*Gymnorhinus cyanocephalus*  
*Haemorhous cassinii*  
*Haliaeetus leucocephalus*  
*Junco phaeonotus*  
*Lanius ludovicianus*  
*Melanerpes lewis*  
*Melanerpes uropygialis*  
*Numenius americanus*  
*Oreothlypis virginiae*  
*Psiloscops flammeolus*  
*Riparia riparia*  
*Setophaga graciae*  
*Setophaga nigrescens*  
*Vireo bellii*  
*Cardellina rubrifrons*  
*Myioborus pictus*  
*Oreothlypis luciae*  
*Sphyrapicus thyroideus*  
*Leptonycteris nivalis*  
*Corynorhinus townsendii*  
*Euderma maculatum*  
*Martes caurina*  
*Neovison vison*  
*Mineral Creek Mountainsnail*  
*Ashmunella ashmuni*  
*Ashmunella thomsoniana*  
*Deroceras heterura*  
*Thamnophis rufipunctatus*  
*Nucifraga columbiana*  
*Sialia currucoides*  
*Sialia mexicana*  
*Sitta pygmaea*  
*Anaxyrus microscaphus*  
*Empidonax traillii extimus*  
*Strix occidentalis lucida*  
*Vireo vicinior*  
*Zapus hudsonius luteus*  
*Lampropeltis getula californiae*  
*Tamias minimus atristriatus*  
*Antrostomus arizonae*  
*Pseudacris maculata*  
*Microtus montanus arizonensis*

**Great Plains Wet Meadow, Marsh and Playa**

Western narrow-mouthed toad  
plains leopard frog  
burrowing owl  
mountain plover  
snowy plover  
long-billed curlew  
least shrew  
boreal chorus frog

*Gastrophryne olivacea*  
*Lithobates blairi*  
*Athene cunicularia*  
*Charadrius montanus*  
*Charadrius nivosus*  
*Numenius americanus*  
*Cryptotis parva*  
*Pseudacris maculata*

**Arid West Interior Freshwater Emergent Marsh**

Western narrow-mouthed toad  
Nothorn leopard frog  
plains leopard frog  
American bittern  
snowy plover  
long-billed curlew  
eared grebe  
bank swallow  
Clark's grebe  
least shrew  
spotted bat  
Western river cooter  
plain-bellied water snake  
arid land ribbonsnake  
southwestern willow flycatcher  
yellow-billed cuckoo  
pinyon jay  
least tern  
Mexican spotted owl  
Noel's amphipod  
Pecos assimineia  
ovate vertigo snail  
big bend slider  
Neotropic cormorant  
Rio Grande leopard frog

*Gastrophryne olivacea*  
*Lithobates pipiens*  
*Lithobates blairi*  
*Botaurus lentiginosus*  
*Charadrius nivosus*  
*Numenius americanus*  
*Podiceps nigricollis*  
*Riparia riparia*  
*Aechmophorus clarkii*  
*Cryptotis parva*  
*Euderma maculatum*  
*Pseudemys gorzugi*  
*Nerodia erythrogaster*  
*Thamnophis proximus*  
*Empidonax traillii extimus*  
*Coccyzus americanus*  
*Gymnorhinus cyanocephalus*  
*Sternula antillarum*  
*Strix occidentalis lucida*  
*Gammarus desperatus*  
*Assimineia pecos*  
*Vertigo ovata*  
*Trachemys gaigeae*  
*Phalacrocorax brasilianus*  
*Lithobates berlandieri*

**Desert Alkali-Saline Wetland**

Western narrow-mouthed toad  
Northern leopard frog  
plains leopard frog  
Bendire's thrasher

*Gastrophryne olivacea*  
*Lithobates pipiens*  
*Lithobates blairi*  
*Toxostoma bendirei*

sagebrush sparrow	<i>Artemisospiza nevadensis</i>
burrowing owl	<i>Athene cunicularia</i>
mountain plover	<i>Charadrius montanus</i>
snowy plover	<i>Charadrius nivosus</i>
common ground dove	<i>Columbina passerina</i>
bald eagle	<i>Haliaeetus leucocephalus</i>
loggerhead shrike	<i>Lanius ludovicianus</i>
long-billed curlew	<i>Numenius americanus</i>
Botteri's sparrow	<i>Peucaea botterii</i>
least tern	<i>Sternula antillarum</i>
least shrew	<i>Cryptotis parva</i>
Cassin's sparrow	<i>Peucaea cassinii</i>
Southwestern willow flycatcher	<i>Empidonax traillii extimus</i>
yellow-billed cuckoo	<i>Coccyzus americanus</i>
peregrine falcon	<i>Falco peregrinus</i>
gray vireo	<i>Vireo vicinior</i>
Sonoran desert toad	<i>Incilius alvarius</i>

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