Saltcedar and Russian Olive Interactions with Wildlife

By Heather L. Bateman and Eben H. Paxton

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Introduction

Riparian areas of flood plains typically provide a mosaic of productive habitats (Stanford and others, 2005; Latterell and others, 2006) capable of supporting many wildlife species, particularly in the arid and semiarid Western United States. The establishment of nonnative invasive plants can alter riparian habitat by inhibiting native plant recruitment and by increasing the risk of wildfire (Howe and Knopf, 1991; Busch and Smith, 1995). However, the effects of nonnative plants are not necessarily always negative. Many wildlife species will use the exotic plants to some extent, especially when mixed with native vegetation (van Riper and others, 2008), but overall, species of wildlife exhibit a negative or neutral response to exotic habitat. In many areas of the Western United States where riparian systems have been degraded via anthropogenic activities (for example, flood control or groundwater pumping), native vegetation may have difficulty persisting and nonnative vegetation may provide the only available habitat for some species of wildlife (Katz and Shafroth, 2003; Stromberg and others, 2007). Therefore, where possible, the ultimate goal of ecological restoration activities should be the reestablishment of native riparian plant communities and a return to more natural hydrological regimes.

Nonnative saltcedar (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*) are the third and fourth most abundant plants in riparian areas in the Western United States (see chap. 2, this volume; Friedman and others, 2005). Methods for controlling nonnative vegetation can alter riparian areas, often in unpredictable ways, and have the potential to impact a variety of habitat types used by wildlife (Bateman, Chung-MacCoubrey, Finch, and others, 2008). Therefore, understanding how wildlife utilize saltcedar and Russian olive and the effects of control activities on wildlife are important for resource managers who must balance management decisions such as nonnative plant control with protecting critical wildlife habitat.

In this chapter, we present a synthesis of published literature on the use of saltcedar and Russian olive by wildlife and discuss how wildlife respond or are likely to respond to control measures for saltcedar and Russian olive and subsequent restoration efforts. We discuss responses of several groups of wildlife, including arthropods, birds, mammals, herpetofauna, and fish.

Arthropods

Arthropods (insects, arachnids, and crustaceans) constitute by far the greatest diversity of animal species in riparian habitats. Multiple studies have documented high diversity in riparian arthropod communities that can change from site to site, among and within years, and between vegetation types (Liesner, 1971; Cohan and others, 1978; Stevens, 1985; Nelson and Andersen, 1999; Ellis and others, 2000; Yard and others, 2004; Wiesenborn, 2005; Durst and others, 2008). Given the dynamic nature of arthropod communities, it is difficult to generalize about the negative or positive influences of exotic vegetation. In general, one would expect changes in vegetation to lead to changes in the arthropod community. In particular, arthropods that specialize on cottonwood (*Populus* spp.) and willow (*Salix* spp.) would be expected to respond negatively to saltcedar, especially in monotypic stands.

Overall, arthropod diversity appears to be greater in native vegetation (Yong and Finch, 1997; DeLoach and others, 2000; Dudley and DeLoach, 2004; Nelson and Wydoski, 2008), although the level of diversity varies among locations and over time. Arthropod diversity in mixed native/nonnative habitat can be intermediate or equivalent to that of native habitats, as Durst and other (2008) found in saltcedar/willow and arundo (*Arundo donax*)/willow habitats (Herrera and Dudley, 2004). A study in Arizona found that diversity was greatest overall in native plant communities compared to monotypic patches of saltcedar, but diversity varied by year and season (Durst and others, 2008). Additionally, there was no difference in arthropod biomass, suggesting that the two vegetation types support different, but equally productive, arthropod communities; however, more studies are needed to understand if this is a general phenomenon in western riparian systems. Because saltcedar flowers

throughout the summer, overlapping minimally with spring-flowering native riparian tree species, saltcedar may benefit pollinators by producing flowers over an extended period (Drost and others, 2001; Yard and others, 2004; McGrath and van Riper, 2005). Insect pollinators may benefit from Russian olive as well, but two studies (cited in Katz and Shafroth, 2003) suggest that arthropod diversity and densities are lower in Russian olive stands than in native vegetation.

One well-studied group of arthropods is cicadas, which are numerous in riparian forests. Andersen (1994a) found that cicadas were common in saltcedar habitat along the lower Colorado River; however, cicadas using cottonwood-willow habitats emerged earlier compared to those using saltcedar or burned riparian forests (Andersen, 1994a; Smith and others, 2006), and cicada densities were correlated with canopy cover from native riparian trees like cottonwoods (Smith and others, 2006) or willows (Ellingson and Andersen, 2002). The later emergence of cicadas, which are an important prey species for many bird species, could influence the temporal availability of resources for breeding birds, and may negatively influence population dynamics of cicadas (as suggested by the difference in densities). Likewise, leaf-litter arthropod communities will be affected by different compositions of native or exotic species; laboratory experiments documented that invertebrate growth was greater in saltcedar litter than in native litter (Going and Dudley, 2008; Moline and Poff, 2008), but a field-based study found that diversity in saltcedar litter was generally lower than in native cottonwood leaf litter (Bailey and others, 2001). Arthropod communities are complex and dynamic, and they are difficult to understand even in completely native habitats; much more study is needed to understand how saltcedar and Russian olive affect particular specific species and entire communities of arthropods.

Birds

Across the arid Western United States, and in particular the desert Southwest, riparian woodlands are critical habitat for birds. More than 50 percent of landbirds that breed in the Southwest are estimated to be directly dependent on riparian habitats, and most other landbird species utilize this habitat at some point in their annual cycle (Anderson and others, 1977; Knopf and others, 1988). Although a number of authors have assumed *a priori* that exotic vegetation will negatively impact avian species (DeLoach and others, 2000; Dudley and DeLoach, 2004), the evidence to date suggests a mixed effect that varies by species and geographic region (Sogge and others, 2008; van Riper and others, 2008). However, for many bird species, information on responses is lacking.

Multiple studies have documented that saltcedar can provide habitat for breeding-bird communities in some parts of the Southwest (Brown and others, 1987; Hunter and others, 1988; Livingston and Schemnitz, 1996; Fleishman and others, 2003; Holmes and others, 2005; Sogge and others, 2005; Hinojosa-Huerta, 2006). Corman and Wise-Gervais (2005) found that 76 percent of low- to mid-elevation breeding riparian-bird species nested in saltcedar, and Sogge and others (2008) documented 49 species throughout the Western United States for which there are records of nesting in saltcedar. Whereas these species records do not measure the quality of the exotic habitat for the birds, the widespread usage suggests a substantial habitat value for a diverse group of birds (Sogge and others, 2008).

In general, saltcedar use is most common among riparian generalists (that is, birds that breed in a variety of different native riparian habitat types), but saltcedar is clearly not suitable habitat for all native riparian birds. Some that have very specific habitat requirements—such as woodpeckers, secondary cavity nesters, or raptors requiring large branches to support their nests—often do not adapt well to saltcedar and hence can be less numerous or absent in saltcedar stands (Anderson and others, 1977; Hunter and others, 1988; Ellis, 1995; Walker, 2006). Also, bird abundance and diversity can be lower in saltcedar than in nearby native-dominated riparian vegetation in some areas. On the lower Colorado River in Arizona and Mexico, avifauna diversity is lower in saltcedar-dominated areas compared with native-plant-dominated areas, and some riparian species apparently are absent (Hunter and others, 1988; Hinojosa-Huerta and others, 2004; Hinojosa-Huerta, 2006). Thus, the value of saltcedar as habitat for birds may vary regionally and may be poor habitat for birds with specific habitat needs, but saltcedar appears to be suitable for a number of generalist avian species.

We know much less about Russian olive as habitat for birds. A study of birds nesting in Russian olive in New Mexico found that a little more than half of riparian breeding species (primarily cavity nesters) did not nest in this tree, but there was no significant difference in nesting productivity for those species that did breed in it (Stoleson and Finch, 2001). Russian olive produces abundant fruit that is eaten by a large number of bird species (reviewed in Katz and Shafroth, 2003) and can provide important structural habitat for birds, especially at the edges of riparian areas (Knopf and Olson, 1984). However, habitat usage will probably vary among taxa with some species preferentially using Russian olive for nesting and others avoiding it (Stoleson and Finch, 2001; Katz and Shafroth, 2003).

Bird Taxonomic and Feeding Guilds

Raptors.—Raptors use riparian woodlands primarily for nesting and hunting. Nesting substrate requires large, primarily horizontal branches to support the large stick nests raptors construct. Saltcedar does not provide the necessary support structure for nesting. Typically, Sonoran desert raptors nest in large cottonwood trees and large willows, not in shorter, dense-foliage habitat typical of saltcedar, Russian olive, or young native trees. Whether exotic vegetation differs from native vegetation in terms of foraging quality is unknown.

Waterfowl and shorebirds.—Typically, waterfowl and shorebirds do not use riparian vegetation and should not be affected by its composition unless it has indirect effects on their prey base. Wading birds that breed in the Southwest are an exception to this, as they require nesting structures. Great Egrets (*Ardea alba*), Great Blue Herons (*Ardea herodias*), Black-crowned Night-Herons (*Nycticorax nycticorax*), and Green Herons (*Butorides virescens*) will nest in the Southwest, and therefore are potentially affected by riparian vegetation. The larger waders require large trees—typically large cottonwoods—to form communal nesting sites. Green Herons build small nests in relatively dense vegetation and have been known to nest in saltcedar (Corman and Wise-Gervais, 2005).

Passerines.—The primary avian users of riparian woodlands are the passerines and other landbirds (for example, cuckoos, woodpeckers, and hummingbirds). As discussed above, many such species will nest in saltcedar and Russian olive, but more studies are needed on the relative quality of exotic versus native vegetation for breeding (Sogge and others, 2008).

Bird Species of Concern

Southwestern Willow Flycatcher.—the Southwestern Willow Flycatcher (*Empidonax traillii extimus*) is a Federally endangered species, having declined markedly over the last 100–200 years, primarily due to the loss of riparian breeding habitat (U.S. Fish and Wildlife Service, 2002). Although nearly half (43 percent) of Southwestern Willow Flycatcher territories are found in riparian patches consisting primarily (greater than 90 percent) of native trees such as willow (*Salix* spp.), 6 percent of known breeding territories are in monotypic (greater than 90 percent) saltcedar, 22 percent are in habitats dominated by saltcedar (50–100 percent), and another 28 percent are in native habitats where saltcedar and other exotics provide 10–50 percent of the habitat structure (fig. 1) (Durst and others, 2007). Flycatchers likely select their breeding sites based more on the structural characteristics of vegetation than on species composition (U.S. Fish and Wildlife Service, 2002). Because the flycatcher breeds in both native and exotic habitat types, often in the same drainage, it is possible to evaluate whether flycatchers breeding in saltcedar habitats are affected negatively by a poor food base, reduced survivorship, and low productivity, or whether saltcedar is functionally of similar quality to native habitat. Recent research on flycatchers breeding in saltcedar has found no evidence of a depauperate diet (DeLay and others, 1999; Drost and others, 2001; Durst, 2004), and Owen and others (2005) concluded that the physiological condition of birds breeding in saltcedar did not differ from that of birds nesting in native habitats. Similarly, Sogge and others (2006) found no evidence of reduced survivorship or productivity among flycatchers breeding in saltcedar habitats compared to those breeding in native vegetation at Roosevelt Lake in central Arizona. Thus, saltcedar appears to provide habitat quality similar to that provided by native vegetation for flycatchers in at least some locations and is considered an important habitat for recovery of this species (U. S. Fish and Wildlife Service, 2002).

However, much of the saltcedar along riparian systems is not used by flycatchers and is presumably unsuitable; for example, flycatchers are absent today from some areas where they historically bred and where saltcedar is now dominant and widespread (for example, the lower Colorado River near Yuma, Ariz.). Furthermore, fire is considered one of the greatest threats to flycatcher breeding sites (U.S. Fish and Wildlife Service, 2002), and the presence of saltcedar may increase the likelihood of large fires due to its flammability. Additional research is needed to evaluate whether saltcedar in these unoccupied areas fails to provide the necessary ecological functions and environmental conditions for flycatchers, or whether Southwestern Willow Flycatchers do not have the population numbers necessary to occupy all suitable habitat present in the Southwest. One study of Willow Flycatchers nesting in Russian olive found higher rates of nest parasitism but no difference in nesting success when compared to flycatchers nesting in native vegetation (Stoleson and Finch, 2001).

Yellow-billed Cuckoo.—The Yellow-billed Cuckoo (*Coccyzus americanus*) has been extirpated from much of its western range; currently the western population is a candidate for Federal Endangered Species listing (U.S. Fish and Wildlife Service, 2001). Cuckoos generally prefer mature riparian habitats and are most commonly associated with cottonwood (*Populus fremontii*) or other native forests (Hughes, 1999). However, Yellow-billed Cuckoos breed extensively in the dense saltcedar stands along parts of the Pecos River in New Mexico (Hunter and others, 1988; Livingston and Schemnitz, 1996). Although the cuckoos in this region are not considered to be of the western population, Howe (1986) described how a large cuckoo breeding population developed along the Pecos River by the mid-1980s concurrent with the establishment of large stands of saltcedar that created new riparian woodlands. Livingston and Schemnitz (1996) later reported that dense saltcedar stands are important habitat for the cuckoo along the Pecos River. Whereas there are no specific studies on the relative breeding success of cuckoos in saltcedar, the notable population expansion along the Pecos River (Howe, 1986) suggests that successful breeding did occur. However, the frequency with which cuckoos use saltcedar varies geographically. Within New Mexico, saltcedar use is common on the Pecos River, more limited on the Rio Grande (and usually associated with a native component), and absent on the Gila River (Howe, 1986; Hunter and others, 1988; Woodward and others, 2003). Outside of New Mexico, cuckoos have not been found breeding in saltcedar-dominated habitats (Johnson and others, 2006, 2007), though saltcedar can be a component of the habitat patch. This suggests that the suitability of saltcedar as breeding habitat for cuckoos, as with other bird species, varies across the landscape, with local environmental factors determining its relative habitat value. Cuckoos have not been recorded nesting in Russian olive, which suggests that they avoid or rarely use this tree species; however, it is unknown how extensively Russian olive has been surveyed for cuckoos.

Figure 1. Nest and chicks of the Federally endangered Southwestern Willow Flycatcher (*Empidonax traillii extimus*) in a saltcedar shrub on the Salt River, Arizona. (Photo by M. Zimmerman.)

Bird Species, Saltcedar and Russian Olive Control, and Riparian Restoration

Whereas studies indicate that saltcedar seldom supports the same avian species richness, guilds, and population sizes as native habitat, saltcedar can fulfill an important habitat role for some species (U.S. Fish and Wildlife Service, 2002; Walker, 2006), especially in areas where degraded riparian systems preclude the establishment of native vegetation (Shafroth and others, 2005). If an area dominated by saltcedar that currently supports riparian breeding birds is replaced by nonriparian vegetation, or by a much smaller amount of native riparian habitat, there may be a net loss of riparian habitat value (Shafroth and others, 2005) and possible local/regional loss of some or all riparian birds due to changes in the vegetation structure (Fleishman and others, 2003; Walker, 2006). For example, restoration efforts that involved clearing exotic vegetation under cottonwood gallery forests in New Mexico led to a decrease in lower- and mid-story avian species, presumably due to the loss of vegetation structure at those heights (Bateman, Chung-MacCoubrey, Finch and others, 2008). Yellow-billed Cuckoos have all but disappeared in the lower Pecos River valley from Six-Mile Dam near Carlsbad, N. Mex., to the Texas border following a large-scale saltcedar removal project from 1999 through 2006 (Travis, 2005; Hart and others, 2003), and the Southwestern Willow Flycatcher recovery plan (U.S. Fish and Wildlife Service, 2002) expressed concerns about large-scale saltcedar control or removal at occupied flycatcher sites because flycatchers require very dense vegetation for breeding sites. Although Russian olive is not as well studied, it should be presumed until demonstrated otherwise that control of Russian olive would have similar effects on wildlife as that of saltcedar control.

Whether particular avian species would be negatively impacted by saltcedar eradication efforts depends in large part on the value of the particular saltcedar stands as habitat and the extent and pace of both saltcedar loss and the development of replacement habitat. Geographic factors (for example, climate and elevation), stand characteristics, and the type and structure of adjacent and interspersed habitats are key factors in determining the habitat value of saltcedar (Hunter and others, 1988; Livingston and Schemnitz, 1996; Walker, 2006). Likewise, the return of native riparian woodlands following saltcedar control is far from certain (Harms and Hiebert, 2006), and the degree to which recovery occurs is influenced by a number of physical, ecological, and restoration technique factors (Shafroth and others, 2008). Therefore, careful restoration planning, execution, and follow up is needed to ensure that saltcedar is replaced by native vegetation and not by other vegetation that has even lower habitat value or greater negative effects, such as other exotic vegetation (D'Antonio and Meyersen, 2002; Harms and Hiebert, 2006; Shafroth and others, 2008).

Mammals

Small mammal species in the arid and semiarid Western United States are often more numerous in riparian habitats than in adjacent uplands (Stamp and Ohmart, 1979; Doyle, 1990; Falck and others, 2003). Some studies have documented mammal foraging behavior and populations in saltcedar and Russian olive habitats.

Ellis and others (1997) captured more species of small mammals in monotypic stands of saltcedar compared to native cottonwood forests in New Mexico. However, this increase in species richness was likely caused by the proximity of saltcedar stands to source populations in adjacent grassland. Five species of rodents (*Perognathus flavus, Dipodomys ordii, Peromyscus maniculatus, Onychomys leucogaster,* and *Sigmodon hispidus*) captured in saltcedar stands were not captured in cottonwood sites but were typical of grassland habitats. White-footed mice (*Peromyscus leucopus*) were predominant in both cottonwood and saltcedar stands and did not differ in reproductive parameters between habitats. Shrews are also abundant in riparian habitats, but often overlooked in small-mammal studies because shrews avoid live traps. Chung-MacCoubrey and others (2009) captured large numbers of Crawford's Gray Shrews (*Notiosorex crawfordi*) in mixed stands of cottonwood, saltcedar, and Russian olive forests in New Mexico.

Some studies have documented certain mammal species feeding on saltcedar and Russian olive, whereas others avoid saltcedar. Pocket gophers (*Thomomys bottae*) occasionally feed on saltcedar tap roots (Manning and others, 1996). Mice eat Russian olive and can prevent it from establishing; however, granivory is not likely to prevent the spread of Russian olive (Katz and others, 2001). Beaver (*Castor canadensis*) prefer willows and cottonwoods over saltcedar and will feed only on saltcedar if it is the sole food source or when a deterrent is applied to desirable plants (Kimball and Perry, 2008). Some studies in other Western States suggest that beaver promote saltcedar growth by selectively foraging on native riparian plants, allowing saltcedar to flourish through competitive release (Lesica and Miles, 2004; Mortenson and others, 2008). In river systems with dam-building beaver, flooding could hinder saltcedar establishment and promote the growth of early-successional native plants (Albert and Trimble, 2000; Longcore and others, 2007). In larger streams, where 'bank' beaver occur, saltcedar abundance likely will be determined by a suite of site-specific factors rather than beaver activity.

Bats use riparian areas for roosting, foraging, and commuting (Swystun and others, 2007). Bats along the middle Rio Grande were documented foraging above the canopy of mixed habitats containing cottonwood, saltcedar, and Russian olive (Chung-MacCoubrey and Bateman, 2006). One study in Arizona compared bat activity in native riparian cottonwood stands to saltcedar-dominated stands (Buecher and Sidner, 2006). Preliminary results showed that bat activity was greater in the cottonwood stands.

Although the present literature suggests small mammals could continue to be successful in stands dominated by exotic vegetation, other factors, like precipitation and arthropod or seed productivity, could be ultimate factors regulating small-mammal populations in the semiarid and arid Western United States (Brown and Heske, 1990; Ernest and others, 2000; Morrison and others, 2002).

Mammal Species, Saltcedar and Russian Olive Control, and Riparian Restoration

Few studies have experimentally compared populations of mammals in habitats where saltcedar or Russian olive have been removed to habitats where nonnative plants have remained intact. Along the lower Colorado River, Andersen (1994b) monitored small-mammal populations for one year in a site cleared five years earlier of saltcedar and replanted with native riparian trees and shrubs. The habitat supported 9 out of 15 native small mammal species expected to be resident in riparian habitat. This quasi-natural habitat was a source habitat or was supporting stable populations of white-throated woodrat (*Neotoma albigula*), cactus mouse (*Peromyscus eremicus*), Merriam's kangaroo rat (*Dipodomys merriami*), Arizona cotton rat (*Sigmodon arizonae*), and southern grasshopper mouse (*Onychomys torridus*). The habitat also appeared to serve as a population sink for deer mice (*Peromyscus maniculatus*) (Andersen 1994b). Although small-mammal biomass increased during one year, this population was not tracked over time.

Crawford's Gray Shrews were monitored along the middle Rio Grande during a seven-year project to remove saltcedar and Russian olive from cottonwood forests (Chung-MacCoubrey and others, 2009). Capture rates of shrews varied by month, but did not appear to be affected by removal treatments. Similar to what was revealed in studies of desert rodents, shrew populations also showed great annual variation and may be more influenced by precipitation in desert systems.

In the same middle Rio Grande study, bat activity increased to a greater extent in sites where saltcedar and Russian olive were removed compared to nonremoval sites. When activity was related to habitat variables before treatments, sites with less midstory canopy cover had more bat activity. Therefore, nonnative plant removal may have created a more open environment for a wider variety of bat species to forage in treated sites (Chung-MacCoubrey and Bateman, 2006).

Herpetofauna

Amphibians and reptiles are common but often overlooked inhabitants of riparian areas. Amphibians and reptiles represent important components of riparian ecosystems. Herpetofauna provide a large amount of protein to other vertebrates (Burton and Likens, 1975) and are major consumers of terrestrial arthropods, thereby linking arthropods to higher vertebrates like birds and mammals (Burton and Likens, 1975). Herpetofauna respond to structural changes to their habitat (Pianka, 1967); therefore, their presence and abundance can be good indicators of healthy riparian ecosystem structure and function. Despite this documented ecological importance, few studies have focused on the impacts of nonnative vegetation on amphibians and reptiles. However, a seven-year study in New Mexico documented 8 species of amphibians, 11 species of lizards, and 13 species of snakes in mixed stands of cottonwood, saltcedar, and Russian olive forests along the Rio Grande (Bateman, Chung-MacCoubrey, and Snell, 2008; Bateman, Harner, and Chung-MacCoubrey, 2008). Western pond turtles (*Clemmys marmorata*) occur in habitats where saltcedar has invaded, but there are no comparisons of their occurrences in native habitats (Lovich and Meyer, 2002).

Herpetofaunal Species, Saltcedar and Russian Olive Control, and Riparian Restoration

Saltcedar and Russian olive control methods can alter the structural or thermal environment of a habitat and may affect some reptiles. For example, a study along the middle Rio Grande in New Mexico found that treatments to remove saltcedar, Russian olive, and woody fuels appeared beneficial or at least nondamaging to species of lizards (Bateman, Chung-MacCoubrey, and Snell, 2008). Compared to nonremoval sites, Prairie Lizards (*Sceloporus consobrinus*) and New Mexico Whiptails (*Aspidoscelis neomexicana*) increased in abundance after plant removal (fig. 2). No negative effects were detected for several other species of lizards. Chihuahuan Spotted Whiptails (*A. exsanguis*), Desert Grassland Whiptails (*A. uniparens*), and Side-blotched Lizards (*Uta stansburiana*) were either positively associated with habitat in removal sites or negatively associated with habitat in nonremoval sites. The open understory found in removal sites may have provided more basking opportunities for reptiles by allowing solar radiation to penetrate to the ground (Bateman, Chung-MacCoubrey, and Snell, 2008). During the same study, no negative effects were detected for abundances of amphibians. Toads (*Anaxyrus woodhousii* and *A. cognatus*) responded to hydrologic variables such as spring flooding and summer precipitation instead of nonnative plant and fuels removal (Bateman, Harner, and Chung-MacCoubrey, 2008).

Fish

Given the abundance of saltcedar and Russian olive along waterways in the Western Unites States, fish undoubtedly occupy habitats influenced by nonnative vegetation. Saltcedar can potentially impact stream ecosystem structure and function through input of allochthonous leaf litter (litter provided by sources outside the stream; Kennedy and Hobbie, 2004; Going and Dudley, 2008; Moline and Poff, 2008) and, in turn,

Figure 2. (*A*) Prairie lizards (*Sceloporus consobrinus*) are sit-and-wait foragers; whereas (*B*) Chihuahuan Spotted Whiptails (*Aspidoscelis exsanguis*) are active pursuers. Even though these two lizards have different foraging styles, they responded similarly to nonnative plant removal by increasing in abundance in the riparian forest of the middle Rio Grande. (Photos by H.L. Bateman.)

influence the aquatic invertebrate community as prey for many species of fish. For example, Moline and Poff (2008) found that crane fly (*Tipula* spp.) larvae had higher growth rates when fed saltcedar compared to larvae fed cottonwood, but Russian olive-fed larvae had lower growth rates compared to those fed native leaves. Perhaps larvae grew faster on saltcedar litter because of leaf morphology or high nitrogen-to-carbon ratios. However, when conducting field studies, Moline and Poff (2008) found that native leaf packs, which provide food and substrate for aquatic invertebrates, were retained in the stream bed and may be available to shredders longer, whereas saltcedar leaves were relatively scarce in the stream channel.

Fish Species, Saltcedar and Russian Olive Control, and Riparian Restoration

Saltcedar removal may be an effective restoration tool in managing native fishes in spring habitats. In Nevada, saltcedar removal led to significant increases in density of native pupfish (*Cyprinodon nevadensis mionectes*) and decreases in nonnative crayfish (*Procambarus clarkia*; Kennedy and others, 2005). Removal decreased the amount of shading in a spring and increased algal productivity, which were consumed by the pupfish. Crayfish, which are opportunistic and can prey on native fish eggs and young, consumed saltcedar leaf litter and were not dependent upon algal food sources. In reaches downstream from the spring habitat, saltcedar removal seemed to increase native dace (*Rhinichthys osculus nevadensis*) density and decrease nonnative mosquitofish (*Gambusia affinis*) density. This was significant because mosquitofish can act as competitors for invertebrates and prey on the eggs and fry of native fish. Finally, saltcedar and Russian olive control may negatively impact native fish populations by altering the quality and timing of allochthonous inputs into stream channels and, in turn, influence the aquatic invertebrate community (Going and Dudley, 2008).

Conclusions, Data Gaps, and Future Research Needs

Given the vast extent of saltcedar and Russian olive on the landscape and the large number of riparian restoration efforts that are focused on their eradication or control, it is important to fully understand the benefits and costs of exotic riparian vegetation management to wildlife. Saltcedar is the third most abundant plant in riparian areas in the Western United States (Friedman and others, 2005). Alterations to riparian areas resulting from nonnative plant control can change a variety of habitats used by wildlife, such as the surface and thermal environment for reptiles, the structural breeding habitat for birds, and aerial foraging habitat for bats (Bateman, Chung-MacCoubrey, Finch, and others, 2008). Unfortunately, as highlighted by this review of the literature, we have a relatively poor understanding of this complex system, which hinders efforts to guide management actions.

There is a need for research that focuses on multiple taxa and employs both control and experimental sites over several-year periods. Few experimental studies have explored the impacts of saltcedar and Russian olive removal on fish and terrestrial wildlife. Past studies have focused mostly on terrestrial wildlife and ecosystems. The three fish studies suggested a need for investigating how riparian vegetation, in terms of both species composition and habitat structure, could affect fish communities. We encourage experimental projects comparing saltcedar-invaded habitats to native habitats and saltcedar removal sites to both native and nonremoval sites. In addition, monitoring of sites post-control efforts will be important to understand the short- to long-term effects of control efforts on wildlife, both beneficial and negative.

Summary of Saltcedar and Russian Olive Effects on Wildlife

- **Arthopods.** Community composition differs among native, exotic, and mixed vegetation types, with diversity typically being higher in native habitats, but biomass can be similar among vegetation types. Cicadas, an important and often abundant food source in riparian areas, emerge later and exist in lower densities in nonnative than in native habitat, which could negatively impact breeding wildlife that depend on them for food. Some aquatic larvae grow faster when fed native vegetation than when fed nonnative vegetation, which could negatively impact fish consumers of macroinvertebrates. Gaps in our knowledge include (1) how community- or guild-level structure differs in native and nonnative habitats, (2) whether the diversity of arthropods in saltcedar habitats is actually being sustained by the vegetation or whether the arthropods are primarily supported by other habitats, and (3) what arthropod communities are found within Russian olive-dominated habitats.

- **Birds.** Many birds will use saltcedar and Russian olive for nesting. For some species the exotic habitat appears to be functionally equivalent to native vegetation; however, other than knowing that birds will use it occasionally for breeding substrate, for most species, we know very little about the value of the vegetation. Although birds are the best studied group in terms of how saltcedar and Russian olive affect wildlife, there is still great uncertainty about the functional role that exotic habitats play for riparian obligate species. More comparative studies of avian communities in native-dominated and exotic-dominated habitats are needed, as well as pre- and post-treatment studies to evaluate the effects of eradication and restoration efforts on the avifauna.

- **Mammals.** Small mammals are abundant in riparian habitats; however, few studies document differences in species composition and biomass in native and nonnative habitats. Small-mammal studies could highlight how nonnative plants affect resources by focusing on different mammalian feeding guilds (for example, granivores, herbivores, or insectivores). Bats are a species-rich group of mammals that have been mostly overlooked in the context of saltcedar and Russian olive research.
- **Herpetofauna.** Amphibians and reptiles are often overlooked in research comparing native and nonnative riparian habitats. Of the information available, species of lizards seem to respond positively to removal of saltcedar and Russian olive; however, this may be a function of changes in habitat structure rather than changes in plant species composition. Amphibians and aquatic turtles are largely absent from efforts to compare native and nonnative riparian habitats.
- **Fish.** Fish could be negatively impacted by nonnative vegetation due to changes in food resources (arthropods) and habitat (stream shade).

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