

Tamarix as Habitat for Birds: Implications for Riparian Restoration in the Southwestern United States

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Abstract

Exotic vegetation has become a major habitat component in many ecosystems around the world, sometimes dramatically changing the vegetation community structure and composition. In the southwestern United States, riparian ecosystems are undergoing major changes in part due to the establishment and spread of the exotic *Tamarix* (saltcedar, tamarisk). There are concerns about the suitability of *Tamarix* as habitat for birds. Although *Tamarix* habitats tend to support fewer species and individuals than native habitats, Arizona Breeding Bird Atlas data and Birds of North America accounts show that 49 species use *Tamarix* as breeding habitat. Importantly, the relative use of *Tamarix* and its quality as habitat vary substantially by geographic location and bird species. Few studies have examined how breeding in *Tamarix* actually affects bird survivorship and productivity; recent research on Southwestern Willow Flycatchers has found no negative effects

from breeding in *Tamarix* habitats. Therefore, the ecological benefits and costs of *Tamarix* control are difficult to predict and are likely to be species specific and site specific. Given the likelihood that high-quality native riparian vegetation will not develop at all *Tamarix* control sites, restoration projects that remove *Tamarix* but do not assure replacement by high-quality native habitat have the potential to reduce the net riparian habitat value for some local or regional bird populations. Therefore, an assessment of potential negative impacts is important in deciding if exotic control should be conducted. In addition, measurable project objectives, appropriate control and restoration techniques, and robust monitoring are all critical to effective restoration planning and execution.

Key words: biocontrol, *Coccyzus americanus*, *Diorhabda*, *Empidonax traillii extimus*, riparian birds, *Tamarix*.

Introduction

The issue of non-native plant species around the world is receiving increasing attention from land managers, conservation organizations, and the public. In the United States, there are many hundreds of known exotic species and the number is expected to increase over time. A small fraction of non-natives become highly invasive and cause major changes to landscapes and ecosystems (Lodge et al. 2006). Although some high-profile exotic species have been well studied, the potential impacts of many on native species, habitats, or ecosystems are not well known or documented; despite this, detrimental effects are frequently hypothesized or assumed (Catling 2005). As a result, many ecological restoration programs focus on efforts to eliminate or control non-native species specifically to improve wildlife habitat.

However, studies from multiple countries and ecosystems suggest that a more nuanced perspective is needed when evaluating the impacts of exotic vegetation on wild-

life. In the case of avian species, research studies indicate that the response to exotic vegetation can range from negative to positive depending on the bird species, exotic plant, and ecosystem. For example, arid grasslands in the southwestern United States are dominated in many areas by invasive grasses, and some studies have linked exotics to reduced abundance and richness of bird communities (Flanders et al. 2006) or lower nest success (Lloyd & Martin 2005; Ortega et al. 2006). However, in other areas where they provide the same structure as native habitat, exotic grasses can serve as important habitat of equal quality in terms of reproductive success (Jones & Bock 2005). Likewise, grassland birds in Argentina (Isacch et al. 2005) and Brazil (Francisco 2006) occupy exotic grasslands that effectively increase the amount of habitat available to them. Similarly, exotic shrubs can provide important nesting substrate that decrease nest predation in some areas, such as for the Veery (*Catharus fuscescens*) in forests of the eastern United States (Heckscher 2004; Schmidt et al. 2005) but not for others such as the Blackcap (*Sylvia atricapilla*) in the Czech Republic (Remes 2003). The structure of vegetation, native or exotic, may be more important to birds than the actual species composition (Hausner et al. 2002; Jones & Bock 2005), and different species of birds will respond differently (Gjerde & Saetersdal 1997). The complexity of

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responses by bird communities to exotics in different ecosystems around the world suggests that negative impacts by exotics cannot be universally assumed; rather, evaluation of impacts should be conducted species by species with attention to geographic differences.

One target of many riparian restoration efforts, particularly in the southwestern United States, is a complex of tree–shrub species in the genus *Tamarix* (saltcedar; tamarisk; *Tamarix ramosissima*, *T. chinensis*, or the hybrid *T. ramosissima* × *chinensis*; Gaskin & Schaal 2002; hereafter referred to as *Tamarix*). A native tree–shrub of Eurasia, *Tamarix* spreads after being intentionally introduced in the western United States in the 1800s and now covers over one-half million hectare in at least 23 states (Zavaleta 2000); its distribution in Mexico is poorly documented but extends at least as far south as the Yaqui River Valley in Sonora (Glenn & Nagler 2005). Due to its deep root system, tolerance for saline conditions, and prolific seed production, *Tamarix* has thrived throughout much of the American West, most commonly where flows and spring floods have declined, the water table has become too deep, and soils are too salty for mesic native vegetation to survive (Lovich & De Gouvenain 1998; Glenn & Nagler 2005; Shafroth et al. 2005). Because the spread of *Tamarix* occurred concurrently with the decline of native riparian habitats in the West, *Tamarix* is often viewed as a key factor in that decline and the cause of associated reductions in many riparian breeding birds (DeLoach et al. 2000). Accordingly, many *Tamarix* management and control programs include the objective of improving riparian bird habitat.

Given the vast extent of *Tamarix* on the landscape and the large number of riparian restoration efforts that are focused on its eradication or control, it is important to fully understand the benefits and costs of *Tamarix* management on birds. In this article, our goal is to highlight the fact that many bird species do breed in *Tamarix* habitats and that there are relatively few data available to suggest that birds experience negative ramifications in doing so. Therefore, restoration projects that remove *Tamarix* but do not assure replacement by high-quality native habitat have the potential to reduce the net riparian habitat value for some local or regional bird populations. In presenting these considerations, we are not suggesting that *Tamarix* is preferable to or provides the same habitat value as native riparian vegetation; indeed, it likely has lower value than native habitats in most situations. Nor are we proposing that *Tamarix* control is, in and of itself, unnecessary or unwise. Rather, we believe that objective-based planning, use of the right control and restoration techniques, and post-management monitoring are necessary to maximize the benefits and minimize the unintended consequences of *Tamarix* management on avifauna and other wildlife.

How Extensive Is Bird Use of *Tamarix*?

A first step to understanding potential effects of *Tamarix* management on southwestern riparian avifauna is to eval-

uate whether birds use or avoid the exotic habitat. Multiple studies have documented that *Tamarix* can provide important habitat for regional breeding bird communities in some parts of the American Southwest. Hunter et al. (1988) were among the first to describe the riparian bird communities breeding in *Tamarix* along the Pecos River and the Rio Grande in New Mexico and the lower Colorado River in Arizona and California. Although birds were overall less abundant in *Tamarix* and some species were lacking compared to similar native riparian habitats, *Tamarix* stands accounted for a significant amount of riparian habitat in those regions, resulting in larger local and regional riparian bird populations than would have been present in the absence of *Tamarix* (Hunter et al. 1988). Similarly, Livingston and Schemnitz (1996) reported that *Tamarix* along the Pecos River in New Mexico supported a diverse and abundant breeding bird community, having three to four times the number of birds than did the adjacent grassland or grassland/shrub habitats that would be present if *Tamarix* did not occur there. Further west along the Colorado River in the Grand Canyon, *Tamarix* flourished and dramatically increased along the river edge following construction of Glen Canyon Dam, and the riparian bird community increased in abundance and diversity (Brown et al. 1987). Several of the bird species that benefited from increased *Tamarix* riparian habitats were species of regional and national concern (Holmes et al. 2005). Sogge et al. (2005) reported that the area and volume of *Tamarix* habitat patches within the Grand Canyon were among the best positive predictors of bird species abundance, richness, and diversity along the river corridor. In yet another drainage, Fleishman et al. (2003) reported that the species richness of native birds (up to 45 breeding species per site) along the Muddy River in the Mojave Desert was best predicted by total vegetation volume, and bird species richness was not negatively affected by invasion of non-native plants (including *Tamarix*), provided that the vegetation community retained structural diversity. In the Colorado River delta in Mexico, bird diversity was more positively influenced by the presence of surface water than by whether habitat was composed of *Tamarix* or native riparian vegetation (Hinojosa-Huerta 2006). However, bird abundance and diversity may be lower in *Tamarix* than it would be in native-dominated riparian in the same area. The lower Colorado River in Arizona and Mexico is one such area, where avifauna is greatly reduced in *Tamarix*-dominated areas compared with native-dominated areas, and some riparian species are apparently absent (Hunter et al. 1988; Hinojosa-Huerta et al. 2004; Hinojosa-Huerta 2006). Thus, local factors apparently influence the habitat quality of *Tamarix*, and *Tamarix* appears to provide lower-quality habitat than native riparian in certain areas.

Although studies have shown that bird communities can be supported by *Tamarix* in at least some locations, it is reasonable to expect that the use and value of *Tamarix* as habitat may vary from species to species. To evaluate

the use of *Tamarix* among individual bird species, we reviewed nesting habitat data from the recently completed Arizona Breeding Bird Atlas (Corman & Wise-Gervais 2005) and the Birds of North America species accounts (<http://bna.birds.cornell.edu/BNA/>). Of the 29 species considered by the Arizona Breeding Bird Atlas as lowland riparian breeders (Table 1), 22 (76%) were recorded by atlas observers as breeding in *Tamarix*. Our text search of the online Birds of North America using the key words “saltcedar,” “salt cedar,” “tamarisk,” and “tamarix” found records of 32 species of birds breeding in *Tamarix* in at least some parts of their range (Table 2). Collectively, the Arizona Breeding Bird Atlas and Birds of North America accounts identified 49 species as having bred in *Tamarix* to varying degrees. Atlas and species accounts generally lacked quantitative data for a robust comparison of differences of use among species, and there is virtually no information for assessing *Tamarix* use versus availability on the landscape. Overall, however, the number of bird species that do breed in *Tamarix* suggests a substantial habitat value for a diverse group of birds.

Only two southwestern riparian breeding bird species, both of conservation concern, have been the subject of

Table 1. Lowland riparian breeding birds in Arizona, based on habitat descriptions in the Arizona Breeding Bird Atlas (Corman and Wise-Gervais 2005).

Abert's Towhee*	<i>Pipilo aberti</i>
American Dipper*	<i>Cinclus mexicanus</i>
Anna's Hummingbird	<i>Calypte anna</i>
Bell's Vireo*	<i>Vireo bellii</i>
Belted Kingfisher*	<i>Ceryle alcyon</i>
Bewick's Wren*	<i>Thryomanes bewickii</i>
Black Phoebe*	<i>Sayornis nigricans</i>
Black-chinned Hummingbird*	<i>Archilochus alexandri</i>
Blue Grosbeak*	<i>Guiraca caerulea</i>
Broad-billed Hummingbird	<i>Cynanthus latirostris</i>
Brown-crested Flycatcher	<i>Myiarchus tyrannulus</i>
Brown-headed Cowbird*	<i>Molothrus ater</i>
Bullock's Oriole*	<i>Icterus bullockii</i>
Cliff Swallow*	<i>Petrochelidon pyrrhonota</i>
Common Yellowthroat*	<i>Geothlypis trichas</i>
Hooded Oriole	<i>Icterus cucullatus</i>
Indigo Bunting*	<i>Passerina cyanea</i>
Lazuli Bunting*	<i>Passerina amoena</i>
Lucy's Warbler*	<i>Vermivora luciae</i>
Northern Beardless-Tyrannulet	<i>Camptostoma imberbe</i>
Northern Rough-winged Swallow*	<i>Stelgidopteryx serripennis</i>
Red-winged Blackbird*	<i>Agelaius phoeniceus</i>
Song Sparrow*	<i>Melospiza melodia</i>
Summer Tanager*	<i>Piranga rubra</i>
Thick-billed Kingbird	<i>Tyrannus crassirostris</i>
Willow Flycatcher*	<i>Empidonax traillii</i>
Yellow Warbler*	<i>Dendroica petechia</i>
Yellow-billed Cuckoo	<i>Coccyzus americanus</i>
Yellow-breasted Chat*	<i>Icteria virens</i>

Overall, 22 of 29 species (indicated by asterisks) were recorded as breeding in *Tamarix* habitats. The relative degree of *Tamarix* use varied by species and could not be readily quantified because atlas search efforts were not proportional among habitat types.

Table 2. Avian species documented using *Tamarix* as breeding habitat, based on habitat descriptions in the Birds of North America (<http://bna.birds.cornell.edu/BNA/>).

Abert's Towhee	<i>Pipilo aberti</i>
Ash-throated Flycatcher	<i>Myiarchus cinerascens</i>
Bell's Vireo	<i>Vireo bellii</i>
Bewick's Wren	<i>Thryomanes bewickii</i>
Black-crowned Night Heron	<i>Nycticorax nycticorax</i>
Black-tailed Gnatcatcher	<i>Poliophtila melanura</i>
Blue Grosbeak	<i>Guiraca caerulea</i>
Brown Thrasher	<i>Toxostoma rufum</i>
Bullock's Oriole	<i>Icterus bullockii</i>
Cactus Wren	<i>Campylorhynchus brunneicapillus</i>
Cattle Egret	<i>Bubulcus ibis</i>
Chihuahuan Raven	<i>Corvus cryptoleucus</i>
Common Moorhen	<i>Gallinula chloropus</i>
Common Yellowthroat	<i>Geothlypis trichas</i>
Crissal Thrasher	<i>Toxostoma crissale</i>
Elf Owl	<i>Micrathene whitneyi</i>
Gambel's Quail	<i>Callipepla gambelii</i>
Greater Roadrunner	<i>Geococcyx californianus</i>
Lucy's Warbler	<i>Vermivora luciae</i>
Mourning Dove	<i>Zenaida macroura</i>
Pyrrhuloxia	<i>Cardinalis sinuatus</i>
Roseate Spoonbill	<i>Ajaia ajaia</i>
Song Sparrow	<i>Melospiza melodia</i>
Summer Tanager	<i>Piranga rubra</i>
Tri-colored Blackbird	<i>Agelaius tricolor</i>
Verdin	<i>Auriparus flaviceps</i>
White-faced Ibis	<i>Plegadis chihii</i>
White-winged Dove	<i>Zenaida asiatica</i>
Willow Flycatcher	<i>Empidonax traillii</i>
Yellow Warbler	<i>Dendroica petechia</i>
Yellow-breasted Chat	<i>Icteria virens</i>
Yellow-headed Blackbird	<i>Xanthocephalus xanthocephalus</i>

The relative degree of *Tamarix* use varied by species but was not quantitatively described in most species accounts.

enough research to evaluate whether *Tamarix* is used as breeding habitat across most of their ranges and to what degree. One such species is the Yellow-billed Cuckoo (*Coccyzus americanus*), the western United States population of which is a candidate for federal endangered species status due to riparian habitat loss. It generally prefers mature riparian habitats and is most commonly associated with cottonwood (*Populus fremontii*) or other native forests (Hughes 1999). However, Yellow-billed Cuckoos breed extensively in the dense *Tamarix* stands along parts of the Pecos River in New Mexico (Hunter et al. 1988; Livingston & Schemnitz 1996). Although the cuckoos in this region are not considered to be of the candidate western population, Howe (1986) described how a large cuckoo breeding population developed along the Pecos River by the mid-1980s and linked this to the conversion of riverbank grasslands and shrublands to *Tamarix*. Livingston and Schemnitz (1996) later reported that dense *Tamarix* stands are important habitat for the cuckoo along the Pecos River. Although there are no specific studies on

the relative breeding success of cuckoos in *Tamarix*, the notable population expansion along the Pecos River (Howe 1986) suggests that successful breeding did occur. However, the frequency that Yellow-billed Cuckoos use *Tamarix* clearly varies geographically. Within New Mexico, 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 et al. 1988; Woodward et al. 2003). More broadly, Yellow-billed Cuckoos have not been found breeding in *Tamarix*-dominated habitats outside of New Mexico (Johnson et al. 2006, 2007), though *Tamarix* may be a component of the habitat patch. This suggests, as with other bird species, that the suitability of *Tamarix* as breeding habitat for cuckoos varies across the landscape, with local environmental factors determining its relative habitat value.

Although documenting breeding within *Tamarix* habitats is the first step in understanding *Tamarix*'s value to bird species, bird presence does not necessarily equate to habitat quality (van Horne 1983), and it is possible that poor-quality habitat could attract birds (i.e., an ecological trap; Robertson & Hutto 2006). To truly evaluate the quality of *Tamarix* as habitat requires intensive research to assess a suite of factors, such as measures of lifetime fitness (e.g., productivity and survivorship), physiological condition, and food availability. To date, only one bird species, the Southwestern Willow Flycatcher (*Empidonax traillii extimus*), has received enough research attention to evaluate habitat quality of *Tamarix* at this level. A federally endangered species and neotropical migrant, the flycatcher breeds in dense, generally mesic riparian areas throughout most of the southwestern United States (USFWS 2002). Although most Southwestern Willow Flycatchers breed in riparian patches dominated by native trees such as willow (*Salix* spp.), roughly 25% of known breeding territories are in habitats dominated by *Tamarix* and another 25% are in native habitats where *Tamarix* and other exotics provide more than 10% of the habitat structure (Durst et al. 2006). Likely, the flycatcher selects its breeding sites based on structural characteristics more so than species composition (USFWS 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 *Tamarix* habitats might suffer from a poor food base, reduced survivorship, and low productivity or whether *Tamarix* is functionally of similar quality to flycatchers as native habitat. Recent research on flycatchers breeding in *Tamarix* has found no evidence of a depauperate diet (DeLay et al. 1999; Drost et al. 2001; Durst 2004), and studies by Owen et al. (2005) concluded that there was no indication that birds breeding in *Tamarix* were suffering negative physiological effects compared to those in native habitats. Similarly, Sogge et al. (2006) found no evidence of reduced survivorship or productivity among Southwestern Willow Flycatchers breeding in *Tamarix* habitats compared to native vegetation at Roosevelt Lake in central Arizona. Clearly, *Tamarix* can

provide similar habitat quality as native vegetation for Southwestern Willow Flycatchers in at least some locations and is considered an important habitat for recovery of this species (USFWS 2002). On the other hand, there are areas where *Tamarix* is dominant and widespread and in which flycatchers bred historically (e.g., the lower Colorado River near Yuma, Arizona) but are absent from today. Additional research is needed to evaluate whether *Tamarix* in these unoccupied areas does not provide the necessary ecological functions and environmental conditions required by flycatchers or whether Southwestern Willow Flycatchers do not have the population numbers necessary to occupy all suitable habitat present in the southwest.

In general, *Tamarix* use is most common among riparian generalists (i.e., those birds that breed in a variety of different native riparian habitat types), but *Tamarix* is clearly not a suitable habitat for all native riparian birds. Those 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 *Tamarix* and hence can be reduced or absent in *Tamarix* stands (Anderson et al. 1977; Hunter et al. 1988; Ellis 1995; Walker 2006). Some species do breed in *Tamarix* but in reduced density in some circumstances or not at all in others (Rosenberg et al. 1991; DeLoach et al. 2000). Therefore, *Tamarix* will not have the same habitat value to all bird species, nor even to the same species in different areas. A well-known example of this is the lower Colorado River near the United States/Mexico International Boundary where changing water regimes have impacted native riparian forests and led to vast *Tamarix* stands, contributing to the decline in riparian bird abundance and diversity (Hunter et al. 1988; Rosenberg et al. 1991; Hinojosa-Huerta et al. 2004; Hinojosa-Huerta 2006). Thus, a key point to remember is that different species will respond to different *Tamarix* habitats in different ways, and the question of *Tamarix* as bird habitat cannot be addressed from a simple "yes/no" perspective.

Why Do Some Birds Use *Tamarix*?

Tamarix does support riparian-dependent birds that may not be present or might otherwise have declined more rapidly without it (Howe 1986; Hunter et al. 1988; Rosenberg et al. 1991; Ellis 1995, 1997; Rodriguez 2006). In some areas, *Tamarix* can provide the vertical structure, foliar cover, and food resources needed by a number of species dependent upon riparian vegetation and serves as an acceptable substitute where fire, lack of water, and salinity are preventing establishment of native riparian vegetation (Shafroth et al. 2005). Geographic factors, the type and structure of adjacent and interspersed habitats, and stand characteristics are key in determining the habitat value of *Tamarix* (Hunter et al. 1988; Livingston & Schemnitz 1996; Walker 2006). Thus, in some places, *Tamarix* can provide the structural complexity and microhabitat characteristics

needed by riparian birds; however, in other areas, low elevation, extremely hot desert climates, and lack of proximity to surface water can result in *Tamarix* stand structure and microclimate that is of lower habitat value for birds.

For insectivorous birds, a crucial component of habitat quality is the arthropod communities that a particular habitat can support. Studies conducted to date suggest that the arthropod communities supported by *Tamarix* vary geographically, which may be one reason why birds will occupy *Tamarix* in some areas but not in others. Along the middle Rio Grande in New Mexico, arthropod species richness and abundance were similar in *Tamarix* and cottonwood habitats (Ellis et al. 2000). On the lower Colorado River, several of the most common insect families in riparian habitat occur in comparable or greater abundance in *Tamarix* than in most native vegetation (Anderson et al. 2004), and at Roosevelt Lake in Arizona, Durst (2004) found no difference in invertebrate biomass in native versus *Tamarix* patches. However, other studies (Yong & Finch 1997; DeLoach et al. 2000; Dudley & DeLoach 2004; Nelson & Wydoski 2008) found evidence for reduced arthropods in *Tamarix* habitats and noted that this could reduce habitat quality for birds. This variability suggests that a suite of factors—including internal patch structure and heterogeneity, adjacent habitats and land uses, proximity to water or saturated soils, attractiveness to pollinating insects, understory plant characteristics, climate, and local environmental characteristics—may be the primary determinants of invertebrate abundance and diversity within individual *Tamarix* habitats.

Could *Tamarix* Control Negatively Impact Some Birds?

The relative value of *Tamarix* control as part of riparian restoration to benefit birds will vary based on geography, stand characteristics, and, perhaps most importantly, the type of habitat that would replace the *Tamarix*. *Tamarix* likely seldom supports the same wildlife species richness, guilds, and population sizes as native habitat, but it can fulfill an important habitat role for some species (USFWS 2002; Walker 2006), especially in areas where degraded riparian systems preclude the establishment of native vegetation. These considerations move us beyond the simple question of whether there are as many birds in *Tamarix* as in native riparian habitats to the more relevant restoration and conservation issue of whether a given area of *Tamarix* provides higher net riparian habitat value than does the replacement habitat. If *Tamarix* is replaced with a comparable amount of quality native riparian vegetation, there would presumably be a net benefit. However, if an area of *Tamarix* that currently supports riparian breeding birds is replaced by non-riparian vegetation or by only a fractional amount of native riparian habitat, there may be a net loss of riparian habitat value (Shafroth et al. 2005) and possible local/regional loss of riparian birds (Fleishman et al. 2003; Walker 2006). Without careful restoration planning, execution, and follow-up,

it is also possible that *Tamarix* will be replaced by other invasive vegetation that has even lower habitat value or greater negative effects (D'Antonio & Meyerson 2002; Harms & Hiebert 2006; Shafroth et al. 2008).

Concerns of habitat loss are especially acute for endangered and sensitive species. Howe (1986) considered past and future large-scale *Tamarix* control on the Pecos River as a possible threat to the persistence of Yellow-billed Cuckoos there. Livingston and Schemnitz (1996) stated that cuckoos would lose essential habitat when *Tamarix* is removed along this river. Subsequently, cuckoos have all but disappeared in the lower Pecos valley from Six-Mile Dam near Carlsbad to the border of Texas following a large-scale *Tamarix* removal project from 1999 through 2006 (Travis 2005; Hart et al. 2006), and Williams and Travis (2003) concluded that *Tamarix* defoliation from aerial spraying, mechanical removal, and biocontrol continues to be a threat. Similarly, the Southwestern Willow Flycatcher recovery plan (USFWS 2002) expressed concerns about large-scale *Tamarix* control or removal at occupied flycatcher sites and noted that extensive defoliation via biocontrol insects, even without complete *Tamarix* mortality, could reduce the vegetative cover at flycatcher breeding sites sufficiently to render them unsuitable or inferior to their precontrol state.

To explore whether additional species have the potential to be negatively affected by widespread *Tamarix* control, we compiled a list (Table 3) of riparian birds that breed in *Tamarix*-dominated habitats (>75% *Tamarix*) in at least part of their range within Arizona and New Mexico (Bureau of Reclamation, unpublished data; Hunter et al. 1988; McKernan & Braden 2002; Corman & Wise-Gervais 2005; Sogge et al. 2005). The resulting list includes nine additional species (beyond the cuckoo and the flycatcher), many of which are considered priority species by Partners in Flight (Rich et al. 2004; Intermountain West Joint Venture 2005; Sonoran Joint Venture Technical Committee 2006) or birds of management concern by the USFWS (2004). Whether these or other species would actually experience local population reductions depends in large part on the geographic location and the extent and pace of both *Tamarix* loss and the development of replacement habitat, all of which are influenced by a number of physical, ecological, and restoration technique factors (Shafroth et al. 2008).

Even when restoration will lead to replacement of *Tamarix* with native riparian vegetation, it is important to consider the rate at which this will occur. In desert environments, removal of *Tamarix* may be followed by long-term depauperate plant communities, especially where sufficient surface water, groundwater, and flooding regimes are not present (Harms & Hiebert 2006). If *Tamarix* is removed rapidly but replacement riparian habitat develops only slowly, the interim loss of riparian vegetation could lead to reduction or loss of local populations of riparian birds, at least in the short-term (Fleishman et al. 2003). It is likely that most riparian bird species would become reestablished once the new riparian habitat develops and

Table 3. Bird species that breed in habitats composed of more than 75% *Tamarix* within Arizona and New Mexico and therefore subject to potential local declines in population following *Tamarix* control.

Species	Partners in Flight Priority Species		U.S. Fish and Wildlife Service Birds of Management Concern	
	Regional	National Watch List	Regional	National
Bell's Vireo (<i>Vireo bellii</i>)	X	X	X Endangered, Least ssp.	X Other ssp.
Bewick's Wren (<i>Thryomanes bewickii</i>)	X			
Black-chinned Hummingbird (<i>Archilochus alexandri</i>)	X			
Blue Grosbeak (<i>Guiraca caerulea</i>)				
Lucy's Warbler (<i>Vermivora luciae</i>)	X	X		
Summer Tanager (<i>Piranga rubra</i>)	X	X		
White-winged Dove (<i>Zenaida asiatica</i>)	X			
Willow Flycatcher (<i>Empidonax traillii</i>)	X	X	X Endangered, Southwestern ssp.	
Yellow Warbler (<i>Dendroica petechia</i>)	X		X	
Yellow-billed Cuckoo (<i>Coccyzus americanus</i>)	X		X Western ssp.	
Yellow-breasted Chat (<i>Icteria virens</i>)				

Sources: Bureau of Reclamation (unpublished data), Hunter et al. (1988), McKernan & Braden (2002), Corman & Wise-Gervais (2005), Sogge et al. (2005). Species with Partners in Flight (Rich et al. 2004; Intermountain West Joint Venture 2005; Sonoran Joint Venture Technical Committee 2006) or USFWS (2004) conservation priority in at least part of the Southwestern Willow Flycatcher's range are indicated by an "X."

becomes suitable, but for some rare or endangered species, even the temporary loss may be of management concern.

Management Implications

Non-native species control can be a technically and ecologically complex issue, especially when done in the context of native habitat restoration (D'Antonio & Meyerson 2002; Harms & Hiebert 2006; Shafroth et al. 2008). Approaching restoration by focusing only on invasive control is problematic and unlikely to prove successful; restoration plans should factor in local physical and ecological conditions and address the potential need for activities such as planting, supplemental watering, or reduction of other local stressors (Bay & Sher 2008; Shafroth et al. 2008). A long-term riparian restoration strategy that directly manages *for* native species by focusing on favorable processes, rather than simply *against* exotics, is likely to be more successful than simple removal of *Tamarix* (Briggs 1996; Stromberg & Chew 2002; Harms & Hiebert 2006; Hinojosa-Huerta 2006).

Thus, there are many challenges to effective riparian restoration, especially at large scales, and there are no guarantees such efforts will produce the desired outcome or result in the same vegetative communities that were present before *Tamarix* became established (D'Antonio & Meyerson 2002; Harms & Hiebert 2006; Shafroth et al. 2008). Still, given amenable conditions and active restoration activities (Bay & Sher 2008; Shafroth et al. 2008), there are places where native habitat can be restored to provide higher benefit to birds and other wildlife (Lovich & De Gouvenain 1998; DeLoach et al. 2000). In addition, there can be negative consequences to not controlling *Tamarix* in some areas, such as increased or continued high fire risk, continued loss of the native vegetation at a site, establishment of *Tamarix*

in new areas, and persistent exclusion of riparian "specialist" birds such as cavity nesters. *Tamarix* control may also be undertaken for reasons unrelated to habitat improvement (e.g., reduce fire risk, Shafroth et al. 2008), so the success or value of all *Tamarix* control projects cannot be based solely on their net benefit to birds or other wildlife.

There are a variety of techniques available for *Tamarix* control and riparian restoration, and different techniques vary widely in cost, the scale and rate at which they act, and the degree to which they can be targeted at or retained within a particular area. Because all these variables influence how birds will be affected by *Tamarix* control, it is important to use the control technique(s) best suited for a given situation or set of objectives (Shafroth et al. 2008). For example, mechanical removal or herbicides can be applied to specific sites at a relatively fine scale and even to selectively remove only a portion of the *Tamarix* at a given site. This approach could prove valuable when attempting to minimize impacts that might arise from large-scale loss of habitat or to allow a gradual conversion from *Tamarix* to native vegetation that might promote continued occupation by riparian birds (Livingston & Schemnitz 1996; USFWS 2002; Fleishman et al. 2003). In contrast, biocontrol insects such as *Diorhabda elongata* can rapidly reduce *Tamarix* cover over very large areas at a relatively low cost (DeLoach et al. 2000) but cannot be selectively targeted. Since 2001, *Diorhabda* beetles defoliated approximately 50,000 ha of *Tamarix* at sites in Nevada, Utah, Wyoming, and Colorado, and have already dispersed approximately 60 km from a release site in Nevada (DeLoach 2006; DeLoach et al. 2006). Given the above, we believe that the *Diorhabda* beetles will probably spread widely across the southwestern United States, both naturally and with human assistance. Thus, the introduced beetle is likely to have

geographically widespread effect on *Tamarix*, irrespective of whether the affected habitat is of high or low quality to bird species. Selective control may be preferable for some objectives because several studies have shown that a small increase in native habitat can have a large positive effect on the bird community (Ellis 1995; Holmes et al. 2003; van Riper et al. 2008). Ultimately, evaluation of success requires scientifically valid and statistically robust postcontrol monitoring and evaluation; the use of inappropriate techniques and response measures, or failure to consider site-specific data, can risk producing erroneous or misleading conclusions (Kus & Beck 2003; Walker 2006). Unfortunately, most *Tamarix* control projects to date have not included effective or long-term avian or wildlife monitoring (Walker 2006, Nelson & Wydoski 2008; Shafroth et al. 2008).

Globally, managers contemplating habitat restoration through the control of invasives are faced with a complex task, in part because there are still large gaps in our understanding of which exotics are truly of concern and of the relationships between wildlife and exotic plants (Fleishman et al. 2003). This creates substantial challenges in predicting the outcome of exotic plant control in terms of wildlife habitat and animal populations. The goals of biological conservation and management will be best served by a careful evaluation of whether the planned activities will entail more positive than negative ecological impacts, and embarking only on those that provide a net positive outcome. To do otherwise risks violating the long-standing credo of "first, do no harm."

Implications for Practice

- Many birds use exotic vegetation such as *Tamarix* as breeding habitat. For *Tamarix*, the degree of use varies by bird species, geographic area, and stand structure and characteristics. This variation makes it difficult to predict the ecological benefits and costs of *Tamarix* control or removal because the effects are likely to be species specific and site specific.
- *Tamarix* control has the potential to reduce local or regional populations of some riparian bird species, depending upon the scale of control, techniques used, whether higher-quality riparian habitat replaces the *Tamarix*, and how long it takes for replacement to occur. Removal or control of *Tamarix*, in the absence of effective restoration activities, may decrease the net riparian habitat value for birds.
- Decisions on whether to control exotics, and any efforts to do so, will be most effective if they are based on objective evaluation of potential positive and negative impacts, tailored to the individual site. Measurable goals and objectives are also important to the success of control and restoration projects, as are the use of appropriate techniques and robust and effective monitoring.

Acknowledgments

This work was supported by salary and research funds from the Bureau of Reclamation and the U.S. Geological Survey. Valuable data were provided by the Arizona Game and Fish Department; we especially thank T. Corman for sharing his knowledge and insights on the birds of Arizona. C. Beardmore graciously provided guidance on Partners in Flight bird prioritization. S. O. Williams, III, shared information on the status of Yellow-billed Cuckoos in New Mexico. We thank T. Dudley, K. Paxton, T. J. Tibbitts, C. van Riper, III, and two anonymous reviewers for helpful comments on earlier drafts, and L. Sogge for editorial assistance with the manuscript.

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