Case Study No. 2

Tamarisk (*Tamarix* spp.)

This is one of two case studies that demonstrate how the data collected during the REA process can be applied to management issues of concern. Case studies delve into greater detail to cover the underlying ecological and human influences affecting the selected conservation element or change agent and to articulate the nature of regional issues and associated management questions. Case studies also demonstrate how REA data and results can be applied to land use planning and resource management. Tamarisk was selected for a case study because it represents a key invasive-species, but it also relates to discussions of river regulation, flow regime changes, groundwater, and changes in native riparian species distribution and biodiversity.

Photo: Columbia University Invasive Species Summary Project

The history of the expansion of tamarisk throughout the riparian areas of the southwestern U.S. parallels the development and allocation of water resources in arid and semi-arid ecosystems in the 20th and 21st centuries. Tamarisk (or saltcedar) is an invasive shrub that has been designated as a change agent in the Colorado Plateau REA because it affects native riparian ecosystems and aquatic sites of conservation concern. The name *tamarisk* refers to a number of related species in the genus *Tamarix* (e.g., *T. ramosissima* and *T. chinensis*) that are similar in appearance and that hybridize freely (Gaskin and Shafroth 2005). The species did not become widely distributed in the U.S. until the 1800s. It is presently found throughout nearly all western and southwestern states (Lovich 2000). In a survey of 475 gaging stations across the western U.S., Friedman et al. (2005) found tamarisk to be the third most frequently-occurring riparian woody plant in the West. Tamarisk is widely distributed across the Colorado Plateau ecoregion (Figures 1 and 2). Any depiction of its distribution derived from remotely-sensed data is likely to underestimate its actual distribution as the species is not always distinguishable when mixed with native vegetation.

Tamarisk occurs in low-lying areas such as riparian habitats, washes, and playas. It tolerates a range of soil types, but it is most commonly found in alkaline and saline soils that are seasonally saturated (Brotherson and Field 1987). Although tamarisk can spread in the absence of disturbance (DiTomaso 1998, Cooper et al. 2003, Merritt and Poff 2010), human activities enhance the establishment of this species, through the damming of free-flowing rivers (with subsequent changes to flow regimes and seasonal flooding cycles), groundwater pumping, grazing, agriculture, irrigation, and urban development (Figure 3, Conceptual Model, Development and Disturbance). All of these activities have negatively affected native riparian vegetation and resulted in the conversion of many diverse southwestern riparian zones to nonnative monocultures. Tamarisk exerts competitive pressure on native riparian vegetation through a variety of pathways: it 1) tolerates a greater depth to groundwater than native species; 2) outcompetes native species in saline conditions; 3) reduces seedling recruitment of natives through its prodigious seed production, dense cover, and underlying litter layer; and 4) increases riparian zone fire frequency (Zouhar 2003, Busch and Smith 1995, Lite and Stromberg 2005). Dense stands of tamarisk also create overbank flooding that alters stream channel structure and sediment deposition (Figure 3, Geomorphology, Flooding Regime, and Hydrology Changes, Lovich 2000, Dudley et al. 2000, Cooper et al. 2003).

Case Study No. 2

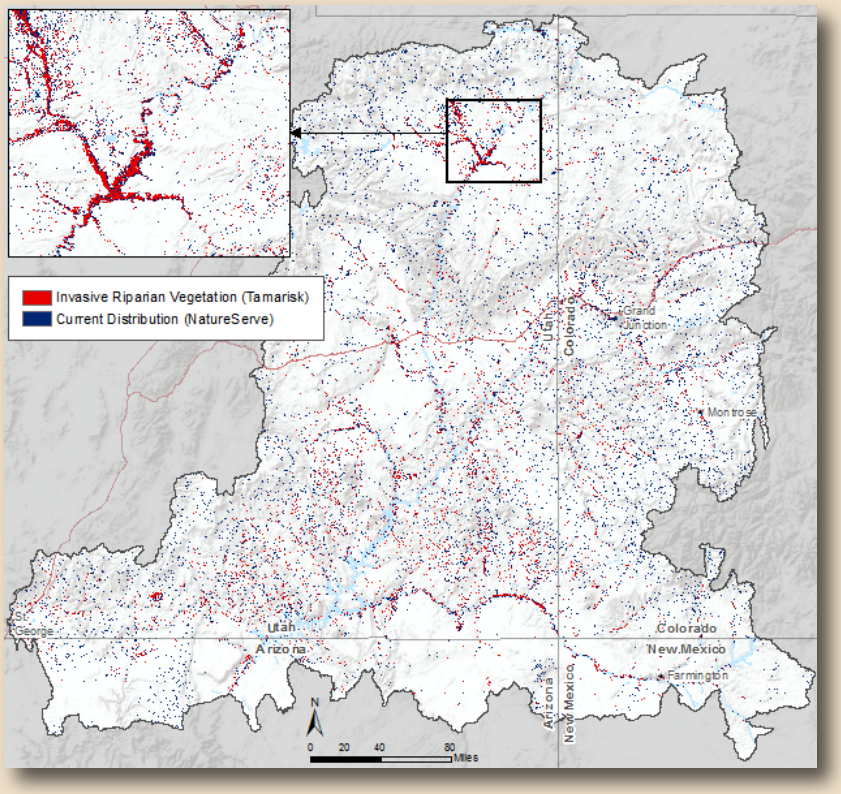

Figure 1. Distribution of tamarisk (in red) relative to the distribution of other riparian vegetation (NatureServe landcover dataset).

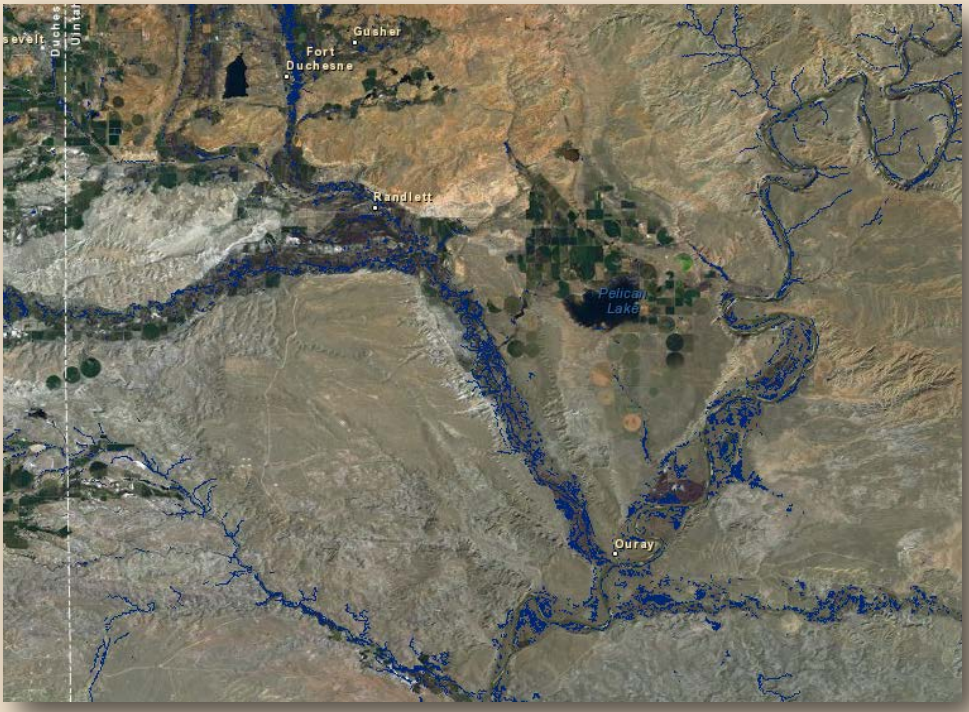

Figure 2. Detail of current distribution of tamarisk (in blue) near Fort Duchesne, Uinta Basin, Utah as mapped for the REA. See Appendix A for modeling approach and region-wide results.

Flow Alteration. Although it is likely that native riparian species would have declined with the extensive flow alteration of western U.S. streams and rivers regardless of the presence of invasive species (Merritt and Poff 2010), flow regulation has facilitated the spread of tamarisk. The creation of dams and reservoirs has enhanced tamarisk establishment and survival by altering the frequency, timing, and velocity of flows, reducing the frequency of seasonal flooding, and providing stable substrates for colonization (Figure 4, Shafroth et al. 2002, Zouhar 2003, Lite and Stromberg 2005, Stromberg et al. 2007b, Merritt and Poff 2010). Even slight modifications in flow regime affect cottonwood recruitment (Merritt and Poff 2010). While native riparian species produce seeds during a narrow germination period that corresponds to a former spring flooding time frame, tamarisk produces hundreds of thousands of seeds over the entire growing season; in regions with summer rainfall, tamarisk seeds may germinate late in the season following monsoonal storm events (Shafroth et al. 1998, Stromberg et al. 2007b).

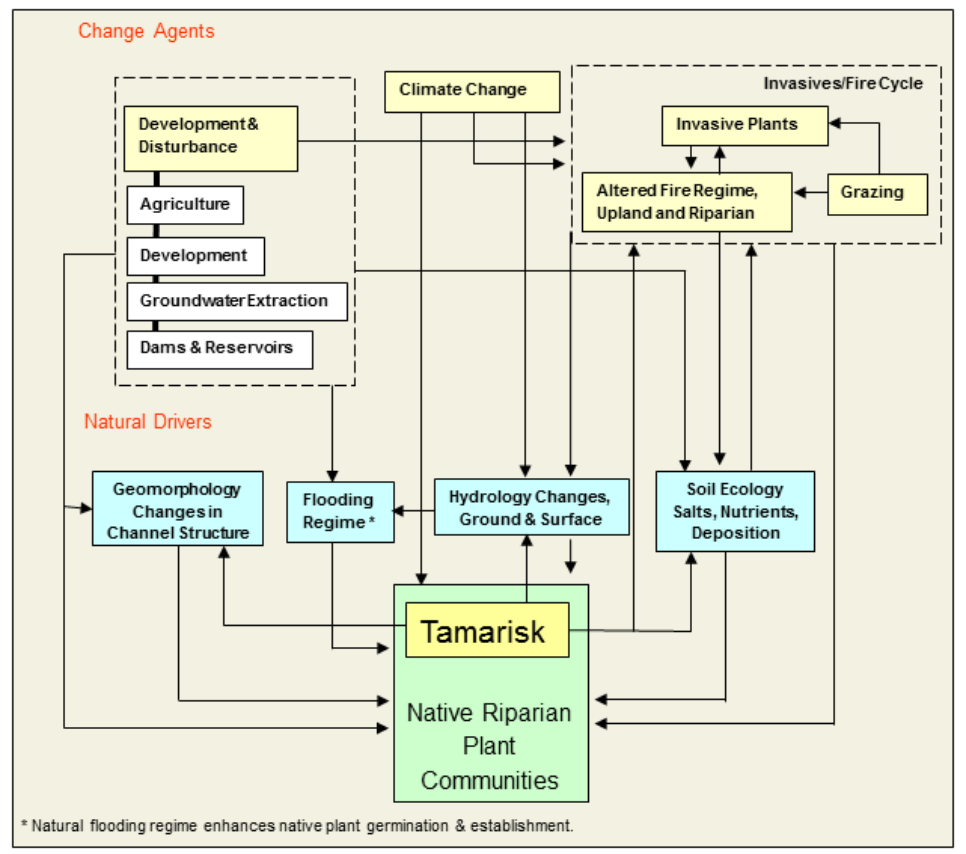

Figure 3. Conceptual model for tamarisk in the Colorado Plateau ecoregion.

Flow regulation also increases stream and riparian soil salinity in arid aquatic systems by eliminating regular flooding and subsequent flushing of accumulated salts from natural sources and irrigation return water (Busch et al. 1992, Merritt and Poff 2010). Tamarisk has greater salt tolerance than native species; it alters the breakdown of organic materials in desert streams (Kennedy and Hobbie 2004) and concentrates salt in leaf litter, inhibiting other species' germination and growth (Figure 3, Soil Ecology, Brotherson and Field 1987, Glenn et al. 1998, Busch and Smith 1995, Vandersande et al. 2001). Busch et al. (1992) compared reaches along the Bill Williams River in Arizona having intact native riparian vegetation to disturbed reaches along the Colorado River that were dominated by tamarisk; they found that, where cottonwood and willow competed

successfully with tamarisk, soil salinity levels were 1–3 g/l NaCl compared to 6–8 g/l NaCl where invasive tamarisk was dominant. Glenn et al. (1998) supported these field results with a greenhouse experiment, concluding that a native cottonwood-willow association is not competitive with tamarisk above about 4 g/l NaCl.

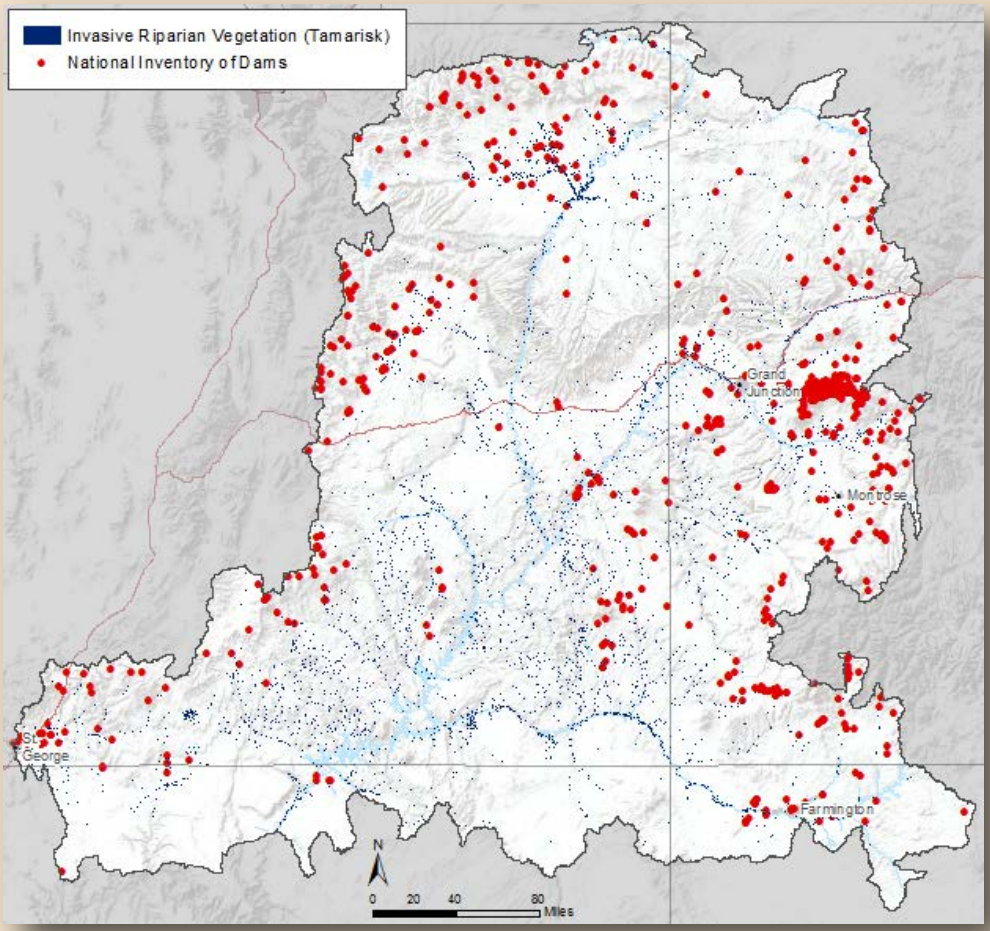

Figure 4. Distribution of tamarisk relative to the distribution of dams in the Colorado Plateau.

Thus, although natural flow conditions do not deter the recruitment of tamarisk on the Colorado Plateau, managing to imitate natural flow conditions and flooding regimes to promote native species allows natives to compete more successfully with tamarisk (Cooper et al. 2003, Birken and Cooper 2006, Merritt and Poff 2010).

Depth to Groundwater. Groundwater withdrawals for human use put native species at risk and promote the spread of invasives such as tamarisk. In semiarid and arid aquatic ecosystems, permeable floodplain substrates do not retain moisture, and shallow groundwater serves as a more reliable source of water than surface water for riparian plant communities. Depth to groundwater is a limiting factor that affects the distribution of native plant species within the riparian zone (Stromberg et al. 1996, Lite and Stromberg 2005, Nagler et al. 2009). Stromberg et al. (1996) found in a study of riparian vegetation on the San Pedro River in Arizona, that optimal groundwater levels were <0.25 m for obligate wetland herbaceous species, < 1 m for cottonwood and willow seedlings, and < 3 m for mature cottonwood. Tamarisk tolerates a wide range of

groundwater depths as a seedling and adult (up to a depth of 10 m) and thus it can out-compete other more sensitive native species (Stromberg et al. 1996, Stromberg et al. 2007a). Lite and Stromberg (2005) discussed the need to 1) refine the hydrologic thresholds that indicate a shift in composition between native and exotic riparian vegetation and 2) determine the groundwater levels at which drought-tolerant species tend to assert dominance. Over a two-year study period, Lite and Stromberg (2005) found that where surface flow persisted >75% of the time, with inter-annual groundwater fluctuation < 0.5 m, and average maximum depth to groundwater < 2.6 m, native cottonwood and willow remained dominant over tamarisk. At increasing groundwater depths between 2.5 and 3.5 m and groundwater fluctuations between 0.5 and 0.8 m annually, cottonwood persisted alongside tamarisk, but willow, which requires shallower groundwater levels, declined sharply.

Fire in Riparian Zones. Fire is increasing in frequency in riparian areas of the southwestern U.S. for a number of reasons in addition to typical or climate change-induced drought cycles: increased human ignitions, a lack of flood flows, a buildup of litter and woody debris, lowered water tables, and the increasing dominance of fire-adapted invasive species (Ellis 2001). Unlike native riparian vegetation that lacks fire adaptations to resist burn damage or to repopulate burned areas, tamarisk readily re-sprouts from the roots after fire, and it is better able to utilize remaining post-fire soil moisture (Busch and Smith 1993, Busch 1995). A buildup of leaves and litter under dense growth increases fire frequency in riparian areas dominated by tamarisk; fire risk is magnified in regulated systems that lack regular flood flows to flush out accumulated litter (Figure 3, Altered Fire Regime, Busch and Smith 1993, Busch and Smith 1995, Ellis et al. 1998, Ellis 2001, Zouhar 2003).

Effects on Wildlife Habitat. Tamarisk affects native wildlife by changing the composition of forage plants and the structure of native riparian systems. Tamarisk reduces the value of critical habitat for some wildlife species dependent on specific native riparian habitats, particularly those that require mature canopy trees (Cohan et al. 1978, Hunter et al. 1988, Johnson et al. 1999, Chen 2001), but it does provide some habitat value for other species (D'Antonio 2000, Dudley et al. 2000, van Riper et al. 2008). For example, the southwestern willow flycatcher, a listed endangered species that occurs as far north as southern Utah, will use tamarisk for nesting (McCarthey 2005, Cardinal and Paxton 2005, Sogge et al. 2005, Sogge et al. 2008). However, increased fire risk in tamarisk-dominated riparian areas is also one of the greatest threats to willow flycatcher breeding sites (USFWS 2002). Brown and Trosset (1989) found that, besides willow flycatcher, five other species nested regularly in tamarisk along the Colorado River in the Grand Canyon: Bell's vireo (*Vireo bellii*), yellow warbler (*Dendroica petechia*), yellowthroat (*Geothlypis trichas*), yellow-breasted chat (*Icteria virens*), and Bullock's oriole (*Icterus bullockii*). Many songbirds, woodpeckers, and other cavity nesters are never found in tamarisk and prefer cottonwood groves in all seasons (Ellis 1995).

Tamarisk also affects instream habitats and aquatic species. Tamarisk removal at a spring in Ash Meadows National Wildlife Refuge in Nevada resulted in an increased density of Ash Meadows pupfish, because the shade produced by the dense tamarisk thickets reduced the algae necessary to sustain the pupfish (Kennedy et al. 2005). In studies examining the response of aquatic macroinvertebrates to exotic riparian vegetation, Bailey et al. (2001) found a two-fold decrease in macroinvertebrate richness and a four-fold decrease in total abundance of macroinvertebrates on tamarisk leaf packs vs. native Fremont cottonwood leaf packs placed in an Arizona perennial stream; and Moline and Poff (2008) noted that native leaf packs remained in the stream longer than leaves from tamarisk, making the leaves available longer to macroinvertebrate leaf shredders.

Restoration of Native Riparian Species

Present riparian restoration efforts to reverse the spread of tamarisk (and other riparian exotics such as Russian olive [*Elaeagnus angustifolia*]) cover a management spectrum from the restoration or imitation of fluvial processes that favor the natural establishment of native species to mechanical and chemical tamarisk clearing operations and irrigated native tree planting. Tamarisk removal may be a lower priority or even

unnecessary on perennial free-flowing rivers where fluvial processes remain more intact and native species can compete with invasives (Stromberg et al. 2007b). Stabilizing groundwater levels by limiting groundwater withdrawals (Stromberg et al. 1996) and managing to reduce salinity levels to < 4 g/l NaCl (Busch et al. 1992, Glenn et al. 1998) protect existing native riparian plant communities. In areas of tamarisk dominance, clearing and planting efforts are not likely to be successful without a concurrent restoration of accessible shallow groundwater. If tamarisk clearing is pursued, a more gradual or patch replacement of tamarisk, such as might occur with scouring floods, may ensure that enough tamarisk woodland remains available during a transitional period for bird species that use tamarisk for nesting. Bateman and Paxton (2009) provide a thorough review of wildlife use of tamarisk and likely wildlife responses to tamarisk control.

Restoration of native riparian vegetation with a return to natural fluvial processes requires active management to allow (or mimic) regional hydrologic regimes with characteristic perennial stream flows, flood timing and intensity, and available shallow groundwater. Native species recruitment may occur in sections of rivers below dams if larger flood flows exceed the storage capacity of the dam or if flood flows are managed through spring water releases (Shafroth et al. 1998). Outcomes will vary with flood timing and intensity; high volume spring flooding may scour the stream channel, rearrange sediments, and provide a seedbed for native species early in the season. Summer water releases for irrigated agriculture in reaches below dams, on the other hand, may favor tamarisk dominance because tamarisk is able to take advantage of moist summer seedbeds (Shafroth et al. 1998, Stromberg et al. 2007a, b).

Rivers that retain more of their natural flow regime as well as available groundwater reserves provide a better opportunity for recovery of native vegetation following riparian fire. Although mature cottonwood tree mortality is very high following moderate to severe riparian burns, cottonwoods do respond with stem and root sprouts and root suckering following lighter fires (Smith et al. 2009). Native cottonwood seeds may sprout after a riparian fire if managed post-fire flooding is employed during the spring cottonwood seed dispersal period (Ellis 2001, Smith et al. 2009). Finally, as a preventative measure, reducing fuel loads and litter in riparian zones through mechanical removal or through re-establishing flooding regimes could reduce the incidence of riparian fires in mature riparian canopies (Ellis 2001).

Tamarisk dominance on perennial free-flowing streams and rivers where native species should be competitive may indicate past or present heavy grazing pressure and suggest a need for a change in grazing management (Stromberg et al. 2007b). Livestock selectively forage on the shoots of native species and find tamarisk to be less desirable than native species. Hughes (2000) found on the Arizona Strip that when livestock were restricted to winter use and kept out of riparian areas in the spring and summer, native species were able to compete with tamarisk.

Tamarisk Beetle. During the late 2000s, the U.S. Department of Agriculture (USDA) allowed tamarisk control using defoliating *Tamarix* leaf beetles (*Diorhabda carinulata*) north of the 38th parallel to avoid conflict with southwest willow flycatcher nesting territories to the south. When a later release of a different subspecies of beetle near St. George, Utah threatened to allow beetle invasions southward into Arizona, a lawsuit prompted the USDA to ban the release or interstate transport of the *Diorhabda* beetle in 2010 (Center for Biological Diversity 2009, Lamberton 2011). Field studies in the Colorado Plateau to monitor yearly beetle infestations (Figure 5) and subsequent tamarisk mortality suggest that tamarisk is not weakened as much as had been hoped by beetle defoliation; shrubs re-sprout yearly and the amount of shrub mortality varies by location and post-defoliation conditions (Tamarisk Coalition 2010, Nagler et al. 2011). Cooperating land management agencies have the opportunity to respond promptly with comprehensive restoration plans should the extent of tamarisk mortality expand widely enough to create candidate areas for riparian restoration. Areas of beetle-killed tamarisk may present atypical soil and site conditions that may require different management techniques to avoid colonization by other noxious weeds (Dennison et al. 2009, Hultine et al. 2010).

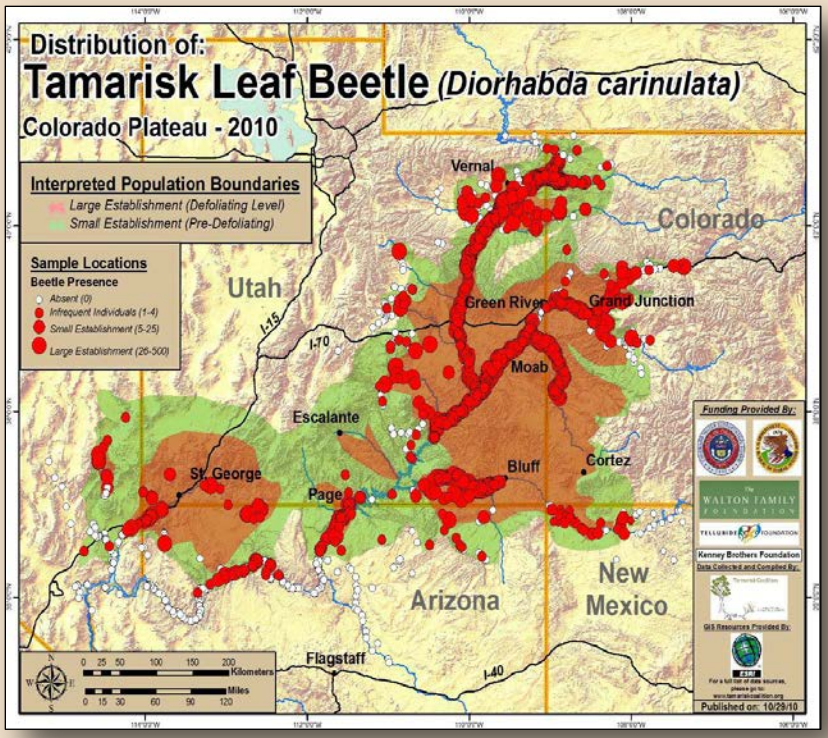

Figure 5. Map of tamarisk beetle distribution across the Colorado Plateau (Tamarisk Coalition 2010). Brown areas show areas of defoliation and green areas indicate beetle presence with low defoliation.

Climate Change

Tamarisk has a higher drought tolerance than many native riparian species (Glenn and Nagler 2005). Climate change models predict that rising temperatures are unlikely to adversely affect tamarisk distribution, with the majority of habitat remaining suitable and only a small percentage of currently invaded lands becoming climatically unsuitable by 2100 (Bradley et al 2009). The effects of climate change, such as warming temperatures and increased fire frequency and intensity, are hypothesized to enhance tamarisk invasion and expansion, while limiting native riparian plant communities even more than currently (Figure 3, Altered Fire Regime, Climate Change, Merritt and Poff 2010, Seager et al. 2007). Climate change projections predict declining river flows (with maximum spring flows coming earlier in the season), more frequent droughts, and increasing human water consumption with its pressures on groundwater levels; all of these conditions will make it more difficult for native species to reproduce and compete with invasives in riparian areas (Smith et al. 2009).

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Photo: Desolation Canyon riparian vegetation. BLM