Middle Rio Grande Endangered Species Collaborative Program

Est. 2000

Bibliography of Literature Published in 2019

Literature Cited

Caldwell, C. A., H. Falco, W. Knight, M. Ulibarri, and W. R. Gould. 2019. Reproductive Potential of Captive Rio Grande Silvery Minnow. *North American Journal of Aquaculture* 81: 47-54.

Dudley, R. K., S. P. Platania, and G. C. White. 2019*a*. Rio Grande Silvery Minnow Population Monitoring During April 2019. Prepared by American Southwest Ichthyological Researchers, L.L.C. Prepared for U.S. Bureau of Reclamation.

Hamilton, S. G., S. L. King, G. D. Russo, and M. D. Kaller. 2019. Effect of hydrologic, geomorphic, and vegetative conditions on avian communities in the Middle Rio Grande of New Mexico. *Wetlands* 39: 1029-1042. https://doi.org/10.1007/s13157-019-01156-9.

Knutson, A. E., J. L. Tracy, C. Ritzi, P. J. Moran, T. Royer, and C. J. Deloach. 2019. Establishment, Hybridization, Dispersal, Impact, and Decline of Diorhabda spp. (*Coleoptera: Chrysomelidae*) Released for Biological Control of Tamarisk in Texas and New Mexico. *Environmental entomology* 48: 1297-1316.

Mahoney, S. M., J. B. Mike, J. M. Parker, L. S. Lassiter, and T. G. Whitham. 2019. Selection for genetics-based architecture traits in a native cottonwood negatively affects invasive tamarisk in a restoration field trial. *Restoration ecology* 27: 15-22.

Mahoney, S. M., A. N. B. Smith, P. J. Motyka, E. J. Lundgren, R. R. Winton, B. Stevens, and M. J. Johnson. 2019. Russian olive habitat along an arid river supports fewer bird species, functional groups and a different species composition relative to mixed vegetation habitats. *Journal of arid environments* 167: 26-33.

Mortensen, J. G., R. K. Dudley, S. P. Platania, and T. F. Turner. 2019. Rio Grande Silvery Minnow Biology and Habitat Syntheses Final Report. Prepared by American Southwest Ichthyological Researchers, L.L.C. Prepared for U.S. Bureau of Reclamation.

Murray, L., B. Schutte, C. Sutherland, L. Beck, A. Ganguli, and E. Lehnhoff. 2019. Integrating conventional management methods with biological control for enhanced Tamarix management. *Invasive Plant Science and Management* 12: 176-185.

Murray, L., B. J. Schutte, A. C. Ganguli, and E. A. Lehnhoff. 2019. Impacts of Tamarix (L.) Litter and Mycorrhizal Amendments on *Baccharis salicifolia* (Ruiz & Pav.) Pers. Competitiveness and Mycorrhizal Colonization. *Agronomy 9*: 453.

Platania, S. P., J. G. Mortensen, M. A. Farrington, W. H. Brandenburg, and R. K. Dudley. 2020. Dispersal of Stocked Rio Grande Silvery Minnow (*Hybognathus amarus*) in the Middle Rio Grande, New Mexico. *The Southwestern Naturalist* 64: 31-42.

Rubin, Z., B. Rios-Touma, G. M. Kondolf, M. E. Power, P. Saffarinia, and J. Natali. 2019. Using prey availability to evaluate Lower Colorado River riparian restoration. *Restoration ecology* 27: 46-53.

Snyder, K. A. and R. L. Scott. 2019. Longer term effects of biological control on tamarisk evapotranspiration and carbon dioxide exchange. *Hydrological Processes*. <https://doi.org/10.1002/hyp.13639> Accessed on 20 Feb 2020.

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Caldwell, C. A., H. Falco, W. Knight, M. Ulibarri, and W. R. Gould. 2019. Reproductive Potential of Captive Rio Grande Silvery Minnow. *North American Journal of Aquaculture* 81: 47-54.

Key words: silvery minnow reproduction; reproduction; Rio Grande

Abstract: Captive propagation and augmentation of the Rio Grande Silvery Minnow Hybognathus amarus is necessary for continued persistence of the species until habitat can be restored. Augmentation occurs using captive fish within the first year (age 0) through age 2; however, older year-classes (ages 3–4) have been released into the wild. We quantified fecundity and compared egg quality across four reproductive age-classes (1–4) of hatchery-reared Rio Grande Silvery Minnow. Batch fecundity (total number of spawned eggs) ranged from 2,029 eggs in age-1 fish to 10,588 eggs in age-4 fish. Standing stock of vitellogenic (i.e., yolked) oocytes remaining in ovaries after spawning increased from 988 oocytes at age 1 to 4,924 oocytes at age 4. Total fecundity (i.e., batch fecundity plus standing stock of yolked oocytes) increased from 3,017 eggs and yolked oocytes in age-1 fish to 15,522 eggs and yolked oocytes in age-4 fish. Of note, batch fecundity ranged from 57% to 68% across the four age-classes indicating that over half of the total fecundity occurs in the first spawn. Average percent fertilization of eggs (63–82%) was not detectably different across the four age-classes, while average egg diameter (4.1–5.5 mm) increased as age increased. Fecundity increased across all four reproductive age-classes of Rio Grande Silvery Minnow, with the larger portion of total fecundity occurring in the first spawn across all age-classes. The timing of spawning with optimal conditions in the Rio Grande is critical for survival and ultimately recruitment into the wild fish population.

DOI: 10.1002/naaq.10068

Dudley, R. K., S. P. Platania, and G. C. White. 2019*a*. Rio Grande Silvery Minnow Population Monitoring During April 2019. Prepared by American Southwest Ichthyological Researchers, L.L.C. Prepared for U.S. Bureau of Reclamation.

Key words: Rio Grande Silvery Minnow, population monitoring, sampling

Summary: The April population monitoring efforts were conducted at the 20 standard sites and at the 10 additional sites. Ten sites were located in the Angostura Reach, ten sites were located in the Isleta Reach, and ten sites were located in the San Acacia Reach. For April 2019, comparisons were made between standard sites and all sites (i.e., standard and additional sites). For the 2019 monthly trends, data were based on all sites (i.e., standard and additional sites) to maintain consistency across all monthly reports. A list of all collection localities is appended (Appendix A). Adult and juvenile fish were obtained by rapidly drawing a 3.1 m x 1.8 m small mesh (ca. 5 mm) seine through discrete mesohabitats. Larval fish were collected with a 1.0 m x 1.0 m fine mesh (ca. 1.5 mm) seine. All fishes were identified to species and enumerated. We used length-age relationships to assign ages (i.e., age-0, age-1, and age2+) to all Rio Grande Silvery Minnow collected. Age-0 individuals are only present, however, after annual spring spawning occurs (ca. April–June). Figures illustrating fish densities (i.e., fish per 100 m2) were prepared for the ten focal species to facilitate comparisons across reaches.

Angostura Reach

Mean daily discharge in the Angostura Reach (Rio Grande at Albuquerque, NM; USGS Gage 08330000) averaged 1,822.9 and ranged from 1,010 to 2,640 cfs from 16 March to 15 April. Water temperatures ranged from 10.0 to 16.3 o C during the Angostura Reach sampling efforts (ca. 0830–1530 h). Secchi disk measurements of water clarity ranged from 6 to 29 cm. Sampling for fishes in the Angostura Reach during April yielded 1,486 individuals with a cumulative fish density of 28.3 individuals/100 m2 sampled. The overall sampling effort in the Angostura Reach covered 5,244.1 m2 (surface area) of water. Densities of all fish species combined ranged from 8.0 to 96.1 individuals per 100 m2 at the different sampling sites. In April, there were 13 fish species collected in the Angostura Reach. Red Shiner was the most abundant taxon (n = 988), followed by Flathead Chub (n = 237), and Longnose Dace (n = 95). We collected Rio Grande Silvery Minnow (n = 10) in 9 of the 147 seine hauls that yielded fish, and its site-specific densities ranged from 0.0 to 0.6 individuals per 100 m2.

Isleta Reach

In the Isleta Reach, mean daily discharge (Rio Grande at Isleta Lakes near Isleta, NM; USGS Gage 08330875) averaged 1,702.9 and ranged from 1,030 to 2,530 cfs from 16 March to 15 April. Water temperatures ranged from 8.7 to 16.6 o C throughout the sampling localities during the day (ca. 0930– 1600 h). Secchi disk measurements ranged from 3 to 12 cm during sampling. Isleta Reach population monitoring efforts produced 2,183 individuals in April with a cumulative fish density of 39.9 individuals/100 m2 sampled. The total sampling effort in the

Isleta Reach during April covered 5,472.9 m2 (surface area) of water. Fish densities (all species combined) at the sampling sites ranged from 4.2 to 88.8 individuals per 100 m2 sampled. There were 11 fish species collected in the Isleta Reach during April. Red Shiner was the most abundant taxon (n = 1,931), followed by Channel Catfish (n = 130), and Western Mosquitofish (n = 63). We collected Rio Grande Silvery Minnow (n = 1) in 1 of the 116 seine hauls that yielded fish, and its site-specific densities ranged from 0.0 to 0.2 individuals per 100 m2.

San Acacia Reach

Mean daily discharge at San Acacia (Rio Grande Floodway at San Acacia, NM; USGS Gage 08354900) from 16 March to 15 April was generally higher (average = 1,455.6; range = 831–2,370 cfs) as compared to San Marcial (Rio Grande Floodway at San Marcial, NM; USGS Gage 08358400) during the same period (average = 960.8; range = 402–1,690 cfs). Water temperatures in April for the San Acacia Reach ranged from 10.5 to 14.6 o C (ca. 0930–1600 h). Secchi disk measurements ranged from 2 to 4 cm during sampling. Population monitoring efforts in the San Acacia Reach during April yielded 1,037 individuals with a cumulative fish density of 20.9 individuals per 100 m2 sampled. Sampling in the San Acacia Reach covered an area of 4,970.7 m2 of water. Fish densities (all species combined) ranged from 0.4 to 63.0 individuals per 100 m2 at sites sampled in the San Acacia Reach. In April, there were 9 fish species collected in the San Acacia Reach. Red Shiner was the most abundant taxon (n = 847), followed by Flathead Chub (n = 106), and Channel Catfish (n = 43). We collected Rio Grande Silvery Minnow (n = 6) in 5 of the 111 seine hauls that yielded fish, and its site-specific densities ranged from 0.0 to 0.6 individuals per 100 m2.

Standard Sites

During April, sampling covered 10,374.7 m2 (surface area) of water and yielded 3,076 fish. There were no dry sampling sites. Cumulative fish density during April was 29.6 individuals/100 m2 sampled. The three most common species were Red Shiner (n = 2,515), Flathead Chub (n = 212), and Channel Catfish (n = 145). The sampling sites yielded a total of 14 fish species. Rio Grande Silvery Minnow was present in 9 of the 249 seine hauls that yielded fish and at 6 of the 20 sampling sites. Densities of unmarked and marked individuals were 0.05 (n = 5) and 0.05 (n = 5) individuals/100 m2 sampled, respectively. Densities of age-0, age-1, and age-2+ individuals were 0.00 (n = 0), 0.07 (n = 7), and 0.03 (n = 3) individuals/100 m2 sampled, respectively. During April 2019, the overall density of Rio Grande Silvery Minnow was 0.10 (n = 10) individuals/100 m2 sampled. Based on all April surveys since 1993, its overall density averaged 1.82 (range = 0.08–10.84) individuals/100 m2 sampled.

All Sites

During April, sampling covered 15,687.7 m2 (surface area) of water and yielded 4,706 fish. There were no dry sampling sites. Cumulative fish density during April was 30.00

individuals/100 m2 sampled. The three most common species were Red Shiner (n = 3,766), Flathead Chub (n = 363), and Channel Catfish (n = 244). The sampling sites yielded a total of 15 fish species. Rio Grande Silvery Minnow was present in 15 of the 374 seine hauls that yielded fish and at 9 of the 30 sampling sites. Densities of unmarked and marked individuals were 0.04 (n = 7) and 0.06 (n = 10) individuals/100 m2 sampled, respectively. Densities of age-0, age-1, and age-2+ individuals were 0.00 (n = 0), 0.08 (n = 12), and 0.03 (n = 5) individuals/100 m2 sampled, respectively. During April 2019, the overall density of Rio Grande Silvery Minnow was 0.11 (n = 17) individuals/100 m2 sampled. Based on all April surveys since 1993, its overall density averaged 1.82 (range = 0.08–10.84) individuals/100 m2 sampled.

DOI: Report

Hamilton, S. G., S. L. King, G. D. Russo, and M. D. Kaller. 2019. Effect of hydrologic, geomorphic, and vegetative conditions on avian communities in the Middle Rio Grande of New Mexico. *Wetlands* 39: 1029-1042.

Key words: Rio Grande; vegetation, New Mexico

Abstract: We evaluated relationships among hydrogeomorphology, vegetation structure and composition, and avian communities among three subreaches of the San Acacia Reach of the Middle Rio Grande (MRG) River of New Mexico. The subreaches varied in degradation, with Subreach 1 being severely entrenched and hydrologically disconnected, Subreach 2 being the least impacted, and Subreach 3 being intermediately disturbed. Avian point count and habitat surveys were conducted to determine avian community structure and abundance, geomorphic feature, surface flooding, and vegetation structure and composition. Ground-nesting birds and low shrub-nesting birds were insensitive to hydrogeomorphic changes as they do not rely on native understory but can use exotic understory or woody debris. In contrast, canopy-nesting birds required native overstory; therefore, they were sensitive to hydrogeomorphic changes as native overstory species require surface floods to germinate and establish. Additionally, native overstory did not vary as expected as the moderately impacted subreach, Subreach 3, had more native overstory ($\bar{x}\bar{x}$ = 30.04%, SE = ±4.57) than the least disturbed subreach, Subreach 2 ($\bar{x}\bar{x}$ = 11.20%, SE = ±1.96). These findings were a result of temporal asynchrony between hydrogeomorphic conditions and overstory composition. No subreach is unaltered and all have been affected by the hydrologic and geomorphic changes on the MRG.

DOI: 10.1007/s13157-019-01156-9

Knutson, A. E., J. L. Tracy, C. Ritzi, P. J. Moran, T. Royer, and C. J. Deloach. 2019. Establishment, Hybridization, Dispersal, Impact, and Decline of Diorhabda spp. (*Coleoptera: Chrysomelidae*) Released for Biological Control of Tamarisk in Texas and New Mexico. *Environmental entomology* 48: 1297-1316.

Key words: biocontrol; dispersal; hybrid swarm; nontarget attack

Abstract: Three *Diorhabda* spp. tamarisk beetles (Coleoptera: Chrysomelidae) were established in Texas from 2003 to 2010 for biological control of tamarisk (*Tamarix* spp.): Mediterranean tamarisk beetles, *D. elongata* (Brullé) from Greece, also established in New Mexico; subtropical tamarisk beetles, *D. sublineata* (Lucas) from Tunisia; and larger tamarisk beetles, *D. carinata* (Faldermann) from Uzbekistan. More than one million tamarisk beetles were released at 99 sites. Species establishment success ranged from 52 to 83%. All three species now co-occur in New Mexico with the northern tamarisk beetles, *D. carinulata* (Desbrochers). A phenotypic hybrid scoring system was developed to assess *Diorhabda* phenotype distributions and character mixing in hybrid zones. Widespread field populations of bispecific hybrid phenotypes for *D. carinata/D. elongata* and *D. sublineata/D. elongata* rapidly appeared following contact of parental species. Initial distributions and dispersal of *Diorhabda* spp. and hybrids are mapped for Texas, New Mexico, Oklahoma, and Kansas, where they produced large-scale tamarisk defoliation and localized dieback for 3–4 yr. However, populations subsequently severely declined, now producing only isolated defoliation and allowing tamarisk to recover. *Diorhabda sublineata* and *D. elongata* temporarily produced nontarget spillover defoliation of ornamental athel, *Tamarix aphylla* (L.) Karst, along the Rio Grande. Hybrid phenotypes were generally bimodally distributed, indicating some degree of reproductive isolation. Additional diagnostic phenotypic characters in males allowed more precise hybrid scoring. Character mixing in some hybrid populations approached or reached that of a hybrid swarm. The significance of hybridization for tamarisk biocontrol is discussed.

DOI: 10.1093/ee/nvz107

Mahoney, S. M., J. B. Mike, J. M. Parker, L. S. Lassiter, and T. G. Whitham. 2019. Selection for genetics-based architecture traits in a native cottonwood negatively affects invasive tamarisk in a restoration field trial. *Restoration ecology* 27: 15-22.

Key words: common garden; *Populus fremontii*; restoration; *Tamarix* spp; tree architecture

Abstract: Climate change and competition from invasive species remain two important challenges in restoration. We examined the hypothesis that non-native tamarisk (Tamarix spp.) reestablishment after aboveground removal is affected by genetics-based architecture of native Fremont cottonwood (Populus fremontii) used in restoration. As cottonwood architecture (height, canopy width, number of stems, and trunk diameter) is, in part, determined by genetics, we predicted that trees from different provenances would exhibit different architecture, and mean annual maximum temperature transfer distance from the provenances would interact with the architecture to affect tamarisk. In a common garden in Chevelon, AZ, U.S.A. (elevation 1,496 m), with cottonwoods from provenances spanning its elevation distribution, we measured the performance of both cottonwoods and tamarisk. Several key findings emerged. On average, cottonwoods from higher elevations were (1) two times taller and wider, covered approximately 3.5 times more basal area, and were less shrubby in appearance, by exhibiting four times fewer number of stems than cottonwoods from lower elevations; (2) had 50% fewer tamarisk growing underneath, which were two times shorter and covered 6.5 times less basal area than tamarisk growing underneath cottonwoods of smaller stature; and (3) the number of cottonwood stems did not affect tamarisk growth, possibly because the negative relationship between cottonwood stems and basal area. In combination, these findings argue that cottonwood architecture is affected by local conditions that interact with genetics-based architecture. These interactions can negatively affect the growth of reinvading tamarisk and enhance restoration success. Our study emphasizes the importance of incorporating genetic and environmental interactions of plants used in restoration.

DOI: 10.1111/rec.12840

Mahoney, S. M., A. N. B. Smith, P. J. Motyka, E. J. Lundgren, R. R. Winton, B. Stevens, and M. J. Johnson. 2019. Russian olive habitat along an arid river supports fewer bird species, functional groups and a different species composition relative to mixed vegetation habitats. *Journal of arid environments* 167: 26-33.

<u>Key words:</u> Russian olive; *Elaeagnus angustifolia*; native birds; non-native; riparian corridors

<u>Abstract:</u> The establishment and naturalization of non-native Russian olive (Elaeagnus angustifolia) in southwestern US riparian habitats is hypothesized to have negative implications for native flora and fauna. Despite the potential for Russian olive establishment in new riparian habitats, much of its ecology remains unclear. Arid river systems are important stopover sites and breeding grounds for birds, including some endangered species, and understanding how birds use Russian olive habitats has important implications for effective non-native species management. We compared native bird use of sites that varied in the amount of Russian olive and mixed native/ non-native vegetation along the San Juan River, UT, USA. From presence/absence surveys conducted in 2016 during the breeding season, we found 1) fewer bird species and functional groups used Russian olive habitats and 2) the composition of species within Russian olive habitats was different from the composition of species in mixed native/non-native habitats. Our results suggest Russian olive may support different bird compositions during the breeding season and as Russian olive continues to naturalize, bird communities may change. Finally, we highlight the paucity of research surrounding Russian olive ecology and stress the need for rigorous studies to improve our understanding of Russian olive ecology.

<u>DOI:</u> 10.1016

Mortensen, J. G., R. K. Dudley, S. P. Platania, and T. F. Turner. 2019. Rio Grande Silvery Minnow Biology and Habitat Syntheses Final Report. Prepared by American Southwest Ichthyological Researchers, L.L.C. Prepared for U.S. Bureau of Reclamation.

Key words: Rio Grande silvery minnow; population monitoring

Summary: The Rio Grande Silvery Minnow Population Monitoring Program has conducted long-term systematic monitoring of the MRG fish community at numerous sites between Angostura Diversion Dam and Elephant Butte Reservoir every year since 1993 (except 1998). Preliminary studies (1987–1992) revealed a rapid decline of the Rio Grande Silvery Minnow and provided justification for listing of the species as endangered under the ESA (Platania 1993a). Since 1993, the Population Monitoring Program has documented wide fluctuations (i.e., order of magnitude increases and decreases) in the abundance of Rio Grande Silvery Minnow and identified relationships to hydrologic conditions and environmental factors. The primary objective of the Population Monitoring Program is to assess temporal trends in the abundance of Rio Grande Silvery Minnow throughout the MRG and evaluate how those trends are affected by changes in annual discharge patterns (Dudley et al. 2018b). Additional objectives include determining general habitat use patterns, determining variation in density estimates based on repeated sampling, documenting changes in relative abundance among native and nonnative fish species, and evaluating changes in site occupancy status temporally. For a synopsis of monitoring results, refer to the Rio Grande Silvery Minnow Population Monitoring Summary 1993–2017 within this report, and for more detailed descriptions of study design and specific modifications, sampling and data analysis methods, and monitoring results, refer to annual reports submitted to USBR (Albuquerque Area Office) by American Southwest Ichthyological Researchers (ASIR; e.g., Dudley et al. 2018b).

DOI: Report

Murray, L., B. J. Schutte, A. C. Ganguli, and E. A. Lehnhoff. 2019. Impacts of Tamarix (L.) Litter and Mycorrhizal Amendments on *Baccharis salicifolia* (Ruiz & Pav.) Pers. Competitiveness and Mycorrhizal Colonization. *Agronomy*.

Key words: tamarisk; mule-fat; mycorrhizal inoculant; riparian restoration; saltcedar

Abstract: *Tamarix* spp. are ecological threats in the Southwest U.S.A. because they displace native vegetation, increase soil salinity, and negatively affect soil microbial communities. After *Tamarix* L. removal, legacy effects often necessitate restoration to improve ecosystem services of *Tamarix*-impacted communities. Commercial mycorrhizae fungal inoculation has been recommended to improve restoration success, although inoculation treatments are rarely tested on lesser-known facultative riparian species. Our study asked two questions: (1) Can a commercial mycorrhizal fungal inoculant increase native *Baccharis salicifolia* (Ruiz & Pav.) Pers. (mule-fat) performance against *Tamarix chinensis* Lour. (i.e., tamarisk) and is this influenced by tamarisk leaf litter? (2) Is mycorrhizal colonization of mule-fat roots influenced by tamarisk stem density and leaf litter? A greenhouse experiment was performed with mule-fat cuttings in soil collected from a tamarisk monoculture. Treatments were factorial combinations of tamarisk stem densities (0, 1, 2, 3, 4 stems pot^{-1}) with or without mycorrhizal inoculation and tamarisk litter. There were five replications and two greenhouse runs. The total biomass of both species was determined and mule-fat arbuscular mycorrhizal colonization rates were determined via the magnified intersection method. Increasing tamarisk biomass negatively affected mule-fat biomass, but there were interactions with tamarisk biomass, litter and mycorrhizal inoculation, with litter and inoculation increasing mule-fat growth at high tamarisk biomass. Arbuscular mycorrhizal colonization was high in all treatments, yet at higher tamarisk stem densities, inoculation and litter improved colonization. Interestingly, litter did not negatively impact mule-fat as predicted. Moreover, litter and mycorrhizal inoculum interacted with tamarisk to improve mule-fat growth at higher tamarisk biomass, suggesting an opportunity to improve restoration success when in competition with tamarisk.

DOI: 10.3390/agronomy9080453

Murray, L., B. Schutte, C. Sutherland, L. Beck, A. Ganguli, and E. Lehnhoff. 2019. Integrating conventional management methods with biological control for enhanced Tamarix management. ***Invasive Plant Science and Management***

Key words: tamarisk leaf beetle; Middle Rio Grande

Abstract: Invasive shrubs like *Tamarix* spp. are ecological and economic threats in the U.S. Southwest and West, as they displace native vegetation and require innovative management approaches. *Tamarix* control typically consists of chemical and mechanical removal, but these methods may have negative ecological and economic impacts. Tamarisk leaf beetles (*Diorhabda* spp.) released for biocontrol are becoming increasingly established within Western river systems and can provide additional control. Previous *Diorhabda* research studied integration of beetle herbivory with fire and with mechanical management methods and herbicide application (e.g., cut stump), but little research has been conducted on integration with mowing and foliar herbicide application, which cause minimal soil disturbance. At Caballo Reservoir in southern New Mexico, we addressed the question: "How does *Tamarix* respond to chemical and mechanical control when *Diorhabda* is well established at a site?" A field experiment was conducted by integrating mowing and foliar imazapyr herbicide at standard (3.6 g ae L^{-1} [0.75% v/v] and low (1.2 g ae L^{-1} [0.25% v/v]) rates with herbivory. Treatments were replicated five times at two sites—a dry site and a seasonally flooded site. Beetles and larvae were counted and green foliage was measured over 2 yr. Mowing and full herbicide rates reduced green foliage and limited regrowth compared with low herbicide rate and beetles alone. Integrating conventional management such as mowing and herbicide with biocontrol could improve *Tamarix* management by providing stresses in addition to herbivory alone.

DOI: 10.1017/inp.2019.20

Platania, S. P., J. G. Mortensen, M. A. Farrington, W. H. Brandenburg, and R. K. Dudley. 2020. Dispersal of Stocked Rio Grande Silvery Minnow (*Hybognathus amarus*) in the Middle Rio Grande, New Mexico. ***The Southwestern Naturalist.***

Key words: Rio Grande; Silvery Minnow; Spawning

Abstract: Pelagic-broadcast spawning riverine fishes (pelagophils), species that produce eggs and larvae that drift laterally and downstream with the current, are declining throughout their native ranges in North America. Persistence and recolonization of pelagophils require upstream dispersal of later life stages; however, observations of dispersal are limited. We performed a mark–recapture study of stocked Rio Grande silvery minnow (Hybognathus amarus) in the Middle Rio Grande, New Mexico, during 2002 to assess dispersal of this imperiled pelagophil. Approximately 11,500 hatchery-reared Rio Grande silvery minnows marked with a fluorescent-colored visible implant elastomer were released by the Southwestern Native Aquatic and Technology Center (Dexter, New Mexico) at two locations in the 94.1-km San Acacia Reach of the Middle Rio Grande in January 2002. We recaptured 66 marked individuals (0.57%) through May 2002, upstream and downstream of both release locations. Distances traveled ranged from 0.0 to 25.2 km (0.3 – 5.3 km [mean – SD]), and movement rates ranged from 0.0 to 220 m/day (19 – 63 m/day). We recaptured two individuals >20 km upstream of their release location. Overall, stocked fish tended to disperse downstream. We often recaptured marked fish with wild conspecifics, implying repatriation of a portion of stocked fish. Gravid and spent marked female Rio Grande silvery minnows recaptured during April and May indicated that stocked fish were reproductively active concurrent with the wild population. Our study documented long-distance upstream dispersal of stocked Rio Grande silvery minnows and thus has conservation implications for restoring connectivity in the Middle Rio Grande to support the recovery of this federally listed endangered species.

DOI: 10.1894/0038-4909-64-1-31

Rubin, Z., B. Rios-Touma, G. M. Kondolf, M. E. Power, P. Saffarinia, and J. Natali. 2019. Using prey availability to evaluate Lower Colorado River riparian restoration. *Restoration ecology*.

Key words: aquatic-terrestrial subsidies, desert rivers, ecological assessment, effectiveness monitoring, Lower Colorado River Multi-species Conservation Program, southwestern willow flycatcher

Abstract: The Lower Colorado River Multi-species Conservation Program (MSCP) is charged with restoring habitat for 26 species such as the southwestern willow flycatcher (Empidonax traillii extimus) impacted by water development projects on the river. As of 2015, the MSCP had spent $200 million to create 1,200 ha of habitat at nine sites, but the benefits to these insectivorous birds and other target species have not been quantified. Many MSCP projects emphasized riparian plantings of willow (Salix exigua, Salix gooddingii) and cottonwood (Populus fremontii) on high terraces disconnected from the river. We documented prey availability for insectivores in constructed habitats as an indicator of restoration effectiveness. Using sticky traps as a proxy to estimate aerial insect flux, we found the number of aquatic insects, proportion of aquatic insects, total number of insects, and number of insect orders were all significantly lower in MSCP plantation sites than at the river's edge. Riparian restoration sites over 100 m from the river had only 4% of the aquatic insects, 20% of the total insects, and only half as many insect orders as sites adjacent to the river. Thus, food availability and overall habitat quality for insectivores are likely low in restoration sites that are distant from the river.

DOI: 10.1111/rec.12829

Snyder, K. A. and R. L. Scott. 2019. Longer term effects of biological control on tamarisk evapotranspiration and carbon dioxide exchange. *Hydrological Processes*.

Key words: tamarisk beetle; Middle Rio Grande; populations

Abstract: Biological control of *Tamarix* spp. (tamarisk) with *Diorhabda* spp. (tamarisk beetle) was initiated in several states in the Western United States in 2001. We analysed 12 years of evapotranspiration (ET), net ecosystem production (NEP), and beetle abundance data from a tamarisk-invaded site in Western Nevada along the Truckee River. *Diorhabda carinulata* (northern tamarisk beetle) appeared at the site in 2007. Large beetle outbreaks and associated defoliation of the tamarisk occurred in 2008 and 2009, then the beetle population was highly variable from year to year. Since 2016, the beetle population declined. Growing season ET noticeably declined from direct beetle herbivory in 2008, 2009, and 2010, but the decline in ET was seasonally transient as trees regrew leaves. In 2012 and 2013, total growing season ET was low, likely due to the combined effects of drought and beetle herbivory pressure. Total seasonal ET losses and NEP were primarily driven by annual precipitation with higher values in wetter years and reduced values when precipitation fell below 100 mm. In the last 2 years of the study, 2017–2018, there were few to no beetles observed at the site, and we measured increased tamarisk leaf area index, ET, and NEP. Since 2010 at the study site, no further releases of the beetles have occurred due to wildlife concerns, and subsequent declines in beetle populations where such that the "outbreak" conditions apparently required to impair tamarisk physiological function and significantly reduce ET have not occurred. ET and photosynthesis were highly correlated ($r^2 \geq .91$) to the Landsat-satellite normalized difference vegetation index (NDVI). Using a relationship between growing season ET and NDVI, we estimated ET for five additional tamarisk sites along several southwestern U.S. rivers. In the 2005 to 2018 analysis period, NDVI-estimated ET declined at all sites after beetle arrival with three sites showing a recovery in pre-beetle ET rates in subsequent years. At the other three sites, ET rates have not recovered to pre-beetle levels.

DOI: 10.1002/hyp.13639

Valdez, R. A., G. M. Haggerty, K. Richard, and D. Klobucar. 2019. Managed spring runoff to improve nursery floodplain habitat for endangered Rio Grande silvery minnow. *Ecohydrology*.

Key words: degree-days to spawning, larval hatch time, managed runoff, nursery habitat, restored floodplains, Rio Grande silvery minnow

Abstract: Water managers in New Mexico, USA, stored water in El Vado Reservoir and coordinated releases into the Chama River that augmented the runoff of the Rio Grande, resulting in a discharge >1,500 ft3 /s (42.5 m3 /s) for 35 days (May 17 to June 20, 2016) at Albuquerque. The managed runoff inundated over 400 ha of previously restored floodplains in the Middle Rio Grande, thereby providing spawning and nursery habitat for the endangered Rio Grande silvery minnow (Hybognathus amarus, RGSM). Spawning began April 9 at annual cumulative degree-days of 717, during daily increases in discharge of 200–300 ft3 /s (5.7–8.5 m3 /s), and hatch dates were normally distributed over 53 days (April 11 to June 3). RGSM were 73% of larvae collected in six restored floodplain sites and found in shallow water (mean = 19.6 cm), low velocity (mean = 3.9 cm/s), near vegetative cover, and with 75% within 1 m of the water's edge. Declining proportions of early to late larval phases and a near absence of juveniles indicate a gradual departure from floodplains as postflexion mesolarvae and metalarvae 14–22 days post hatch (dph), with most leaving by the juvenile stage 40 dph. The annual RGSM October census showed an increase of 0.16 to 7.20 fish/100 m2 from 2015 to 2016, indicating that the managed runoff resulted in a positive population response. This study showed that constructing floodplains and managing river and reservoir operations to inundate those floodplains during and after RGSM spawning can provide nursery habitat that improves reproductive success and recruitment.

DOI: 10.1002/eco.2134