RESPONSES OF SMALL MAMMAL COMMUNITIES TO FLOW RESTORATION AND VEGETATION ALONG THE SANTA CRUZ RIVER

By

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ABSTRACT

Release of treated effluent at stretches of a dewatered river can alter the water resources, vegetation, and small mammal communities found at them. Previous research on this subject is scarce and has primarily focused on comparisons of riparian and upland habitats adjacent to non-effluent-dependent rivers. We investigated the impacts of flow restoration and vegetation on small mammal communities along the Santa Cruz River in Tucson, Arizona. We surveyed a dry site along the river and a wet site where effluent is being released. Surveying was done through trapping small mammals along transects and recording vegetation and water data at each trap site. We evaluated how vegetation differed between the sites and how small mammal abundance, diversity, and habitat selection differed. Vegetation diversity was higher at the dry site than the wet site, and species were not found to use vegetation types uniformly. Small mammal species diversity was higher at the dry site than the wet site. However, capture abundance was much higher at the wet site than the dry site. These results suggest that river flow restoration through effluent release may benefit some small mammal species significantly more than others. Our study was limited by its sample size and the number of sites surveyed, so future studies should be done to present a more comprehensive picture of the relationship between flow restoration, vegetation, and small mammal communities.

INTRODUCTION

Portions of the Santa Cruz River in southern Arizona that historically were dewatered are now flowing again due to the discharge of treated effluent from wastewater treatment plants (Webb et al. 2014). In arid regions, the release of effluent has been shown to be important as it provides flow to streams that no longer flow due to anthropogenic impacts (Hamdhani et al. 2020). While flow restoration clearly creates habitat for aquatic species, its impacts on riparian species, including small mammals, are not well known (Bogan et al. 2020, Hamdhani et al. 2020).

Riparian habitats are frequently found to support significant biodiversity due to their complex habitat structure and a greater diversity of vegetation (Ellison and van Riper 1998). This is especially apparent in areas like the arid Southwest, where water is a limiting factor (Ellison and van Riper 1998, Sánchez-Montoya et al. 2017). Riparian areas support a greater vegetation diversity due to their high productivity resulting from greater soil nutrient content, high soil moisture, and higher gaseous exchange rates (Falck et al. 2003, Andersen 1994).

Higher vegetation diversity and cover tend to support higher small mammal abundances and species diversity, especially in riparian habitats (Ellison and van Riper 1998). One potential driver may be that higher vegetation richness is associated with increases in insect biomass and forage quality, thus providing increased food resources for small mammals (Reed et al. 2006). Higher vegetation cover is also associated with increased abundance due to increased cover from predators (Madden et al. 2019). High vegetation productivity and cover result in greater niche availability, which supports the ability of several species to coexist and use the same resources in an area. Overall, an increase in vegetative factors, such as richness, diversity, cover, and productivity, tend to be associated with higher small mammal diversity and abundances because of their benefits to the species (Ellison and van Riper 1998, Reed et al. 2006).

The purpose of this project was to analyze the effects of vegetation structure and flow restoration via effluent on small mammal communities along the Santa Cruz River. We hypothesized that effluent would increase resource availability in ways similar to what is seen in natural riparian areas. If effluent increases resource availability, then we predict greater diversity of (1) vegetation where effluent is being released, (2) small mammals captured where effluent is being released, and (3) small mammals where there is more plant diversity due to increased resource availability.

METHODS

Study Area

We conducted surveys along the Santa Cruz River in Tucson, Arizona. The Santa Cruz River runs from its headwaters in the San Rafael Valley near the Arizona-Sonora border to its terminus at the Gila River near Phoenix, Arizona (Webb et al. 2014). It is located on the ancestral lands of the Akimel, Sobaipuri, and Tohono O'odham (Native Land Digital 2023). In the 1940s, the Santa Cruz River became ephemeral due to groundwater pumping and diversions, but the release of effluent beginning in the 1970s has restored perennial surface flow to some stretches of the river (Webb et al. 2014, Bogan et al. 2020).

We surveyed two sites along the river: a wet site and a dry site (Fig. 1). Heritage, the wet site, is located near West Starr Pass Boulevard. Discharge of effluent at this site began in 2019 (Bogan et al. 2020). Drexel, the dry site, is located near West Drexel Road. This site does not receive any effluent and only flows for short periods of time following heavy precipitation.

Figure 1. Left: Heritage site. Right: Drexel site. Image Credit: Google Earth, 2019

Data Collection

We did surveys for three consecutive trap nights at the Drexel and Heritage sites in November 2022. At each site, we placed forty Sherman live traps in four 10-meter transects with traps evenly spaced in one-meter intervals. We placed transects approximately 10 meters apart in the active river channel. Traps were baited with peanut butter and oat balls. We set the traps at sunset each night and checked at sunrise.

During processing, we recorded the trap location, species, sex, weight, hind foot length, tail length, and recapture status of each capture. We clipped hair to help identify recaptures, and the hind foot length, tail length, and weight measurements helped to identify each rodent to the species level. We recorded microsite data at each trap location and included the type of vegetation at the species level, distance to vegetation, percent vegetation cover, and distance to water.

Data Analysis

Data cleaning occurred to group vegetation into categories and exclude any uncertain identifications from the analyses. We used the dominant plant species at each trap site to place each site into one of five vegetation categories based on structure: forb, grass, mixed, sedge/Typha, and shrubs. We determined these categories after analyzing the species of vegetation at each trap site and determining their structures. We placed any trap sites that contained plant species from more than one vegetation category into the mixed category. Finally, any rodents captured that were not identified to the species level were excluded from the analyses. Any individuals whose recapture status was not known were assumed to be new individuals rather than recaptures.

We conducted all analyses in R (v4.3.2; R Core Team 2023) including abundances, vegetation counts, Shannon's diversity index, chi-square test (*stats*; *R* Core Team 2023), post-hoc test (*chisq.posthoc.test*; Ebbert 2019), and resource selection function. We computed the resource selection function for each species using a generalized linear mixed effects model with the glmer() function (*lme4*; Bates et al. 2015) and the dredge method (*MuMIn*; Bartoń 2023). All data and analyses for this project can be found at this GitHub repository: https://github.com/eolstead/santa-cruz-rodents.

RESULTS

Species Richness and Diversity

A total of six species of small mammals were found between the two sites. We found five species at Drexel, and two species at Heritage. We captured *Chaetodipus* *pencillatus*, *Dipodomys merriami*, *Neotoma albigula*, *Peromyscus eremicus*, and *Sigmodon ochrognathus* at Drexel. We captured *Reithrodontomys megalotis* and *S. ochrognathus* at Heritage. When calculated across all captures, the Shannon diversity index was 1.42 for Drexel and 0.63 for Heritage.

Abundance

A total of 10 individuals were captured at Drexel, and 31 individuals were captured at Heritage (Fig. 2). We found *P. eremicus* to be the most abundant species at Drexel with four individuals. *S. ochrognathus* was found to be the most abundant species at Heritage with 21 individuals. Recaptures included two *C. pencillatus* at Drexel, one *P. eremicus* at Drexel, and four *S. ochrognathus* at Heritage. Recapture rates were 2.00 for *C. pencillatus*, 0.25 for *P. eremicus*, and 0.19 for *S. ochrognathus*. Other species were not recaptured.

Vegetation at Trap and Capture Locations

Across all trap locations at Drexel and Heritage, the most common vegetation type was grass, occurring at approximately 30% of trap locations (Fig. 3). The least common vegetation type was forb, which only occurred at 5% of trap locations. Both sites had each vegetation type present, with the exception of sedge/Typha, which only occurred at Heritage. Of vegetation types present, grass was the most common at both Drexel and Heritage. The least common at Drexel was mixed, and the least common at Heritage was forb.

Overall, grass was found to be the most common vegetation type at capture sites and forb was found to be the least common (Fig. 4). Sedge/Typha was not present at Drexel. Shrub was present at Heritage, but no captures occurred in this vegetation type. The most common vegetation type at capture locations at Drexel was mixed, and the least common type was grass. At Heritage, the most common type at capture locations was sedge/Typha, and the least common type was forbs.

Regarding the vegetation types that each species was captured near, we captured *C. pencillatus* and *D. merriami* in different vegetation types each time they were caught (Fig. 5). *N. albigula* were only captured in shrubs. *P. eremicus* were primarily captured at sites with shrubs, and *R. megalotis* were primarily captured at sites with grass. We most frequently trapped *S. ochrognathus* at locations with sedge/Typha.

Small Mammal Captures by Vegetation Type

There was a significant relationship between the small mammal species and the vegetation where they were trapped (X^2 = 41.70, df = 20, p = 0.003). A post-hoc test was then performed to determine what caused the significant chi-square test result. The only significant result was between *P. eremicus* and shrubs, residual = 3.39, p = 0.02.

A resource selection function was computed to assess aspects of the trap sites that lead species to being captured. Sedge/Typha was used as the reference category. The resource selection function was run for each species captured, and the only significant result was for *S. ochrognathus*. Distance to water was significant with an estimate of -1.326e+00 ± 5.811e-01 (SE). Grass was also significant with an estimate of -1.891e+00 ± 9.340e-01 (SE).

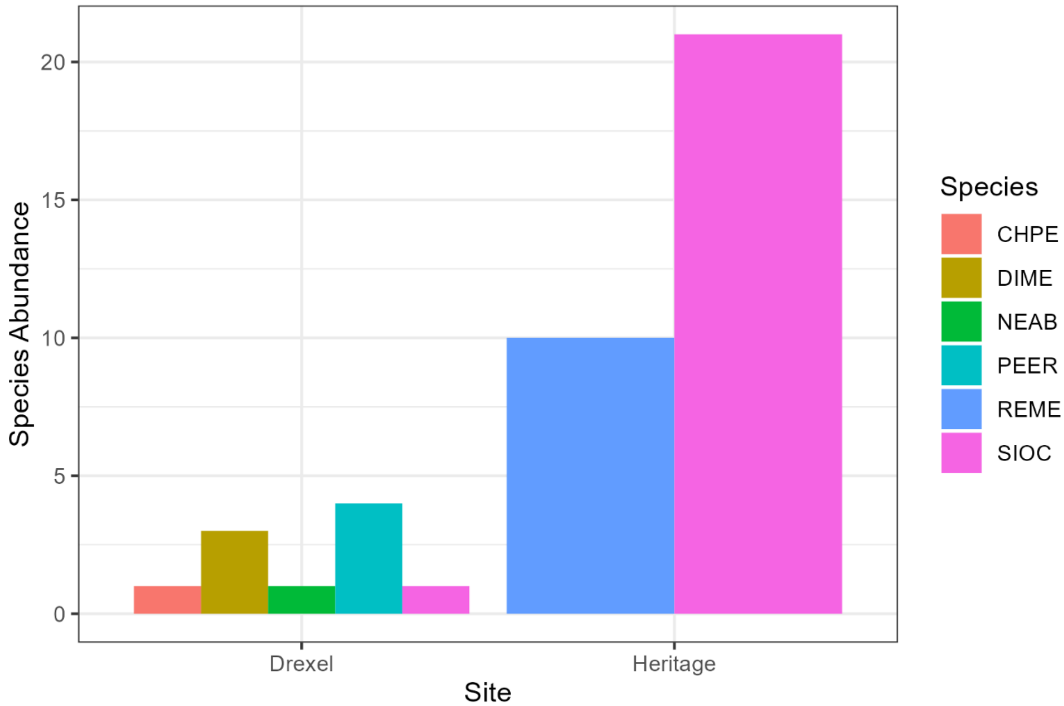

Figure 2. Small mammal species abundances at our two study sites along the Santa Cruz River.

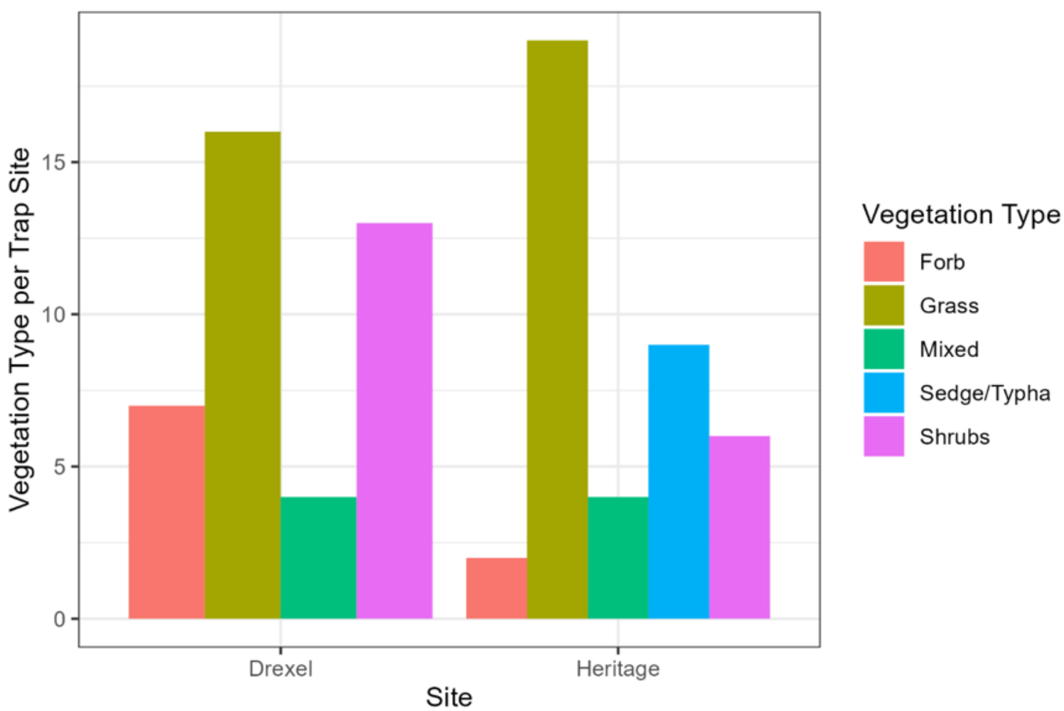

Figure 3. Vegetation types per site for each small mammal trap location along the Santa Cruz River.

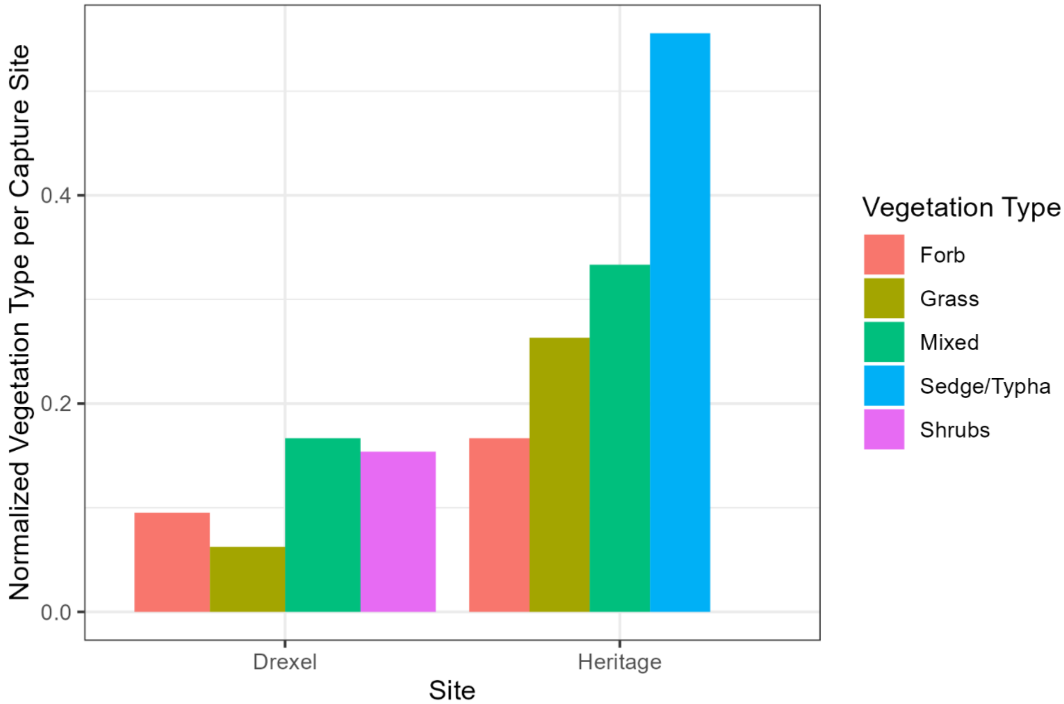

Figure 4. Normalized vegetation types per site for each small mammal capture location along the Santa Cruz River.

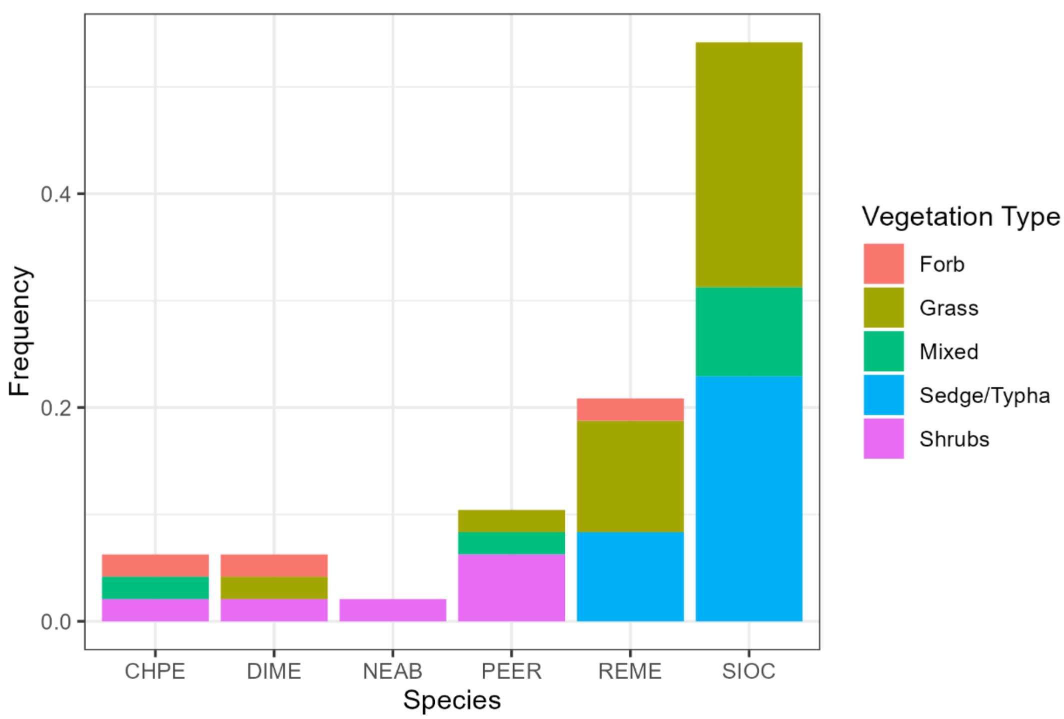

Figure 5. Frequency of vegetation type at capture sites per small mammal species found at two sampling locations along the Santa Cruz River.

DISCUSSION

We sought to determine how small mammal communities along the Santa Cruz River differed with different water resources and vegetation. Our results did not support the prediction that there would be a greater diversity of small mammals where effluent is being released. A greater number of species were found at Drexel, where no effluent is released (Fig. 2), and its Shannon diversity index was greater in value. The prediction that there would be a greater diversity of small mammals where there is a greater diversity of vegetation also failed to be supported when considering overall vegetation types at each site (Fig. 3). Drexel had four vegetation types compared with five at Heritage, yet it had the higher species diversity.

The results of the chi-square test indicated that species did not use vegetation types uniformly. Specifically, the post-hoc test showed that *P. eremicus* used shrubs disproportionately higher than other vegetation types available, indicating selection for shrub habitat. *P. eremicus* can often be observed climbing and foraging in vegetation off of the ground (Schmidly and Bradley 2016). This significant climbing activity may indicate why the species used shrubs at a higher rate.

The resource selection function showed that *S. ochrognathus* were less likely to be captured as the distance to water increased. It also showed that the species was less likely to be captured in traps near grass when compared to those near sedges or Typha. These findings may be explained by the species being associated with riparian areas (Schmidly and Bradley 2016). These results delineated the Drexel and Heritage sites as sedge/Typha was only found at Heritage and a long distance to water represented Drexel, the dry site.

The results of our study suggest that, for most of the species we captured, proximity to water resources and greater vegetation diversity may not be as important in habitat selection as we thought. Ellison and van Riper (1998), who looked at how small mammal communities differed on the upper and lower terrace of a riparian corridor, found similar results. Contrary to their predictions, small mammal diversity was significantly higher on the upper terrace, further from water resources. The upper terrace also contained lower vegetation diversity than the lower terrace, meaning the greater small mammal species diversity was found where there was less vegetation diversity. However, other studies have come to opposite conclusions. Falck et al. (2003) and Szaro and Belfit (1987) both found greater species diversity at riparian sites surveyed than those without riparian water resources.

While access to riparian sources may not increase diversity, we observed differences in community composition, suggesting that effluent can mimic intermittent or perennial streams by creating habitat for riparian species that may not otherwise be found in the area. Our dry site hosted desert specialists, including *D. merriami* and *C. pencillatus*, whereas our wet site hosted *R. megalotis* as well as *S. ochrognathus*, which are more grassland and riparian species that generally are not found in more arid Sonoran Desert vegetation (Schmidly and Bradley 2016). Though our diversity on a local level did not increase, our overall regional diversity may have increased as a result of the effluent.

Overall, more data is needed to make more definitive conclusions about small mammal diversity along the Santa Cruz River. Despite the same protocol being done at each of the two sites, abundances of small mammal species captured at Drexel were significantly lower than Heritage. These inconsistencies may have led to skewed results and made it difficult to determine the true effects of water and vegetation on small mammal communities. Future studies could be done in which more trap nights are done, trapping grids are larger, and more sites are surveyed across a broader range of vegetation types. As the release of treated wastewater becomes more common, these types of studies will be important to land managers and may have significant management implications.

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REFERENCES

Andersen, D. C. 1994. Demographics of small mammals using anthropogenic desert riparian habitat in Arizona. The Journal of Wildlife Management 58(3):445-454.

Bartoń, K. 2023. MuMIn: Multi-Model Inference. R package version 1.47.5. https://CRAN.R-project.org/package=MuMIn

Bates, D., M. Maechler, B. Bolker, and S. Walker. 2015. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software 67:1-48. https://doi.org/10.18637/jss.v067.i01

Bogan, M. T., D. E. Eppehimer, H. Hamdhani, and K. Hollien. 2020. If you build it, they will come: Rapid colonization by dragonflies in a new effluent-dependent river reach. PeerJ 8:e9856.

Ebbert, D. 2019. chisq.posthoc.test: A Post Hoc Analysis for Pearson's Chi-Squared Test for Count Data. R package version 0.1.2. https://CRAN.R-project.org/package=chisq.posthoc.test

Ellison, L. E., and C. van Riper III. 1998. A comparison of small-mammal communities in a desert riparian floodplain. Journal of Mammalogy 79(3):972-985. https://doi.org/10.2307/1383105

Falck, M. J., K. R. Wilson, and D. C. Andersen. 2003. Small mammals within riparian habitats of a regulated and unregulated aridland river. Western North American Naturalist 63(1):35-42.

Hamdhani, H., D. E. Eppehimer, and M. T. Bogan. 2020. Release of treated effluent into streams: A global review of ecological impacts with a consideration of its potential use for environmental flows. Freshwater Biology 65(9):1657-1670. https://doi.org/10.1111/fwb.13519

Madden, H., T. Van Andel, J. Miller, M. Stech, K. Verdel, and E. Eggermont. 2019. Vegetation associations and relative abundance of rodents on St. Eustatius, Caribbean Netherlands. Global Ecology and Conservation 20:e00743. https://doi.org/10.1016/j.gecco.2019.e00743

Native Land Digital. 2023. Native Land Digital. https://native-land.ca/

R Core Team. 2023. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Reed, A. W., G. A. Kaufman, and D. W. Kaufman. 2006. Species richness-productivity relationship for small mammals along a desert-grassland continuum: Differential responses of functional groups. Journal of Mammalogy 87(4):777-783.

Sánchez-Montoya, M. M., M. Moleón, J. A. Sánchez-Zapata, and D. Escoriza. 2017. Chapter 4.6 - The Biota of Intermittent and Ephemeral Rivers: Amphibians, Reptiles, Birds, and Mammals. Pages 299-322 *in* Intermittent Rivers and Ephemeral Streams. Elsevier Inc. https://doi.org/10.1016/B978-0-12-803835-2.00011-5

Schmidly, D. J., and R. D. Bradley. 2016. Order Rodentia—Rodents. Pages 436-630 *in* The Mammals of Texas. University of Texas Press, Austin, Texas, USA.

Szaro, R. C., and S. C. Belfit. 1987. Small mammal use of a desert riparian island and its adjacent scrub habitat. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station: RM-473.

Webb, R. H., J. L. Betancourt, R. R. Johnson, and R. M. Turner. 2014. Requiem for the Santa Cruz: An Enviornmental History of an Arizona River. University of Arizona Press. https://doi.org/10.2307/j.ctv23khmh8