Final Report on a Lois Webster Fund Project: "Survey of Native Plains Fish Assemblages after a Recent Discovery of Invasive Mosquitofish in Arickaree River"

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Abstract

To understand spatial distributions of a recent invader, western mosquitofish (*Gambusia affinis*), and native plains fishes, I surveyed 12 sites (100m in length per site) in Arickaree River, located on The Nature Conservancy's Fox Ranch, in May and August of 2019. Using mainly backpack electrofishing and seining, I collected a total of 2,806 individuals in May and 6,683 individuals composed of seven native species and one non-native species (i.e., mosquitofish). Mosquitofish were most typically found in slow-moving waters (backwaters in May and pools in August), and were the second most abundant species in May (597 individuals) and the most abundant species in August (3,048 individuals). Despite their high abundance, native species were also common, including state-listed brassy minnow (*Hybognathus hankinsoni*: threatened) and orangethroat darter (*Etheostoma spectabile*: Special Concern). However, plains killifish (*Fundulus zabrinus*), a native species similar ecologically to mosquitofish, were not collected, indicative of potential negative interactions with mosquitofish. Relative composition of species changed from May to August, as the river discharge declined through summer, exacerbated by groundwater pumping for agricultural irrigation. In August, some sites retained flowing channels but others with only isolated standing waters; relative composition of mosquitofish increased at drying sites, suggesting that declining river discharge may facilitate invasion and persistence of mosquitofish. Overall, the effects of mosquitofish on native plains fishes were not clearly demonstrated, but continued monitoring is warranted given that mosquitofish invaded the study sites at Arickaree River only recently (within 1-2 years) and this non-native species has widely affected native Prairie fishes elsewhere.

Introduction

Arickaree River is a tributary of the Republican River located in the Great Plains of eastern Colorado. The river originates in Elbert County in the High Plains region and is a truly "plains river" because snowmelt in the Rocky Mountains does not affect stream flow but instead flow is maintained by groundwater. Groundwater pumping for agricultural irrigation has reduced stream flow and habitat, and accordingly fish assemblages in Arickaree River (Falke et al. 2011; Perkin et al. 2017). However, fish assemblages on The Nature Conservancy's Fox Ranch had been dominated by native species until 2017 or 2018, when non-native western mosquitofish were collected in high abundance on an annual class field trip, which I conduct at Colorado State University. Mosquitofish are listed as one of the worst 100 invasive species globally by the International Union of Conservation of Nature. Given the recent discovery of this non-native species, I conducted a survey of fish assemblages at 12 sites (100 m in length each) on the Fox Ranch in May and August, 2019, to characterize their spatial distributions and their effects on native fishes. Arickaree River is known to harbor brassy minnow (state threatened) and orangethroat darter (state special conservation). Thus, Arickaree River is an aquatic habitat of high conservation value in the Great Plains.

Study objectives

The objectives of this study were four-fold:

(1) How abundant and widespread are the invasive mosquitofish on the Fox Ranch? Have native plains fishes persisted despite the recent invasion by mosquitofish?

(2) Do mosquitofish fish occur more commonly in certain habitat types (e.g., pool, run, backwater)?

(3) How are fish assemblages structured spatially and seasonally? That is, do fish assemblages differ from site to site irrespective of the season, or do they primarily vary between early and late summer as river discharge decline through summer and drying channels increase.

(4) How does relative composition of mosquitofish change depending on stream flow intermittency (flowing versus drying sites) in August, when river discharge is low?

Study area and field survey

This study was conducted at 12 sites on The Nature Conservancy's Fox Ranch in Arickaree River (Fig. 1). Seven sites were located downstream of U Road in Yuma County, and five sites were upstream. Each site was approximately 100m in length.

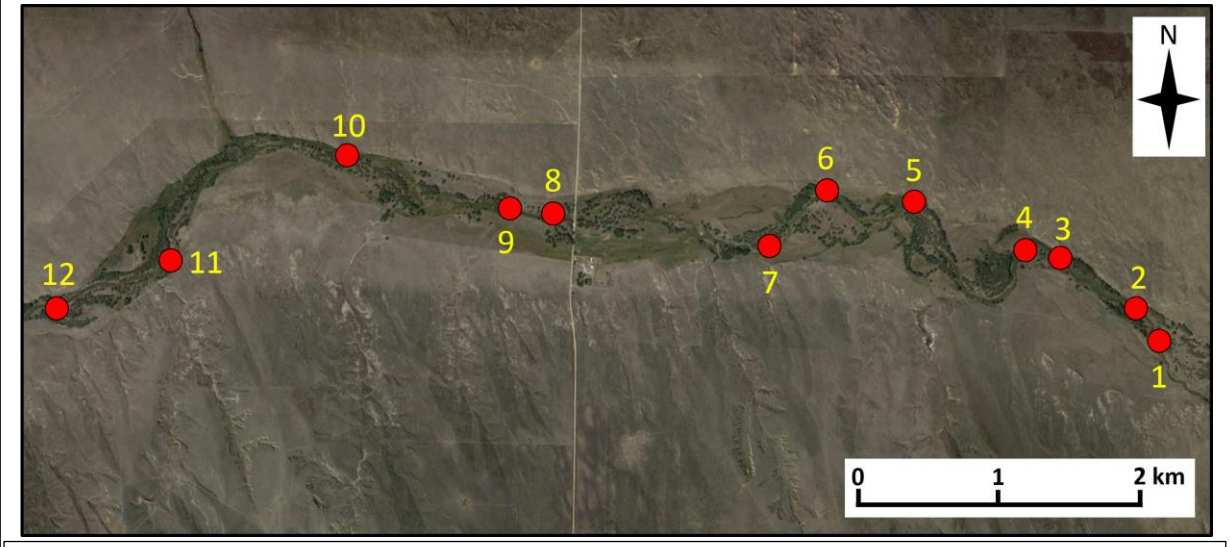

Fig. 1. Twelve study sites located on The Nature Conservancy's Fox Ranch in Arickaree River. County U Road runs from north to south near the center of the study area. The river flows from west to east.

Fish surveys were conducted at 12 sites on May 25-29 and August 12-15, 2019. The two survey periods corresponded to early and late summer, when river flow and habitat differed greatly (Fig. 2). In May, river flow was higher, and run (shallower reaches with faster water velocity) and pool (deeper reaches with slower velocity) habitats were clearly distinguishable by vision. Due to high river flows, channel margins were inundated, which created backwater habitats (shallow, slow moving water typically with vegetation). By August, river flows declined due partly to groundwater pumping for agricultural irrigation. Run habitats were found only at flowing sites, and drying sites were left with isolated pools. Backwater habitats were not present in August: sites were classified as "flowing" (Site 1, 2, 3 and 5), "intermediate" (Site 4, 6, 7 and 8), and "drying" (Site 9, 11 and 12) to evaluate relative composition of mosquitofish in relation to flow intermittency (Objective 4).

Fish were collected using backpack electrofishing and seining (Fig. 2). In May, each site was typically surveyed by two passes of electrofishing and a third pass by a combination of a seine and shocker. Dip nets were used to collect mosquitofish in backwater habitats. Deep or densely vegetated pools could not be effectively sampled in May. In August, two passes of electrofishing were used, except seines were used to collect fish in pools. A third pass was not conducted due to high efficiency of fish capture with lowered water levels in August. Fish were identified to species and enumerated by habitat type (run, pool and backwater in May, and run, pool, and run/pool (or a mix of run and pool habitats)). Upon processing, all fish were returned alive to the site of original capture.

Run habitat in May

C. Campbell (undergraduate) standing in an isolated pool at a drying site, where flow ceased in August

Seining in a pool in May

Y. Kanno with a backpack electrofisher in August

Backwater habitat in May

Fig. 2. A variety of habitat types and fish sampling gear used.

Results

Objective 1: How abundant and widespread are the invasive mosquitofish on the Fox Ranch? Have native plains fishes persisted despite the recent invasion by mosquitofish?

A total of 2,806 individuals were collected in May and 6,683 individuals in August (Fig. 3a), composed of seven native species and one non-native species (i.e., mosquitofish). Mosquitofish were the second most abundant species in May (597 individuals from 11 sites) and the most abundant species in August (3,048 individuals from all 12 sites) (Fig. 3b). Still, native species were also common, including state-listed brassy minnow (threatened) and orangethroat darter (Special Concern) (Fig. 4). Central stoneroller were the most abundant species in both months.

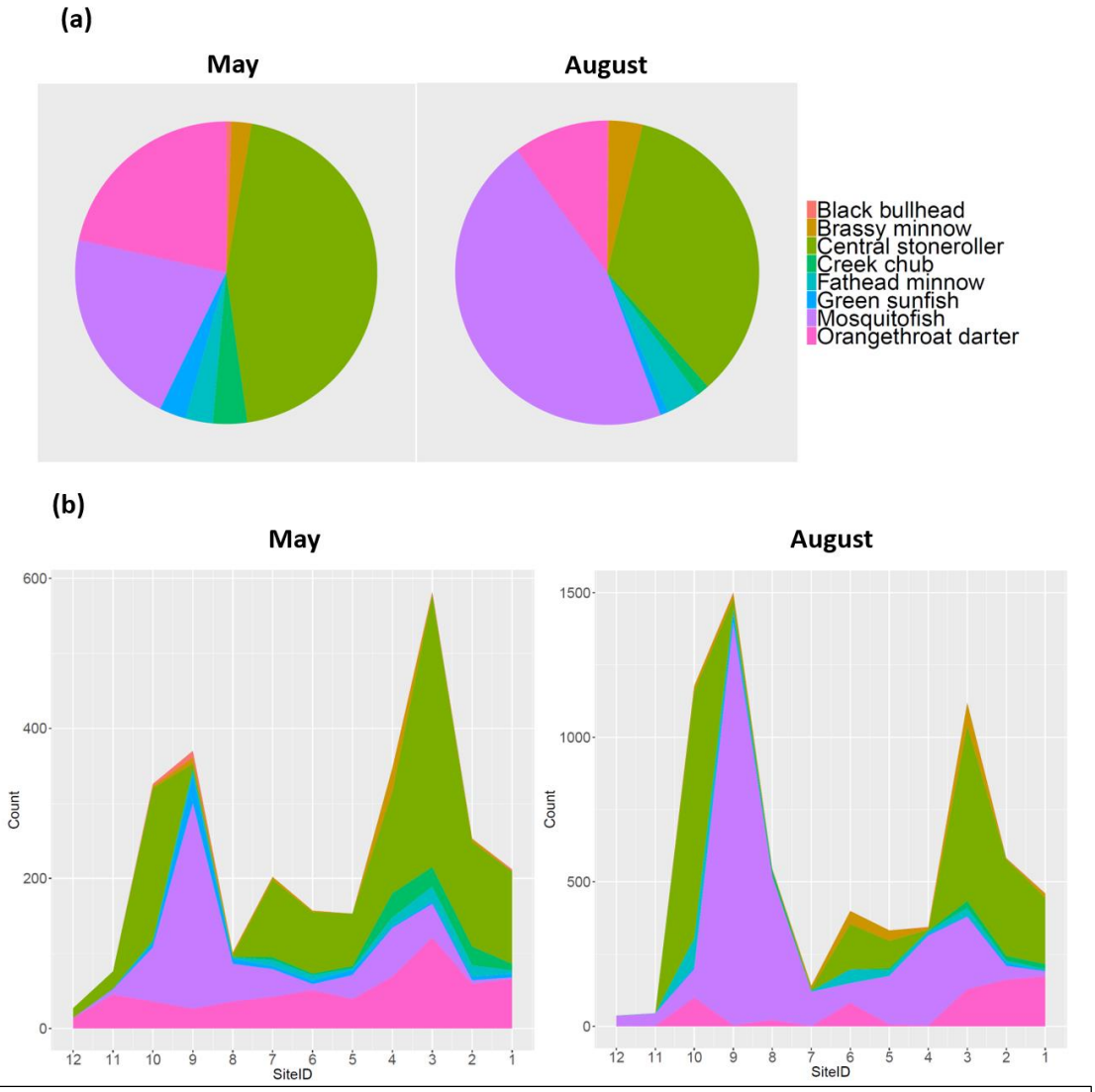

Fig. 3. (a) Percent composition of each species combined across 12 sites. (b) Count of individuals for each species by site. River runs from left to right (Site 1 is most downstream).

Black bullhead

Fathead minnow

Brassy minnow

Green sunfish

Central stoneroller

Western mosquitofish

Creek chub

Orangethroat darter

Fig. 4. Species captured in this study. All species, except western mosquitofish, are native to Arickaree River. Photo credit: S. Kim.

Results (Cont'd)

Objective 2: Do mosquitofish fish occur more commonly in certain habitat types (e.g., pool, run, backwater)?

Mosquitofish occurred most commonly in stagnant (non-flowing) habitats in May and August (Fig. 5). Mosquitofish were by far the most common species collected in backwaters in May; 90% of total individuals were mosquitofish. Relative composition of mosquitofish declined to 30% in pools, and they were rarely present (4%) in runs in May. A total of 456 individuals were collected in backwaters, 377 individuals in pools, and 1,973 individuals in runs when all species were combined. With higher flows in May, the run habitat was ubiquitous and I collected more individuals in this habitat type compared to backwaters and pools.

In August, backwater habitats were not present due to lowered flows, and mosquitofish dominated fish assemblages in pools (85% of total individuals). Relative composition of mosquitofish in runs increased to 18% in August, relative to May, and mosquitofish accounted for 17% of individuals in runs/pools, a habitat group that contained a mixture of these two habitats. Reduced flows in August made it more difficult to distinguish these two habitat types. Overall, mosquitofish were the most common species in pools in August, as opposed to backwaters in May.

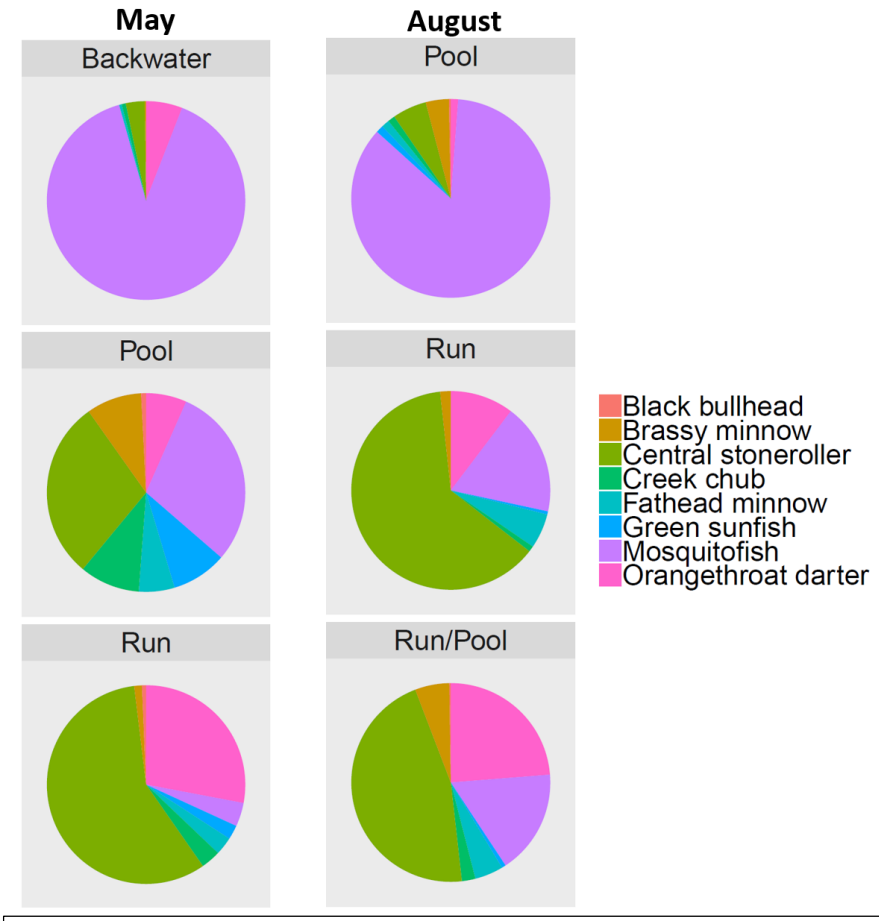

Fig. 5. Percent composition of species by habitat type. Data were aggregated across 12 sites to create a pie chart for each habitat type.

Results (Cont'd)

Objective 3: How are fish assemblages structured spatially and seasonally?

Principal Component Analysis (PCA) was used to examine spatial and seasonal fish assemblage structures. Percent composition of species at each site was arcsine-square-root transformed, and then scaled to standardize unit variance so that all species are weighted equally in analysis. Data from May and August were analyzed together (12 sites × 2 months = 24 samples). PCA was conducted using the *prcomp* function in Program R.

Seasons played a primary role in structuring fish assemblages in Arickaree River (Fig. 6). Samples in each month were clustered closer to each other along the first two axes, which cumulatively accounted for 58.2% of variance. The clusters of samples reflected compositional changes in fish species between May and August, with the first axis indicating that mosquitofish occurred abundantly in samples in which central stoneroller and orangethroat darter were not common. The second axis indicated that brassy minnow and fathead minnow were common in samples in which black bullhead and green sunfish were not common.

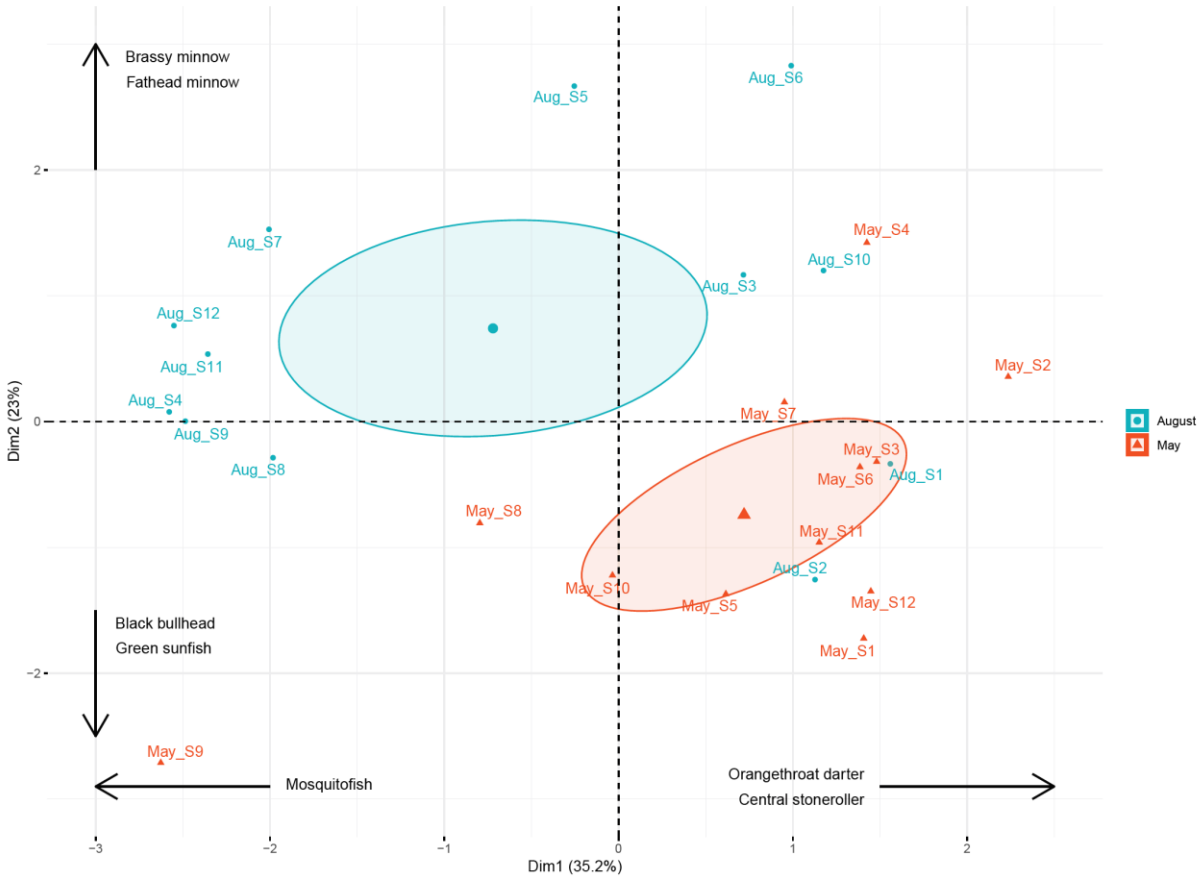

Fig. 6. Principal Component Analysis of relative proportions of species at sites, showing the first axis that accounted for 35.2% of variance and the second axis (23%). Samples were labeled with the first three letters indicating months (May or August) and Site ID is shown after the underscore (e.g., S1 = Site 1). Labels along each axis show species with the highest loadings. Centroids and 95% confidence ellipses are shown for May and August.

Results (Cont'd)

Objective 4: How does relative composition of mosquitofish change depending on stream flow intermittency (flowing versus drying sites) in August, when river discharge is low?

Relative composition of mosquitofish increased at sites with more intermittent flows (Fig. 7). At four sites that still contained flowing reaches in August, the mean relative composition of mosquitofish was 19%. Central stoneroller (53%) and oragenthroat darter (17%) were the two most common native species at flowing sites. However, the mean relative composition of mosquitofish increased to 71% at intermediate sites and 95% at drying sites. This spatial pattern of fish assemblages indicated that stream drying may create an abiotic condition that favors mosquitofish at the expense of native species.

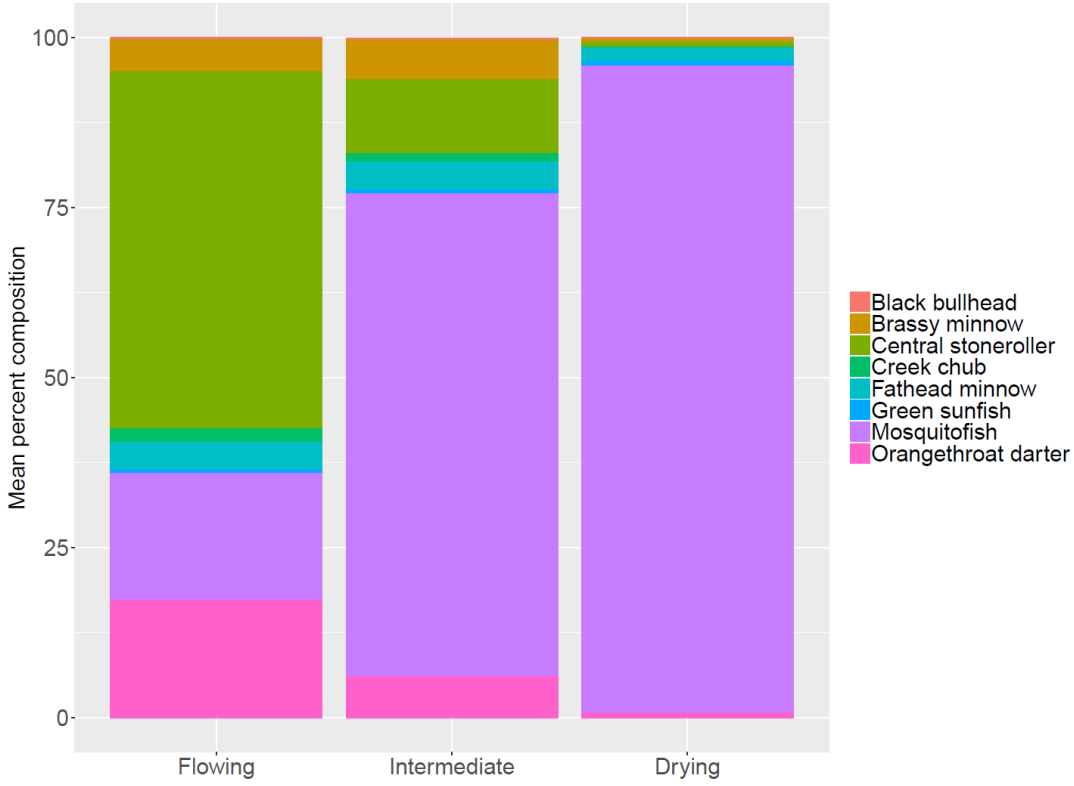

Fig. 7. Mean percent composition of species averaged across sites belong to each flow intermittency category. Flowing: Site 1, 2, 3, 5; Intermediate: Site 4, 6, 7, 8; Drying: Site 9, 11, 12

Discussion

This survey showed that western mosquitofish have established high abundance throughout The Fox Ranch at Arickaree River but native species were also common. Despite an intensive survey, I did not collect any individual of plains killifish (*Fundulus zebrinus*), a native species similar ecologically to mosquitofish that was known to occur in the study area as recently as 2018, based on data collected by the National Science Foundation through its National Ecological Observatory Network program (https://www.nsf.gov/news/special_reports/neon/data/). Plains killifish may never have been abundant in the study segment of Arickaree River (Falke et al. 2010a), but its complete absence may be a sign that this native species has been displaced by mosquitofish through negative interactions.

We collected all other native species expected to occur in the study area (Falke et al. 2011) and some were abundant (e.g., central stoneroller and orangethroat darter). This finding suggests that negative effects of mosquitofish have been limited so far, but it is also possible that the invasion by mosquitofish is so recent (within 1-2 years) that this conclusion is only preliminary. For example, state-threatened brassy minnow use backwaters for spawning in spring (Falke et al. 2010b), which was the habitat type primarily used by mosquitofish in May. Continued monitoring of fish assemblages is warranted to make a more conclusive judgement on the impact of mosquitofish on native fishes in Arickaree River.

Fish assemblages were structured seasonally, with an increase in relative composition of mosquitofish and a concurrent decrease in native species from May to August. Typical of plains streams, flows at Arickaree River decline through summer naturally, and groundwater pumping has accelerated summer drying in this study region (Falke et al. 2011). The stream channel contained flowing waters in May, but flows reduced or ceased at some sites by August. This seasonal change in flows resulted in decreased run and increased pool habitats, which explained partly why we collected more mosquitofish in August compared to May. I believe that compositional change between seasons were also due to sampling bias. Sampling deep and highly vegetated locations, although not frequent, was challenging in May and August, so is sampling backwaters in May. Efficiency of electrofishing is body-size-dependent, and mosquitofish evaded capture by electrofishing due to their small body size. Despite challenges of sampling plains fish habitats, the intensity of sampling effort and sample size (2,806 individuals in May and 6,683 in August) should provide a representative view of fish assemblages at Arickaree River.

In August, relative composition of mosquitofish increased as flow intermittency increased; that is, mosquitofish were more common at drying sites relative to flowing sites. Mosquitofish prefer slow-moving waters such as ponds and the littoral zone of lakes. My findings suggest that stream drying and isolated pools that result may facilitate invasion and persistence of mosquitofish in Arickaree River. The effect of mosquitofish on native species may depend on abiotic conditions (Alcaraz et al. 2008), but such context-dependency is largely unknown in relation to flow conditions and requires additional research.

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