RIO GRANDE SILVERY MINNOW AUGMENTATION IN THE MIDDLE RIO GRANDE, NEW MEXICO

Annual Report 2022

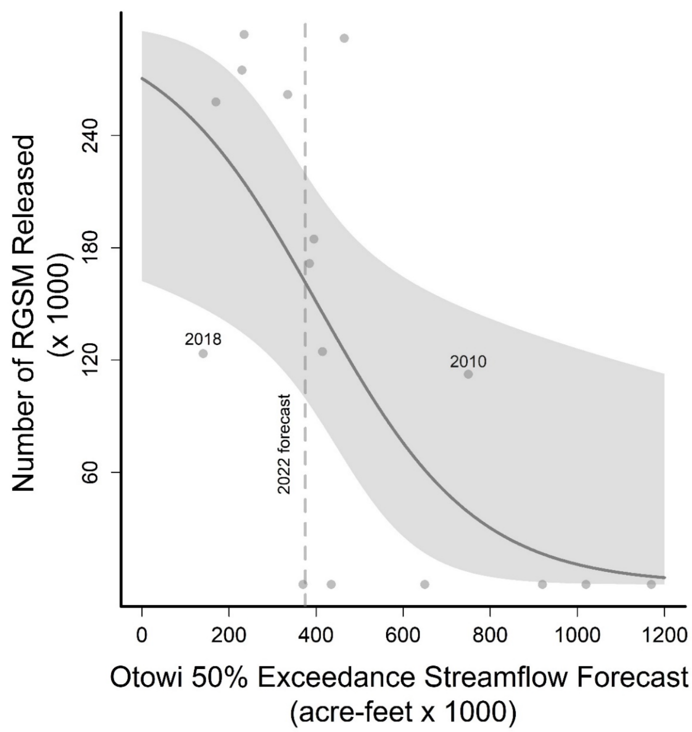

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TABLE OF CONTENTS

LIST OF FIGURES 4
LIST OF TABLES 5
EXECUTIVE SUMMARY 6
INTRODUCTION 7
METHODS 8
Study Area 8
Spring Estimation of Production Needs 9
Collection of Wild-caught Eggs for Broodstock and Refuge Population 9
Autumn Augmentation Needs 10
Fish Condition Factor 10
Tagging 11
Fish Releases 11
Recapture Data From Other Research 11
RESULTS 12
Spring Estimation of Production Needs 12
Collection of Wild-caught Eggs for Broodstock and Refuge Population 13
Autumn Augmentation Needs 13
Fish Condition Factor 15
Tagging 15
Fish Releases 15
Recapture Data from Other Researchers 15
DISCUSSION 18
ACKNOWLEDGEMENTS 19
DATA AVAILABILITY STATEMENT 19
LITERATURE CITED 20
Appendix A: 23

LIST OF FIGURES

Figure 1- Association between numbers of Rio Grande Silvery Minnow released in autumn and the forecasted spring-summer streamflow at the Otowi gage in the Rio Grande, New Mexico. The gray area represents the 95% confidence interval for numbers of hatchery fish actually required in each year. The model is updated yearly. The dashed line represents the forecasted 2021 spring flows and is used to estimate production of age-0 RGSM in May. 12

Figure 2-Locations in the Middle Rio Grande, New Mexico, where hatchery-reared Rio Grande Silvery Minnow were released in 2022. 16

Figure 3- Map depicting the location of the 2022 mark-recapture study and the division of the sub-reaches along the 1.6 km long reach that was assessed. 27

Figure 4- Location of visible implant elastomer (VIE) marks used during the study to indicate the sub-reach the fish was captured in. 28

LIST OF TABLES

Table 1- Rio Grande Silvery Minnow monitoring sites, approximate surface area (ha) between it and the next site downstream during baseflows, and observed CPUE in September 2021, in the Middle Rio Grande, New Mexico. DD = Diversion Dam, NWR = National Wildlife Refuge, RRWWTP = Rio Rancho Wastewater Treatment Plant, SM = San Marcial................................ 14

Table 2- Rio Grande Silvery Minnow release sites and dates in the Middle Rio Grande, the color of the hatchery mark, the source of the fish (Southwestern Native ARRC = Southwestern Native Aquatic Resources and Recovery Center, ABQ = Albuquerque BioPark Aquatic Conservation Facility, LLSMR = Los Lunas Silvery Minnow Refugium), date released, and the number released. PIT = passive integrated transponder tag.. 17

DISCLAIMER

The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

EXECUTIVE SUMMARY

- This report covers New Mexico Fish and Wildlife Conservation Office (NMFWCO) Rio Grande Silvery Minnow (RGSM) augmentation activities for the 2022 cohort.
- Spring runoff in early 2022 was moderately low, resulting in a request of 230,000 hatchery-reared age-0 fish to supplement the wild 2021 cohort and an additional 10,000 RGSM for a movement study.
- The visible implant elastomer (VIE) tags used for identifying RGSM released in 2022 was red left dorsal for all facilities.
- Based on September 2022 population monitoring, the Middle Rio Grande valley had < 1.0 RGSM per $100m^2$ and >50% occupied sites in all reaches, leading to a final request of 269,000 RGSM. However, due to poor reproduction, growth, and survival of hatchery fish, this production request was not met. An additional 10,000 were held back as emergency broodstock for future use if required, reducing total numbers available to release further.
- 126,504 hatchery-reared age-0 Rio Grande Silvery Minnow were released in November and December 2022. All were given a red left VIE tag prior to release.
- 2,993 PIT tagged fish were released in March 2022
- 454 VIE-marked fish were recaptured between January and December 2022, with 7 from the 2020 cohort, 1 former broodstock, 3 PIT-tagged fish, and the remaining 443 from the 2021 cohort. The majority of recaptures (N = 366) were during fish rescue activities, including all fish from the 2020 cohort.
- A pilot mark-recapture study was initiated to determine the feasibility of robust-design mark recapture to estimate monthly survival, movement, and capture efficiency of Rio Grande Silvery Minnow.

INTRODUCTION

In 2001, the Rio Grande Silvery Minnow *Hybognathus amarus* (RGSM) Augmentation Plan (USFWS 2001) was developed to help prevent extinction of the species by increasing their numbers in the Rio Grande. Since that time, ~3.3 million hatchery-reared RGSM have been released into the Middle Rio Grande (MRG), New Mexico. The initial goal of the RGSM Augmentation Plan was to produce 500,000 RGSM each year for release based on the expected capacities of propagation facilities, along with current population status and suggestions from geneticists. Stocking and monitoring efforts were focused in the Angostura Reach (also known as the Albuquerque Reach) where catch rates of wild RGSM were extremely low and the expected benefit of augmentation could be maximized (Remshardt and Davenport 2003). However, actual production has been limited to 300,000 or less per year since 2010 and stocking has occurred in the Angostura, Isleta, and San Acacia Reaches when needed based on autumn abundance.

Varying numbers of RGSM have been released in the MRG each year ranging from 0 to 400,000 depending on river conditions. Between 2002 and 2004, 100,000 to 200,000 RGSM were released annually in the Angostura Reach. Annual releases were based on calculations to reach target densities of 1 fish/100m^2. Starting in 2005, augmentation expanded to include the Isleta and San Acacia Reaches. In addition to augmentation and other conservation measures such as habitat improvement, improved spring runoff and habitat conditions improved survival in 2005 allowing RGSM to increase in abundance. Between 2005 and 2007, 100,000 to 400,000 RGSM were released annually throughout all reaches (Remshardt 2008). In 2008, USFWS began implementing a revised 5-year RGSM Augmentation Plan, in which the Angostura Reach was purposely not stocked in order to evaluate the effect of hatchery augmentation. Favorable spring run-off conditions for recruitment beginning in 2008 meant that no augmentation was needed that year; however, the number of RGSM stocked during the low spring run-off years of 2012 to 2014 was near maximum capacity of production facilities. Following slightly increased recruitment in 2015 and 2016, the 2017 cohort of RGSM was one of the strongest observed in the MRG. Declines during the drought years of 2020-2021 lead to an increase in the numbers of hatchery fish released.

This report summarizes augmentation planning and release activities during the 2022 calendar year. This effort addresses management needs identified in Item A.2.2 of the Middle Rio Grande Endangered Species Collaborative Program (MRGESCP), Tasks 8b and 8d of the Rio Grande Silvery Minnow Recovery Plan, 1st Revision, (Recovery Plan; USFWS 2010), and Reasonable and Prudent Measure #5 of the Biological Opinion (USFWS 2016). These tasks include development and refinement of augmentation protocols for use in the Middle Rio Grande (Task 8b) and annual monitoring of augmented populations is identified as a needed task (Task 8d).

A recovery outcome of a self-sustaining population of RGSM in the Middle Rio Grande requires numerous actions outlined in the Recovery Plan. The goal of augmentation is to support the wild population of RGSM in the Middle Rio Grande by bolstering resistance and resilience to disturbance and other environmental stressors (Archdeacon et al. 2023), until such time as the population becomes self-sustaining. Augmentation accomplishes this goal by improving the abundance and distribution of RGSM in the Middle Rio Grande, thereby improving the demographic resilience of the species. Long-term objectives of this project are to promote the recovery of RGSM through 1) augmenting populations within the MRG with hatchery-raised fish as necessary; and 2) evaluating stocking efforts and methods to improve effectiveness of these actions.

Specific objectives of augmentation in 2022 were to implement the 5-year augmentation and stocking protocol (Archdeacon 2022), including assisting with spring production estimates, collection of eggs for broodstock and refuge populations, calculating the number of RGSM necessary to meet target densities of 1 fish/100m^2 within each reach.

METHODS

Study Area

This investigation concentrated on areas within the Angostura, Isleta, and San Acacia reaches (Figure 1). The Angostura Reach (~41 mi) extends from Angostura Diversion Dam (River Mile [RM] 209.7) to Isleta Diversion Dam (RM 169.3) and includes the cities of Bernalillo, Corrales, and Albuquerque. The Isleta Reach (~53 mi) extends from Isleta Diversion Dam to San Acacia Diversion Dam, and includes the southern portion of Isleta Pueblo, cities of Bosque Farms, Valencia, Los Lunas, Belen, and smaller villages such as La Joya, and Bernardo, along with Sevilleta National Wildlife Refuge, all within Bernalillo, Valencia, and Socorro Counties. The San Acacia Reach (~64 mi) extends from San Acacia Diversion Dam to the headwaters of Elephant Butte Reservoir (the exact location of the lower boundary varies depending upon reservoir water-surface elevation). This reach is relatively remote, including only the city of Socorro and villages of San Acacia, Lemitar, Escondida, and San Antonio along with Bosque del Apache National Wildlife Refuge, within Socorro and Sierra Counties.

Spring Estimation of Production Needs

Hatchery facilities must plan for spring spawning by May of each year and require estimates of numbers of fish needed for autumn augmentation. Spring planning numbers are estimated from the April 1 streamflow forecast of each year and are incorporated in a regression model that is updated with new data each year. The forecasted 50% exceedance streamflow, in thousands of acre-feet (KAF), March through July at the Otowi gage (available at https://www.nrcs.usda.gov/wps/portal/wcc/home/snowClimateMonitoring/snowpack/basinDataReports/) is used to predict the actual numbers of fish released in the autumn (described below). A generalized linear regression model was used to relate actual numbers of fish needed to the spring forecast. As a conservative measure, the upper 95% confidence interval is used for the spring estimation of augmentation needs. As more years are included, the model will be able to incorporate other parameters, including existing numbers of fish from previous cohorts, which should improve the precision of predictions of fish required for augmentation.

Collection of Wild-caught Eggs for Broodstock and Refuge Population

Rio Grande Silvery Minnow spawning typically occurs in May and June (Archdeacon et al. 2020; Dudley et al. 2021). Rio Grande Silvery Minnow release neutrally-buoyant, non-adhesive eggs directly into the water column (Platania and Altenbach 1999). During times of high spawning activity and lower discharge, eggs can be easily collected from the river (Altenbach et al. 2000). These eggs may be transported to rearing facilities to serve as broodstock or a refuge population, or in returned to the river in years when large numbers are collected (Archdeacon et al. 2023).

Autumn Estimation of Augmentation Needs

Following the revised RGSM Augmentation Plan 2018-2022 (Archdeacon 2022), augmentation efforts were focused on all three reaches (Angostura, Isleta, and San Acacia) in 2022. September catch-rates (e.g., catch-per-unit-effort; fish/100m^2) from population monitoring results (Dudley et al. 2022b) were used as criteria to determine the need for augmentation and the number of fish required. If the entire reach average was >1.0 fish/100m^2 and >50% of monitoring sites were occupied, then augmentation was not required. If either of the criteria was not met, augmentation occurred and the total number of fish for the reach was calculated as given below (Archdeacon 2022). Surface area between sites was estimated from aerial imagery and average wetted conditions.

The number of fish to augment for each site (S_i) was determined using the following formula:

$$S_i = (C_t - C_o) \times (\text{total estimated area m}^2 \text{ between } S_i \text{ and } S_{i+1})$$

where; C_t = Target catch rate at each site, or 1 fish / 100 m^2,

C_o = Observed catch rate at site i in September

S_i = Number of fish to release at site i

S_{i+1} = Next downstream site of site i

Once the required number of fish per site was determined, it was summed per reach. The total number of fish per reach was spread among at least three release locations per reach.

Fish Condition Factor

We weighed (0.01 g) and measured (1 mm) standard and total length of at least 100 haphazardly selected (and assumed representative) fish from each facility. We calculated Fulton's condition factor (K_{tl}; see Froese 2006) for these fish; augmentation guidelines are that fish should be 45 mm TL and have a condition factor of $K_{tl} > 0.80$ to improve survival and reproduction post-release (Archdeacon 2022).

Tagging

Tagging followed the standard operating procedures for tagging Rio Grande Silvery Minnow with VIE tags (Archdeacon 2019, Appendix E). For fish released in 2022, tags were placed in the left dorsal position. All facilities used red VIE tags for marking.

Fish Releases

Rio Grande Silvery Minnow are loaded in large transport tanks at the hatcheries and are transported to a site where trucks can get close to flowing water. River water was used to temper the tanks to within 1°C of the river water. The RGSM are then released directly from the trucks into areas of low or zero velocity water at stocking sites. If the transport trucks are unable to get access to the river, RGSM are loaded into smaller transport tanks in the back of off-road vehicles following transport protocols developed for RGSM fish rescue along with the tempered water, and then driven to the river and released into low velocity habitats. Specific timing and release sites are chosen to avoid releasing fish directly at standard monitoring sites. A minimum of three release locations are chosen for each reach, based on the areas with the lowest densities and river access (Archdeacon 2022).

Recapture Data from Other Researchers

Recapture data collected from other researchers continue to provide valuable information on movement and survival of VIE marked fish. Included in this year's summary are collections from standard population monitoring work for RGSM conducted by ASIR (American Southwest Ichthyological Researchers, LLC), data from NMFWCO RGSM fish rescue projects, the U.S. Bureau of Reclamation, the New Mexico Interstate Stream Commission, and the University of New Mexico (UNM) genetic monitoring. These researchers were asked to provide recapture information on VIE-marked RGSM. These projects have varying objectives and methods, but a summary of recaptures can provide an overall view of RGSM movement and retention in release areas.

RESULTS

Spring Estimation of Production Needs

The forecasted 50% exceedance flow at Otowi for March through July was 330 KAF (Figure 1). This resulted in a request for 230,000 age-0 Rio Grande Silvery Minnow to be spawned and reared for augmentation in autumn (Figure 1).

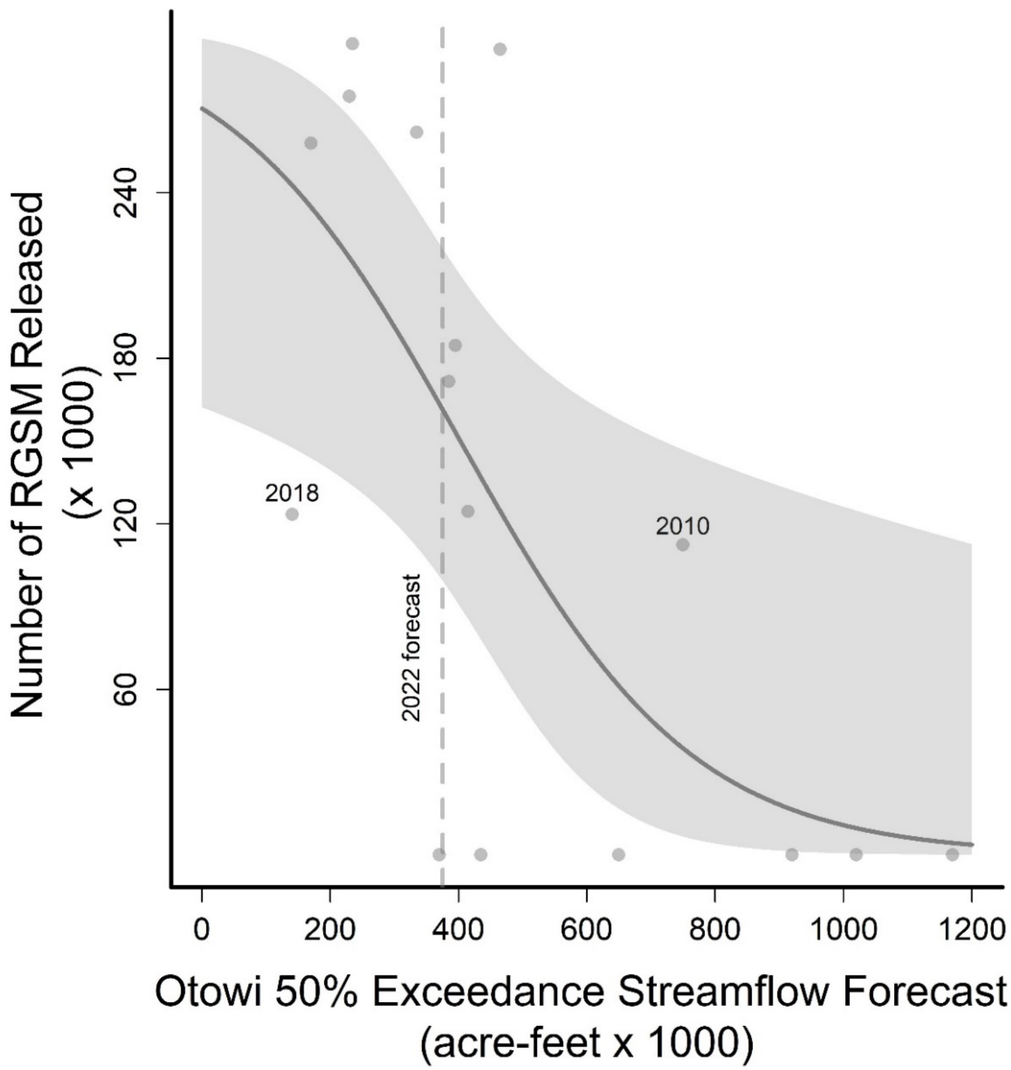

Figure 1- Association between numbers of Rio Grande Silvery Minnow released in autumn and the forecasted spring-summer streamflow at the Otowi gage in the Rio Grande, New Mexico. The gray area represents the 95% confidence interval for numbers of hatchery fish actually

required in each year. The model is updated yearly. The dashed line represents the forecasted 2021 spring flows and is used to estimate production of age-0 RGSM in May.

Collection of Wild-caught Eggs for Broodstock and Refuge Population

Few eggs were observed during reproductive monitoring. Only a single RGMS egg was collected during a planned spawning flow pulse in the Isleta Reach. The NMFWCO retained no RGSM eggs for broodstock during 2022.

Estimation of Augmentation Needs

Based on September 2022 catch rates from the standard RGSM monitoring program conducted by ASIR (Dudley et al. 2021b), all three reaches had < 50% site occupancy and CPUE < 1.0 (Table 1). The total fish requested was 269,000.

Table 1- Rio Grande Silvery Minnow monitoring sites, approximate surface area (ha) between it and the next site downstream during baseflows, and observed CPUE in September 2021, in the Middle Rio Grande, New Mexico. DD = Diversion Dam, NWR = National Wildlife Refuge, RRWWTP = Rio Rancho Wastewater Treatment Plant, SM = San Marcial.

Reach	*Site*	*Area (ha)*	*Density (fish/100m^2)*	*Fish required*
Angostura	Angostura DD	165.7	0.00	17,000
	Bernalillo	72.6	1.08	0
	RRWWTP	425.1	0.00	43,000
	Central	141.8	0.00	14,000
	Rio Bravo	428.1	0.43	24,000
	Reach Total/Average	-	0.30	98,000
Isleta	Los Lunas	280.4	0.00	28,000
	Belen	148.9	0.00	15,000
	Jarales	235.4	0.00	24,000
	Bernardo	40.8	0.00	4,000
	La Joya	149.0	0.00	15,000
	Above San Acacia DD	20.4	0.00	2,000
	Reach Total/Average	-	0.00	88,000
San Acacia	San Acacia DD	15.5	0.00	2,000
	Below San Acacia DD	218.9	0.00	22,000
	Socorro	167.5	0.18	14,000
	Neil Cupp	81.9	0.21	7,000
	San Antonio	97.8	0.00	10,000
	Bosque NWR	107.1	0.00	11,000
	San Marcial	70.6	0.00	7,000
	8 Mile below SM	15.6	0.00	2,000
	10 Mile below SM	77.9	0.00	8,000
	Reach Total/Average	-	0.04	83,000

Fish Condition Factor

Haphazardly selected fish, presumed representative of the cohort, were weighed and measured 25 October 2022 (BioPark and LLSMR) or 3 November 2021 (Southwestern Native ARRC). Fish from Southwestern Native ARRC averaged 55.2 mm TL and had an average K_{tl} = 0.97. Fish from the LLSMR averaged 53.8 mm TL and had an average K_{tl} = 0.84. However, fish from the LLSMR raised in the outdoor refugium had significantly lower K_{tl} of 0.79 compared to 0.88 for fish raised in the D-series tanks; these fish were released anyway because of the shortage of fish. Fish from the BioPark and transferred to the LLSMR had an average TL of 32.4 mm and K_{tl} = 1.00; however the average weight was 0.38g and excess water likely contributed to the high condition factor. Nonetheless, these fish were too small to be tagged and were not released. Fish from the BioPark averaged 43.1 mm TL but had an average K_{tl} = 0.76. These fish were graded and the largest 16,700 were tagged and released. The remaining fish will be held until the length and condition factor improves to acceptable levels. See the data availability section for raw measurements.

Tagging

Tagging was completed at Southwestern Native ARRC, LLSMR and the BioPark. All fish were given red left dorsal VIE markings.

Fish Releases

A total of 129,497 RGSM were released among seven sites in 2022 (Figure 2). Age-0 fish totaled 126,504 and were released among three sites in November and December 2022 in the MRG (Table 3). A small number of RGSM (n = 2,993) were tagged with passive integrated transponder tags and released at three sites in March, 2022 (Table 3).

Recapture Data from Other Researchers

454 VIE-marked fish were recaptured between January and December 2022, with 7 from the 2020 cohort, 443 from the 2021 cohort, 1 ex-broodstock, and 1 PIT-tagged RGSM. The majority of recaptures (N = 366) were during fish rescue activities. The longest fish at large was 612 days.

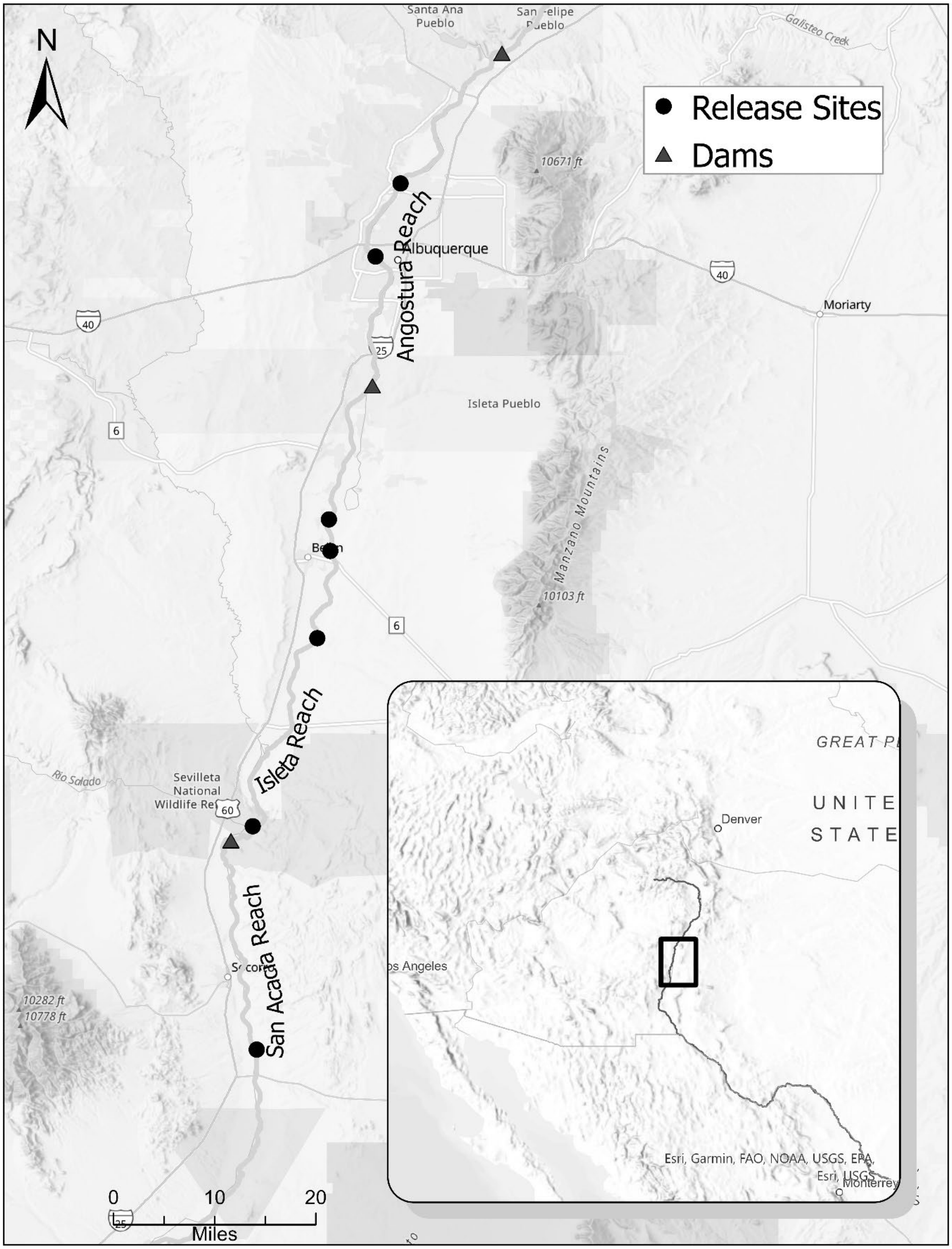

Figure 2-Locations in the Middle Rio Grande, New Mexico, where hatchery-reared Rio Grande Silvery Minnow were released in 2022.

Table 2- Rio Grande Silvery Minnow release sites and dates in the Middle Rio Grande, the color of the hatchery mark, the source of the fish (Southwestern Native ARRC = Southwestern Native Aquatic Resources and Recovery Center, ABQ = Albuquerque BioPark Aquatic Conservation Facility, LLSMR = Los Lunas Silvery Minnow Refugium), date released, and the number released. PIT = passive integrated transponder tag.

Reach	*Site*	*Source*	*Number*	*Date*	*RM*	*Mark*
Albuquerque	Alameda	Southwestern ARRC	35,990	11/22/2022	206.3	Red left dorsal
	Central	ABQ	22,500	12/05/2022	182.8	Red left dorsal
Isleta	Belen	LLSMR	28,960	11/22/2022	151.2	Red left dorsal
	Sevilleta	SNARRC	1,042	3/7/2022	118.9	PIT
	Jarales	SNARRC	1,011	3/7/2022	141.3	PIT
	Peralta	SNARRC	940	3/7/2022	154.5	PIT
San Acacia	Neal Cupp	SNARRC	39,324	11/22/2022	92.3	Red left dorsal
Total			129,497			

DISCUSSION

Over the preceding decade, RGSM densities have varied greatly from year to year. Beginning in 2015, numbers began to increase through 2017. In 2017, high spring runoff led to very densities of RGSM. However, after poor recruitment in 2018 and 2020-2022, the annual numbers of fish needed for augmentation increased. The association between the spring hydrograph and the density of RGSM detected the following October is well established Yackulic et al. 2022). The spring 2022 estimate based on forecasted streamflow underestimated RGSM needed for augmentation by ~60,000. Early, low spring runoff peak, lack of a strong spawning cue, and low abundance of fish in the river likely contributed to the lack of egg collections, while contributing to poor recruitment and underestimation of augmentation needs. There is still considerable variability and uncertainty in autumn planning needs when average flows are between approximately 50 and 80%, though the years 2010 and 2018 appear to be outliers. As more data is collected, this relationship should be clarified, allowing for more precise estimates of augmentation needs in spring. The variability is likely linked to the abundance of the previous years' cohort.

Fish from Southwestern ARRC exhibited good body condition. Fish from the BioPark were generally in poor condition ($K_{tl} < 0.80$), whereas fish from LLSMR raised in raceways were in good condition but those raised in the refugium were in poor condition (see raw data). Approximately 42,000 RGSM were held back due to being too small and may be released prior to spawning in 2023. Future research should include studies on how body condition of hatchery fish influences survival and performance after release. Making these determinations will help guide and improve propagation practices.

Rio Grande Silvery Minnow exhibit an opportunistic life-history with high demographic resilience (Winemiller 2005), with relatively high fecundity for body size (Caldwell et al. 2019), high mobility (Archdeacon et al. 2018, Platania et al. 2020), and a short lifespan (Horwitz et al. 2018). Having high demographic resilience allows the population to rebound quickly after disturbance. Over the previous five years, populations increased in 2017, followed by four years of extreme annual variability in spring runoff. Populations rebounded in 2019 after poor runoff and recruitment conditions in 2018 (Archdeacon et al. 2020). Thus, continued augmentation will be necessary in some years if spring run-off continues to be low and below average.

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DATA AVAILABILITY STATEMENT

All Rio Grande Silvery Minnow release and recapture data are available on Mendeley Data at doi: 10.17632/nwc7k6rm47.5

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Appendix A:
Feasibility of Robust-Design Mark-Recapture for Rio Grande Silvery Minnow

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Introduction

The Rio Grande Silvery Minnow is a small-bodied minnow that currently only found in the middle Rio Grande in central New Mexico. The range of the Rio Grande Silvery Minnow (*Hybognathus amarus)* has been severely reduced and it now inhabits only 5% of its historical range, occurring from Cochiti Dam downstream to Elephant Butte Reservoir (Bestgen and Platania 1991). This loss of habitat has been caused by fragmentation due to dams constructed for water diversions, which has also led to modified flow regimes and periodic channel drying during summer months. Due to this severe decline, the Rio Grande Silvery Minnow was listed as endangered in 1994 (USFWS 1994) and since then has been the focus of regular monitoring, augmentation, and relocation during dewatering (USFWS 2010). In order to evaluate recovery efforts, catch per unit effort (CPUE) is used as a metric as part of both the Rio Grande Silvery Minnow Recovery Plan and Annual Augmentation Plan.

In support of improving the knowledge of the biology and ecology of Rio Grande Silvery Minnow, the New Mexico FWCO will work to improve the reliability of the CPUE metric. Several reviews of the long-term population monitoring program (e.g., Dudley et al. 2022) have recommended determining additional studies on the relationship between CPUE and abundance and developing correction factors to account for variable capture efficiencies among sites, years, and discharges (Hubert et al. 2016; Noon et al. 2017) improve the reliability of CPUE.

Capture-recapture is the gold standard in wildlife and fisheries studies for making inferences about demographic rates and overall abundance. While it is possible to estimate these quantities without marking individuals, approaches that rely on unmarked fish are less precise and less robust to violations of assumptions. For managers, the costs of imprecise estimates are a poorer understanding of the drivers of population dynamics and less clarity regarding the appropriate management responses. In recent years, modelling approaches have been developed to integrate intensive capture-recapture data collected over limited spatial scales and temporal scales with more extensive, but less informative data (e.g., catch per unit effort data) to reach robust inferences that build on the relative strengths on these two data types. Survival and abundance estimate from RGSM capture-recapture would be invaluable for evaluating estimates from models based on cruder data and would be integrated to improve our overall understanding of RGSM demography and the impacts of various management actions on RGSM population dynamics.

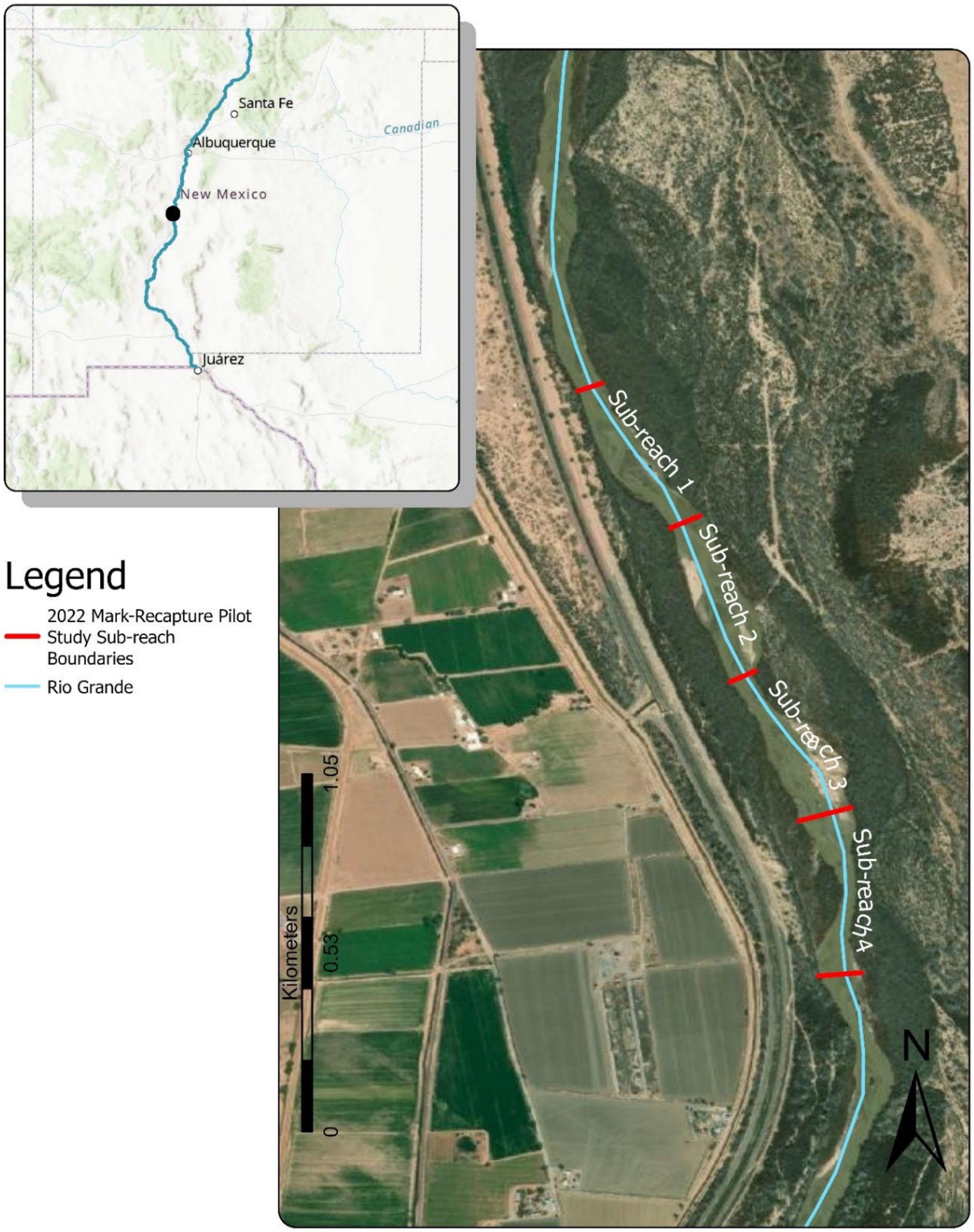
Objectives

The overarching objectives of this mark-recapture study is to estimate abundance of Rio Grande Silvery Minnow within a small section of the MRG, estimating and accounting for survival between sampling periods, immigration and emigration between sampling periods, and capture efficiency. After sampling in multiple areas and years, we plan to synthesize results to improve the utility of CPUE, which can be collected on a much larger spatial scale with less effort. We determined that an initial pilot study would be beneficial to determine the feasibility of initial study design and expected recapture rates. Full methodology will be developed after this initial study and yearly review. Here, we examined sub-reach lengths and number of hauls that would be reasonable to sample to determine expected capture and recapture rates. These may need to be adjusted during years of high abundance. In years of low abundance of RGSM, other species may be marked (i.e. flathead chub [*Platygobio gracilis]* and longnose dace [*Rhinichthys cataractae*]). Visible implant elastomer (VIE) tags will be used to mark RGSM and surrogate species greater than 30 mm standard length (SL), the color and placement of the tag indicating the time period and sub-reach in which it was caught. Thus, both capture history and movement among sub-reaches can be determined and used to estimate population size, capture efficiency of seines, monthly survival, and to a limited extent, movement.

Methods

For the initial pilot study, a 1.6 km portion of the San Acacia reach was chosen and divided into four equal-length sections of 400 m (Figure 1). The sampling location was chosen arbitrarily with the intention of having relatively more RGSM present for capture because it has not experienced river drying in at least the past two decades (Archdeacon and Reale, 2020) and had a variety of mesohabitats present. We conducted sampling three times every two weeks, covering a total sampling period of five weeks. Sampling began in sub-reaches 1 and 2 and were sampled by conducting 10 seine hauls per 100 m of stream length, totaling 40 seine hauls per sub-reach. We employed a seine (3.0 x 1.0 m, mesh size = 3.2 mm) and varied the habitat and length evaluated as much as possible. On the second day, sub-reaches 3 and 4 were sampled with the same methodology. We tagged all RGSM and flathead chub captured that were >30 mm in length.

Fish were marked with a unique VIE color in one of several locations, allowing movement among sub-reaches to be inferred. We used yellow VIE for sampling trip 1 and green VIE for sampling trip 2. The location of the VIE mark indicated which sub-reach the fish was caught in, starting with the pre-dorsal for sub-reach 1 and moving clockwise around the dorsal fin for the other three reaches (Figure 2). Days 1 and 2 were repeated on days 3 and 4 to increase the numbers of marked fish (no fish were double-tagged during the second pass). During the third sampling trip, we did not mark any new fish and only noted if the fish did or did not have a VIE tag from a previous trip.



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207 Figure 3- Map depicting the location of the 2022 mark-recapture study and the division of the
208 sub-reaches along the 1.6 km long reach that was assessed.

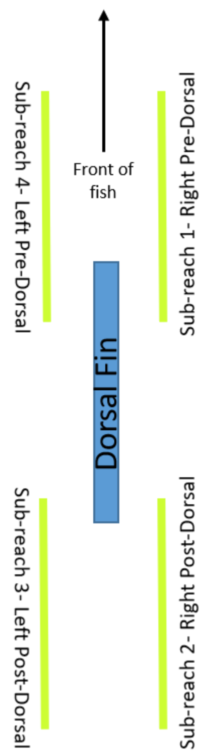

Figure 4- Location of visible implant elastomer (VIE) marks used during the study to indicate the sub-reach the fish was captured in.

Results, Discussion, and Recommendations

Very few fish were captured in total. Among 4 total marking passes (640 seine hauls, 16,173 m^2 sampled), we collected 8 species and 470 individuals. Of those, only six were Rio Grande Silvery Minnow and 158 were Flathead Chub. All seven Rio Grande Silvery Minnow were large enough to mark, but only 71 of the Flathead Chub were large enough. No marked Rio Grande Silvery Minnow were recaptured, compared 10 recaptures of Flathead Chub. No fish were marked in the fifth and final pass, and we collected one additional Rio Grande Silvery Minnow and 41 Flathead Chub. Of the Flathead Chub, 23 were too small to have been marked and one fish was a recaptured fish. All Rio Grande Silvery Minnow were large enough to be marked. Summary of new and recaptured fish by species, period, and segment are given Table 1. All fish collections are given in Table 2.

The number of target species were too low to use mark-recapture models. However, we still were able to meet the objective of the pilot study. First, the length of stream and number of seine hauls is reasonable to sample in a 4-day sampling period. In years of very high abundance of Rio Grande Silvery Minnow, the length of each section may need to be shorter. Simulation analyses may be useful in determining whether shortening each section and increasing the number of marking passes within a period is more efficient than longer sections with fewer marking passes within a time period.

Table 1-Number of new captures (NC) and recaptures (RC) of Flathead Chub and Rio Grande Silvery Minnow in September and October of 2022. Fish were captured in four contiguous 400-m sections of the Middle Rio Grande during two marking periods with two passes each, and one recapture period sampled with a single pass.

PERIOD	**SECTION**	**FLATHEAD CHUB**		**RIO GRANDE SILVERY MINNOW**	
		NC	RC	NC	RC
1	1	15	1	0	0
1	2	12	4	0	0
1	3	8	2	0	0
1	4	11	0	0	0
2	1	4	0	0	0
2	2	3	0	2	0
2	3	5	0	3	0
2	4	3	4	1	0

Streamflow was variable among sampling periods (Figure 3). Intuitively, increasing streamflow should have a negative affect on catch rates, as fish are spread throughout more habitat and deeper, faster habitat that is harder to sample increases. However, this did not appear to be the case as total numbers of fish captured in all periods were similar, and the most Rio Grande Silvery Minnow were captured during the intermediate flows in period 2. Peak streamflow during the study was about 700 cfs, though the highest observed during a sampling event was around 550 cfs. Apart from sampling difficulties during high monsoon flows, an additional consideration is the effect flooding may have on fish distribution. Accounting for movement during lower, stable flows will be critical to determining fish turnover due to movement during floods.

Despite choosing the sampling location with the intentions of capturing relatively more Rio Grande Silvery Minnow, the segment was relatively poor. Although the site should ideally be representative, choosing a site with enough fish to mark and recapture is essential for estimating movement, survival, and abundance. Although there were apparently more Rio Grande Silvery Minnow in the Angostura Reach (Dudley et al. 2022b), there were still likely too few to have good estimates of these parameters. Nonetheless, it is worth exploring as an option to help expand the inferences that can be gained from just CPUE alone.

Our primary recommendation for 2023 are primarily to choose a better sampling section, likely within the Angostura Reach. Simulations and more data are needed to determine if the length of sampling segment and effort are sufficient or should be adjusted to allow more within-period passes. The sampling period could be moved to earlier in the year, beginning in late August, as all Rio Grande Silvery Minnow were large enough to VIE mark. However, this should be balanced against water temperatures and stress of marking wild fish to avoid unnecessary tagging mortality. This may be less of an issue in the Angostura Reach than the San Acacia Reach, because water temperatures are more buffered and only rarely exceed 30° C (Archdeacon et al. 2020). Recaptures of Flathead Chub within a period were marginal, enough that some estimates of capture efficiency and abundance may be possible. However, recaptures between time periods were insufficient to evaluate any movement or survival estimates. Regardless of the sampling methods, if there are not sufficient numbers of Rio Grande Silvery Minnow in the sampling segment to allow recapture within and among time periods, no estimates of survival, movement, or abundance can be made.

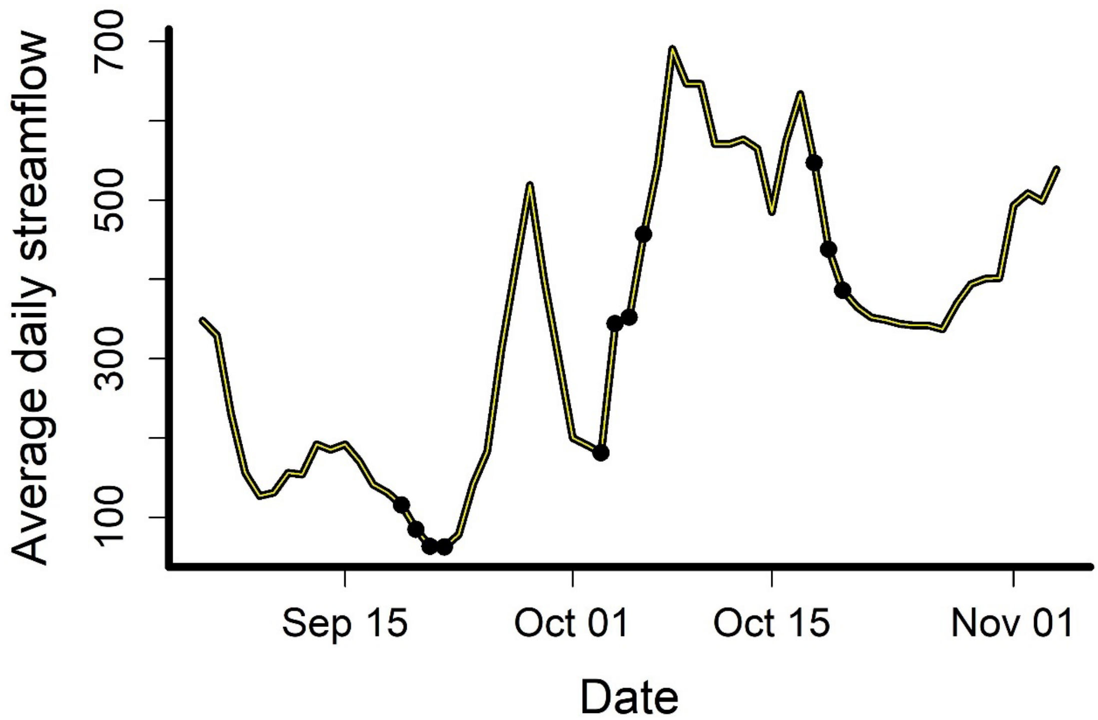

Figure 3-Streamflow (cfs) at the San Acacia gage (U.S.G.S. gage 80354900) during the mark-recapture study period in the Middle Rio Grande, 2022. Points indicate days sampling occurred.

Table 2-Collection ID, date, area sampled (m^2), period, section, pass, and numbers of fish caught during mark-recapture in the Middle Rio Grande, 2022. CARCAR = River Carpsucker, CYPCAR = Common Carp, CYPLUT = Red Shiner, GAMAFF = Western Mosquitofish, HYBAMA = Rio Grande Silvery Minnow, ICTPUN = Channel Catfish, PIMPRO = Fathead Minnow, PLAGRA = Flathead Chub.

Collection	Date	area	period	section	pass	CARCAR	CYPCAR	CYPLUT	GAMAFF	HYBAMA	ICTPUN	PIMPRO	PLAGRA
MEB22-001	9/19/2022	840.325	1	1	1	0	1	3	0	0	1	0	14
MEB22-002	9/19/2022	826.75	1	2	1	0	1	4	1	0	0	0	8
MEB22-003	9/20/2022	858.75	1	3	1	0	2	19	2	0	5	0	17
MEB22-004	9/20/2022	938.75	1	4	1	0	0	4	1	0	0	1	6
MEB22-005	9/21/2022	901.5	1	1	2	0	0	7	0	0	1	1	5
MEB22-006	9/21/2022	1015	1	2	2	2	2	37	0	0	2	0	13
MEB22-007	9/22/2022	1013.25	1	3	2	0	1	22	3	0	5	0	23
MEB22-008	9/22/2022	1128.5	1	4	2	0	0	8	0	0	3	0	5

MEB22-009	10/3/2022	957.25	2	1	1	0	0	1	0	0	5	0	4
MEB22-010	10/3/2022	1036.5	2	2	1	0	0	10	4	0	1	0	2
MEB22-011	10/4/2022	1081.75	2	3	1	0	3	33	12	2	1	0	19
MEB22-012	10/4/2022	1009	2	4	1	0	0	32	2	0	0	0	18
MEB22-013	10/5/2022	1191.5	2	1	2	0	0	18	0	0	3	0	1
MEB22-014	10/5/2022	1036.75	2	2	2	0	1	10	2	2	2	0	4
MEB22-015	10/6/2022	1211.75	2	3	2	0	1	11	2	1	0	0	5
MEB22-016	10/6/2022	1125.5	2	4	2	0	0	4	2	1	5	1	14
MEB22-017	10/18/2022	1114	3	1	1	0	0	5	0	0	2	0	10
MEB22-018	10/19/2022	1049.5	3	2	1	0	0	1	1	0	1	0	4
MEB22-019	10/20/2022	969.5	3	3	1	0	2	12	18	0	2	0	14

MEB22-020	10/20/2022	1021.25	3	4	1	0	1	3	0	1	6	0	13

Acknowledgments

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