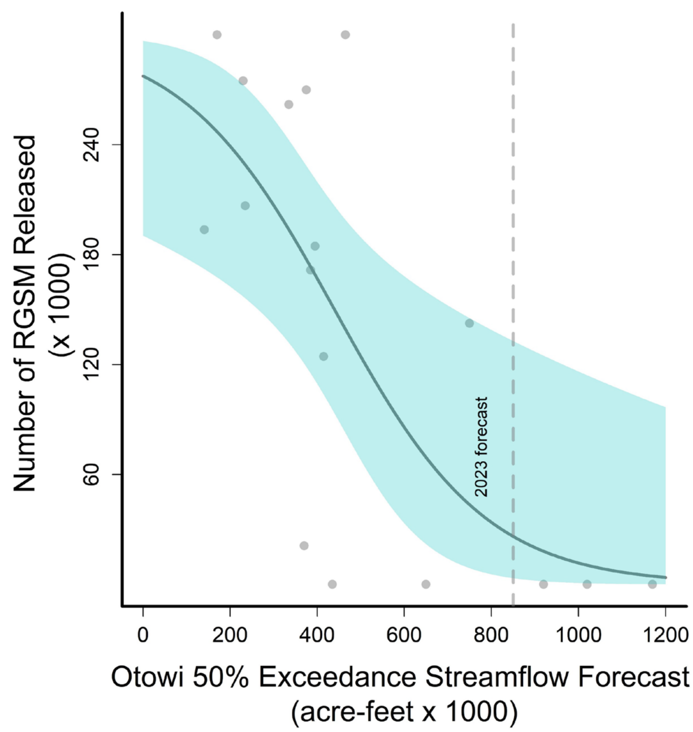
RIO GRANDE SILVERY MINNOW AUGMENTATION IN THE MIDDLE RIO GRANDE, NEW MEXICO

Annual Report 2023



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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 2023 cohort.
- Spring runoff in early 2023 was high, resulting in a request of 60,000 hatchery-reared age-0 fish to supplement the wild 2023 cohort.
- The color of visible implant elastomer (VIE) tags used for identifying RGSM released in 2023 was red right dorsal for all facilities.
- Based on September 2023 population monitoring, the Middle Rio Grande valley had > 1.0 RGSM per $100m^2$ but <50% occupied sites in the San Acacia Reach, leading to a final request of 46,000 RGSM for release in the San Acacia Reach.
- 46,484 hatchery-reared age-0 Rio Grande Silvery Minnows were released in November and December 2023. All were given a red right VIE tag prior to release.
- Fish from the Los Lunas Silvery Minnow Refugium did not meet minimum condition factor requirements and were held back to grow out to a larger size.
- 120 VIE-marked fish were recaptured between January and December 2023, all from the 2023 cohort. The majority of recaptures (N = 85) were during fish rescue activities.
- A pilot mark-recapture study continued in 2023 to determine the feasibility of robust-design mark recapture to estimate monthly survival, movement, and capture efficiency of Rio Grande Silvery Minnow. A total of 3,983 Rio Grande Silvery Minnow were captured in 2023, compared to 7 in 2022.

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 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 on 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 increased recruitment in 2015 and 2016, the 2017 cohort of RGSM was one of the strongest observed in the MRG. Declines in abundance 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 2023 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. 2023b), until such time the population is 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 2023 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, and 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 (~40 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 (~54 km) 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 (~76 km) 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). 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 both the precision and accuracy of predictions. 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.

Collection of Wild-caught Eggs for Broodstock and Refuge Population

Rio Grande Silvery Minnow spawning typically occurs in May and June (Archdeacon et al. 2023a). Rio Grande Silvery Minnow release semi-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 returned to the river in years when large numbers are collected (Archdeacon et al. 2023b). During high-flow years, larvae or juveniles are collected during summer and autumn months.

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 preliminary population monitoring results (R. Dudley, personal communication) 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 were 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. For fish released in 2023, tags were placed in the right 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. Up to three release locations were 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, 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 850 KAF (Figure 1). This resulted in a request for 60,000 age-0 Rio Grande Silvery Minnow to be spawned and reared for augmentation in autumn (Figure 1).

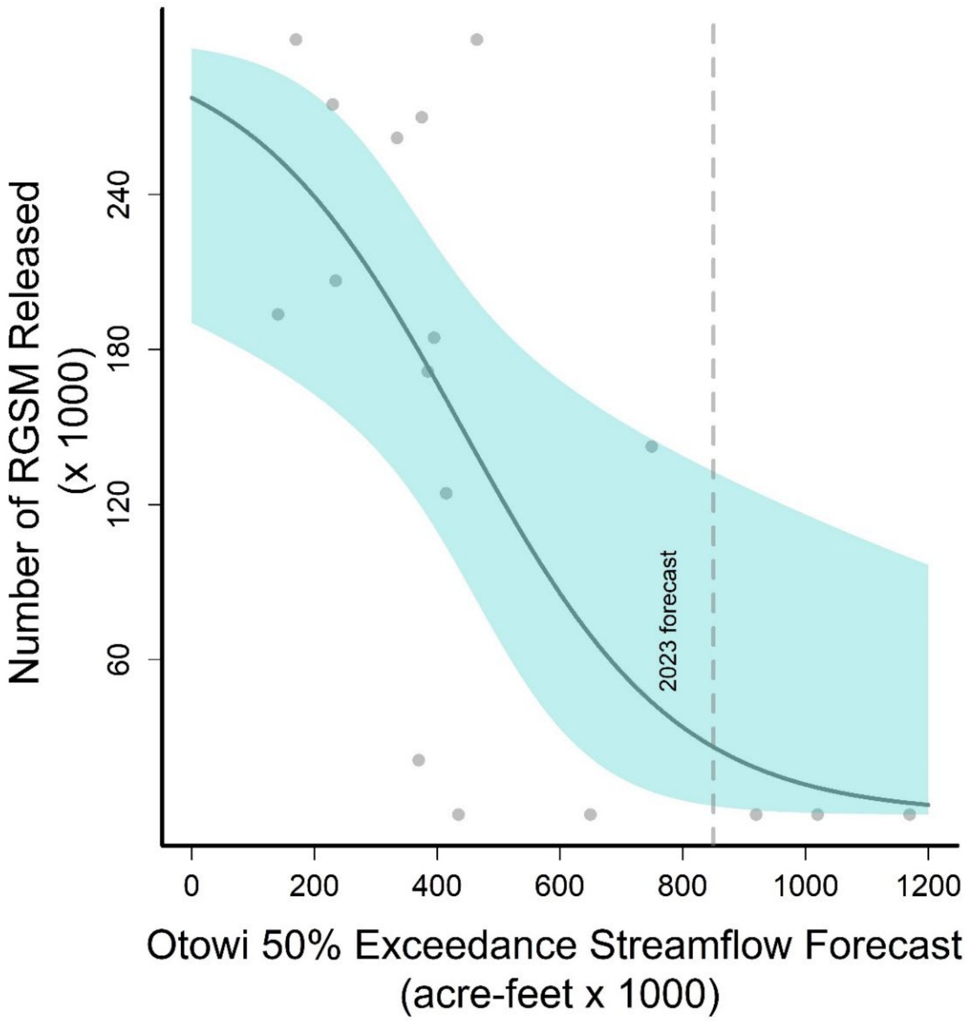

Figure 1- Association between numbers of Rio Grande Silvery Minnow released in autumn and the forecasted spring-summer streamflow at the Otowi gage in the Rio Grande, New Mexico. The gray area represents the 95% confidence interval for numbers of hatchery fish actually required in each year. The model is updated yearly. The dashed line represents the forecasted 2023 spring flows and is used to estimate hatchery production of age-0 RGSM in May.

Collection of Wild-caught Eggs for Broodstock and Refuge Population

Due to high flows, the NMFWCO collected no RGSM eggs for broodstock during 2023. However, multiple collections of larvae and juveniles resulted in >5,000 RGSM transferred to the Albuquerque BioPark for rearing (Appendix A). These fish were treated for infections and reared to a size large enough to identify. After identification, some of these fish were transferred to SNARRC.

Estimation of Augmentation Needs

Based on September 2023 catch rates from the standard RGSM monitoring program conducted by ASIR, all three reaches had CPUE > 1.0 fish 100 m^{-2}, but the San Acacia Reach had < 50% site occupancy < 1.0 (Table 1). The total fish requested was 46,000 to be released in the San Acacia Reach.

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 2023, in the Middle Rio Grande, New Mexico. DD = Diversion Dam, NWR = National Wildlife Refuge, RRWWTP = Rio Rancho Wastewater Treatment Plant, SM = San Marcial. *No stocking was necessary because CPUE was > 1.0 fish 100 m^{-2} and reach occupancy > 0.50.

Reach	*Site*	*Area (ha)*	*Density (fish/100m^2)*	*Fish required*
	Angostura DD	165.7	0	17,000
	Bernalillo	72.6	0.63	3,000
Angostura	RRWWTP	425.1	2.76	0
	Central	141.8	3.97	0
	Rio Bravo	428.1	2.59	0
	Reach Total/Average	-	1.99	0*
	Los Lunas	280.4	47.29	0
	Belen	148.9	13.38	0
	Jarales	235.4	15.26	0
Isleta	Bernardo	40.8	16.3	0
	La Joya	149.0	3.38	0
	Above San Acacia DD	20.4	0.75	1,000
	Reach Total/Average	-	16.06	0*
	San Acacia DD	15.5	50.29	0
	Below San Acacia DD	218.9	10.68	0
	Socorro	167.5	4.81	0
	Neil Cupp	81.9	0	8,000
San Acacia	San Antonio	97.8	0	10,000
	Bosque NWR	107.1	0	11,000
	San Marcial	70.6	0	7,000
	8 Mile below SM	15.6	0	2,000
	10 Mile below SM	77.9	0	8,000
	Reach Total/Average	-	7.31	46,000

Fish Condition Factor

Fish were weighed and measured 17 October (LLSMR), 18 October (BioPark), or 16 November 2023 (Southwestern ARRC). Fish from Southwestern ARRC averaged 54.8 mm TL and had an average K_{tl} = 0.90. Fish from the LLSMR averaged 48.2 mm TL and had an average K_{tl} = 0.74. However, fish from the LLSMR raised in the outdoor refugium had significantly lower K_{tl} of 0.70 compared to 0.78 for fish raised in the D-series tanks. Because these fish were in poor condition both visibly and had $K_{tl} < 0.80$, none were released.

Tagging

Tagging was completed at Southwestern ARRC and the BioPark. All fish were given red right VIE markings.

Fish Releases

A total of 46,484 RGSM were released at one site in 2023 (Figure 2).

Recapture Data from Other Researchers

A total of 120 VIE-marked fish were recaptured between January and December 2023, all from the 2022 release cohort. The majority of recaptures (N = 85) were during fish rescue activities. The longest fish at large was 210 days.

Figure 2-Locations in the Middle Rio Grande, New Mexico, where larval and juvenile fish were collected for broodstock and hatchery-reared Rio Grande Silvery Minnow were released in 2023.

Table 2-Sites in the Middle Rio Grande, New Mexico, where Rio Grande Silvery Minnow were released in November and December 2023, the color of the hatchery mark, the source of the fish (Southwestern ARRC = Southwestern Native Aquatic Resources and Recovery Center, ABQ = Albuquerque BioPark Aquatic Conservation Facility, date released, and the number released.

Reach	*Site*	*Source*	*Number*	*Date*	*RM*	*Mark*
San Acacia	North Boundary Bosque del Apache	Southwestern ARRC	10,484	11/28/2023	86.6	Red right dorsal
San Acacia	North Boundary Bosque del Apache	Albuquerque BioPark	35,438	11/16/2023	86.6	Red right dorsal
San Acacia	North Boundary Bosque del Apache	Albuquerque BioPark	562	12/14/2023	86.6	Red right dorsal
Total			46,484			

DISCUSSION

Over the past decade, RGSM densities have varied from year to year. Beginning in 2015, RGSM abundance began to increase through 2017. In 2017, high spring runoff led to high 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 2023 estimate based on forecasted streamflow suggested no fish would be needed in the autumn, but 60,000 were requested as minimum production. The high spring runoff peak prevented large egg collections, but many larvae and juveniles were collected when flows began to recede. Considerable drying in the San Acacia Reach resulted in the need to stock fish, as <50% of the monitoring sites had RGSM present. 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 are collected, this relationship should become clearer, allowing for more precise estimates of augmentation needs in spring. The variability in augmentation needs is linked to the abundance of the previous years' cohort as well as spring runoff.

Fish from Southwestern ARRC and the BioPark were generally in good condition ($K_{tl} <$ 0.80). Unfortunately, fish from LLSMR were in poor condition, particularly those raised in the refugium (see raw data). Approximately 30,000 RGSM were not released due to being too small but may be released in 2024 depending on their size. 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 short generation times, high reproductive effort (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 and no other options to improve recruitment exist. However, continued and heavy hatchery augmentation to stave off extinction has eroded RGSM genetics (Osborne et al. 2024). Further refinement of production, release, as well as refining release numbers may help improve the effectiveness of augmentation but will not replace habitat and flow restoration.

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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/nwc7k6rm47.6

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Appendix B:

Broodstock Collection Summary

col.num	date	gear	rkm	latitude	longitude	notes
TPA23-006	25-May-23	light trap	278.2	34.06525	-106.87428	1 carp
TPA23-007	25-May-23	light trap	279	34.073	-106.87068	100 suspected RGSM
TPA23-008	25-May-23	light trap	294.1	34.21585	-106.88641	50 likely carp
TPA23-009	26-May-23	light trap	278.2	34.06525	-106.87428	No fish
TPA23-010	26-May-23	light trap	279	34.073	-106.87068	100 suspected RGSM
TPA23-011	26-May-23	light trap	294.1	34.21585	-106.88641	too small to ID, likely carp
PMD23-001	6-Jun-23	light trap	258.5	33.87288	-106.84918	A few fish, not likely RGSM
PMD23-002	6-Jun-23	light trap	266.6	33.95574	-106.8502	5 carp, some small fish
PMD23-003	6-Jun-23	light trap	273	34.01593	-106.86362	No fish
PMD23-004	6-Jun-23	light trap	278.9	34.07199	-106.87093	10 suspected RGSM
PMD23-005	6-Jun-23	light trap	284.6	34.12449	-106.8868	1 carp
PMD23-006	6-Jun-23	light trap	292	34.19681	-106.88776	20 carp
TPA23-012	7-Jun-23	light trap	294.1	34.21585	-106.88641	10 larval fish
TPA23-013	7-Jun-23	light trap	284.6	34.12449	-106.8868	Carp, gambusia
TPA23-014	7-Jun-23	light trap	279	34.073	-106.87068	25-50 RGSM
TPA23-015	7-Jun-23	light trap	266.6	33.95574	-106.8502	No fish
TPA23-016	7-Jun-23	light trap	294.1	34.21585	-106.88641	25-50 suspected RGSM
TPA23-017	8-Jun-23	light trap	294.1	34.21585	-106.88641	No fish
TPA23-018	8-Jun-23	light trap	279	34.073	-106.87068	20 carp, 1+ RGSM
TPA23-019	8-Jun-23	light trap	266.6	33.95574	-106.8502	200-400 fish, cyplut or RGSM
TPA23-020	8-Jun-23	light trap	294.1	34.21585	-106.88641	100-200 cyplut
TPA23-021	9-Jun-23	light trap	294.1	34.21585	-106.88641	100-150 cyplut
TPA23-022	9-Jun-23	light trap	279	34.073	-106.87068	20 fish a couple RGSM
TPA23-023	9-Jun-23	light trap	266.6	33.95574	-106.8502	100 fish, carp?
TPA23-024	13-Jun-23	light trap	304	34.27557	-106.85487	No fish, not submerged
TPA23-025	13-Jun-23	light trap	304.8	34.27804	-106.84651	10-20 minnows
TPA23-026	13-Jun-23	light trap	305.5	34.28225	-106.84049	No fish
TPA23-027	13-Jun-23	light trap	305.8	34.28511	-106.83894	No fish
TPA23-028	14-Jun-23	light trap	304.8	34.27804	-106.84651	Many potential RGSM
TPA23-029	14-Jun-23	light trap	305.5	34.28225	-106.84049	No fish
TPA23-030	15-Jun-23	light trap	304.8	34.27804	-106.84651	Some RGSM
TPA23-031	21-Jun-23	light trap	266.6	33.95574	-106.8502	1000 fish, RGSM or cyplut
TPA23-032	22-Jun-23	light trap	266.6	33.95574	-106.8502	1000 fish, RGSM or cyplut
TPA23-033	23-Jun-23	light trap	266.6	33.95574	-106.8502	1000 fish, RGSM or cyplut
PMD23-007	27-Jun-23	light trap	266.6	33.95574	-106.8502	500 RGSM
TPA23-034	28-Jun-23	light trap	266.6	33.95574	-106.8502	500 RGSM

TPA23-035	29-Jun-23	light trap	266.6	33.95574	-106.8502	500 RGSM
TPA23-036	12-Jul-23	seine hauls	292.1	34.19778	-106.88827	145 RGSM
TPA23-037	17-Jul-23	seine hauls	405.4	35.19284	-106.645	215 RGSM
TPA23-040	19-Jul-23	seine hauls	405.4	35.19284	-106.645	1295 rgsm
TPA23-041	7-Sep-23	seine hauls	386.6	35.02697	-106.67282	25 rgsm
TPA23-041a	8-Sep-23	seine hauls	391	35.07019	-106.66051	78 rgsm
TPA23-042	8-Sep-23	seine hauls	393.7	35.08971	-106.68176	81 rgsm
TPA23-043	8-Sep-23	seine hauls	394.6	35.09539	-106.68898	124 rgsm
TPA23-053	10-Oct-23	seine hauls	364.5	34.81726	-106.71198	193 rgsm

Appendix B:
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, two weeks apart, covering a total sampling period of five weeks. Sampling began on September 11 and concluded October 12. On the first day, sub-reaches 1 and 2 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. In 2023, RGSM were abundant and we chose not to tag other species of fish. All RGSM captured were >30 mm in length and VIE tagged.

Fish were marked with a unique VIE color in one of several locations, allowing movement among sub-reaches to be inferred. We used orange VIE for sampling trip 1 and yellow 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 (i.e., no fish were double-tagged with the same color and position 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.

Additionally, we examined mortality due to handing and marking. We collected 90 RGSM and tagged 50 with VIE. All fish were held in the same mesh cage, approximately 1-m by 1-m and placed in a pool approximately 0.6 m deep. We held fish for 3 days and counted mortalities.

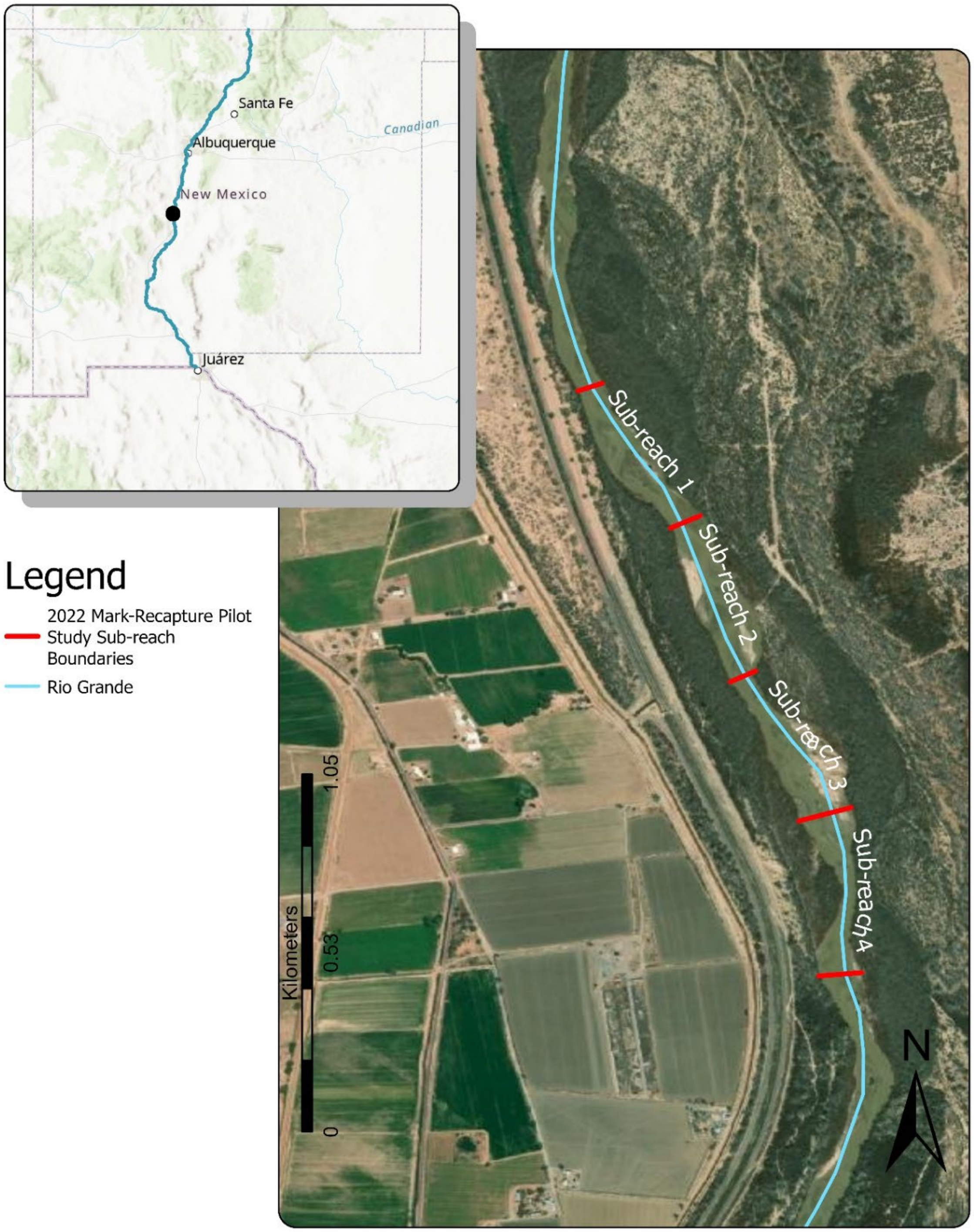

Figure 3- Map depicting the location of the 2023 mark-recapture study and the division of the sub-reaches along the 1.6 km long reach that was assessed.

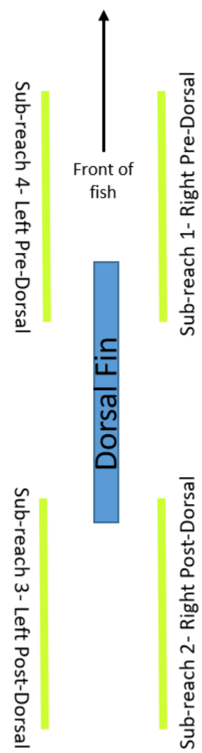

Figure 4- Location of visible implant elastomer (VIE) marks used during the study to indicate the sub-reach where the fish was captured.

Results, Discussion, and Recommendations

Compared to 2022, many fish were captured in total. We did not attempt to count other species after the first pass. Among 4 total marking passes (640 seine hauls), we collected 2,861 RGSM. No fish were marked in the fifth and final pass, and we collected one additional 738 Rio Grande Silvery Minnow. All Rio Grande Silvery Minnow were large enough to be marked. Summary of capture histories are given Table 1.

The number of target species may allow use of mark-recapture models. Despite capturing three orders of magnitude more fish in 2023, the length of stream and number of seine hauls is reasonable to sample in a 4-day sampling period. Unfortunately, recaptures were still relatively low. Potentially, shortening the time interval between marking events may increase the number of recaptures, as our results make it evident that capture probability*availability is low, fish are moving among segments and likely out of the study area, and we are increasing mortality by handling fish. We observed 5% mortality in unmarked fish during the cage study, whereas marked fish had 16% mortality. Moving sampling dates to later in September may also improve handling survival as fish appeared to be in markedly better physical condition in October samples.

Table 1-Frequency of mark-recapture histories for batch-marked Rio Grande Silvery Minnow in September and October of 2023. Fish were captured in four contiguous 400-m sections of the Middle Rio Grande during two marking periods (T1 and T2) with two passes each (P1 and P2), and one recapture period sampled with a single pass (T3). Cell number indicate in which of the four sections fish were marked and recaptured.

T1.P1	T1.P2	T2.P1	T2.P2	T3	Frequency
1	0	0	0	0	138
2	0	0	0	0	177
3	0	0	0	0	155
4	0	0	0	0	126
0	1	0	0	0	118
0	2	0	0	0	174
0	3	0	0	0	216
0	4	0	0	0	198
0	0	1	0	0	216
0	0	2	0	0	309
0	0	3	0	0	135
0	0	4	0	0	181
0	0	0	1	0	179
0	0	0	2	0	159
0	0	0	3	0	135
0	0	0	4	0	163
0	0	0	0	2	199
0	0	0	0	3	203
0	0	0	0	4	169
0	0	0	0	0	149
1	1	0	0	0	1
1	2	0	0	0	1
1	3	0	0	0	1
1	4	0	0	0	1
1	0	1	0	0	1
1	0	0	1	0	1
1	0	0	4	0	2

1	0	0	0	2	1
2	0	0	2	0	1
2	0	0	4	0	2
2	0	0	0	1	1
3	1	0	0	0	1
3	3	0	0	0	5
3	0	3	0	0	1
3	0	4	0	0	1
4	4	0	0	0	4
0	0	1	1	0	8
0	0	1	3	0	2
0	0	1	0	1	1
0	0	2	3	0	2
0	0	2	4	0	1
0	0	2	0	1	1
0	0	3	3	0	1
0	0	3	0	3	2
0	0	3	0	4	2
0	0	0	4	4	1

Streamflow was relatively stable among sampling periods (Figure 3). However, a small flow pulse occurred between time period 1 and 2. Number of fish captured remained similar, but fish may have redistributed during flow increases (Franssen), reducing the number of recaptures. Accounting for movement during lower, stable flows will be critical to determining fish turnover due to movement during floods. Our primary recommendation for 2024 is to condense sampling to consecutive weeks and begin in autumn to improve survival and recapture. 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.

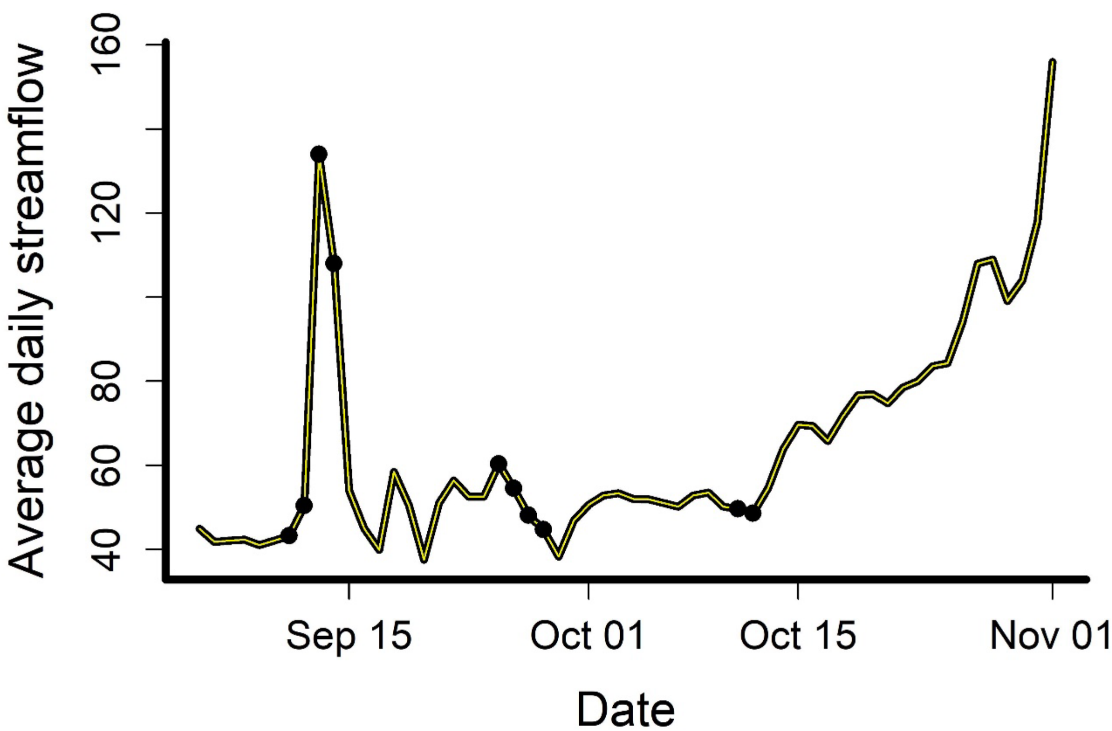

Figure 3-Streamflow (cfs) at the Escondida gage (U.S.G.S. gage 08355050) during the mark-recapture study period in the Middle Rio Grande, 2023. Points indicate days sampling occurred.

Acknowledgments

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