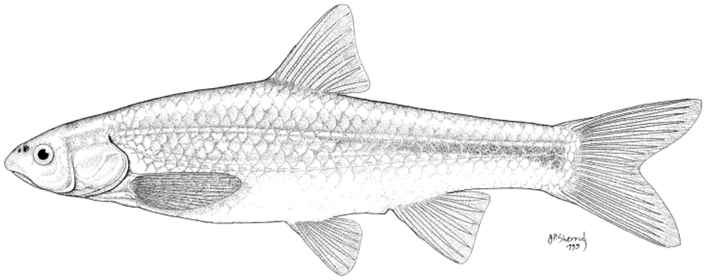
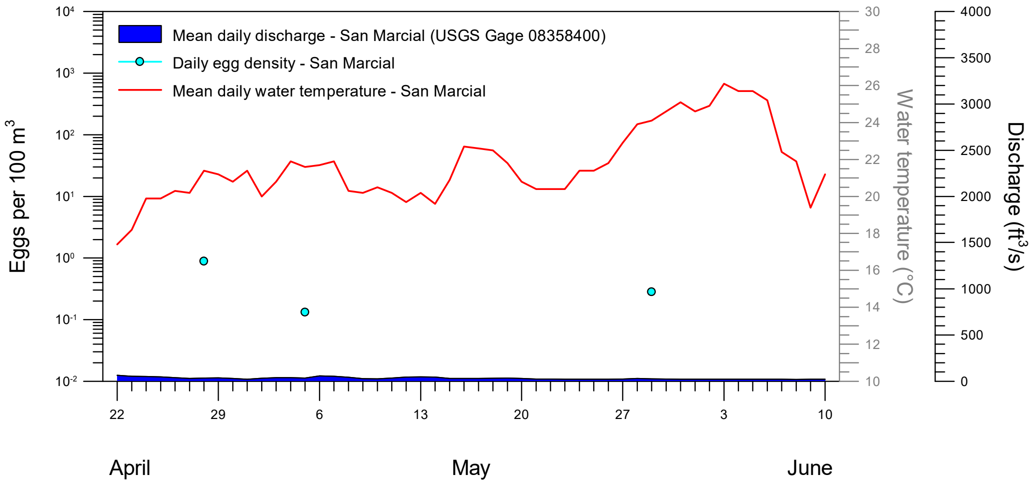
# *Rio Grande Silvery Minnow Reproductive Monitoring during 2020*

## *A U.S. Bureau of Reclamation Funded Research Program*





Final Report

30 September 2020

# RIO GRANDE SILVERY MINNOW REPRODUCTIVE MONITORING DURING 2020

## A U.S. BUREAU OF RECLAMATION FUNDED RESEARCH PROGRAM

**Contract R17PC00033:**

**Requisition 0040483557**
U.S. Bureau of Reclamation
Albuquerque Area Office
555 Broadway NE, Suite 100
Albuquerque, NM 87102

Submitted to:

U.S. Bureau of Reclamation
Albuquerque Area Office
555 Broadway NE, Suite 100
Albuquerque, NM 87102

Robert K. Dudley[1,2], Tessia O. Robbins[1], Steven P. Platania[1,2], and Gary C. White[1,3]

[1] American Southwest Ichthyological Researchers (ASIR); 800 Encino Place NE; Albuquerque, NM 87102
&
[2] Museum of Southwestern Biology (Fishes), Biology, UNM; MSC03-2020; Albuquerque, NM 87131
&
[3] Fish, Wildlife, and Conservation Biology, CSU; 10 Wagar; Fort Collins, CO 80523

Final Report
30 September 2020

# TABLE OF CONTENTS

# LIST OF TABLES

*Appendix B*

## LIST OF FIGURES

# EXECUTIVE SUMMARY

The primary objectives of the Rio Grande Silvery Minnow Reproductive Monitoring Program are to characterize the timing, duration, frequency, and magnitude of spawning for this species in the Angostura, Isleta, and San Acacia reaches of the Middle Rio Grande. Additional objectives include characterizing reach-specific spawning patterns over time; examining the relationships between flow, temperature, and spawning; and assessing linkages between egg passage rates and seasonal flows across years. This long-term monitoring study provides insight into key environmental factors affecting trends in the temporal and spatial spawning patterns of Rio Grande Silvery Minnow, which can assist managers in developing successful strategies for its recovery.

Systematic reproductive monitoring of Rio Grande Silvery Minnow has been conducted annually since 2001. Previous studies demonstrated mid-April to mid-June as the primary period of spawning activity. The 2020 study was a continuation of the long-term monitoring effort in the lower portion of the San Acacia Reach (San Marcial), just upstream of Elephant Butte Reservoir. Two additional sites (one in the Angostura Reach [Albuquerque] and one in the Isleta Reach [Sevilleta]), which had been sampled periodically from 2006 to 2011, were also sampled from 2017 to 2020.

In 2020, we collected drifting eggs from three fish species. Most of the eggs were identified as Rio Grande Silvery Minnow (n = 19,213), some were identified as Common Carp (n = 272), and a few were identified as Flathead Chub (n = 8). Eggs from all three species were collected at the Albuquerque and Sevilleta sites, whereas only Rio Grande Silvery Minnow eggs (n = 5) were collected at the San Marcial site.

Reproductive monitoring of Rio Grande Silvery Minnow was reinitiated at the Albuquerque and Sevilleta sites in 2017, which allowed for spatial comparisons of estimated egg-passage rates ($E(x)$; eggs per second) across years (2006–2011, 2017–2020). Overall, the annual passage rates at Sevilleta and San Marcial were consistently higher than at Albuquerque, with the notable exception of the near absence of eggs at San Marcial in 2018 and 2020. We estimated that 5,478,329 eggs, 44,104,215 eggs, and 1,026 eggs were transported downstream of Albuquerque, Sevilleta, and San Marcial, respectively, during the 2020 sampling season (i.e., 22 April to 10 June).

Long-term spawning patterns and trends (2003–2020) were based solely on data collected at San Marcial, as that was the only site consistently sampled since the initiation of this study. Logistic regression modeling of daily egg presence-absence data from San Marcial revealed strong associations with the percentage change in mean daily discharge (i.e., independent of flow magnitude) just prior to egg collection. The probability of collecting eggs (i.e., daily egg-occurrence probability) was highest when river flows increased substantially across consecutive days. The occurrence probability during a 100% increase in flow was 0.79, whereas the occurrence probability was 0.96 during a 200% increase in flow. Although not as robust as the discharge relationships, daily egg presence-absence data also revealed associations with mean daily water temperature during the study period. The occurrence probability declined with increasing water temperature, ranging from 0.55 (13°C) to 0.22 (27°C).

Annual egg-passage rates, using San Marcial data (2003–2020), were highest in 2011 ($4.22 \cdot 10^{1}$) and lowest in 2020 ($2.37 \cdot 10^{-4}$). There was a steady decline in passage rates from 2011 to 2013, followed by an increase in 2014. Passage rates declined again from 2014 ($7.40 \cdot 10^{0}$) to 2016 ($1.43 \cdot 10^{-1}$). The 2019 and 2020 passage rates ($1.87 \cdot 10^{-2}$ and $2.37 \cdot 10^{-4}$, respectively) were lower than the 2017 rate.

Changes in annual egg-occurrence probabilities and annual egg-passage rates, using San Marcial data, were moderately predicted by differences in seasonal river flows across years (2003–2020). Out of 196 models considered, we found that the top three models, which represented high flows during spring, were most informative (ca. 52% of cumulative model weight) in explaining why some years had lower passage rates (i.e., reduced downstream transport) than others. In summary, we found that occurrence probabilities were slightly higher during years with reduced and truncated spring flows, and that passage rates were slightly lower during years with elevated and extended spring flows.

Despite the seemingly large number of eggs, and presumably larvae, transported downstream into the southern reaches of the Middle Rio Grande each year, some portion of this reproductive effort remains upstream. It is likely that the proportion of individuals retained and successfully recruited upstream is related to the complexity of instream habitat conditions and the availability of nursery habitats. The availability of floodplain habitat could be particularly important, as these areas are likely

locations for the increased retention of drifting fish eggs and larvae. As the successful growth and survival of this species, from the egg phase through the early larval phases, requires about one month, the long-term persistence of these nursery habitats seems essential during this initial developmental period. The future conservation status and recovery of Rio Grande Silvery Minnow appears strongly dependent on reliably ensuring appropriate seasonal flow and habitat conditions that will promote the successful spawning and early recruitment of this imperiled species.

# INTRODUCTION

The Rio Grande between Cochiti Dam and Elephant Butte Reservoir (Middle Rio Grande) has been greatly modified over the last 50 years; this has alternatively led to aggradation, degradation, armoring, and narrowing of the river channel in different portions of this area (Lagasse 1980; Massong et al. 2006). This section of the river flows through the massive Rio Grande rift and historically resulted in a wide floodplain within the sparsely vegetated Rio Grande valley. Extensive braiding of the river through the relatively linear Rio Grande rift valley was common as it flowed over shifting sand and alluvium substrata; flow in the Middle Rio Grande was generally perennial except during times of severe or extended drought (Scurlock 1998).

Historically, the Middle Rio Grande was relatively shallow throughout most of the year because of regionally low precipitation levels (Gold and Denis 1985) but was subjected to periods of high discharge. Flows were generally highest during the annual spring snowmelt runoff (April–June). However, intense localized rainstorms (monsoonal events that generally occur in July and August) often caused severe flooding and were important for maintaining perennial flow throughout the summer. The cyclic pattern of drought and flooding over mobile substrata likely helped to promote the active interaction between the river and its floodplain. Historically, the Middle Rio Grande would have been characterized as a dynamic semiarid river ecosystem.

The reduced species diversity typical of semiarid ecosystems was also reflected in the relatively depauperate ichthyofaunal composition of the Middle Rio Grande (Platania 1991; Platania 1993; Hoagstrom et al. 2010). Despite the reduced overall species richness of the Rio Grande, the river supported numerous native cyprinids that were endemic to this drainage (Platania and Altenbach 1998). However, many of the endemic pelagic-spawning cyprinids that historically occupied the Rio Grande Basin have been extirpated from large portions of their range (Speckled Chub, *Macrhybopsis aestivalis* and Rio Grande Shiner, *Notropis jemezanus*) or have become extinct (Phantom Shiner, *Notropis orca* and Rio Grande Bluntnose Shiner, *Notropis simus simus*) over the past century (Bestgen and Platania 1990). Rio Grande Silvery Minnow, *Hybognathus amarus*, is the only extant pelagic-spawning cyprinid in the Middle Rio Grande (Bestgen and Platania 1991; Platania 1991) and is federally protected as an endangered species (USDOI 1994).

This group of pelagic-spawning cyprinids shared several key life-history characteristics. All were small and short-lived fishes that occupied mainstem habitats. In addition to these shared traits, all five species are members of a reproductive guild of pelagic-spawning fishes (Platania and Altenbach 1998). These fishes spawn non-adhesive eggs that rapidly swell with water and become semibuoyant. Spawning is generally associated with increases in discharge, such as spring runoff or summer rainstorms. The eggs expand from about 1.6 mm to 3.0 mm in diameter shortly after spawning and are passively transported by water currents, to some extent, during development. Eggs usually hatch within one to three days in the warm water temperatures (ca. 20–25°C) typically observed during the spawning season (Platania 2000). Recently hatched larval fish may be subject to additional passive transport for several days (ca. 3–5 days) until development of the gas bladder.

The time necessary for propagules to attain the developmental phase necessary to control their horizontal movements allows for potentially considerable downstream transport of eggs and larvae in the Middle Rio Grande. As has been well documented for other aquatic organisms, it is necessary for some portion of the drifting propagules to settle in appropriate nearby low-velocity habitats or move upstream, as juveniles or adults, to maintain viable populations (Speirs and Gurney 2001). Downstream transport distance of Rio Grande Silvery Minnow progeny is dependent on a variety of factors including flow magnitude and duration, water temperature, and channel morphology (Dudley and Platania 2007). Historically, there were no permanent barriers to upstream dispersal of fishes in the Middle Rio Grande. However, two large dams (Cochiti and Elephant Butte), along with three smaller dams (Angostura, Isleta, and San Acacia), now prevent the upstream movement of fishes and fragment the once continuous range of Rio Grande Silvery Minnow. Although it is unknown how far Rio Grande Silvery Minnow might disperse if unimpeded, VIE-marked adults dispersed over 25 km upstream to the base of San Acacia Diversion Dam within a few months (Platania et al. 2019).

Systematic monitoring of the reproduction of Rio Grande Silvery Minnow was first conducted in 1999 and included sampling in all three reaches of the Middle Rio Grande (Platania and Dudley 2000).

This preliminary, yet extensive, monitoring effort involved quantifying the occurrence and density of eggs from nine sites; spawning was documented from late March to late June of 1999. Limited egg collecting efforts were also conducted at selected sites in the Middle Rio Grande (Platania and Hoagstrom 1996) and in the Low Flow Conveyance Channel (Smith 1998, 1999) from 1996 to 1999.

A long-term monitoring effort was initiated in 2001 to document reproduction by Rio Grande Silvery Minnow in the San Acacia Reach, near the downstream terminus of its range (Platania and Dudley 2002). Sampling also occurred at this site from 2002 to 2004 (Platania and Dudley 2003, 2004, 2005), but sampling did not occur in 2005. Additional monitoring efforts were conducted from 2006 to 2008 (Platania and Dudley 2006, 2007, 2008) in the Angostura, Isleta, and San Acacia reaches. Although monitoring ceased from 2009 to 2016 in the Angostura Reach and from 2012 to 2016 in the Isleta Reach, annual monitoring continued in the San Acacia Reach throughout this period (2009–2016). Consistent reproductive monitoring efforts, for all three reaches, were reinitiated in 2017 and continued into 2020.

The primary objectives of the Rio Grande Silvery Minnow Reproductive Monitoring Program are to characterize the timing, duration, frequency, and magnitude of spawning for this species in the Angostura, Isleta, and San Acacia reaches of the Middle Rio Grande. Additional objectives include characterizing reach-specific spawning patterns over time; examining the relationships between flow, temperature, and spawning; and assessing linkages between egg passage rates and seasonal flows across years. This long-term monitoring study provides insight into key environmental factors affecting trends in the temporal and spatial spawning patterns of Rio Grande Silvery Minnow, which can assist managers in developing successful strategies for its recovery.

## STUDY AREA

The principal area of interest for this study is the reach between the outflow of Cochiti Reservoir and the inflow to Elephant Butte Reservoir; this area encompasses the contemporary range of Rio Grande Silvery Minnow in the Middle Rio Grande (Figure 1). Several large dams and numerous irrigation diversion dams regulate flow in this area. Cochiti Dam has been operational since 1973 and is the primary flood control structure that regulates flows in the Middle Rio Grande. Reach names were taken from the diversion structure at the upstream boundary of each fragmented river reach. There was one sampling site in the Angostura Reach (Angostura Diversion Dam to Isleta Diversion Dam), one site in the Isleta Reach (Isleta Diversion Dam to San Acacia Diversion Dam), and one site in the San Acacia Reach (San Acacia Diversion Dam to Elephant Butte Reservoir).

The reproductive effort of Rio Grande Silvery Minnow has been periodically monitored at a wide variety of collecting localities in the Middle Rio Grande from 1996 to 2020. However, consistent and long-term sampling efforts (2001–2020) have only been conducted in the downstream-most portion of the San Acacia Reach. The San Acacia Reach of the Middle Rio Grande is about 64 miles (102 km) long, extending from the apron of San Acacia Diversion Dam to the inflow to Elephant Butte Reservoir. A wide and braided river channel, sand/silt substrata, high sediment load, and a broad variety of aquatic mesohabitats characterize sections of this reach. Conversely, some segments in this reach are relatively narrow and result in increased water velocity and decreased habitat heterogeneity. The reach of the Rio Grande downstream of San Marcial Railroad bridge crossing is confined to a channel that is frequently less than 50 m wide. Braiding of the channel is uncommon except under conditions of relatively low flow.

Given the downstream drift of eggs, long-term collecting activities have consistently been conducted near the terminus of the San Acacia Reach (San Marcial [UTM: 305552 E; 3711984 N; NAD83]), just upstream of Elephant Butte Reservoir, to maximize the number of eggs collected and to inform local egg rescue efforts. This site was downstream of a U.S. Geological Survey stream gaging station located near San Marcial, New Mexico (# 08358400). In addition to easy accessibility and favorable river conditions (e.g., current being carried through a single river channel, gently sloped banks, and moderate gradient), the only means of vehicle access to this site was gated (i.e., increased safety). This area has been sampled annually from 2001 to 2004 and from 2006 to 2020.

From 2017 to 2020, two additional sites were monitored that had been sampled periodically in the past (i.e., 2006–2011). These sampling sites were located in the downstream portions of the Angostura and Isleta reaches. In the Angostura Reach, the sampling site (Albuquerque [UTM: 346277 E; 3874723 N; NAD83]) was located in the same area that was consistently sampled from 2006 to 2008. In the Isleta Reach, the sampling site (Sevilleta [UTM: 330099 E; 3794552 N; NAD83]) was located in the same area that was consistently sampled from 2006 to 2011. However, we sometimes sampled slightly downstream (UTM: 329063 E; 3794288 N; NAD83) during the highest flows, primarily because of safety concerns. These two additional sites not only allowed for a more detailed assessment of spatial spawning patterns but also enabled direct comparisons across monitoring sites over time.

Discharge patterns, throughout the Middle Rio Grande, were drastically different between 2019 and 2020 (Figure 2). In 2019, there was a large and sustained late spring runoff followed by highly variable seasonal flow pulses. In 2020, flows were uniformly low throughout the study area and dropped dramatically from April to June at downstream locations. In both 2019 and 2020, there was a general trend of lower flow at downstream locations (e.g., U.S. Geological Survey (USGS) San Acacia Gage [#08354900] and USGS San Marcial Gage [#08358400]) as compared to upstream locations (e.g., USGS Albuquerque Gage [#08330000]). Flow conditions in 2019 began to peak in late April and remained elevated throughout May and June. In contrast, there was no spring runoff peak observed during 2020, although several minor flow pulses occurred periodically. As compared with the generalized historical spring runoff (i.e., average mean-daily discharges since 1973 [i.e., Cochiti Dam operational]), the timing, duration, and magnitude of this event were relatively typical in 2019 and markedly atypical in 2020. All discharge data presented in this report are provisional and subject to change.

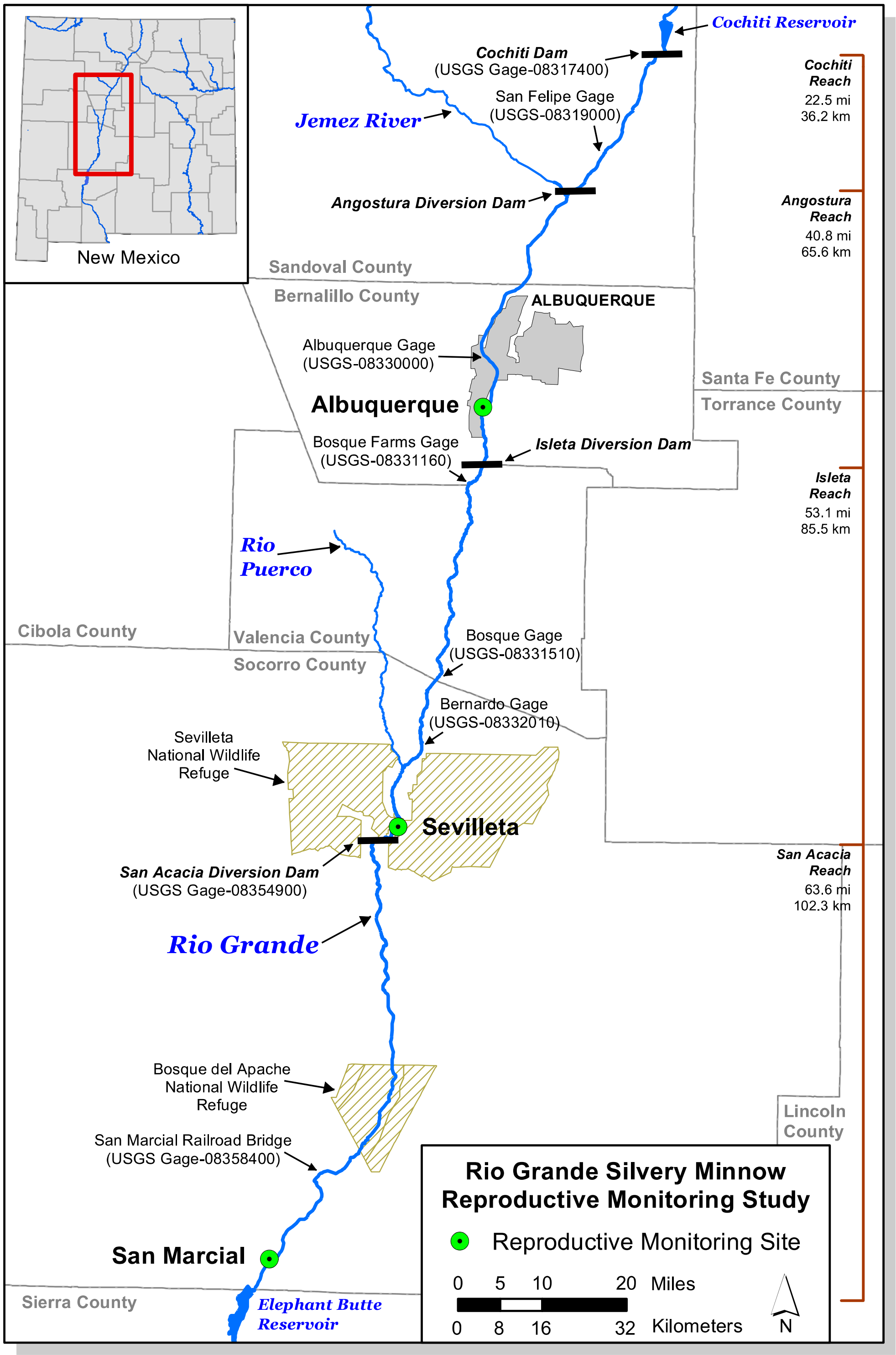


Figure 1. Map of the study area and sampling sites for the Rio Grande Silvery Minnow reproductive monitoring study.

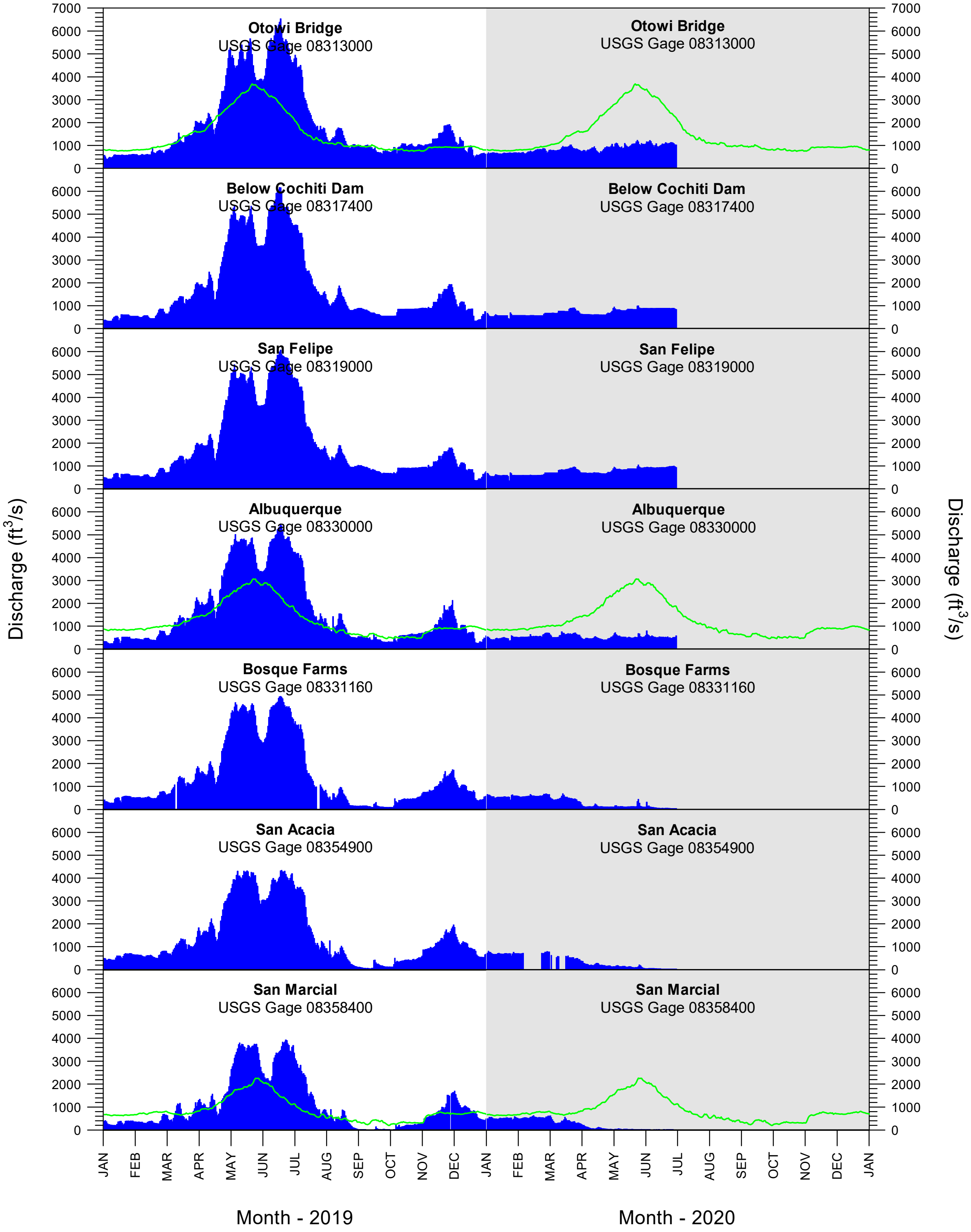


Figure 2. Rio Grande mean-daily discharge, by U.S. Geological Survey (USGS) gaging station, from January 2019 to June 2020. Green lines are the average mean-daily discharges across years (1973–2019).

# METHODS

## *Sampling Equipment*

Temperature-logging devices (Onset [Hobo TidbiT v2]) were mounted to posts in deep water, near the middle of the water column, to record hourly temperatures at each study site. Two loggers (i.e., primary and backup) were set at each site to safeguard against possible data loss and to help ensure overall data integrity. These data loggers have a high level of accuracy (± 0.2°C), from 0°C to 50°C, and their stability (drift) is about 0.1°C per year (Onset Computer Corporation 2019); we limited their use to five years. If data loggers became buried in the substrata or were no longer submerged in the water column, corrective measures were taken to relocate them to a more suitable location. Upon retrieval, temperature data were thoroughly reviewed and compared (i.e., primary vs. backup) to identify any unusual readings (e.g., excessive stability indicating burial or excessive variability indicating exposure). Invalid data were not included in subsequent analyses.

The egg-collecting device, developed specifically for the collection of large numbers of live and undamaged semibuoyant fish eggs (Moore Egg Collector; MEC [Altenbach et al. 2000]), was the only sampling apparatus used in this study. Numerous modifications have been made to the collecting gear, since the original publication detailing the construction and operation of the MEC (Altenbach et al. 2000), which have resulted in increased efficiency of the original MEC (i.e., greater volume of water sampled). A modified filtering screen to separate drifting debris from Rio Grande Silvery Minnow eggs was developed and tested for the MEC in 2009. Experimental tests revealed that the modified screen was more efficient at sampling a larger volume of water than was the old screen, but that the egg density estimates were very similar (Platania and Dudley 2009). Thus, all MECs have been fitted with the modified screen since 2009. All MEC sampling was conducted in flowing portions of the river channel, typically within five meters of the shoreline.

The amount of water sampled was determined by using mechanical flowmeters, which were attached to all MECs (i.e., two MECs per site). Whenever flowmeters malfunctioned (e.g., debris entanglement, jammed gears, etc.), readings were estimated based on an average of the most concurrent, proximal, and reliable flowmeters at a site. We calculated the linear distance ($L$; m) traveled by water flowing through the MECs for each daily sample, based on the flowmeter counts ($C$), the rotor conversion factor ($F$), and a correction constant (General Oceanics, Inc. 2019), using the formula: $L = (C \cdot F) / 999{,}999$. We then computed the total volume of water sampled ($V$; $m^3$), based on $L$ and the area ($A$; $m^2$) of the MEC mouth opening, using the formula: $V = L \cdot A$. The total number of eggs collected during each sample ($n$), relative to the total volume of water sampled, was used to estimate the daily density of drifting eggs ($D$; eggs per 100 $m^3$) at each site, using the formula: $D = ((n / V) \cdot 100)$.

## *Fish Egg Identification*

When the number of eggs collected was too numerous to accurately count in the field, those samples were preserved in 5% buffered formalin, labeled with the appropriate field number, and accessioned into the Division of Fishes (Museum of Southwestern Biology, UNM). Also, large numbers of live eggs were periodically transferred to the Albuquerque Biological Park for their ongoing captive propagation program. No live or preserved eggs were staged (i.e., determining approximate time from spawning), as this would require substantial laboratory work outside of the current objectives of this study. However, all preserved eggs were sorted and enumerated in the laboratory after the field portion of the study. Similarly, any eggs that could not be identified in the field were retained for identification. In 2020, 13,032 Rio Grande Silvery Minnow eggs were retained live, and all were transferred to the Albuquerque Biological Park. No eggs were retained for identification in 2020.

## *Analytical Considerations*

Rio Grande Silvery Minnow egg density values are dependent on flow conditions, thereby precluding unadjusted comparisons of interannual densities. For example, higher flow volume will result in lower density, assuming the number of eggs in the water column remains constant. Sampled daily egg densities (*D*) were standardized to sampled egg-passage rates ($P_e$; eggs per second) based on mean daily discharges ($Q$; $m^3/s$) to account for these differences, using $P_e = ((D / 100) \cdot Q)$. Discharge values were taken from the nearest upstream gaging station for the three sampling sites (i.e., Albuquerque: USGS Gage #08330000, Sevilleta: USGS Gage #08331510 and #08332010, and San Marcial: USGS Gage #08358400). At Sevilleta, we used USGS Gage #08331510 from 2006 to 2011 and USGS Gage #08332010 from 2012 to 2020 because of the limited availability of upstream gaging data over time for the Isleta Reach.

Volumetric determination of the number of eggs collected, as employed in 2001, lacked the rigor necessary to evaluate the relative level of spawning. Changes initiated in the 2002 sampling protocol (e.g., direct counts of all eggs collected) were instituted to increase the rigor of the data acquired from this study. However, the continuous sampling protocols employed in 2002, during peak spawning events, were not used in subsequent years. The data collected in 2002 were also highly skewed, making them less suitable for computing a valid estimate of $E(x)$ (described below). These issues precluded the use of data from 2001 or 2002 for comparison with data from subsequent years. Similarly, any supplemental sampling efforts from 2003 to 2020 (e.g., collecting additional eggs solely for captive propagation or documenting peak-spawning events at night) were excluded from subsequent statistical analyses. We also excluded data from San Marcial in 2018 from all analyses, as extended drying bisected the San Acacia Reach, resulting in only pumped water from the Low Flow Conveyance Channel flowing in the lower portion of that reach. Also, flows in 2018 never exceeded 30 $ft^3/s$ at San Marcial during the study period; more suitable spawning flows occurred only after the termination of sampling. Further, we used the most common sampling period (22 April to 10 June), across all three sites over time, for all statistical analyses.

### *Statistical Analyses*

#### *Logistic regression*

Logistic regression (i.e., based on the binomial distribution) was used to determine how the probability of collecting eggs (i.e., daily egg-occurrence probability), based on daily egg presence-absence data from the San Acacia Reach (2003–2020), changed as a function of different river flows or water temperatures. We chose the San Acacia Reach for this long-term analysis because sampling in the upstream reaches (i.e., Angostura and Isleta) did not begin until 2006 and was characterized by extended annual gaps prior to 2017. The percentage change in mean daily discharge (i.e., independent of flow magnitude) at the San Marcial gage, from two days to one day prior to egg collection at the San Marcial site, was used in the first analysis. This duration was chosen to allow adequate time for the discharge changes occurring at the upstream river gage to reach the sampling site, which was about 21 km downstream of the gage. This delay also incorporated time for Rio Grande Silvery Minnow to both sense and respond to the presumed environmental stimuli associated with changing flows (e.g., aquatic habitats and water quality). Thus, we felt this delayed flow metric best represented the changing environmental conditions that occurred just prior to egg collection. A second analysis was conducted to assess how the daily egg-occurrence probability changed as a function of mean daily water temperature during the sampling period. The associated 95% confidence intervals of the regression lines were constructed using inverse predictions (JMP 2013) of discharge and temperature across the range of modeled occurrence probabilities. The likelihood ratio chi-square statistic ($G^2$; JMP 2013) was calculated to evaluate whether the fitted model (i.e., based on discharge or temperature) was significantly different ($P < 0.05$) from the model with equal occurrence probabilities.

#### *Mixture models*

Mixture models (e.g., combining a binomial distribution with a lognormal distribution) are particularly effective for modeling zero-inflated data (White 1978; Welsh et al. 1996; Fletcher et al. 2005; Martin et al. 2005) and for evaluating the effects of environmental covariates on population parameters.

Long-term Rio Grande Silvery Minnow spawning data (2003–2020) from all three sites were analyzed using PROC NLMIXED (Nonlinear Mixed Models; SAS 2020), a more advanced numerical optimization procedure that retains the key features of PROC FMM (Finite Mixture Models; SAS 2020), by fitting a mixture model consisting of the binomial distribution (i.e., based on presence-absence data) and the lognormal distribution (i.e., based on natural logarithms of nonzero data). We implemented this robust ecological modeling approach to quantitatively assess the effects of environmental variables on trends in occurrence probabilities and passage rates for Rio Grande Silvery Minnow eggs. Logistic regression was used to estimate the annual egg-occurrence probability, and a lognormal model (based on nonzero values of $P_e$) was used to estimate the annual lognormal egg-passage rate based on nonzero data (Appendix A). Numerical optimization of the models provided four estimates ($\delta$ = estimated egg-occurrence probability, $\mu$ = estimated lognormal egg-passage rate, $\sigma$ = standard deviation of the estimated lognormal egg-passage rate, and $E(x)$ = estimated egg-passage rate) for each year (i.e., sampling season). Values of $E(x)$ could not be computed, however, when only a single nonzero value was recorded (i.e., precluding mixture-model estimation of $\sigma$). Naïve passage-rate estimates, computed using the method of moments (Zar 2010), were also added as a reference to all applicable figures. Finally, the number of eggs passing each site, during the 50-day sampling season (i.e., 22 April to 10 June), was estimated ($E(x)_{50d}$) by using the formula: $E(x)_{50d} = E(x) \cdot 86{,}400 \text{ s} \cdot 50 \text{ d}$.

Generalized linear models were based on environmental covariates (i.e., independent variables) and population parameter estimates ($\delta$, $\mu$, and $\sigma$ [i.e., dependent variables]) for the San Acacia Reach (2003–2020), where a logit link was used for $\delta$, an identity link for $\mu$, and a log link for $\sigma$. Upstream reaches were not included in these long-term analyses because of the extended annual gaps in sampling at the Albuquerque and Sevilleta sites prior to 2017. Further, considering the downstream drift of eggs, the San Acacia Reach was most representative of the range-wide reproductive effort across years. In the simplest case with no covariates and no random effects, the mixture-model structure can be considered a zero-inflated lognormal model for estimated egg-passage rates. In all analyses, a categorical covariate for sampling year (Year) was included to represent the maximum variation attributable to time effects. As no other time-effects model can explain all the variation, the Year (or global) model ($\delta$[Year] $\mu$[Year]) represents the upper limit on the amount of explainable variation and the null model ($\delta$[.] $\mu$[.]) represents the lower limit of that variation. Additionally, all nested environmental covariates (e.g., spring flows) varied across Year and were assessed individually as to their effectiveness in explaining the total time-specific variation of the population parameters (i.e., ecological models).

Environmental covariates considered for modeling spawning data included various hydrological metrics based on data from USGS Gage #08358400 (SAN; Rio Grande Floodway at San Marcial, NM). Maximum discharge (SANmax), mean discharge (SANmean), and days exceeding threshold discharge values (days > 500 [SAN>500], 1,500 [SAN>1,500], and 2,500 [SAN>2,500] $\text{ft}^3/\text{s}$) were covariates that represented different spring runoff conditions (22 April to 10 June). A modeled covariate (Inundation), that represented the total estimated inundation of the river floodplain, was based on an average of the five highest flow days in May (USACE 2010); models of recent conditions (2000–2009) were used to estimate inundation since 2010. Fixed-effects models for each covariate were generalized linear models with the corresponding link function. These fixed effects assume that variation in the data is explained by the covariate (Appendix B [Table B - 1]). For $\delta$, there is no over-dispersion or extra-binomial variation, and for $\mu$, no extra variation provided beyond the constant $\sigma$ model. Random-effects models (*R*) were also considered for $\delta$ and $\mu$ to provide additional variation around the fitted line, where a normally-distributed random error with mean zero, and nonzero standard deviation, was used to explain deviations around the fitted covariates. All random effects were integrated out of the likelihood (Pinheiro and Bates 1995) during model fitting.

Goodness-of-fit statistics (logLike = –2[log-likelihood] and $\text{AIC}_c$ = Akaike's information criterion [Akaike 1973] for finite sample sizes) were generated to assess the relative fit of data to various mixture models across all sampling years. Lower values of $\text{AIC}_c$ indicate a better fit of the data to the model. Models were ranked by $\text{AIC}_c$ values, and the top ten models, based on $\text{AIC}_c$ weight ($w_i$), were presented. As nested environmental covariates were only used individually to model the population parameters (i.e., no additive effects), potential issues of multicollinearity were avoided. Further, $\text{AIC}_c$ model selection ranks single-variable models appropriately, even if variables are highly correlated (i.e., resulting $w_i$ values would be similar). An analysis of deviance (ANODEV) was used to determine the relative proportion of deviance in logLike values explained by the environmental covariates, for both $\delta$ and $\mu$ models, and to assess whether that proportion was significantly different from zero ($P < 0.05$) based on an *F*-test (Skalski et al. 1993).

# RESULTS

## *Fish Egg Identification (2020)*

During 2020, all eggs (n = 19,493) were immediately identified in the field as Rio Grande Silvery Minnow, Common Carp, *Cyprinus carpio*, or Flathead Chub, *Platygobio gracilis*. Most of the eggs were identified as Rio Grande Silvery Minnow (n = 19,213), some were identified as Common Carp (n = 272), and a few were identified as Flathead Chub (n = 8). Eggs from all three species were collected at the Albuquerque and Sevilleta sites, whereas only Rio Grande Silvery Minnow eggs (n = 5) were collected at the San Marcial site. Common Carp and Flathead Chub eggs were collected primarily from early to mid-May. Their eggs were smaller (1.5–2.5 mm diameter) than Rio Grande Silvery Minnow eggs (ca. 3–4 mm diameter); Common Carp eggs were smallest and often had a slight amount of fine particulate matter adhered to the chorion (i.e., surface of egg). Also, their perivitelline space (i.e., non-yolk portion of egg) was slightly opaque (Flathead Chub) to very opaque (Common Carp), and the yolk occupied most of the space within the egg (i.e., small perivitelline space).

## *Spatial Spawning Patterns*

### *Recent comparisons (2020)*

Sampling at the Albuquerque, Sevilleta, and San Marcial sites was conducted from 22 April to 10 June 2020 (Appendix C). The cumulative volume of water sampled was highest at Albuquerque, followed by Sevilleta, and San Marcial (51,419.1 $m^3$, 36,131.0 $m^3$, and 31,403.1 $m^3$, respectively). Rio Grande Silvery Minnow eggs were collected from all three sites in 2020 (Table 1 and Figure 3). The three sites cumulatively yielded 19,213 Rio Grande Silvery Minnow eggs; most were collected at Sevilleta (n = 16,940) and very few were collected at San Marcial (n = 5). Although the timing, duration, magnitude, and frequency of spawning varied across sites, the highest numbers of eggs were typically collected during peak flows that occurred from early May to early June. Also, mean daily water temperatures, during peak spawning events, were relatively similar across sites (ca. 17–26°C).

### *Long-term comparisons (2006–2020)*

Based on the most common sampling period (22 April to 10 June), we compared spawning metrics (Tables 2–4) and estimated egg-passage rates ($E(x)$; generated from the year model ($\delta$[Year] $\mu$[Year])) across years at the Albuquerque, Sevilleta, and San Marcial sites (Figure 4 and Table 5). Interannual trends in passage rates, and relationships with seasonal flows, were relatively similar across sites (Figures 4 and 5), with some notable exceptions. For example, estimates were higher ($P < 0.05$) in 2007, as compared with 2006, at Sevilleta and San Marcial but not at Albuquerque. After a multiyear decline, passage rates at both Sevilleta and San Marcial were higher ($P < 0.05$) in 2011 than in 2010. Although there were no clear passage-rate trends at Albuquerque or Sevilleta since 2017, passage rates at San Marcial were lower ($P < 0.05$) in 2020 than in 2017 or 2019. Overall, the passage rates at Sevilleta and San Marcial were consistently higher than at Albuquerque, with the notable exception of the near absence of eggs at San Marcial in 2018 and 2020. The 2020 passage rate at San Marcial ($2.37 \cdot 10^{-4}$) was the lowest ever recorded at that site; the second lowest value was recorded in 2004 ($1.77 \cdot 10^{-3}$). Conversely, the 2020 passage rate at Albuquerque ($1.27 \cdot 10^{0}$) was the highest and that at Sevilleta ($1.02 \cdot 10^{1}$) the second highest ever recorded for those sites. We estimated ($E(x)_{50d}$) that 5,478,329 eggs, 44,104,215 eggs, and 1,026 eggs were transported downstream of Albuquerque, Sevilleta, and San Marcial, respectively, during the 2020 sampling season (i.e., 22 April to 10 June).

Table 1. Rio Grande Silvery Minnow egg abundance, by date and site, during 2020. Blank cells indicate days when it was not feasible to sample at a site.

| **Sampling Date** | **Albuquerque** | **Sevilleta** | **San Marcial** |
|---|---|---|---|
| 22-Apr-20 | 0 | 0 | 0 |
| 23-Apr-20 | 0 | 0 | 0 |
| 24-Apr-20 | 0 | 0 | 0 |
| 25-Apr-20 | 0 | 0 | 0 |
| 26-Apr-20 | 3 | 0 | 0 |
| 27-Apr-20 | 0 | 0 | 0 |
| 28-Apr-20 | 0 | 1 | 2 |
| 29-Apr-20 | 4 | 0 | 0 |
| 30-Apr-20 | 4 | 0 | 0 |
| 01-May-20 | 69 | 1 | 0 |
| 02-May-20 | 365 | 0 | 0 |
| 03-May-20 | 594 | 0 | 0 |
| 04-May-20 | 145 | 2 | 0 |
| 05-May-20 | 69 | 27 | 1 |
| 06-May-20 | 8 | 5 | 0 |
| 07-May-20 | 0 | 0 | 0 |
| 08-May-20 | 2 | 0 | 0 |
| 09-May-20 | 0 | 0 | 0 |
| 10-May-20 |  | 0 | 0 |
| 11-May-20 | 0 | 0 | 0 |
| 12-May-20 | 0 | 0 | 0 |
| 13-May-20 | 0 | 0 | 0 |
| 14-May-20 | 0 | 0 | 0 |
| 15-May-20 | 0 | 0 | 0 |
| 16-May-20 | 0 | 0 | 0 |
| 17-May-20 | 0 | 11 | 0 |
| 18-May-20 | 0 | 0 | 0 |
| 19-May-20 | 0 | 0 | 0 |
| 20-May-20 | 1 | 0 | 0 |
| 21-May-20 | 0 | 0 | 0 |
| 22-May-20 | 0 | 0 | 0 |
| 23-May-20 | 0 | 0 | 0 |
| 24-May-20 | 0 | 0 | 0 |
| 25-May-20 | 0 | 0 | 0 |
| 26-May-20 | 0 | 10,229 | 0 |
| 27-May-20 | 6 | 6,279 | 0 |
| 28-May-20 | 0 | 40 | 0 |
| 29-May-20 | 0 | 1 | 2 |
| 30-May-20 | 0 | 0 | 0 |
| 31-May-20 | 0 | 0 | 0 |
| 01-Jun-20 | 0 | 0 | 0 |
| 02-Jun-20 | 0 | 0 | 0 |
| 03-Jun-20 | 982 | 0 | 0 |
| 04-Jun-20 | 0 | 343 | 0 |
| 05-Jun-20 | 3 | 1 | 0 |
| 06-Jun-20 | 13 | 0 | 0 |
| 07-Jun-20 | 0 | 0 | 0 |
| 08-Jun-20 | 0 | 0 | 0 |
| 09-Jun-20 | 0 | 0 | 0 |
| 10-Jun-20 | 0 | 0 | 0 |
| **Total (eggs)** | **2,268** | **16,940** | **5** |

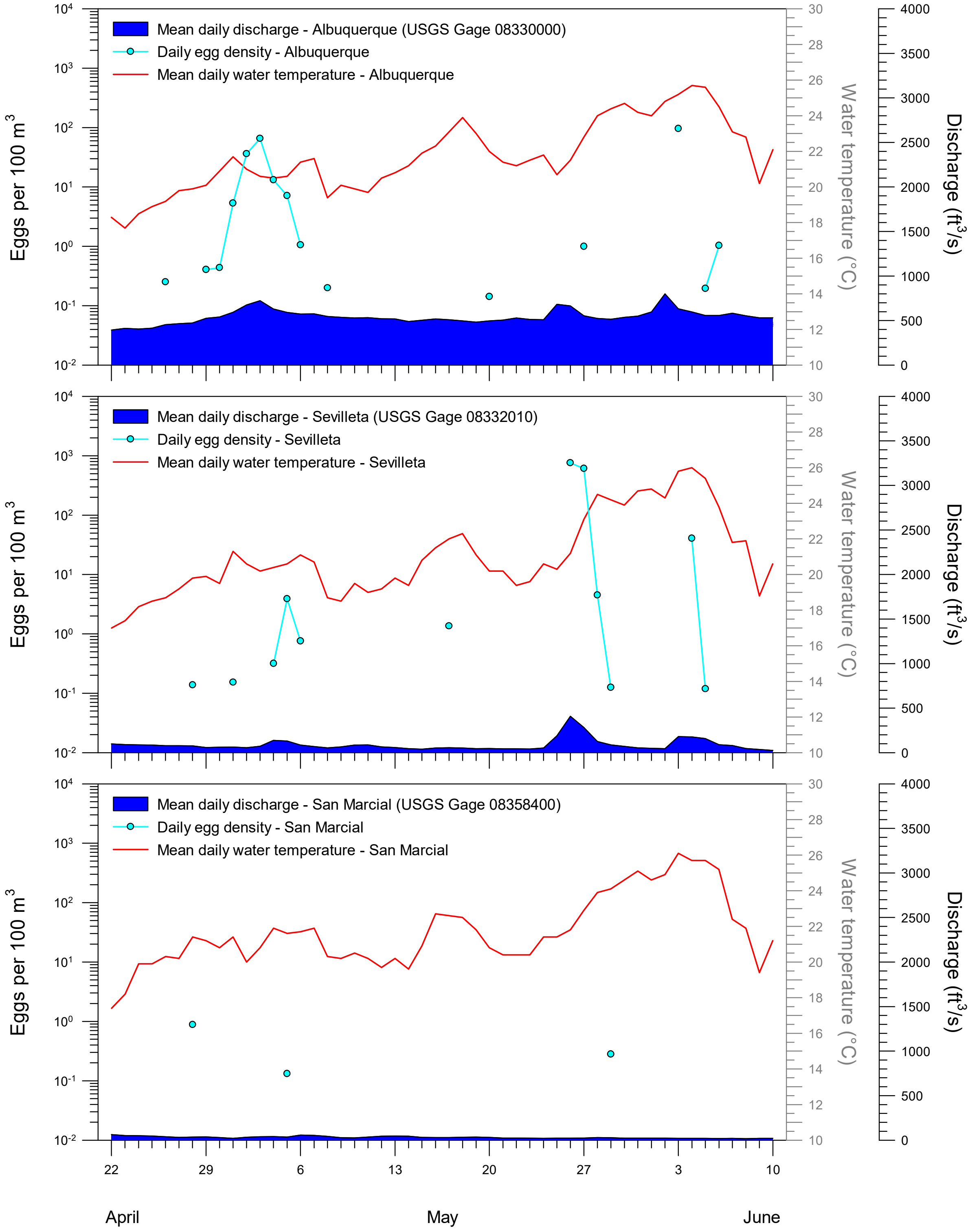


Figure 3. Mean daily discharge, daily egg density, and mean daily water temperature, by site and date, during 2020.

Table 2. Rio Grande Silvery Minnow spawning summary, using Albuquerque data (22 April to 10 June), across years.

| **Year**[1] | **Sampling Effort (days)** | **Eggs Present (days)** | **Eggs Absent (days)** | **Occurrence**[2] **(% freq.)** | **Abundance (eggs)** |
|---|---|---|---|---|---|
| 2006 | 40 | 14 | 26 | 35.0 | 1,067 |
| 2007 | 20 | 11 | 9 | 55.0 | 53 |
| 2008 | 33 | 14 | 19 | 42.4 | 62 |
| 2009 | | | | | |
| 2010 | | | | | |
| 2011 | | | | | |
| 2012 | | | | | |
| 2013 | | | | | |
| 2014 | | | | | |
| 2015 | | | | | |
| 2016 | | | | | |
| 2017 | 40 | 13 | 27 | 32.5 | 42 |
| 2018 | 50 | 19 | 31 | 38.0 | 4,164 |
| 2019 | 50 | 1 | 49 | 2.0 | 1 |
| 2020 | 49 | 15 | 34 | 30.6 | 2,268 |

[1] = Reproductive monitoring was not conducted at Albuquerque from 2009 to 2016.

[2] = Values based on the percentage of days when eggs were present relative to the sampling effort (days).

Table 3. Rio Grande Silvery Minnow spawning summary, using Sevilleta data (22 April to 10 June), across years.

| **Year**[1] | **Sampling Effort (days)** | **Eggs Present (days)** | **Eggs Absent (days)** | **Occurrence**[2] **(% freq.)** | **Abundance (eggs)** |
|---|---|---|---|---|---|
| 2006 | 48 | 19 | 29 | 39.6 | 1,479 |
| 2007 | 34 | 22 | 12 | 64.7 | 2,005 |
| 2008 | 34 | 17 | 17 | 50.0 | 1,917 |
| 2009 | 45 | 14 | 31 | 31.1 | 844 |
| 2010 | 38 | 22 | 16 | 57.9 | 222 |
| 2011 | 47 | 31 | 16 | 66.0 | 24,014 |
| 2012 | | | | | |
| 2013 | | | | | |
| 2014 | | | | | |
| 2015 | | | | | |
| 2016 | | | | | |
| 2017 | 40 | 25 | 15 | 62.5 | 247 |
| 2018 | 50 | 13 | 37 | 26.0 | 16,639 |
| 2019 | 44 | 3 | 41 | 6.8 | 59 |
| 2020 | 50 | 12 | 38 | 24.0 | 16,940 |

[1] = Reproductive monitoring was not conducted at Sevilleta from 2012 to 2016.

[2] = Values based on the percentage of days when eggs were present relative to the sampling effort (days).

Table 4. Rio Grande Silvery Minnow spawning summary, using San Marcial data (22 April to 10 June), across years.

| Year[1] | Sampling Effort (days) | Eggs Present (days) | Eggs Absent (days) | Occurrence[2] (% freq.) | Abundance (eggs) |
|---|---|---|---|---|---|
| 2003 | 37 | 18 | 19 | 486 | 13,293 |
| 2004 | 37 | 3 | 34 | 8.1 | 5 |
| 2005 | | | | | |
| 2006 | 46 | 15 | 31 | 32.6 | 6,022 |
| 2007 | 41 | 39 | 2 | 95.1 | 10,995 |
| 2008 | 41 | 3 | 38 | 7.3 | 155 |
| 2009 | 45 | 13 | 32 | 28.9 | 645 |
| 2010 | 37 | 15 | 22 | 40.5 | 364 |
| 2011 | 50 | 39 | 11 | 78.0 | 96,266 |
| 2012 | 42 | 18 | 24 | 42.9 | 12,398 |
| 2013 | 49 | 13 | 36 | 26.5 | 1,745 |
| 2014 | 44 | 24 | 20 | 54.5 | 9,726 |
| 2015 | 48 | 30 | 18 | 62.5 | 6,356 |
| 2016 | 50 | 20 | 30 | 40.0 | 481 |
| 2017 | 38 | 15 | 23 | 39.5 | 125 |
| 2018 | 50 | 1 | 49 | 2.0 | 1 |
| 2019 | 48 | 7 | 41 | 14.6 | 34 |
| 2020 | 50 | 3 | 47 | 6.0 | 5 |

[1] = Reproductive monitoring was not conducted at San Marcial in 2005.

[2] = Values based on the percentage of days when eggs were present relative to the sampling effort (days).

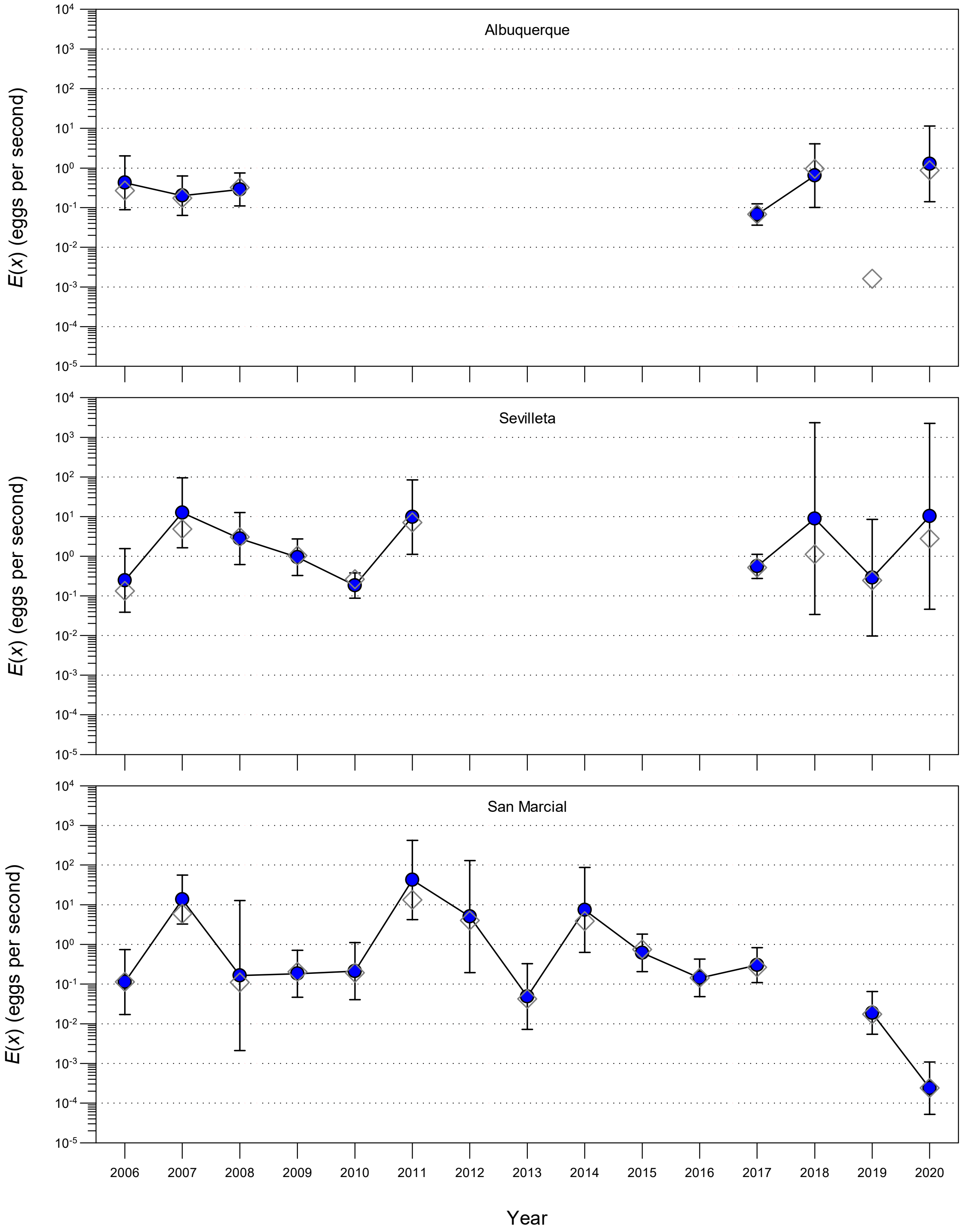


Figure 4. Rio Grande Silvery Minnow egg-passage rates ($E(x)$; estimated using 22 April to 10 June data) across sites and years. Modeled estimates (circles), 95% confidence intervals (bars), and method-of-moments estimates (diamonds) are illustrated.

Table 5. Rio Grande Silvery Minnow egg-passage rates *E*(*x*) and 95% confidence intervals (LCI–UCI), estimated using 22 April to 10 June data, across sites and years. Dashes (-) indicate instances when *E*(*x*) could not be computed, as only a single nonzero value was recorded (i.e., precluding mixture-model estimation of $\sigma$).

| **Year** | **Albuquerque[1]** | **Sevilleta[2]** | **San Marcial[3,4]** |
|---|---:|---:|---:|
| 2003 | | | 1.82 (0.16–20.24) |
| 2004 | | | $1.77 \cdot 10^{-3}$ ($4.63 \cdot 10^{-4}$–$6.78 \cdot 10^{-3}$) |
| 2005 | | | |
| 2006 | 0.43 (0.09–2.04) | 0.25 (0.04–1.56) | 0.11 (0.02–0.74) |
| 2007 | 0.20 (0.06–0.63) | 12.48 (1.64–94.85) | 13.52 (3.26–56.10) |
| 2008 | 0.29 (0.11–0.75) | 2.78 (0.61–12.56) | 0.16 ($2.11 \cdot 10^{-3}$–12.73) |
| 2009 | | 0.95 (0.33–2.74) | 0.18 (0.05–0.71) |
| 2010 | | 0.18 (0.09–0.38) | 0.21 (0.04–1.11) |
| 2011 | | 9.74 (1.12–84.58) | 42.23 (4.25–419.40) |
| 2012 | | | 5.04 (0.19–130.55) |
| 2013 | | | 0.05 (0.01–0.33) |
| 2014 | | | 7.40 (0.63–87.47) |
| 2015 | | | 0.61 (0.21–1.82) |
| 2016 | | | 0.14 (0.05–0.42) |
| 2017 | 0.07 (0.04–0.13) | 0.56 (0.28–1.12) | 0.30 (0.11–0.82) |
| 2018 | 0.64 (0.10–4.09) | 8.87 (0.03–$2.33 \cdot 10^{3}$) | |
| 2019 | - | 0.29 (0.01–8.54) | 0.02 (0.01–0.06) |
| 2020 | 1.27 (0.14–11.36) | 10.21 (0.05–$2.25 \cdot 10^{3}$) | $2.37 \cdot 10^{-4}$ ($5.23 \cdot 10^{-5}$–$1.08 \cdot 10^{-3}$) |

[1] = Reproductive monitoring was not conducted at Albuquerque prior to 2006 or from 2009 to 2016.

[2] = Reproductive monitoring was not conducted at Sevilleta prior to 2006 or from 2012 to 2016.

[3] = Reproductive monitoring was not conducted at San Marcial in 2005.

[4] = Reproductive monitoring at San Marcial in 2018 was excluded from analyses (see Methods).

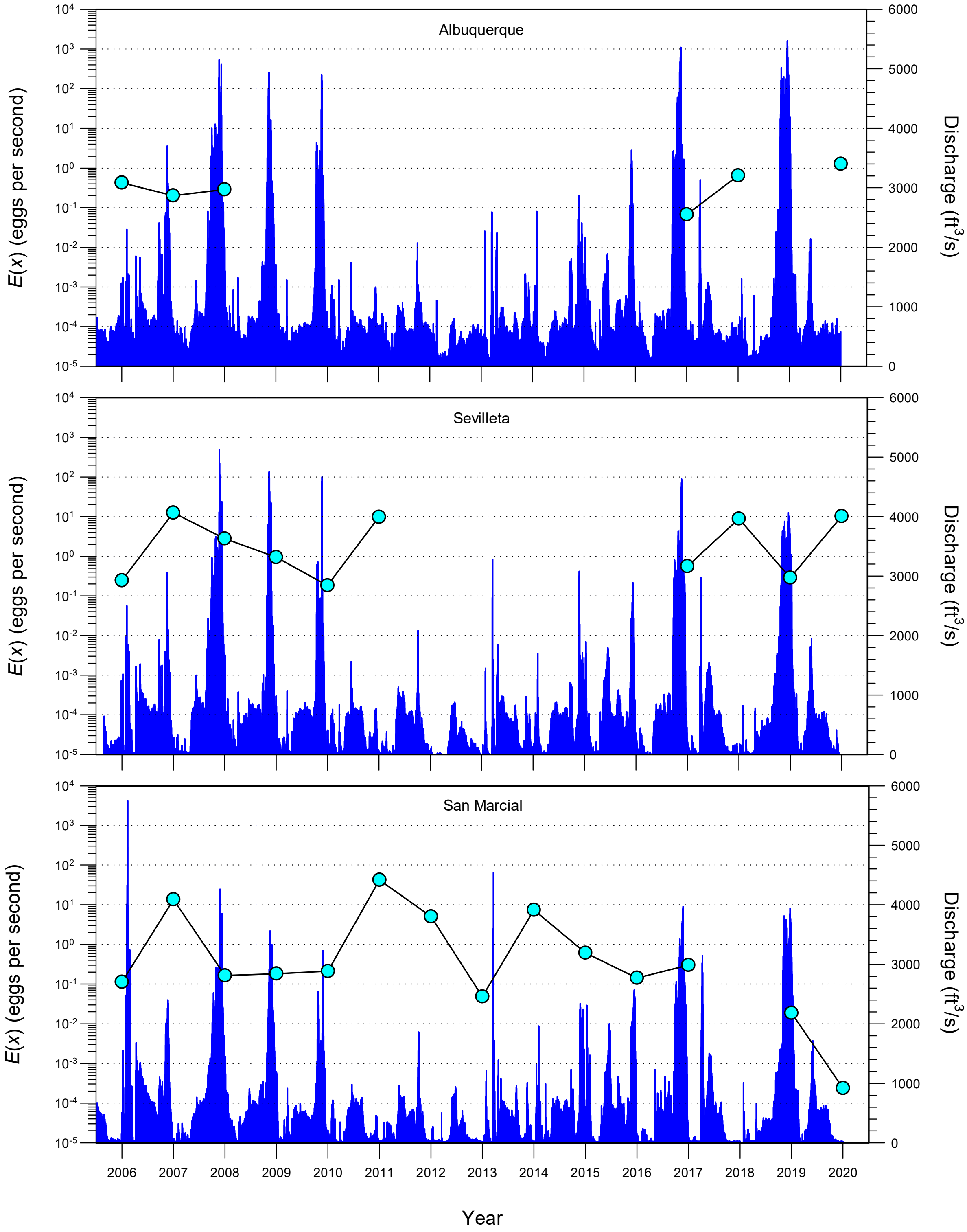


Figure 5. Rio Grande Silvery Minnow egg-passage rates (*E*(*x*); estimated using 22 April to 10 June data), and mean daily discharge data (Albuquerque, Bosque/Bernardo, and San Marcial gages; see Methods), across sites and years.

### *Ecological Relationships (San Marcial)*

#### *Spawning cues (2003–2020)*

Logistic regression modeling of Rio Grande Silvery Minnow daily egg presence-absence data for San Marcial (2003–2020) revealed strong associations with the percentage change in mean daily discharge (i.e., independent of flow magnitude) just prior to egg collection ($G^2 = 34.87$ and $P < 0.001$; Figure 6). Flows used to calculate the percentage change in discharge (Δ), which formed the basis of the modeled results, ranged from 15 to 4,260 $\text{ft}^3$/s. The probability of collecting eggs (i.e., daily egg-occurrence probability) ranged from 0.17 (Δ discharge = - 50%) to 0.35 (Δ discharge = 0%) during periods of declining or stable flows, respectively. The occurrence probability increased rapidly up to about a 100% increase in flow, but then began to level off. The occurrence probability during a 100% increase in flow was 0.79, whereas the occurrence probability was 0.96 during a 200% increase in flow.

Although not as robust as the discharge relationships, daily egg presence-absence data (San Marcial; 2003–2020) also revealed associations with mean daily water temperature during the study period ($G^2 = 10.82$ and $P = 0.001$; Figure 7). The egg occurrence probability steadily decreased from 0.55 at a minimum observed temperature of 13°C to 0.22 at a maximum observed temperature of 27°C. However, there was less certainty in estimated values (i.e., broader confidence intervals) at the cooler or warmer water temperatures.

#### *Spawning dynamics (2003–2020)*

Rio Grande Silvery Minnow annual egg-passage rates ($E(x)$), estimated using San Marcial data from 22 April to 10 June (2003–2020), revealed notable differences across years (Figure 8). Passage rates were highest in 2011 ($4.22 \cdot 10^{1}$) and lowest in 2020 ($2.37 \cdot 10^{-4}$). There was a steady decline ($P < 0.05$) in passage rates from 2011 to 2013, followed by an increase ($P < 0.05$) in 2014. Passage rates declined again ($P < 0.05$) from 2014 ($7.40 \cdot 10^{0}$) to 2016 ($1.43 \cdot 10^{-1}$). The 2019 and 2020 passage rates ($1.87 \cdot 10^{-2}$ and $2.37 \cdot 10^{-4}$, respectively) were lower ($P < 0.05$) than the 2017 rate. Naïve passage-rate estimates, computed using the method of moments, were very similar to model-estimated passage rates ($E(x)$). Combining a plot of $E(x)$ values and mean daily discharge data (2003–2020) revealed a long-term recurrent pattern of reduced passage rates during years with higher spring flows (Figure 9). Values of $E(x)$ decreased slightly with maximum discharge, number of days with discharge exceeding a threshold value, estimated acres of inundation, and mean daily discharge (Figure 10).

Annual egg-occurrence probabilities ($\delta$) and annual lognormal egg-passage rates ($\mu$), estimated from the year model ($\delta$[Year] $\mu$[Year]), were also modestly associated with hydrological metrics across years (2003–2020). Values of $\delta$ generally decreased with higher spring flows (Figures 11 and 12), particularly at the highest flows. However, relationships between $\mu$ and the hydrological metrics were less clearly defined (Figures 13 and 14).

Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using San Marcial data, revealed that the variation in both $\delta$ and $\mu$ was moderately predicted by changes in hydrological metrics across years (2003–2020; Table 6). The top ecological model ($\delta$[SAN>2,500+*R*] $\mu$[SANmax+R]) received 28.8% of the $\text{AIC}_c$ weight ($w_i$) out of the 196 models considered. The top $\delta$ covariate (SAN>2,500) accounted for 14.0% of the deviance ($P = 0.15$) explained by the $\delta$(Year) model over the $\delta$(.) model. Similarly, we found no significant effects for SANmean (5.8%), SAN>1,500 (3.9%), Inundation (3.7%), SAN>500 (2.1%), or SANmax (1.5%). Further, the top $\mu$ covariate (SANmax) accounted for 21.1% of the deviance ($P = 0.03$) explained by the $\mu$(Year) model over the $\mu$(.) model. However, we found no significant effects for SANmean (18.2%), SAN>1,500 (16.8%), SAN>2,500 (15.2%), SAN>500 (14.5%), or Inundation (11.2%). The top three ecological models, which accounted for 52.0% of the cumulative $w_i$, were based on hydrological metrics representing elevated spring flows (e.g., SANmax). In summary, we found that occurrence probabilities ($\delta$) were slightly higher during years with reduced and truncated spring flows, that lognormal passage rates ($\mu$) were also weakly related to flows, and that passage rates ($E(x)$) were slightly lower during years with elevated and extended spring flows.

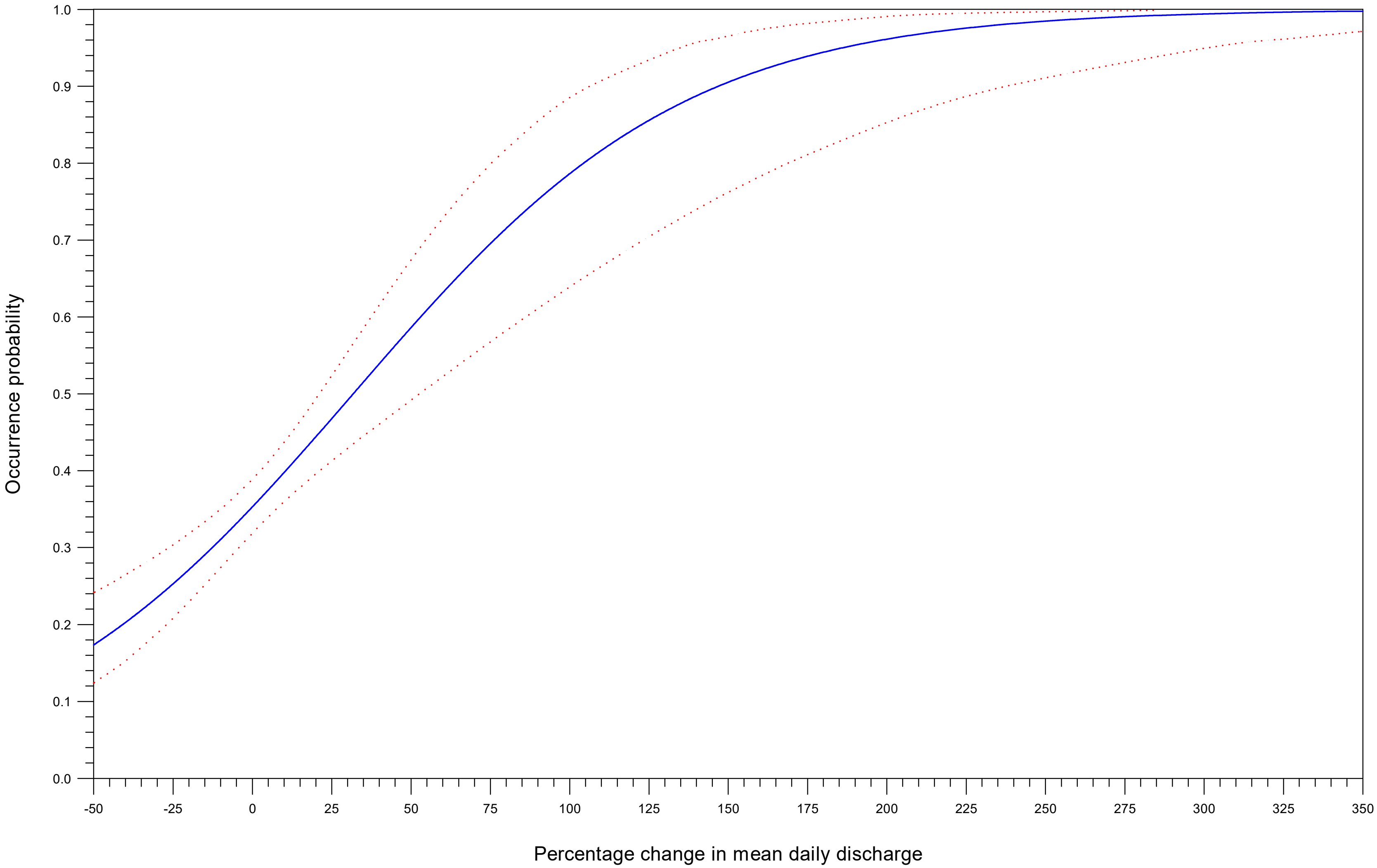


Figure 6. Logistic regression plot, using San Marcial data (22 April to 10 June; 2003–2020), illustrating Rio Grande Silvery Minnow daily egg-occurrence probability as a function of the percentage change in mean daily discharge. Logistic regression line (solid) and 95% confidence intervals (dotted) are illustrated.

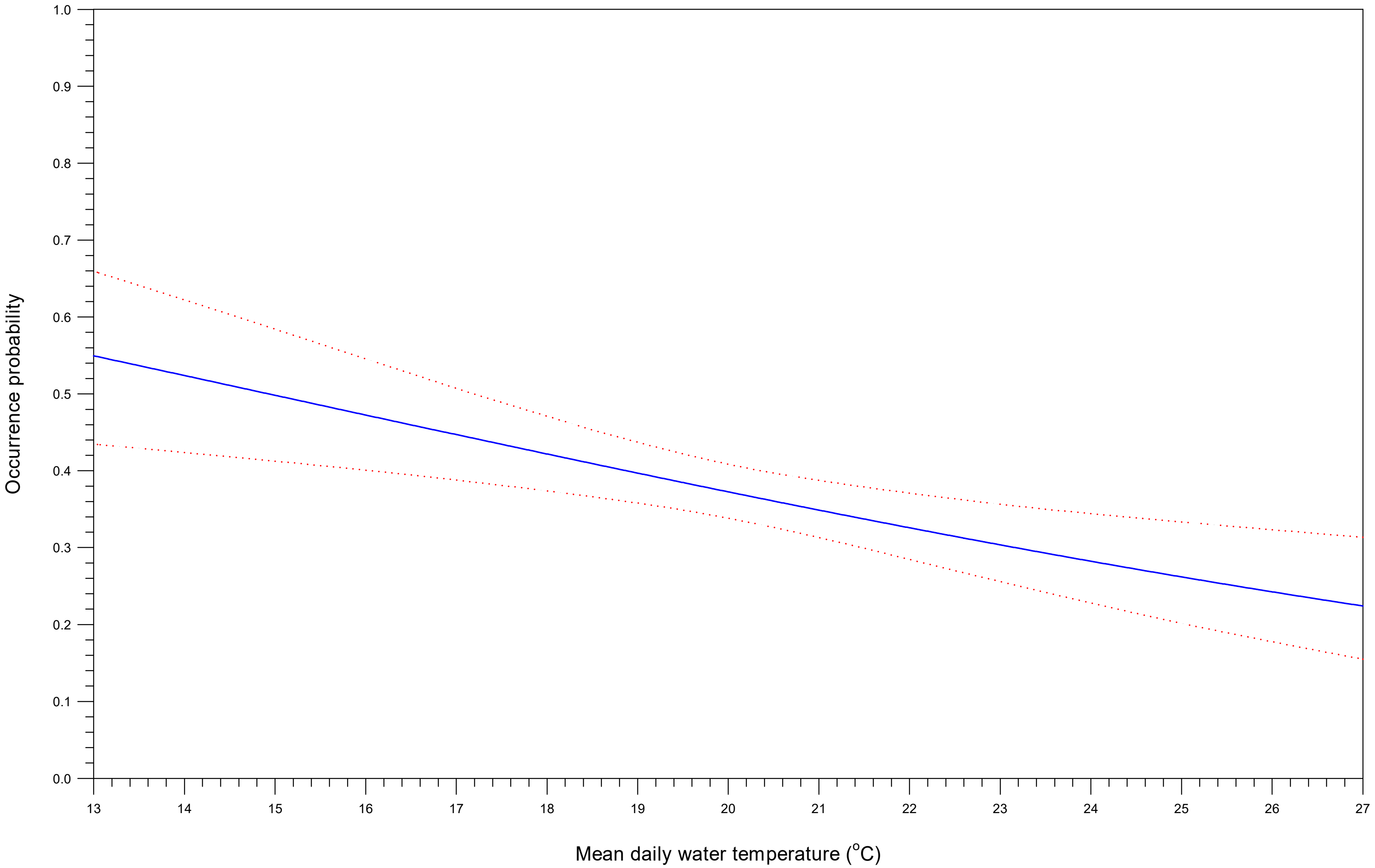


Figure 7. Logistic regression plot, using San Marcial data (22 April to 10 June; 2003–2020), illustrating Rio Grande Silvery Minnow daily egg-occurrence probability as a function of mean daily water temperature. Logistic regression line (solid) and 95% confidence intervals (dotted) are illustrated.

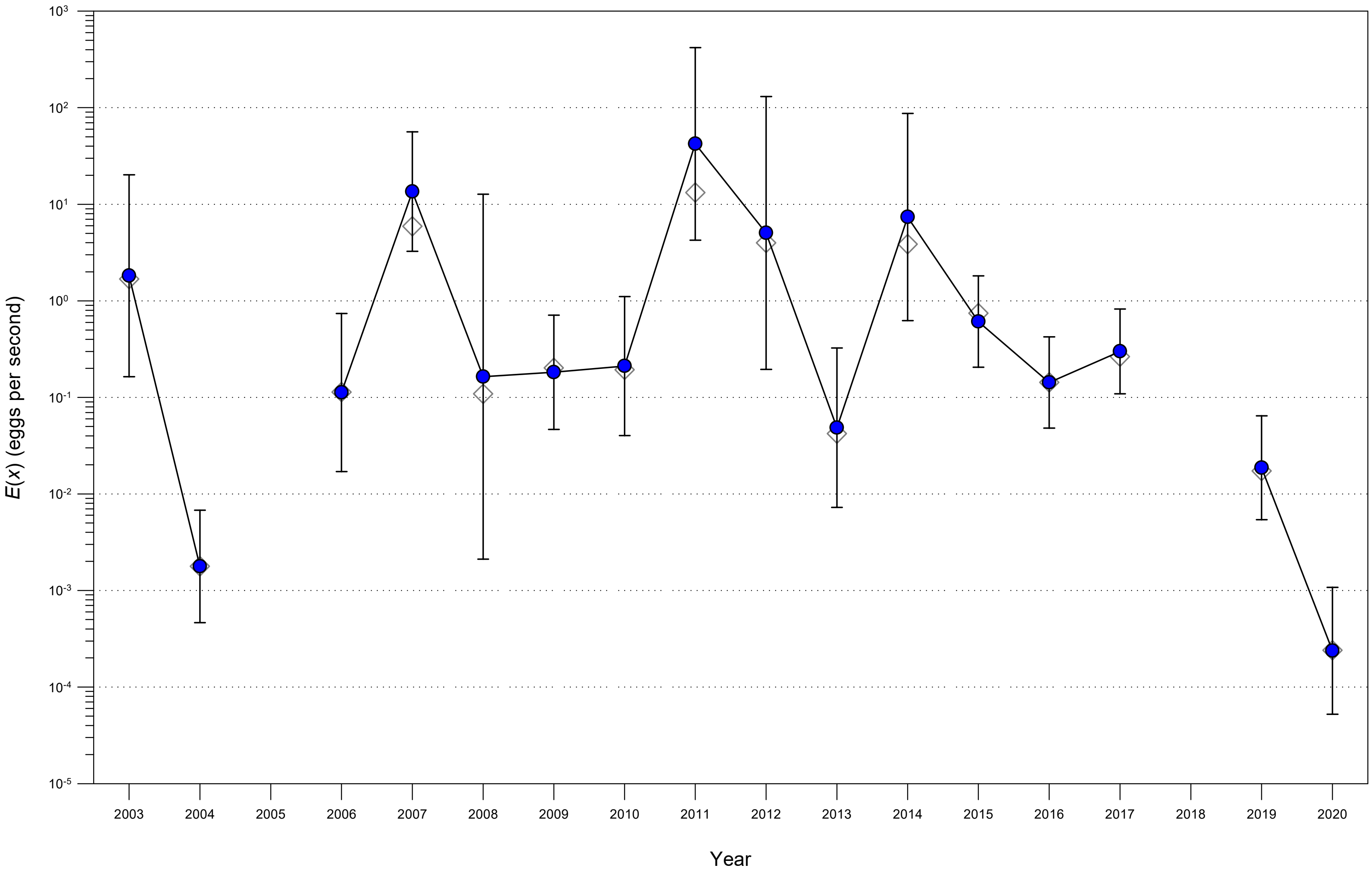


Figure 8. Rio Grande Silvery Minnow egg-passage rates (*E*(*x*); estimated using San Marcial data [22 April to 10 June]) across years. Sampling did not occur in 2005, and 2018 was excluded from analyses (see Methods). Modeled estimates (circles), 95% confidence intervals (bars), and method-of-moments estimates (diamonds) are illustrated.

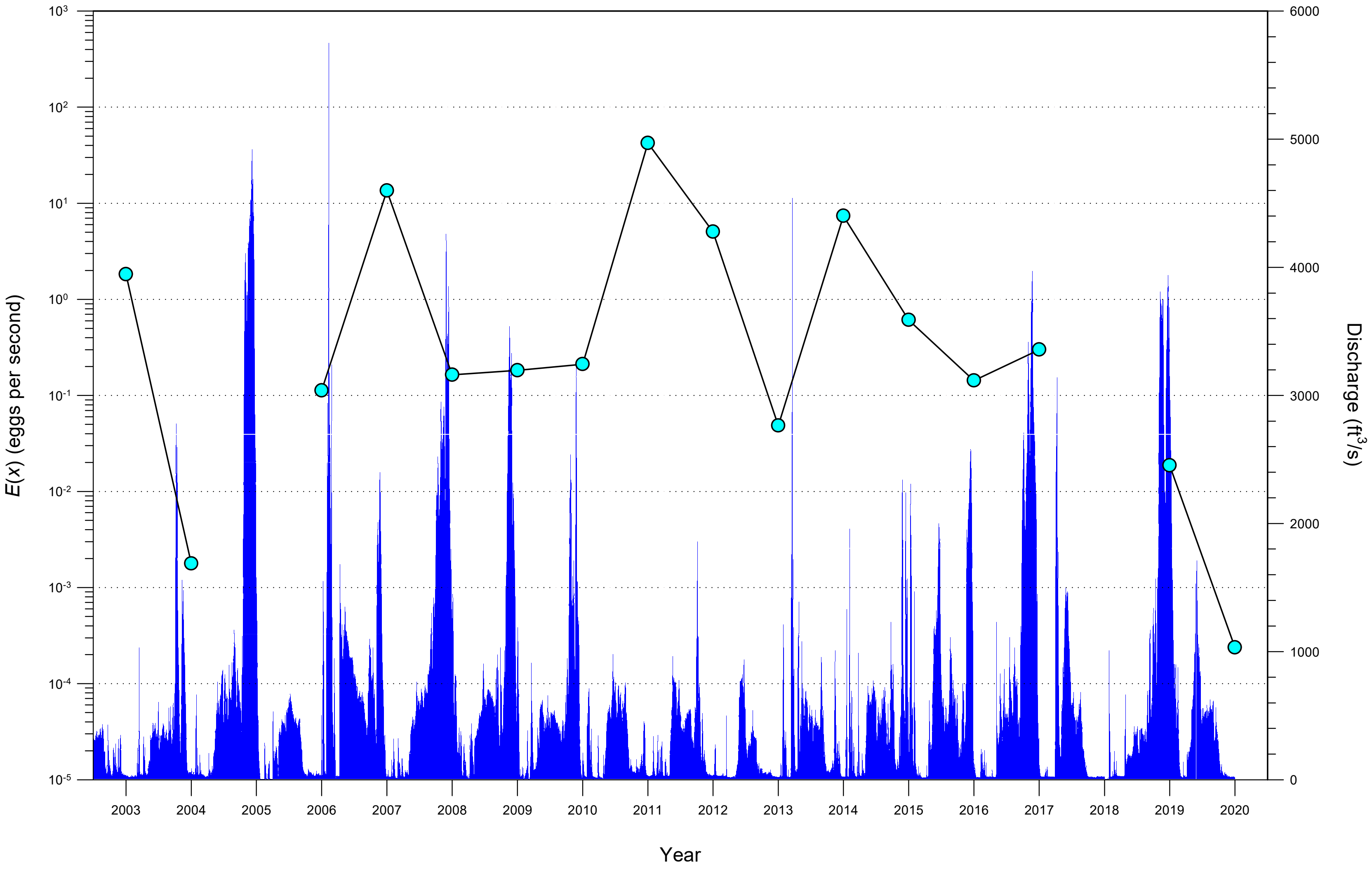


Figure 9. Rio Grande Silvery Minnow egg-passage rates ($E(x)$; estimated using San Marcial data [22 April to 10 June]), and mean daily discharge data from the San Marcial Gage, across years. Sampling did not occur in 2005, and 2018 was excluded from analyses (see Methods).

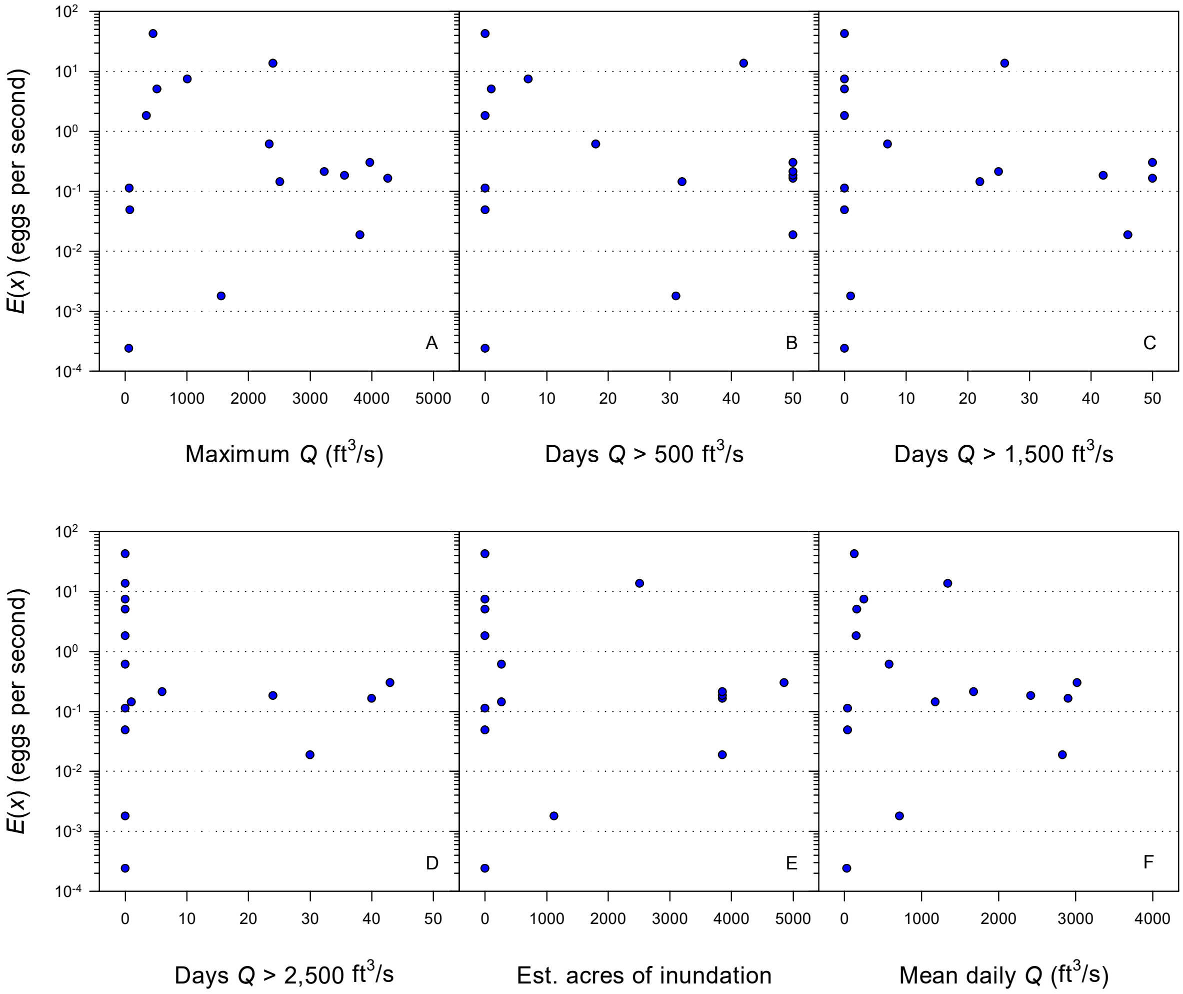


Figure 10. Bivariate plots of Rio Grande Silvery Minnow egg-passage rates (*E*(*x*); estimated using San Marcial data [22 April to 10 June]) and San Marcial Gage data.

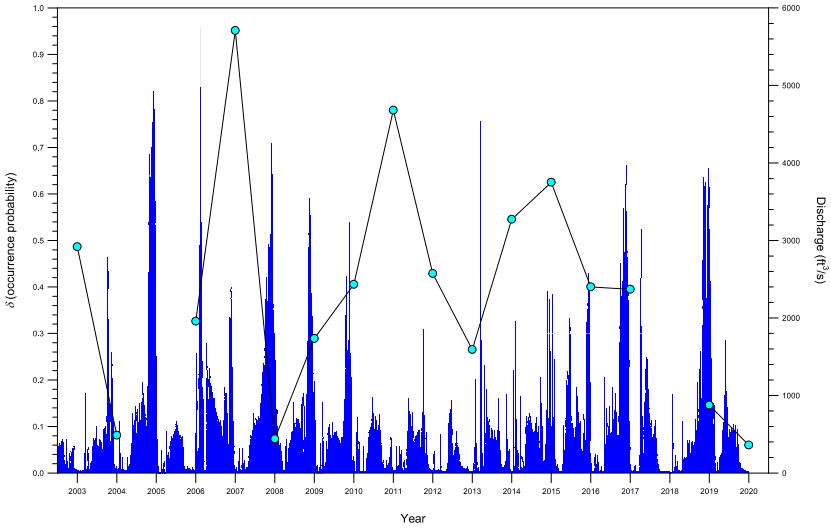


Figure 11. Rio Grande Silvery Minnow egg-occurrence probabilities ($\delta$ ; estimated using San Marcial data [22 April to 10 June]), and mean daily discharge data from the San Marcial Gage, across years. Sampling did not occur in 2005, and 2018 was excluded from analyses (see Methods).

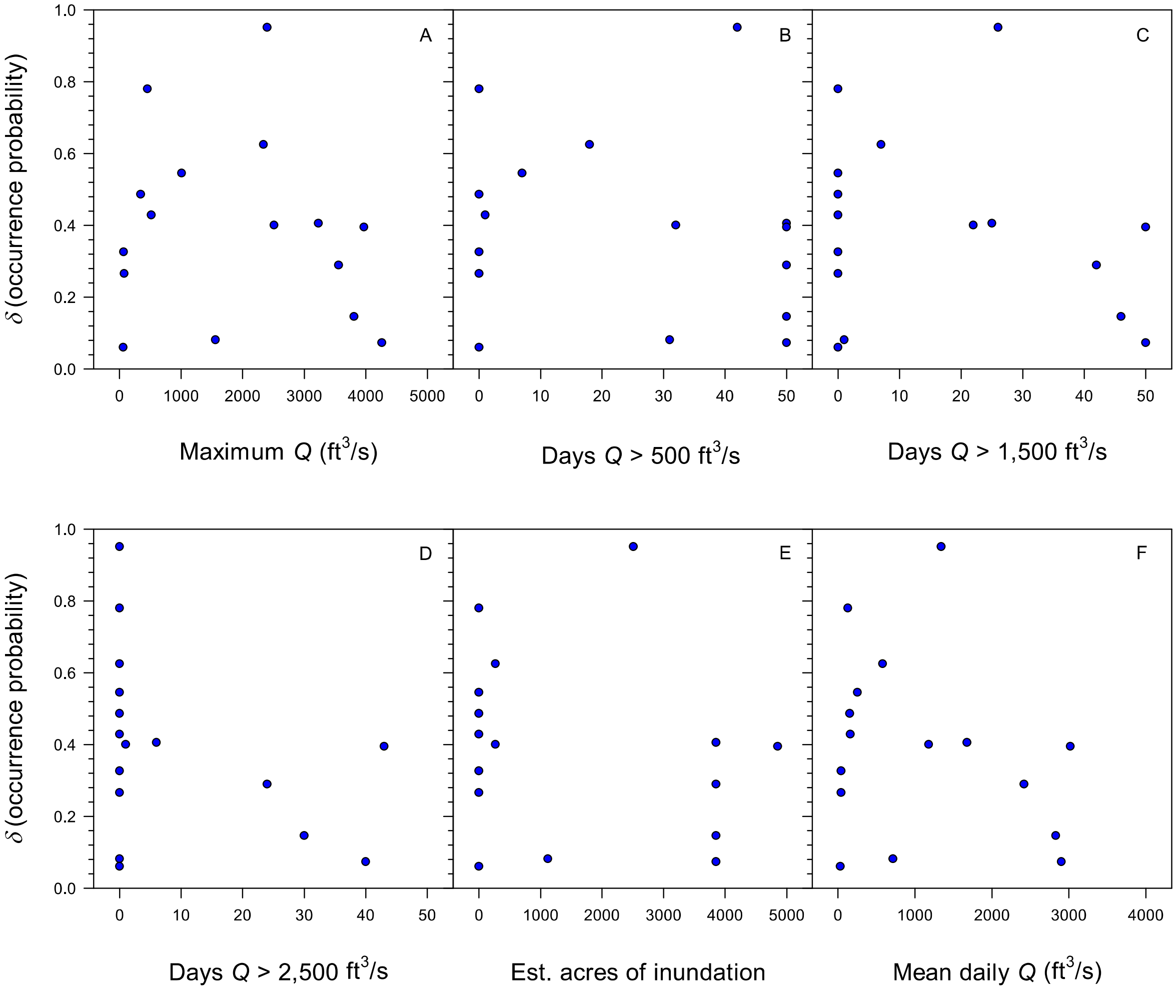


Figure 12. Bivariate plots of Rio Grande Silvery Minnow egg-occurrence probabilities ($\delta$; estimated using San Marcial data [22 April to 10 June]) and San Marcial Gage data.

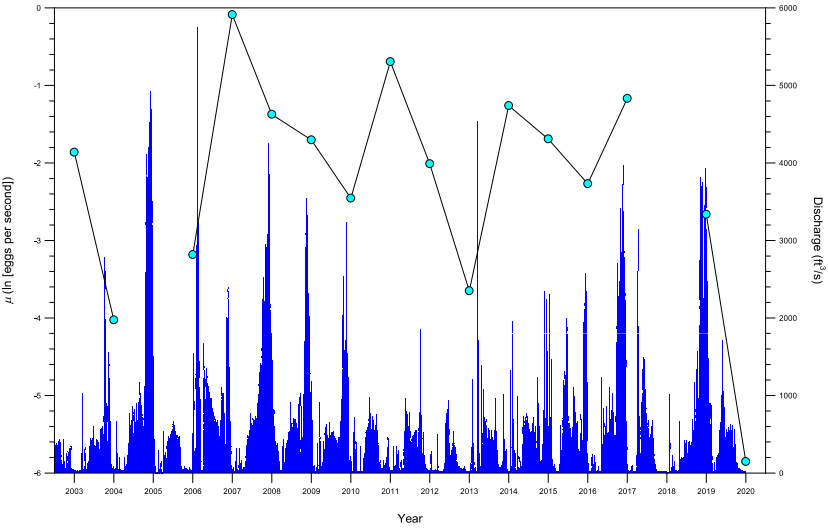


Figure 13. Rio Grande Silvery Minnow lognormal egg-passage rates ($\mu$ ; estimated using San Marcial data [22 April to 10 June]), and mean daily discharge data from the San Marcial Gage, across years. Sampling did not occur in 2005, and 2018 was excluded from analyses (see Methods).

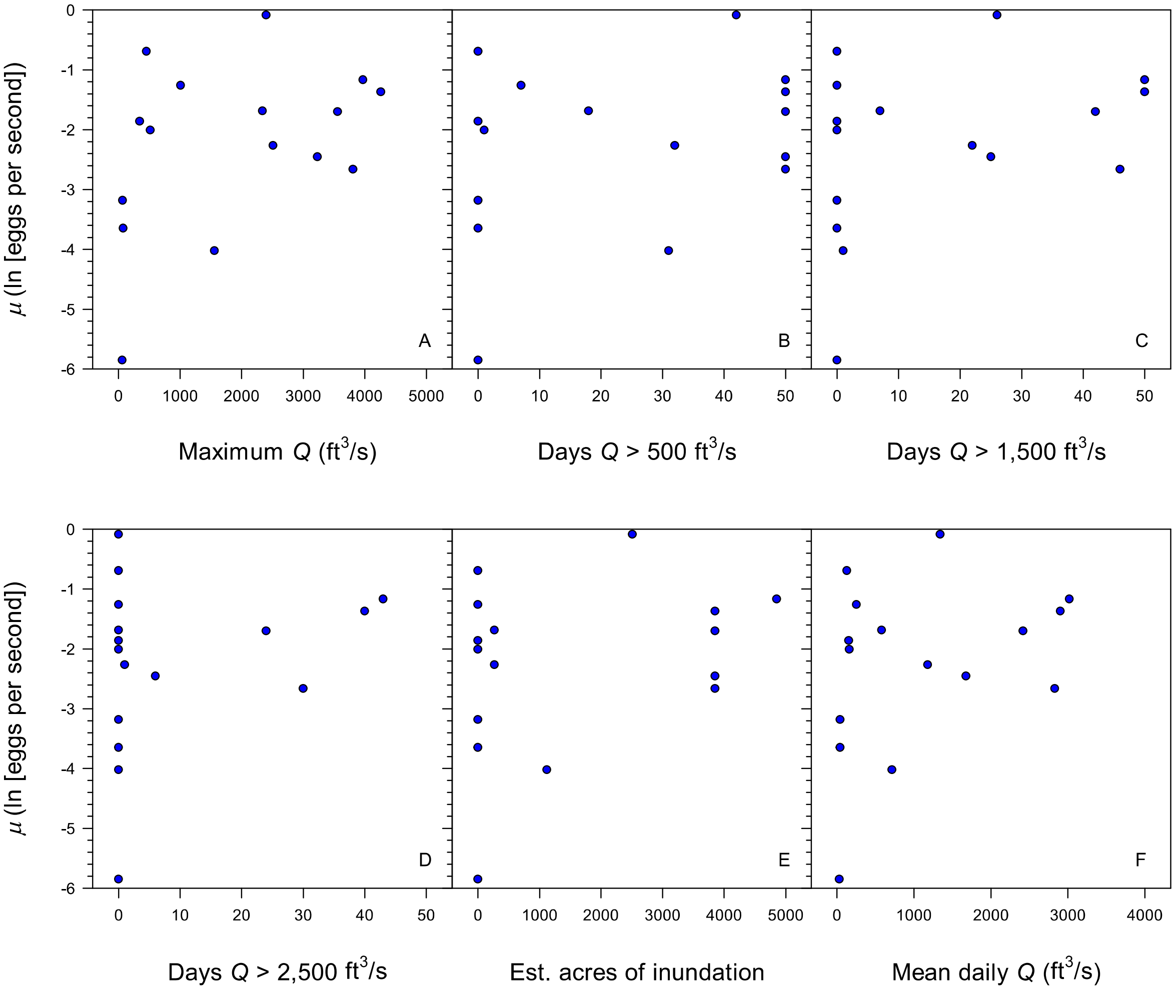


Figure 14. Bivariate plots of Rio Grande Silvery Minnow lognormal egg-passage rates ($\mu$; estimated using San Marcial data [22 April to 10 June]) and San Marcial Gage data.

Table 6. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using San Marcial data (22 April to 10 June; 2003–2020).

| **Model**[1] | **logLike**[2] | **K**[3] | **AIC$_c$**[4] | ***$w_i$***[4] |
|---|---|---|---|---|
| $\delta$(SAN>2,500+*R*) $\mu$(SANmax+*R*) | 1,522.23 | 9 | 1,540.49 | 0.2878 |
| $\delta$(SAN>2,500+*R*) $\mu$(SANmean+*R*) | 1,523.51 | 9 | 1,541.77 | 0.1522 |
| $\delta$(SAN>2,500+*R*) $\mu$(SAN>1,500+*R*) | 1,524.80 | 9 | 1,543.06 | 0.0798 |
| $\delta$(*R*) $\mu$(SANmean+*R*) | 1,527.73 | 8 | 1,543.94 | 0.0514 |
| $\delta$(SAN>2,500+*R*) $\mu$(SAN>500+*R*) | 1,525.76 | 9 | 1,544.02 | 0.0494 |
| $\delta$(*R*) $\mu$(SANmax+*R*) | 1,528.46 | 8 | 1,544.66 | 0.0358 |
| $\delta$(SANmean+*R*) $\mu$(SANmax+*R*) | 1,526.48 | 9 | 1,544.74 | 0.0344 |
| $\delta$(SANmean+*R*) $\mu$(SANmean+*R*) | 1,527.04 | 9 | 1,545.30 | 0.0260 |
| $\delta$(*SAN*>1,500+*R*) $\mu$(SANmax+*R*) | 1,527.20 | 9 | 1,545.46 | 0.0241 |
| $\delta$(*R*) $\mu$(SAN>1,500+*R*) | 1,529.38 | 8 | 1,545.58 | 0.0226 |

[1] = Models included all $\delta$ and $\mu$ combinations of null effects (.), random effects (*R*), and hydrological metrics (with and without *R*) from USGS Gage #08358400 (SAN; Rio Grande Floodway at San Marcial, NM).

[2] = Likelihood (–2[log-likelihood]) was estimated for each model.

[3] = Higher numbers of parameters indicate increased model complexity.

[4] = Top ten models were ranked by Akaike's information criterion (AIC$_c$) and include the AIC$_c$ weight ($w_i$).

## DISCUSSION

### *River and Habitat Modifications*

The negative effects of dam-related modifications on the native fishes of the Great Plains and American Southwest have been well documented (Stanford and Ward 1979; Cross et al. 1983; Cross et al. 1985; Cross and Moss 1987; Winston et al. 1991; Luttrell et al. 1999; Dudley and Platania 2007; Perkin et al. 2015; Worthington et al. 2018). River fragmentation, flow regulation, and habitat loss in these regions have led to the widespread decline or extirpation of several pelagic-spawning cyprinids, whose reproductive propagules often drift downstream of instream barriers or into unsuitable reservoir habitats (Dudley and Platania 2007; Hoagstrom 2015; Worthington et al. 2018). The downstream transport of eggs and larvae, along with the effects of dams and altered flows, likely contributed to the loss of Rio Grande Silvery Minnow from the Cochiti Reach and to its decline in the Angostura Reach (Platania and Altenbach 1998). Population monitoring efforts during October (1993–2019) indicated that the highest densities of juvenile Rio Grande Silvery Minnow were consistently found in the southern reaches (i.e., Isleta and San Acacia) of the Middle Rio Grande (Dudley et al. 2020). One explanation for this long-term pattern of elevated densities of juveniles in downstream reaches is the cumulative longitudinal transport of propagules (drifting eggs and larvae) past instream barriers over time (Dudley and Platania 2007).

In addition to the problems created by river fragmentation, habitat simplification (caused by flow regulation, bank armoring, etc.) also appears to contribute to the downstream transport of Rio Grande Silvery Minnow eggs. The closure of Cochiti Dam resulted in the vastly reduced passage of fine sediments, which has contributed to channel degradation, armoring, and narrowing (Lagasse 1980; Massong et al. 2006). While arroyos, backwaters, and other nursery habitats may result in increased upstream retention of eggs and larvae (Porter and Massong 2004a, 2004b; Pease et al. 2006), these low velocity mesohabitats are relatively rare, particularly in incised sections of the river. Additionally, extensive river drying (i.e., during drought years) has regularly resulted in the loss of Rio Grande Silvery Minnow over substantial portions of its occupied range in the Middle Rio Grande (Archdeacon 2016; Dudley et al. 2020).

### *Fish Egg Identification*

As Rio Grande Silvery Minnow is the only extant species remaining within the original reproductive guild of pelagic-spawning cyprinids in the Middle Rio Grande, the species-specific identification of any semibuoyant egg collected during this study was typically unambiguous. However, we have also periodically collected Common Carp and Flathead Chub eggs from the various sampling sites. Fortunately, there are numerous differences between the eggs of these three species that aid in their identification. Common Carp eggs are relatively small and adhesive (e.g., small particles often attached to the chorion), have an opaque perivitelline space, and the resulting embryos become pigmented very early in development. Flathead Chub produce small nonadhesive eggs that sink faster (i.e., large yolk-to-egg volume ratio) and develop more slowly than pelagic-spawning fishes, like Rio Grande Silvery Minnow, although their eggs may be transported downstream during increased flows, particularly in sand-bedded rivers (Bestgen et al. 2016). In contrast, the perivitelline space of Rio Grande Silvery Minnow is large and clear, eggs are fully nonadhesive, and the embryos lack any discernible pigment (Platania and Altenbach 1998).

### *Spawning Cues and Egg Drift*

Spawning by Rio Grande Silvery Minnow, and other members of its reproductive guild, is triggered by specific environmental cues (Platania and Altenbach 1998). These fishes typically spawn shortly after rapid increases in flow during the late spring and early summer. Elevated flows result in increased water velocities/depths in some areas and inundated habitats in other areas. Additionally, there are changes in water quality that accompany flow increases, particularly when large amounts of soil are carried into the river from formerly dry side channels, eroding shoreline banks, or flowing arroyos. The increased sediment load results in increased turbidity levels (i.e., decreased water clarity), slightly decreased water temperatures, and can lead to substantial increases in salinity levels. It is likely that Rio Grande Silvery Minnow spawns during increased flows because of some combination of these altered aquatic-habitat and water-quality conditions.

Although elevated discharge appears to be the primary spawning cue for Rio Grande Silvery Minnow, water temperature also seems to be an important reproductive cue. For example, gonadosomatic index (GSI) values, which indicate a physiological readiness to spawn, increase rapidly when water temperatures begin to rise in early spring but then decrease rapidly when water temperatures reach elevated levels during early summer (Platania and Altenbach 1996; Archdeacon et al. 2020). Similarly, we found that the probability of collecting eggs (i.e., daily egg-occurrence probability) at San Marcial was consistently higher in the cooler water of mid-spring (ca. late April) than in the warmer water of early summer (ca. early June), across a wide range of mean daily water temperatures (ca. 13–27°C). It is possible that the typical range of spawning temperatures is even broader (Platania and Dudley 2000), but there have been no systematic, long-term studies conducted to fully address this question. However, experimental water temperature treatments for eggs and larvae of Rio Grande Silvery Minnow revealed that their mortality was markedly higher at 15°C or 30°C, as compared with 20°C or 25°C (Platania 2000). It is therefore likely that individuals spawned notably earlier or later in the year (e.g., March or July), when water temperatures are excessively cool or warm, would have an increased rate of mortality.

Eggs spawned in warmer water also hatch more rapidly than those spawned in cooler water (Platania 2000), which might reduce the duration and distance that they drift downstream during summer. Hypothetically, this could lead to lower estimates of occurrence probabilities and passage rates during summer and higher estimates during spring. During average seasonal flows, we would predict only minor differences between these spring/summer estimates, however, because of the relatively short distance between sites, the swift transport velocities in all reaches, and the duration typically needed for eggs to hatch (ca. 1–3 days) after spawning (Platania 2000; Dudley and Platania 2007). Thus, it seems more reasonable that eggs collected at our three sampling sites were closely associated with reach-specific spawning activity. However, an exception to this association might occur during years when river flows are unusually low and water temperatures are unusually high (i.e., reducing egg-drift distances), which could help explain the lower occurrence probabilities and passage rates at San Marcial during extreme drought years (e.g., 2018 and 2020). The complex interactions among discharge, temperature, and the early life-history characteristics of eggs and larvae have also been examined theoretically via experimental studies (Dudley and Platania 2007), which together with the results of this study lend further insight into these multifaceted, yet still uncertain, ecological relationships.

### *Seasonal Recruitment*

The recruitment of Rio Grande Silvery Minnow, through the spring and summer, is likely affected by both abiotic (e.g., flow, temperature, water quality) and biotic (e.g., food availability, competition, predation) factors. Genetic analyses of wild eggs and adults suggest that survival is highly variable, leading to large differences in reproductive success among individuals (Osborne et al. 2005). Additionally, it is unknown if reproductive success varies among individuals according to the spawning strategy employed within a single season (i.e., single spawning vs. multiple spawning). The broad range of conditions that result in Rio Grande Silvery Minnow reproduction could indicate that there is no single ideal spawning cue (i.e., combination of abiotic/biotic conditions) that would consistently result in their increased survival and recruitment success. The closest combination of favorable conditions, based on the last two decades of reproductive monitoring, appears to be elevated and sustained flows that coincide with suitable water temperatures. During years with high spring runoff, these environmental conditions synergistically result in the creation of productive inundated nursery habitats, which are crucial for the growth and development of early life phases (Dudley and Platania 1997; Magaña 2012; Medley and Shirey 2013; Hutson et al. 2018; Tave et al. 2018; Valdez et al. 2019; Dudley et al. 2020). Further, individuals spawned during spring probably have a higher survivorship than those spawned during summer, as there would likely be reduced competition from other larval fishes for food resources (Pease et al. 2006), which become widely available shortly after the initial inundation of floodplain habitats (Junk et al. 1989).

While increased flows can lead to expanded larval fish nursery habitats and presumably higher recruitment success, there is no guarantee that flows will continue to rise or be sustained after spawning. Flows will sometimes briefly increase, and then return to low levels, either as a result of changes in ambient temperature (i.e., affecting the rate of snowmelt) or as a result of short-term precipitation events. The young that are produced as a result of these transitory flow events are subjected to abiotic and biotic conditions that may preclude their successful survival and growth, particularly during the warmer summer months. Excessively elevated water temperatures (> 30°C) in the Rio Grande, caused by warm ambient conditions and low flows, likely reduce the hatching success of eggs and survival of larvae (Platania 2000). In addition to high water temperatures and possibly poor water quality, negative biotic interactions (e.g., competition, predation, and parasitism) also presumably increase as suitable habitats contract during low summer flows.

Based on all reaches over time, the downstream transport of eggs was typically highest during years with reduced and truncated spring flows. These periodic events appear to have been triggered by reach-specific flow conditions. For example, the highest densities of eggs during 2020 coincided with briefly elevated flows in both the Angostura and Isleta reaches. In contrast, very little spawning was detected during 2020 in the San Acacia Reach, likely because flows remained low and stable (i.e., upstream flow increases were either diverted at San Acacia Diversion Dam or attenuated moving downstream). The importance of these sporadic, yet substantial, spawning events is unclear, however, as the number of young Rio Grande Silvery Minnow (i.e., protolarvae, mesolarvae, and metalarvae) collected during summer was often unusually low in years with poor spring runoff (Dudley et al. 2020). Similarly, persistently low flows during spring and summer were found to negatively affect the annual recruitment of Rio Grande Silvery Minnow (Archdeacon et al. 2020; Dudley et al. 2020). It appears that the environmental conditions that immediately follow spawning (e.g., magnitude and duration of flow) need to be sufficiently adequate to result in both the creation and persistence of nursery habitats for larval fish. As growth from the egg phase through the vulnerable early larval phases (i.e., protolarvae and mesolarvae) requires about one month (Platania 1995), the long-term persistence of these habitats seems essential for ensuring the successful recruitment of young to later life phases (i.e., metalarvae and juveniles). Additional research on the early life history of Rio Grande Silvery Minnow (e.g., collecting drifting eggs and drifting larvae concurrently during spring and summer) would help to elucidate these complex ecological relationships, while also potentially providing valuable management insights.

### *Sampling and Analytical Considerations*

The total number of Rio Grande Silvery Minnow eggs collected was generally obtained through direct counting of eggs in the field. This direct counting method was used for nearly all sampling days across sites and years. However, we occasionally needed to preserve egg samples when the total number of eggs collected exceeded our ability to accurately count them, while simultaneously operating the MECs. This threshold was typically exceeded when more than about 1,000 eggs were collected per hour. While these intense spawning events have only occurred a few times since this study began, the need to accurately quantify the number of eggs was particularly crucial during these events. We have only used actual egg counts since 2002, after we established that volumetric estimation of egg counts was a far less reliable method (Platania and Dudley 2003). Based on multiple trials conducted in 2011, we also determined that time-based estimates of the number of eggs collected were even less accurate than volumetric estimates (Dudley and Platania 2011). Thus, only actual egg counts have been used for the purpose of statistically estimating egg passage rates for this study.

The mixture models used to estimate egg passage rates for Rio Grande Silvery Minnow (2003–2020) employed two separate statistical components, an approach that is particularly effective for modeling zero-inflated ecological data (White 1978; Welsh et al. 1996; Fletcher et al. 2005; Martin et al. 2005). Logistic regression was used to estimate the annual egg-occurrence probability, and a lognormal model was used to estimate the annual lognormal egg-passage rate. The two processes (i.e., occurrence probability [$\delta$] vs. passage rate [$\mu$]) that generated $E(x)$ were clearly separated when using the mixture-model approach. Also, it was unnecessary to add some arbitrary positive constant onto observations of zero values, as is commonly done for simple linear regression models using log-transformed data. Further, our approach fully accounts for over-dispersion (e.g., extra-binomial variation around $\delta$, nonconstant $\sigma$ in the lognormal distribution, or additional variation around $\delta$ and $\mu$ for the linear covariate model). Thus, we have produced estimates using a robust, yet highly flexible, approach that avoids many assumptions typically required for traditional statistical analyses (Appendix B [Table B - 1]).

For analytical purposes, we combined the number of Rio Grande Silvery Minnow eggs collected from multiple MECs to obtain a daily total by site. The variation in egg densities across different MECs was negligible compared to the variation across days. The primary purpose of sampling with two MECs, over an extended duration at each site, was to both detect the presence of eggs and to obtain accurate estimates of egg densities over time.

For this report, we also estimated the approximate number of eggs transported downstream of each sampling site based on the number of eggs collected, volume of water sampled, and mean daily discharge. However, this approach required multiple simplifying assumptions including: 1) egg densities were reasonably similar in different locations at a site, 2) egg densities during the morning/afternoon sampling period approximately represented egg densities throughout the day, and 3) discharge at the nearest upstream USGS station approximately represented the discharge at the sampling site. While these assumptions seem reasonable under most circumstances, some non-quantified error was likely introduced into the calculations through these extrapolations, and the resulting estimates should be interpreted cautiously. For example, the use of additional MECs might more accurately characterize spatial differences in the densities of drifting fish eggs across the river channel (Worthington et al. 2013a, 2013b). Also, extending the study by several weeks (i.e., mid-April to mid-June) would likely result in a better characterization of the timing, duration, frequency, and magnitude of spawning across years. Similarly, increased sampling for eggs (i.e., morning, afternoon, evening, and night) could more accurately characterize temporal differences in the densities of drifting fish eggs. For example, we documented several brief, yet substantial, peak-spawning events during continuous multi-day sampling efforts in previous years (e.g., 2001, 2002, and 2018). While these supplemental sampling efforts were unsuitable for assessing long-term trends (i.e., not included in statistical analyses), they indicated that potentially important peak-spawning events sometimes occurred within a relatively short duration. However, the number of eggs estimated to be transported downstream of each sampling site, during peak-spawning events, would still be quite high even with notable violations of these assumptions.

### *Spatial Spawning Patterns*

Reproductive monitoring at the three study sites revealed notable differences in spawning metrics across reaches. Since 2017, the cumulative number of eggs collected was higher at Sevilleta than at either Albuquerque or San Marcial. We were able to estimate the egg passage rate and number of eggs transported downstream at all three sites in 2020. However, we were only able to estimate the egg passage rate and number of eggs transported downstream at Sevilleta and San Marcial in 2019, as eggs were only captured on a single day between 22 April and 10 June (i.e., precluding mixture-model estimation of $\sigma$) at Albuquerque in 2019.

Many eggs were collected in 2018 and 2020 (low-flow years), as compared to 2017 and 2019 (high-flow years), which complicated any meaningful insights into spatial monitoring trends (i.e., across reaches) over the past four years. In 2020, the relatively large numbers of eggs collected at Albuquerque and Sevilleta were in stark contrast to the near absence of eggs at San Marcial. The extended drying that affected the San Acacia Reach in 2018 was not an issue in 2019. River flows were consistently low in 2020 (< 70 $ft^3/s$), however, which resulted in reduced flow connectivity in the San Acacia Reach throughout the study period. It is possible that this less persistent riverine connection resulted in a reduced passage of eggs at San Marcial in 2020, compared to 2019, as eggs spawned farther upstream would have had less chance to drift downstream to our sampling site. Similarly, we observed a notably reduced passage of eggs at San Marcial in prior drought years (e.g., 2006, 2013, and 2018), when flows never exceeded 100 $ft^3/s$ during the study period (22 April to 10 June).

### *Ecological Relationships*

Based on the long-term reproductive monitoring data at San Marcial (2003–2020), reduced and more variable spring flows were associated with slightly higher estimated egg-occurrence probabilities ($\delta$), and elevated and extended spring flows were associated with slightly lower estimated egg-passage rates ($E(x)$). Prolonged and elevated spring flows result in overbank flooding of vegetated areas, formation of inundated habitats within the river channel, and creation of shoreline pools and backwaters. These shallow low-velocity habitats, which typically increase in number and extent during spring runoff, are essential for the successful recruitment of larvae for many freshwater fishes throughout the world (Welcomme 1979; Junk et al. 1989; Matthews 1998). In the absence of adequate spring flows (e.g., during extended droughts), however, pelagic-spawning cyprinids appear to be particularly susceptible to recruitment failure (Perkin et al. 2019). It is likely that similar processes are also affecting the survival and recruitment of native fishes in the Middle Rio Grande, including early life phases of Rio Grande Silvery Minnow (Pease et al. 2006; Turner et al. 2010; Hoagstrom and Turner 2013; Archdeacon et al. 2020; Dudley et al. 2020). Although low egg passage rates for Rio Grande Silvery Minnow might reflect reduced spawning or flow connectivity in some instances (e.g., San Marcial in 2018 and 2020), years with sustained high flows (e.g., 2017 and 2019) typically had the lowest passage rates, which likely reflected a higher retention of eggs in low-velocity habitats (i.e., reduced downstream transport). In contrast, years with lower and more variable flows were often associated with an increased occurrence of eggs, indicating more frequent spawning events.

The timing, duration, frequency, and magnitude of spawning may differ across years, in part, because of specific flow-related reproductive strategies. For example, it might be more beneficial for Rio Grande Silvery Minnow to concentrate spawning at the onset of elevated and sustained flows (i.e., creation of nursery habitats), whereas more frequent spawning (i.e., bet-hedging) might be more beneficial when flows are reduced and more variable. Differences in the timing, duration, frequency, and magnitude of spawning, and the subsequent retention/recruitment of eggs, might also partially explain the increased autumnal density of juvenile Rio Grande Silvery Minnow in years with elevated and extended spring flows (Dudley et al. 2020). However, changes in egg occurrence probabilities and egg passage rates across years appear to be far less important than other key environmental factors, such as the creation and persistence of adequate larval habitats during the post-spawning period, in explaining the substantial density fluctuations of juvenile Rio Grande Silvery Minnow over time (Dudley et al. 2020).

### *Conclusions and Implications*

Despite the seemingly large number of eggs, and presumably larvae, transported downstream into the southern reaches of the Middle Rio Grande each year, some portion of this reproductive effort remains upstream (Dudley and Platania 2007; Widmer et al. 2012). It is likely that the proportion of individuals retained and successfully recruited upstream is related to the complexity of instream habitat conditions and the availability of nursery habitats. The availability of floodplain habitat could be particularly important, as these areas are likely locations for the increased retention of drifting fish eggs and larvae (Dudley and Platania 2007; Widmer et al. 2012; Medley and Shirey 2013; Gonzales et al. 2014; Valdez et al. 2019). As the successful growth and survival of this species, from the egg phase through the early larval phases, requires about one month (Platania 1995), the long-term persistence of these nursery habitats seems essential during this initial developmental period. The future conservation status and recovery of Rio Grande Silvery Minnow appears strongly dependent on reliably ensuring appropriate seasonal flow and habitat conditions that will promote the successful spawning and early recruitment of this imperiled species.

# ACKNOWLEDGMENTS

We thank Martinique J. Chavez, Stephani L. Clark-Barkalow, Richard C. Keller, Jacob G. Mortensen, Alexander J. Schroeder, Andrea D. Urioste, and Aaron C. Wedemeyer (ASIR) for their assistance with the field, laboratory, and data-entry aspects of this project. Donald A. Helfrich (ASIR) prepared the study area map. Emily S. DeArmon and Thomas F. Turner, along with other staff at the Museum of Southwestern Biology (Fishes), graciously provided ongoing assistance with all aspects of curating preserved specimens. Numerous people from a variety of local, state, and federal agencies also collaborated to help make this study possible. The City of Albuquerque (Open Space Division), through the assistance of Dionne L. Epps, allowed us access to our Albuquerque sampling site. The Sevilleta National Wildlife Refuge, with the assistance of Renee L. Robichaud, provided us access to our Sevilleta sampling site. The U.S. Bureau of Reclamation (USBR), through the assistance of Susan Woods, facilitated access to our San Marcial sampling site. Michele A. Gallagher, Joel D. Lusk, and Mary B. Maestas (USBR) assisted with all technical and contract administration aspects of this study. Jennifer A. Bachus (USBR) and Michael D. Porter (USACE) provided insightful and helpful reviews of the draft report. The U.S. Fish and Wildlife Service authorized our handling and collection of Rio Grande Silvery Minnow (Permit TE001623-4). The N.M. Department of Game and Fish authorized our handling and collection of all other native and nonnative fishes (Permit 1896). The Middle Rio Grande Endangered Species Collaborative Program has provided valuable scientific input on our research since 2000. This study was funded by the USBR, and its Albuquerque Area Office and Salt Lake City Regional Office administered all funds (Contract R17PC00033: Requisition 0040483557).

## LITERATURE CITED

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Pages 267–281 *in* B.N. Petrov and F. Csáki, editors. Proceedings of the Second International Symposium on Information Theory. Akadémiai Kiadó, Budapest, Hungary.

Altenbach, C.S., R.K. Dudley, and S.P. Platania. 2000. A new device for collecting drifting semibuoyant fish eggs. Transactions of the American Fisheries Society 129:296–300.

Archdeacon, T.P. 2016. Reduction in spring flow threatens Rio Grande Silvery Minnow: trends in abundance during river intermittency. Transactions of the American Fisheries Society 145:754–765.

Archdeacon, T.P., T.A. Diver-Franssen, N.G. Bertrand, and J.D. Grant. 2020. Drought results in recruitment failure of Rio Grande Silvery Minnow (*Hybognathus amarus*), an imperiled, pelagic broadcast-spawning minnow. Environmental Biology of Fishes. https://doi.org/10.1007/s10641-020-01003-5

Bestgen, K.R., H.J. Crockett, M.R. Haworth, and R.M. Fitzpatrick. 2016. Production of nonadhesive eggs by Flathead Chub and implications for downstream transport and conservation. Journal of Fish and Wildlife Management 7:434–443.

Bestgen, K.R., and S.P. Platania. 1990. Extirpation of *Notropis simus simus* (Cope) and *Notropis orca* Woolman (Pisces: Cyprinidae) from the Rio Grande in New Mexico, with notes on their life history. Occasional Papers of the Museum of Southwestern Biology 6:1–8.

Bestgen, K.R., and S.P. Platania. 1991. Status and conservation of the Rio Grande Silvery Minnow, *Hybognathus amarus*. Southwestern Naturalist 36:225–232.

Cross, F.B., O.T. Gorman, and S.G. Haslouer. 1983. The Red River Shiner, *Notropis bairdi*, in Kansas with notes on depletion of its Arkansas River cognate, *Notropis girardi*. Transactions of the Kansas Academy of Science 86:93–98.

Cross, F.B., and R.E. Moss. 1987. Historic changes in fish communities and aquatic habitats in plains streams of Kansas. Pages 155–165 *in* W.J. Matthews and D.C. Heins, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman, Oklahoma, USA.

Cross, F.B., R.E. Moss, and J.T. Collins. 1985. Assessment of dewatering impacts on stream fisheries in the Arkansas and Cimarron rivers. Museum of Natural History, University of Kansas, Lawrence, Kansas, USA.

Dudley, R.K., and S.P. Platania. 1997. Habitat use of Rio Grande Silvery Minnow. Submitted to the New Mexico Department of Game and Fish, Santa Fe, New Mexico, and to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. DOI: 10.13140/RG.2.1.1874.8324

Dudley, R.K., and S.P. Platania. 2007. Flow regulation and fragmentation imperil pelagic-spawning riverine fishes. Ecological Applications 17: 2074–2086.

Dudley, R.K., and S.P. Platania. 2011. Spatial spawning periodicity of Rio Grande Silvery Minnow during 2011. Submitted to the Middle Rio Grande Endangered Species Collaborative Program and the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. DOI: 10.13140/RG.2.1.2808.7200

Dudley R.K., S.P. Platania, and G.C. White. 2020. Rio Grande Silvery Minnow population monitoring during 2019. Submitted to the U. S. Bureau of Reclamation, Albuquerque, New Mexico, USA. DOI: 10.13140/RG.2.2.30586.52160

Fletcher, D., D. Mackenzie, and E. Villouta. 2005. Modelling skewed data with many zeros: a simple approach combining ordinary and logistic regression. Environmental and Ecological Statistics 12: 45–54.

General Oceanics, Inc. 2018. General Oceanics 2030 and 2031 series mechanical and electronic digital flowmeter operator’s manual. General Oceanics Inc., Miami, Florida, USA.

Gold, R.L., and L.P. Denis. 1985. National water summary: New Mexico surface-water resources. U.S. Geological Survey water-supply paper 2300:341–346.

Gonzales, E.J., D. Tave, and G.M. Haggerty. 2014. Endangered Rio Grande Silvery Minnow use constructed floodplain habitat. Ecohydrology 7:1087–1093.

Hoagstrom, C.W. 2015. Habitat loss and subdivision are additive mechanisms of fish extinction in fragmented rivers. Global Change Biology 21:4–5.

Hoagstrom, C.W., W.J. Remshardt, J.R. Smith, and J.E. Brooks. 2010. Changing fish faunas in two reaches of the Rio Grande in the Albuquerque Basin. Southwestern Naturalist 55:78–88.

Hoagstrom, C.W., and T.F. Turner. 2013. Recruitment ecology of pelagic-broadcast spawning minnows: paradigms from the ocean advance science and conservation of an imperilled freshwater fauna. Fish and Fisheries 16: 282–299.

Hutson, A.M., L.A. Toya, and D. Tave. 2018. Determining preferred spawning habitat of the endangered Rio Grande Silvery Minnow by hydrological manipulation of a conservation aquaculture facility and the implications for management. Ecohydrology 11(e1964):1–12.

JMP. 2013. Version 11.2.0 for Windows. SAS Institute Inc., Cary, North Carolina, USA.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Pages 110–127 *in* D.P. Dodge, editor. Proceedings of the International Large River Symposium. Canadian Special Publications in Fisheries and Aquatic Sciences (106).

Lagasse, P.F. 1980. An assessment of the response of the Rio Grande to dam construction — Cochiti to Isleta reach. Submitted to the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA.

Luttrell, G.R., A.A. Echelle, W.L. Fisher, and D.J. Eisenhour. 1999. Declining status of two species of the *Macrhybopsis aestivalis* complex (Teleostei: Cyprinidae) in the Arkansas River Basin and related effects of reservoirs as barriers to dispersal. Copeia 1999:981–989.

Magaña, H.A. 2012. Habitat use of the Rio Grande Silvery Minnow (*Hybognathus amarus*) during a long-term flood pulse in the Middle Rio Grande, New Mexico. Environmental Biology of Fishes 95:201–212.

Martin, T.G., B.A. Wintle, J.R. Rhodes, P.M. Kuhnert, S.A. Field, S.J. Low-Choy, A.J. Tyre, and H.P. Possingham. 2005. Zero tolerance ecology: improving ecological inference by modelling the source of zero observations. Ecology Letters 8:1235–1246.

Massong, T.M., P.J. Tashjian, and P.W. Makar. 2006. Recent channel incision and floodplain evolution within the Middle Rio Grande, NM. Joint Eighth Federal Interagency Sedimentation Conference and Third Federal Interagency Hydrologic Modeling Conference, Reno, Nevada, USA.

Matthews, W.J. 1998. Patterns in freshwater fish ecology. Chapman and Hall, London, UK.

Medley, C.N., and P.D. Shirey. 2013. Review and reinterpretation of Rio Grande Silvery Minnow reproductive ecology using egg biology, life history, hydrology, and geomorphology information. Ecohydrology 6:491–505.

Onset Computer Corporation. 2018. TidbiT v2 Temp (UTBI-001) Manual. Onset Computer Corporation, Bourne, Massachusetts, USA.

Osborne, M.J., M.A. Benavides, and T.F. Turner. 2005. Genetic heterogeneity among pelagic egg samples and variance in reproductive success in an endangered freshwater fish, *Hybognathus amarus* (Cyprinidae). Environmental Biology of Fishes 73:463–472.

Pease, A.A., J.J. Davis, M.S. Edwards, and T.F. Turner. 2006. Habitat and resource use by larval and juvenile fishes in an arid-land river (Rio Grande, New Mexico). Freshwater Biology 51:475–486.

Perkin, J.S., K.B. Gido, A.R. Cooper, T.F. Turner, M.J. Osborne, E.R. Johnson, and K.B. Mayes. 2015. Fragmentation and dewatering transform Great Plains stream fish communities. Ecological Monographs 85:73–92.

Perkin, J.S., T.A. Starks, C.A. Pennock, K.B. Gido, G.W. Hopper, S.C. Hedden. 2019. Extreme drought causes fish recruitment failure in a fragmented Great Plains riverscape. Ecohydrology 12(e2120):1–12.

Pinheiro, J.C., and D.M. Bates. 1995. Approximations to the log-likelihood function in the nonlinear mixed-effects model. Journal of Computational and Graphical Statistics 4:12–35.

Platania, S.P. 1991. Fishes of the Rio Chama and Upper Rio Grande, New Mexico, with preliminary comments on their longitudinal distribution. Southwestern Naturalist 36:186–193.

Platania, S.P. 1993. The fishes of the Rio Grande between Velarde and Elephant Butte Reservoir and their habitat associations. Submitted to the New Mexico Department of Game and Fish, Santa Fe, New Mexico, USA and to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Platania, S.P. 1995. Reproductive biology and early life-history of Rio Grande Silvery Minnow, *Hybognathus amarus*. Submitted to the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA.

Platania, S.P. 2000. Effects of four water temperature treatments on survival, growth, and developmental rates of Rio Grande Silvery Minnow, *Hybognathus amarus*, eggs and larvae. Submitted to the U.S. Fish and Wildlife Service, Albuquerque, New Mexico, USA.

Platania, S.P., and C.S. Altenbach. 1996. Reproductive ecology of Rio Grande Silvery Minnow *Hybognathus amarus*: clutch and batch production and fecundity estimates. Submitted to the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA.

Platania, S.P., and C.S. Altenbach. 1998. Reproductive strategies and egg types of seven Rio Grande Basin cyprinids. Copeia 1998:559–569.

Platania, S.P., and R.K. Dudley. 2000. Spatial spawning periodicity of Rio Grande Silvery Minnow during 1999. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Platania, S.P., and R.K. Dudley. 2002. Spawning periodicity of Rio Grande Silvery Minnow, *Hybognathus amarus*, during 2001. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Platania, S.P., and R.K. Dudley. 2003. Spawning periodicity of Rio Grande Silvery Minnow, *Hybognathus amarus*, during 2002. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Platania, S.P., and R.K. Dudley. 2004. Spawning periodicity of Rio Grande Silvery Minnow, *Hybognathus amarus*, during 2003. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Platania, S.P., and R.K. Dudley. 2005. Spawning periodicity of Rio Grande Silvery Minnow, *Hybognathus amarus*, during 2004. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Platania, S.P., and R.K. Dudley. 2006. Spatial spawning periodicity of Rio Grande Silvery Minnow, *Hybognathus amarus*, during 2006. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Platania, S.P., and R.K. Dudley. 2007. Spatial spawning periodicity of Rio Grande Silvery Minnow, *Hybognathus amarus*, during 2007. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Platania, S.P., and R.K. Dudley. 2008. Spatial spawning periodicity of Rio Grande Silvery Minnow, *Hybognathus amarus*, during 2008. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Platania, S.P., and R.K. Dudley. 2009. Spatial spawning periodicity of Rio Grande Silvery Minnow, *Hybognathus amarus*, during 2009. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Platania, S.P., and C.W. Hoagstrom. 1996. Response of Rio Grande fish community to an artificial flow spike. Submitted to the U.S. Fish and Wildlife Service, Albuquerque, New Mexico, USA.

Platania, S.P., J.G. Mortensen, M.A. Farrington, W. Howard Brandenburg, and R.K. Dudley. 2019. Dispersal of stocked Rio Grande Silvery Minnow (*Hybognathus amarus*) in the Middle Rio Grande, New Mexico. Southwestern Naturalist 64:31–42.

Porter, M.D., and T.M. Massong. 2004a. Contributions to delisting Rio Grande Silvery Minnow: egg habitat identification. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Porter, M.D., and T.M. Massong. 2004b. Analyzing changes in river channel morphology using GIS for Rio Grande Silvery Minnow habitat assessment. GIS/Spatial Analyses in Fishery and Aquatic Sciences: 433–446.

SAS. 2020. Version 9.4 for Linux. SAS Institute Inc., Cary, North Carolina, USA.

Scurlock, D. 1998. From the rio to the sierra: an environmental history of the Middle Rio Grande Basin. General Technical Report RMRS-GTR-5. U.S. Department of Agriculture, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, USA.

Skalski, J.R., A. Hoffmann, and S.G. Smith. 1993. Testing the significance of individual- and cohort-level covariates in animal survival studies. Pages 9–28 *in* J. D. Lebreton and P. M. North, editors. Marked individuals in the study of bird population. Birkhäuser Verlag, Basel, Switzerland.

Smith, J.R. 1998. Summary of Low Flow Conveyance Channel fish investigations for fiscal year 1997. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Smith, J.R. 1999. A summary of easy egg catching in the Low Flow Conveyance Channel in the 9 mile study reach during spring 1998 operations. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.

Speirs, D.C., and W.S.C. Gurney. 2001. Population persistence in rivers and estuaries. Ecology 82:1219–1237.

Stanford, J.A., and J.V. Ward. 1979. Stream regulation in North America. Pages 215–236 *in* J.V. Ward and J.A. Stanford, editors. The ecology of regulated streams. Plenum Press, New York, New York, USA.

Tave, D., L.A. Toya, and A.M. Hutson. 2018. Behavioral observations of the endangered Rio Grande Silvery Minnow in a conservation aquaculture facility. Croatian Journal of Fisheries 76:7–26.

Turner, T.F., T.J. Krabbenhoft, and A.S. Burdett. 2010. Reproductive phenology and fish community structure in an arid-land river system. Pages 427–446 *in* K.B. Gido and D.A. Jackson, editors. Community ecology of stream fishes: concepts, approaches, and techniques. American Fisheries Society, Symposium Series 73, Bethesda, Maryland, USA.

USACE (U.S. Army Corps of Engineers). 2010. Historic inundation analysis along the Middle Rio Grande for the period 1990 to 2009. Submitted to the Middle Rio Grande Endangered Species Collaborative Program, Population Viability Analysis Work Group, Albuquerque, New Mexico, USA.

USDOI (U.S. Department of the Interior). 1994. Endangered and threated wildlife and plants; final rule to list the Rio Grande Silvery Minnow as an endangered species. Final Rule. Federal Register 59:138(20 July 1994):36988-36995.

Valdez, R.A., G.M. Haggerty, K. Richard, and D. Klobucar. 2019. Managed spring runoff to improve nursery floodplain habitat for endangered Rio Grande Silvery Minnow. Ecohydrology 12(e2134):1–18.

Welcomme, R.L. 1979. The fisheries ecology of floodplain rivers. Longman, London, UK.

Welsh, A.H., R.B. Cunningham, C.F. Donnelly, and D.B. Lindenmayer. 1996. Modelling the abundance of rare species: statistical models for counts with extra zeros. Ecological Modelling 88: 297–308.

White, G.C. 1978. Estimation of plant biomass from quadrat data using the lognormal distribution. Journal of Range Management 31:118–120.

Widmer, A.M., J.J. Fluder III, J.W. Kehmeier, C.N. Medley, and R.A. Valdez. 2012. Drift and retention of pelagic spawning minnow eggs in a regulated river. River Research and Applications 28:192–203.

Winston, M.R., C.M. Taylor, and J. Pigg. 1991. Upstream extirpation of four minnow species due to damming of a prairie stream. Transactions of the American Fisheries Society 120:98–105.

Worthington, T.A., S.K. Brewer, and N. Farless. 2013a. Spatial and temporal variation in efficiency of the Moore Egg Collector. North American Journal of Fisheries Management 33:1113–1118.

Worthington, T.A., S.K. Brewer, T.B. Grabowski, and J. Mueller. 2013b. Sampling efficiency of the Moore Egg Collector. North American Journal of Fisheries Management 33:79–88.

Worthington, T.A., A.A. Echelle, J.S. Perkin, R. Mollenhauer, N. Farless, J.J. Dyer, D. Logue, S.K. Brewer. 2018. The emblematic minnows of the North American Great Plains: a synthesis of threats and conservation opportunities. Fish and Fisheries 19:271–307.

Zar, J.H. 2010. Biostatistical Analysis. Fifth edition. Prentice Hall Inc., Upper Saddle River, New Jersey, USA.

# APPENDIX A (Statistical Methods)

## REPRODUCTIVE MONITORING

Egg passage-rate data, for Rio Grande Silvery Minnow, comprise either zeros (i.e., eggs not detected) or positive (nonzero) values (i.e., eggs detected) for each day at the three sampling sites. The nonzero data range widely across days and can include very large values, particularly when large numbers of eggs are drifting downstream. The lognormal probability density function is most appropriate for modeling these wide-ranging values:

$$f(x) = \frac{1}{\sigma\left(x\sqrt{2\pi}\right)} \exp\left[\frac{-\left(\log(x) - \mu\right)^2}{2\sigma^2}\right]$$

where $x$ is a continuous covariate > 0, with scale parameter $\sigma > 0$, and location parameter $-\infty < \mu < \infty$. The parameter $\mu$ can be thought of as the mean (on the log scale). However, the lognormal distribution has no probability mass function for zeros (i.e., $x > 0$). To appropriately model the zeros, a mixture distribution is needed for the probability of a positive value ($\delta$) and the probability of a zero value ($1-\delta$). Thus, each observation is evaluated with the Bernoulli distribution and, if positive, evaluated with the lognormal distribution.

The resulting log-likelihood function of this mixture-model distribution for a single day is computed using the following equations:

$$\text{if } x_i = 0, \quad \log L(x_i) = \log(1-\delta)$$

$$\text{else for } x_i > 0, \quad \log L(x_i) = \log(\delta) - \frac{\left(\log(x_i) - \mu\right)^2}{2\sigma^2} - \log(\sigma)$$

where $x$ = daily egg-passage rate, $\delta$ = probability of a nonzero value, and where $\mu$ and $\sigma$ are the lognormal parameters. The following term is not included in the log-likelihood function, as it is constant and not a function of the model parameters:

$$\log\left(x\sqrt{2\pi}\right)$$

The log-likelihood for an entire sampling season, for each site, is then the sum of the log-likelihoods from all site-specific sampling days:

$$\log L = \sum_{i=1}^{n} \log L(x_i)$$

However, some modifications of the log $L(x)$ function are required for sparse data. When no $x > 0$ are observed, only $\delta$ is estimated. When only one $x > 0$ is observed, only $\delta$ and $\mu$ can be estimated. Thus, the log $L(x)$ function is modified to just $\log(\delta) - \left(\log(x_i) - \mu\right)^2$ for a single positive value of $x$.

Numerical maximization of this log-likelihood is computed using PROC NLMIXED (Nonlinear Mixed Models; SAS 2020) to obtain the maximum likelihood estimates of $\delta$, $\mu$, and $\sigma$ for each year. Further, PROC NLMIXED can be structured to provide generalized linear models for each of these parameters based on the appropriate link functions:

$$\delta = \text{expit}\left[\beta_{\delta 0} + \beta_{\delta 1} \cdot \text{Covariate}\right]$$
$$\mu = \beta_{\mu 0} + \beta_{\mu 1} \cdot \text{Covariate}$$
$$\sigma = \exp\left[\beta_{\sigma 0} + \beta_{\sigma 1} \cdot \text{Covariate}\right]$$

The link function for $\delta$ is the logit link (i.e., reverse logit specified as the expit function), for $\mu$ is the identity link, and for $\sigma$ is the log link. While the covariate used could possibly differ for all three parameters, we felt it was more reasonable to maintain the same covariate for $\mu$ and $\sigma$. Conversely, we reasoned that covariates best related to the egg passage rate ($\mu$ and $\sigma$) might be quite different than covariates best related to the occurrence probability ($\delta$).

In addition, random effects are considered by year:

$$\delta = \text{expit}\left[\beta_{\delta 0} + \text{Normal}(0, \sigma_{\delta}^{2})\right]$$
$$\mu = \beta_{\mu 0} + \text{Normal}(0, \sigma_{\mu}^{2})$$

where we assume a normal distribution with a mean of zero and a nonzero standard deviation. The associated variances ($\sigma_{\delta}^{2}$ and $\sigma_{\mu}^{2}$) are estimated from the data, using PROC NLMIXED to numerically integrate out the random effect in the log-likelihood function. When both $\delta$ and $\mu$ have random effects, a covariance term is included in addition to the variances. Also, generalized linear models can either include or ignore random effects when assessing the relative fit of data using goodness-of-fit statistics (logLike = –2[log-likelihood] and AIC$_c$ = Akaike's information criterion [Akaike 1973] for finite sample sizes).

The estimated egg-passage rate $E(x)$, and its standard deviation $\text{SD}\big(E(x)\big)$, are generated from PROC NLMIXED using these equations:

$$E(x) = \delta \exp\left[\mu + \frac{\sigma^{2}}{2}\right]$$
$$\text{SD}\big(E(x)\big) = \left[\exp\big(\sigma^{2} - \delta\big)\delta \exp\big(2\mu + \sigma^{2}\big)\right]^{1/2}$$

Also, profile-likelihood confidence intervals for $E(x)$ are obtained by using a log transformation to maintain LCI > 0:

$$\text{LCI} = \exp\left[\log\big(E(x)\big) - 1.96 \cdot \text{SE}\big(E(x)\big) / E(x)\right]$$
$$\text{UCI} = \exp\left[\log\big(E(x)\big) + 1.96 \cdot \text{SE}\big(E(x)\big) / E(x)\right]$$

where LCI is the lower 95% confidence interval, UCI is the upper 95% confidence interval, and the standard error $\mathrm{SE}\left(E(x)\right)$ is obtained numerically using PROC NLMIXED. Annual values of $E(x)$ with non-overlapping 95% confidence intervals (LCI–UCI) are significantly different ($P < 0.05$).

An essential benefit of our mixture-model approach is that the estimated parameters, and accompanying generalized linear models, provide direct and meaningful insight into key factors affecting egg passage-rate dynamics across years. This is because we estimate, and individually analyze, both the egg occurrence probability (based on $\delta$) and egg passage rate (based on $\mu$ and $\sigma$). Additionally, diverse environmental covariates are used to model the key parameters ($\delta$ and $\mu$), which collectively lend insight into the fundamental, yet complex, egg drift dynamics of Rio Grande Silvery Minnow over time.

# APPENDIX B (Statistical Assumptions)

Table B - 1. Statistical assumptions, violation implications, violation risks, and mitigation precautions for Rio Grande Silvery Minnow reproductive monitoring analyses.

| **Statistical assumptions** | **Violation implications** | **Violation risks** | **Mitigation precautions** |
|---|---|---|---|
| MEC collections composed a reasonably representative daily sample of drifting eggs for each site. | This would reduce our ability to detect meaningful year-to-year differences in egg passage rates. | Low: Run mesohabitats were sampled exclusively to ensure adequate mixing of drifting eggs across the river channel during site-specific sampling. | Monitoring was highly standardized (i.e., timing of daily sampling and high-velocity offshore sampling locations) across sites and years. |
| Eggs were sampled with similar effort over time and space. | This would reduce our ability to detect meaningful year-to-year differences in egg passage rates. | Low: River conditions in run mesohabitats (e.g., adequate depths and velocities) were suitable for efficient and standardized sampling across sites and years. | Monitoring was highly standardized (i.e., duration of daily sampling and MEC sampling effort [flowmeter values]) across sites and years. |
| Egg densities can be validly compared over time and space. | This would reduce our ability to detect meaningful year-to-year differences in egg passage rates. | Low: Daily egg density was standardized to a passage rate of eggs, based on mean daily discharge, for each sampling site over time. | Monitoring was highly standardized (see above) across sites and years. Mean daily discharge was taken from the nearest upstream USGS station to correct for spatial and temporal differences in flow magnitude. |
| Eggs were not recaptured during the same sampling effort. | This would reduce our ability to detect meaningful year-to-year differences in egg passage rates. | Negligible: Eggs were preserved whenever high densities precluded accurate field counts. Sampling sites were adequately spaced so that eggs could hatch before reaching the next site. | Eggs that were not preserved were always released back into the river downstream of the MEC sampling location. |
| Zero data represented samples where no individuals of a species were collected (i.e., none were present in the sampled mesohabitat). | This would reduce our ability to detect meaningful year-to-year differences in egg passage rates. | Negligible: We have extensive experience in identifying all drifting fish eggs to species in the Rio Grande. | Biologists with extensive experience, in both fish egg identification and MEC sampling, were present on all sampling efforts. If there was any uncertainty, eggs were preserved and identified in the laboratory. |
| Species detection probability was reasonably similar across days and sites. | This would reduce our ability to detect meaningful day-to-day, site-to-site, and year-to-year differences in egg passage rates. | Low: We routinely detected remarkably large day-to-day and site-to-site differences in egg passage rates. | Monitoring was highly standardized across days and sites to ensure similar sampling efforts over time and space. |

Table B - 1. Statistical assumptions, violation implications, violation risks, and mitigation precautions for Rio Grande Silvery Minnow reproductive monitoring analyses (continued).

| **Statistical assumptions** | **Violation implications** | **Violation risks** | **Mitigation precautions** |
|---|---|---|---|
| Species detection probability was reasonably similar across years. | This would reduce our ability to detect meaningful year-to-year differences in egg passage rates. | Low: We routinely detected remarkably large year-to-year differences in egg passage rates. | Monitoring was highly standardized across years to ensure similar sampling efforts over time. |
| Nonzero data fit a lognormal distribution reasonably well. | This would reduce our ability to detect meaningful year-to-year differences in egg passage rates. | Low: Goodness-of-fit tests failed to reject the lognormal distribution for nonzero data. | The distributions were fit with two parameters (mean and variance), providing statistically-robust analyses. |
| Generalized linear models were appropriate for the type of data and covariates included in the analyses. | This would reduce our ability to detect meaningful relationships between flows and egg drift dynamics over time. | Low: Generalized linear models were the simplest models to fit, and the data did not warrant overly complex models. | Random-effects models were also included, providing more robust ecological models than simple fixed-effects models. |

# APPENDIX C (Site-Specific Reproductive Monitoring Data)

Site-specific data, collected in 2020, as part of the
Rio Grande Silvery Minnow Reproductive Monitoring Program

# Rio Grande Silvery Minnow Reproductive Monitoring

## April 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-001**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 22 April 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 753.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-001**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 22 April 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 561.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-001**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 22 April 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Wedemeyer, A.C. Effort: 877.2 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## April 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-002**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 23 April 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Wedemeyer, A.C. Effort: 1,375.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-002**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 23 April 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 698.8 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-002**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 23 April 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 704.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## April 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-003**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 24 April 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,040.5 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-003**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 24 April 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 526.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-003**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 24 April 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 346.6 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## April 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-004**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 25 April 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,205.7 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-004**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 25 April 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 722.5 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-004**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 25 April 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 785.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## April 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-005**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 26 April 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,190.8 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 3 |
| 76 | *Platygobio gracilis* | 1 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-005**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 26 April 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Mortensen, J.G. Effort: 511.4 m³

| Family | Species | Total |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-005**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 26 April 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 516.7 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## April 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-006**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 27 April 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,251.4 m³

| Family | Species | Total |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-006**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 27 April 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Wedemeyer, A.C. Effort: 712.0 m³

| Family | Species | Total |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-006**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 27 April 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 303.9 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## April 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-007**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 28 April 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O.; Wedemeyer, A.C. Effort: 1,222.9 m³

| Family | Species | Total |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-007**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 28 April 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 725.3 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 1 |
| 76 | *Platygobio gracilis* | 1 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-007**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 28 April 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 227.7 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 2 |

## Rio Grande Silvery Minnow Reproductive Monitoring

## April 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-008**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 29 April 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 983.2 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Cyprinus carpio* | 1 |
| 76 | *Hybognathus amarus* | 4 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-008**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 29 April 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 568.3 m³

| Family | Species | Total |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-008**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 29 April 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 645.5 m³

| Family | Species | Total |
|---|---|---|

# Rio Grande Silvery Minnow Reproductive Monitoring

## April 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-009**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 30 April 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 913.6 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Cyprinus carpio* | 1 |
| 76 | *Hybognathus amarus* | 4 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-009**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 30 April 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 580.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-009**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 30 April 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 351.7 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-010**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 01 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,292.6 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 69 |
| 76 | *Platygobio gracilis* | 3 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-010**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 01 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 658.3 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 1 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-010**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 01 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 315.9 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-011**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 02 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,008.6 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Hybognathus amarus* | 365 |
| 76 | *Platygobio gracilis* | 1 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-011**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 02 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 691.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Platygobio gracilis* | 1 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-011**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 02 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 520.8 m³

| **Family** | **Species** | **Total** |
|---|---|---|

# Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-012**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 03 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 905.5 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Hybognathus amarus* | 594 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-012**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 03 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Mortensen, J.G. Effort: 610.4 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-012**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 03 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 690.6 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-013**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 04 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,099.7 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Hybognathus amarus* | 145 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-013**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 04 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Mortensen, J.G. Effort: 633.8 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Hybognathus amarus* | 2 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-013**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 04 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 681.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-014**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 05 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 966.8 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 69 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-014**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 05 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 694.1 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Cyprinus carpio* | 2 |
| 76 | *Hybognathus amarus* | 27 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-014**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 05 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Wedemeyer, A.C. Effort: 763.7 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 1 |

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-015**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 06 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 753.5 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 8 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-015**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 06 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 660.8 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 5 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-015**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 06 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Wedemeyer, A.C. Effort: 779.7 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-016**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 07 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 675.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Cyprinus carpio* | 91 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-016**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 07 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 813.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Cyprinus carpio* | 13 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-016**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 07 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 793.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-017**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 08 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,000.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Hybognathus amarus* | 2 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-017**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 08 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 685.3 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Cyprinus carpio* | 7 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-017**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 08 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 902.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

# Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-018**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 09 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,175.6 m³

| Family | Species | Total |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-018**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 09 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 726.2 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Cyprinus carpio* | 5 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-018**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 09 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 270.1 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-019**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 10 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Effort: 0.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

Not Sampled - Not Feasible

New Mexico: Socorro County, Rio Grande Drainage **SEV20-019**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 10 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Mortensen, J.G. Effort: 680.4 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-019**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 10 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 674.4 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-020**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 11 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 924.5 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Cyprinus carpio* | 30 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-020**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 11 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Mortensen, J.G. Effort: 556.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-020**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 11 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 658.6 m³

| **Family** | **Species** | **Total** |
|---|---|---|

# Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-021**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 12 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 1,002.2 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Cyprinus carpio* | 1 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-021**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 12 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 744.2 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-021**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 12 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 791.6 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-022**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 13 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 846.0 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Cyprinus carpio* | 3 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-022**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 13 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 780.4 m³

| Family | Species | Total |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-022**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 13 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 916.6 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-023**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 14 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 729.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-023**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 14 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 732.8 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Cyprinus carpio* | 1 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-023**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 14 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 836.7 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-024**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 15 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,425.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-024**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 15 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Mortensen, J.G. Effort: 595.7 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-024**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 15 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 681.2 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-025**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 16 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,601.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-025**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 16 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Mortensen, J.G. Effort: 716.8 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-025**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 16 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 527.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-026**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 17 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,576.3 m³

| Family | Species | Total |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-026**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 17 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Robbins, T.O. Effort: 817.1 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Cyprinus carpio* | 16 |
| 76 | *Hybognathus amarus* | 11 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-026**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 17 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 709.1 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-027**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 18 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,420.6 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-027**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 18 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Robbins, T.O. Effort: 669.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Cyprinus carpio* | 15 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-027**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 18 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 622.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-028**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 19 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 558.5 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Cyprinus carpio* | 69 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-028**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 19 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 799.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-028**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 19 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 698.5 m³

| **Family** | **Species** | **Total** |
|---|---|---|

# Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-029**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 20 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 703.6 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Cyprinus carpio* | 5 |
| 76 | *Hybognathus amarus* | 1 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-029**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 20 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 832.5 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Cyprinus carpio* | 2 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-029**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 20 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 694.6 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-030**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 21 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 723.9 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Cyprinus carpio* | 3 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-030**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 21 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 665.6 m³

| Family | Species | Total |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-030**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 21 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 524.6 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-031**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 22 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,276.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-031**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 22 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 786.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-031**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 22 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 520.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-032**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 23 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,167.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-032**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 23 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 769.2 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-032**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 23 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 462.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-033**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 24 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,103.2 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Cyprinus carpio* | 2 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-033**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 24 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Robbins, T.O. Effort: 709.3 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-033**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 24 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 723.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-034**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 25 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,225.3 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-034**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 25 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Robbins, T.O. Effort: 779.3 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-034**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 25 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 595.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-035**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 26 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 835.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-035**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 26 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 1,344.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Hybognathus amarus* | 10,229 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-035**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 26 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Wedemeyer, A.C. Effort: 739.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-036**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 27 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 602.6 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 6 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-036**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 27 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Wedemeyer, A.C. Effort: 1,028.2 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 6,279 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-036**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 27 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 586.6 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-037**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 28 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Wedemeyer, A.C. Effort: 1,032.7 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-037**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 28 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 884.7 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Hybognathus amarus* | 40 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-037**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 28 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 531.8 m³

| **Family** | **Species** | **Total** |
|---|---|---|

# Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-038**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 29 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Wedemeyer, A.C. Effort: 825.7 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-038**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 29 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 802.7 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Hybognathus amarus* | 1 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-038**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 29 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 717.4 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Hybognathus amarus* | 2 |

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-039**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 30 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Mortensen, J.G. Effort: 1,107.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-039**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 30 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 829.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-039**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 30 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 576.6 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## May 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-040**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 31 May 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Clark-Barkalow, S.L. Effort: 700.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-040**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 31 May 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Robbins, T.O. Effort: 555.4 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-040**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 31 May 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 731.6 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## June 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-041**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 01 June 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Wedemeyer, A.C. Effort: 1,177.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-041**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 01 June 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Robbins, T.O. Effort: 515.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-041**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 01 June 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 667.4 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## June 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-042**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 02 June 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 1,077.3 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-042**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 02 June 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 827.6 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-042**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 02 June 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 700.3 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## June 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-043**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 03 June 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 1,023.1 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 982 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-043**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 03 June 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 689.9 m³

| Family | Species | Total |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-043**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 03 June 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 729.8 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## June 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-044**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 04 June 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,309.3 m³

| Family | Species | Total |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-044**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 04 June 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 841.2 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 343 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-044**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 04 June 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 606.5 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## June 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-045**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 05 June 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,533.4 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 3 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-045**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 05 June 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 847.4 m³

| Family | Species | Total |
|---|---|---|
| 76 | *Hybognathus amarus* | 1 |

New Mexico: Socorro County, Rio Grande Drainage **SAM20-045**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 05 June 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 622.2 m³

| Family | Species | Total |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## June 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-046**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 06 June 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,257.0 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Hybognathus amarus* | 13 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-046**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 06 June 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 809.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-046**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 06 June 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 526.2 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## June 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-047**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 07 June 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,441.2 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Cyprinus carpio* | 5 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-047**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 07 June 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Robbins, T.O. Effort: 531.4 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-047**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 07 June 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 676.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## June 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-048**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 08 June 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,427.5 m³

| **Family** | **Species** | **Total** |
|---|---|---|
| 76 | *Platygobio gracilis* | 1 |

New Mexico: Socorro County, Rio Grande Drainage **SEV20-048**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 08 June 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Robbins, T.O. Effort: 547.6 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-048**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 08 June 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 668.9 m³

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## June 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-049**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 09 June 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 483.4 $m^3$

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-049**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 09 June 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 844.5 $m^3$

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-049**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 09 June 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Keller, R.C. Effort: 724.5 $m^3$

| **Family** | **Species** | **Total** |
|---|---|---|

## Rio Grande Silvery Minnow Reproductive Monitoring

## June 2020

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ20-050**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 10 June 2020
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Robbins, T.O. Effort: 489.1 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SEV20-050**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 10 June 2020
UTM Easting: 330099 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Urioste, A.D. Effort: 816.3 m³

| **Family** | **Species** | **Total** |
|---|---|---|

New Mexico: Socorro County, Rio Grande Drainage **SAM20-050**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 10 June 2020
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 482.7 m³

| **Family** | **Species** | **Total** |
|---|---|---|