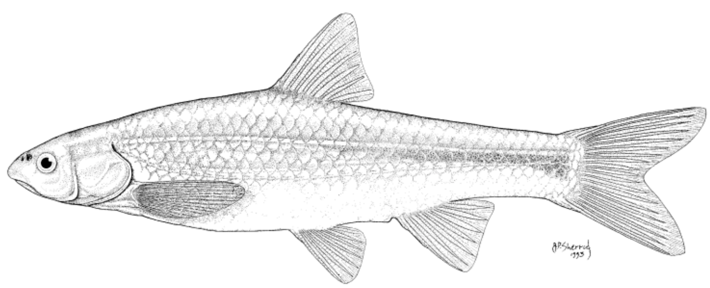
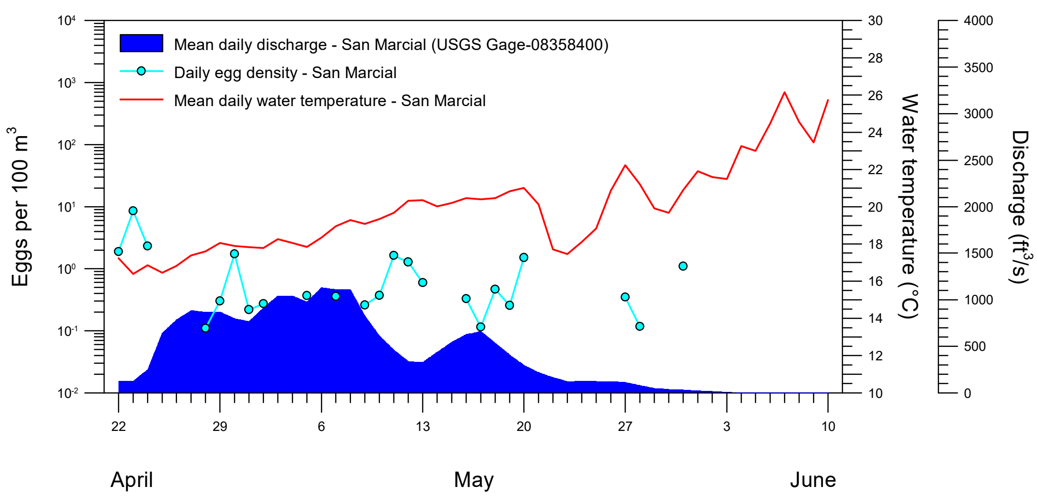
Rio Grande Silvery Minnow Reproductive Monitoring during 2022

A U.S. Bureau of Reclamation Funded Research Program





Final Report
28 October 2022

Rio Grande Silvery Minnow Reproductive Monitoring during 2022

A U.S. Bureau of Reclamation Funded Research Program

Contract 140R4021C0007:

Requisition 0040571030
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], 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), UNM; MSC03-2120; Albuquerque, NM 87131
&
[3] Department of Fish, Wildlife, and Conservation Biology, CSU; 10 Wagar; Fort Collins, CO 80523

Final Report
28 October 2022

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The primary objective of the Rio Grande Silvery Minnow Reproductive Monitoring Program is 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 long-term 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 2022 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 2022.

In 2022, we collected drifting eggs from three fish species. Most of the eggs were identified as Rio Grande Silvery Minnow (n = 573), but a few were identified as Flathead Chub (n = 6) or Common Carp (n = 5). We caught the most Rio Grande Silvery Minnow eggs at San Marcial (n = 331), followed by Albuquerque (n = 166), and Sevilleta (n = 76).

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, 2017–2022). The passage rates at Albuquerque, Sevilleta, and San Marcial were quite similar in 2022 ($1.01 \cdot 10^{-1}$, $5.56 \cdot 10^{-2}$, and $5.01 \cdot 10^{-2}$, respectively). We roughly estimated that about $4.34 \cdot 10^{5}$ eggs, $2.40 \cdot 10^{5}$ eggs, and $2.16 \cdot 10^{5}$ eggs were transported downstream of Albuquerque, Sevilleta, and San Marcial, respectively, during the 2022 sampling season (i.e., 22 April to 10 June).

Long-term spawning patterns and trends were based on all available data across sites (Albuquerque, Sevilleta, San Marcial) and years (2003–2022). Logistic regression modeling of daily egg presence-absence data 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 0.80, whereas the occurrence probability was 0.96 during a 200% increase in flow. In contrast to the robust discharge relationship, daily egg presence-absence data revealed a very weak and nonsignificant association with mean daily water temperature.

Annual egg-passage rates, using data from all sites (2003–2022), were lowest in 2004 ($1.66 \cdot 10^{-3}$) and highest in 2011 ($2.32 \cdot 10^{1}$). There was a steady decline in passage rates from 2011 to 2013, followed by an increase in 2014. Passage rates declined again from 2014 ($7.64 \cdot 10^{0}$) to 2016 ($1.42 \cdot 10^{-1}$). The 2022 passage rate ($6.89 \cdot 10^{-2}$) was lower than in 2021 ($8.21 \cdot 10^{0}$).

Changes in annual egg-occurrence probabilities and annual egg-passage rates, using data from all sites, were moderately predicted by differences in seasonal river flows across years (2003–2022). Out of 224 models considered, we found that the top three models, which represented elevated flows during spring, were most informative (ca. 48% 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 higher during years with low, truncated, and fluctuating spring flows, whereas annual egg-passage rates were lower during years with high, prolonged, and stable 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 positively 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 newly hatched fish require about one month to progress through the early larval phases, the stability and persistence of these

nursery habitats is essential during this initial period (ca. May–June). The current conservation status of Rio Grande Silvery Minnow appears strongly dependent on reliably ensuring sufficient 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, 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 ranges (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; Platania and Altenbach 1998). 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 imperiled 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 characterized by drifting eggs and larvae (Platania and Altenbach 1998). After spawning, their non-adhesive eggs rapidly swell with water and become nearly neutrally-buoyant. Although these eggs (ca. 3 mm diameter) will settle to the bottom in still water, even trace currents (< 1 cm/s) will keep them suspended in the water column, and typical river currents (> 1 cm/s) will passively transport them downstream, to some extent, during development (Platania and Altenbach 1998; Dudley and Platania 1999, 2007). Spawning is generally associated with increases in discharge, such as spring runoff, summer rainstorms, or managed water releases (Valdez et al. 2019; Dudley et al. 2021). 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 be retained 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 back upstream 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. 2020).

Reproductive monitoring 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 2022.

The primary objective of the Rio Grande Silvery Minnow Reproductive Monitoring Program is 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. Our ongoing research 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 promoting the successful spawning and early recruitment of this imperiled species.

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 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 Middle Rio Grande Conservancy District (MRGCD) 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 2022. Consistent and long-term sampling efforts (2001–2022), however, 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 (USGS) gaging station (San Marcial: USGS Gage-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 2022.

From 2017 to 2022, two additional sites were monitored that had been sampled periodically in the past (i.e., 2006–2011). These sampling sites were 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 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 in the same area that was consistently sampled from 2006 to 2011. 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 somewhat different between 2021 and 2022 (Figure 2). In 2021, there was a relatively weak spring runoff that began in late April and persisted into early June. Although there was a similarly weak spring runoff in 2022, it both started and ended earlier than in 2021. In 2021 and 2022, there was a general trend of lower flow at downstream locations (e.g., San Acacia: USGS Gage-08354900 and San Marcial: USGS Gage-08358400) as compared to upstream locations (e.g., Albuquerque: USGS Gage-08330000). River flows in 2022 began to peak by late April but declined rapidly to low levels by late May. As compared to the generalized historical spring runoff (i.e., average mean-daily discharges since 1973 [Cochiti Dam operational]), the timing, duration, and magnitude of flows were somewhat atypical in 2021 and markedly atypical in 2022. All discharge data presented in this report are provisional and subject to change.

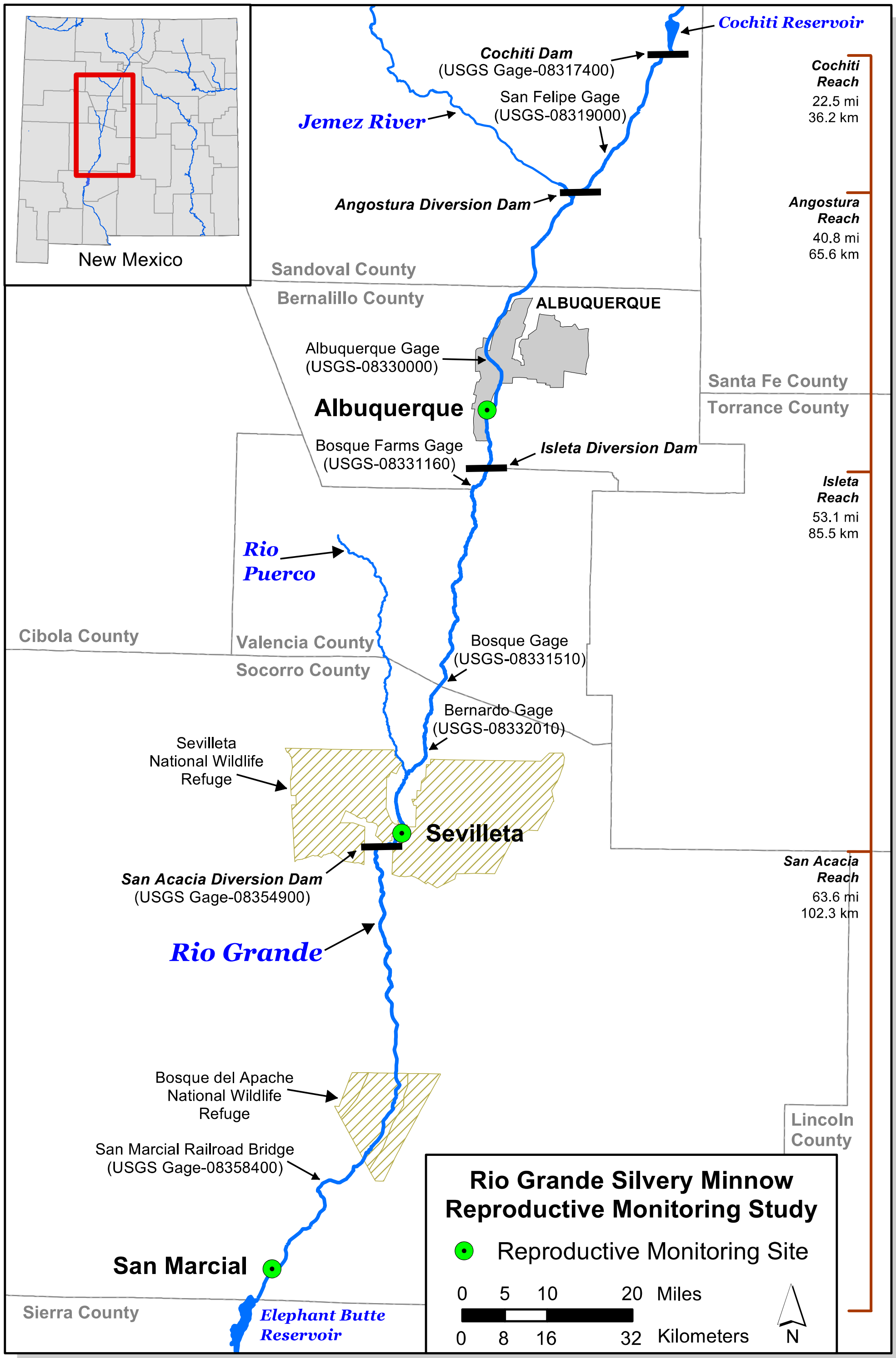


Figure 1. Map of the study area and sampling sites for the Rio Grande Silvery Minnow reproductive monitoring study.

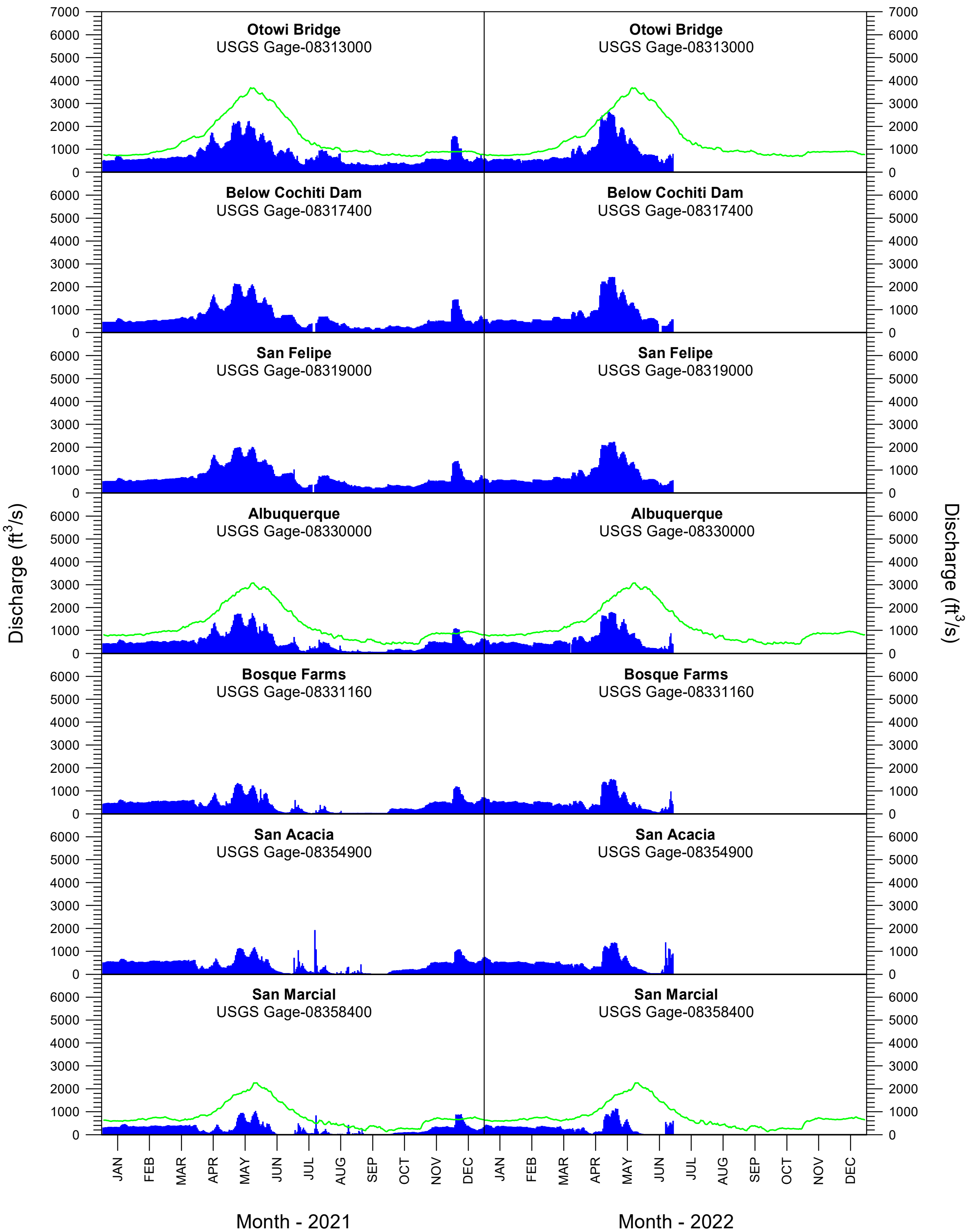


Figure 2. Rio Grande mean-daily discharge, by USGS gaging station, from 1 January 2021 to 30 June 2022. Green lines are the average mean-daily discharges across years (1973–2021).

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 Corp. 2018); 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 drifting fish eggs (Moore Egg Collector; MEC [Altenbach et al. 2000]), was the only sampling apparatus used in this study. Several years after the original publication detailing the construction and operation of the MEC (Altenbach et al. 2000), we substantially increased the overall efficiency of this device (i.e., greater volume of water sampled). A modified filtering screen, to separate drifting debris from Rio Grande Silvery Minnow eggs, was developed over multiple sampling seasons. 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 (ca. four hours per day at each site) 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 or jammed gears), 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 (F) and the rotor constant (R), using the formula: $L = (F \cdot R) / 999{,}999$ (General Oceanics Inc. 2018). We then calculated 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

The eggs of Flathead Chub, *Platygobio gracilis* and Common Carp, *Cyprinus carpio* were smaller (ca. 1.5–2.5 mm diameter) than Rio Grande Silvery Minnow eggs (ca. 3–4 mm diameter). Their eggs were 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). Also, Common Carp eggs often had a slight amount of fine particulate matter adhered to the chorion (i.e., surface of egg).

When the number of Rio Grande Silvery Minnow 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 Museum of Southwestern Biology (Fishes). Also, large numbers of live eggs were periodically transferred to the Albuquerque Biological Park for their ongoing captive propagation program. However, all preserved eggs were sorted and enumerated in the laboratory after the field portion of the study.

Analytical Considerations

Daily egg densities 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. 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 the formula: $P_e = ((D / 100) \cdot Q)$. 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 USGS Gage-08332010, and San Marcial: USGS Gage-08358400). At Sevilleta, we used USGS Gage-08332010 (2003–2005 and 2012–2022) and USGS Gage-08331510 (2006–2011) 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. 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 2022 (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 San Marcial data 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. We also felt it was more reasonable to combine all available data across sites (Albuquerque, Sevilleta, San Marcial) and years (2003–2022), as this resulted in more robust and inclusive statistical analyses. Further, we used the most common sampling period (22 April to 10 June), across sites and years, for all 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 all sampling sites (2003–2022), changed as a function of different river flows or water temperatures. The percentage change in mean daily discharge (Δ) taken from the nearest upstream gaging station, from one day prior to egg collection at each site, was used in the first analysis. This duration was chosen to allow adequate time for the discharge changes occurring at the upstream river gages to reach the sampling sites. We felt this delayed flow metric best represented the changing environmental conditions (e.g., water velocities, aquatic habitats, and water quality) that occurred just prior to egg collection. A second analysis was conducted to assess how the daily egg-occurrence probability, based on daily egg presence-absence data from all sampling sites (2003–2022), changed as a function of mean daily water temperature taken at each site during the sampling period. The associated 95% confidence intervals of the regression lines were constructed using inverse predictions (JMP 2021) of discharge and temperature across the range of modeled occurrence probabilities. The likelihood ratio chi-square statistic (G^2; JMP 2021) 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. Rio Grande Silvery Minnow spawning data (2003–2022), from all sampling sites, were analyzed using PROC NLMIXED (Nonlinear Mixed Models; SAS 2022). This advanced numerical optimization procedure was used to fit our long-term data to a mixture model, which comprised a binomial distribution (i.e., based on presence-absence data) and a 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 (δ = estimated egg-occurrence probability, μ = estimated lognormal egg-passage rate, σ = standard deviation of the estimated lognormal egg-passage rate, and $E(x)$ = estimated egg-passage rate [based on δ, μ, and σ]) 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 σ). Naïve passage-rate estimates (i.e., unmodeled), calculated using the method of moments (Zar 2010), were also added as a reference to 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 (δ, μ, and σ [i.e., dependent variables]), where a logit link was used for δ, an identity link for μ, and a log link for σ. 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 (δ[Year] μ[Year]) represents the upper limit on the amount of explainable variation and the null model (δ[.] μ[.]) 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 Albuquerque (ABQ: USGS Gage-08330000). Maximum discharge (ABQmax), mean discharge (ABQmean), and days exceeding threshold discharge values (days > 1,000 [ABQ>1,000], 2,000 [ABQ>2,000], and 3,000 [ABQ>3,000] ft^3/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 dataset is explained by the covariate (Appendix B [Table B - 1]). For δ, there is no over-dispersion or extra-binomial variation, and for μ, no extra variation provided beyond the constant σ model. Random-effects models (*R*) were also considered for δ and μ 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 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 AIC_c indicate a better fit of the data to the model. Models were ranked by AIC_c values, and the top ten models, based on 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, 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 δ and μ 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 (2022)

During 2022, all eggs (n = 584) were immediately identified in the field as Rio Grande Silvery Minnow (n = 573), Flathead Chub (n = 6), or Common Carp (n = 5). We did not retain or transfer any live Rio Grande Silvery Minnow eggs to the Albuquerque Biological Park. Common Carp and Flathead Chub eggs were collected primarily during May. In contrast, Rio Grande Silvery Minnow eggs were collected primarily during April and May.

Spatial Spawning Patterns

Simple patterns (2022)

Sampling at the Albuquerque, Sevilleta, and San Marcial sites was conducted from 22 April to 10 June 2022 (Appendix C). The cumulative volume of water sampled was highest at Albuquerque, followed by San Marcial and Sevilleta (59,859.4 m^3, 49,389.6 m^3, and 44,867.5 m^3, respectively). Rio Grande Silvery Minnow eggs were collected from all three sampling sites in 2022 (Table 1 and Figure 3). We caught the most eggs at San Marcial (n = 331), followed by Albuquerque (n = 166), and Sevilleta (n = 76). Based on the total sampling effort across all sites (ca. 600 h), we collected about 0.96 eggs/h in 2022. Although the timing, duration, frequency, and magnitude of spawning varied across sites, the highest numbers of eggs were typically collected during peak flows that occurred from late April to mid-May. Rio Grande Silvery Minnow eggs were collected across a broad range of mean daily water temperatures (ca. 16–25°C).

Complex patterns (2003–2022)

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 (δ[Year] μ[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 notably higher 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 from 2017 to 2020, passage rates at San Marcial were lower ($P < 0.05$) in 2020 than in either 2017 or 2019. The passage rates at all three sampling sites were lower ($P < 0.05$) in 2022 than in 2021. The passage rates at Albuquerque, Sevilleta, and San Marcial were quite similar in 2022 ($1.01 \cdot 10^{-1}$, $5.56 \cdot 10^{-2}$, and $5.01 \cdot 10^{-2}$, respectively). Naïve passage-rate estimates (i.e., unmodeled), calculated using the method of moments, were very similar to model-estimated passage rates ($E(x)$). Additionally, we roughly estimated ($E(x)_{50d}$) that about $4.34 \cdot 10^5$ eggs, $2.40 \cdot 10^5$ eggs, and $2.16 \cdot 10^5$ eggs were transported downstream of Albuquerque, Sevilleta, and San Marcial, respectively, during the 2022 sampling season (i.e., 22 April to 10 June).

Table 1. Rio Grande Silvery Minnow egg abundance, by date and site, during 2022. Blank cells indicate days when it was not safe or feasible to sample at a site.

Sampling Date	Albuquerque	Sevilleta	San Marcial
22-Apr-22	0	0	24
23-Apr-22	0	0	134
24-Apr-22	0		38
25-Apr-22	0		0
26-Apr-22	0	4	0
27-Apr-22	0	1	0
28-Apr-22	4	0	1
29-Apr-22	0	9	2
30-Apr-22	6	1	30
1-May-22	9	2	3
2-May-22	15	4	3
3-May-22	46	26	0
4-May-22	5	5	0
5-May-22	1	5	7
6-May-22	0	0	0
7-May-22	8	0	4
8-May-22	11	2	0
9-May-22	3	0	2
10-May-22	3	0	3
11-May-22	0	0	13
12-May-22	0	0	13
13-May-22	3	0	5
14-May-22	2	1	0
15-May-22	14	0	0
16-May-22	10	11	3
17-May-22	12	2	1
18-May-22	2	0	4
19-May-22	0	0	2
20-May-22	0	2	19
21-May-22	0	1	0
22-May-22	0	0	0
23-May-22	0	0	0
24-May-22	0	0	0
25-May-22		0	0
26-May-22	3	0	0
27-May-22	0	0	4
28-May-22	0	0	1
29-May-22	0	0	0
30-May-22		0	0
31-May-22	0	0	15
1-Jun-22	0	0	0
2-Jun-22	0	0	0
3-Jun-22	0	0	0
4-Jun-22	0	0	0
5-Jun-22	0	0	0
6-Jun-22	0	0	0
7-Jun-22	2	0	0
8-Jun-22	0	0	0
9-Jun-22	7	0	0
10-Jun-22	0	0	0
Total (eggs)	**166**	**76**	**331**

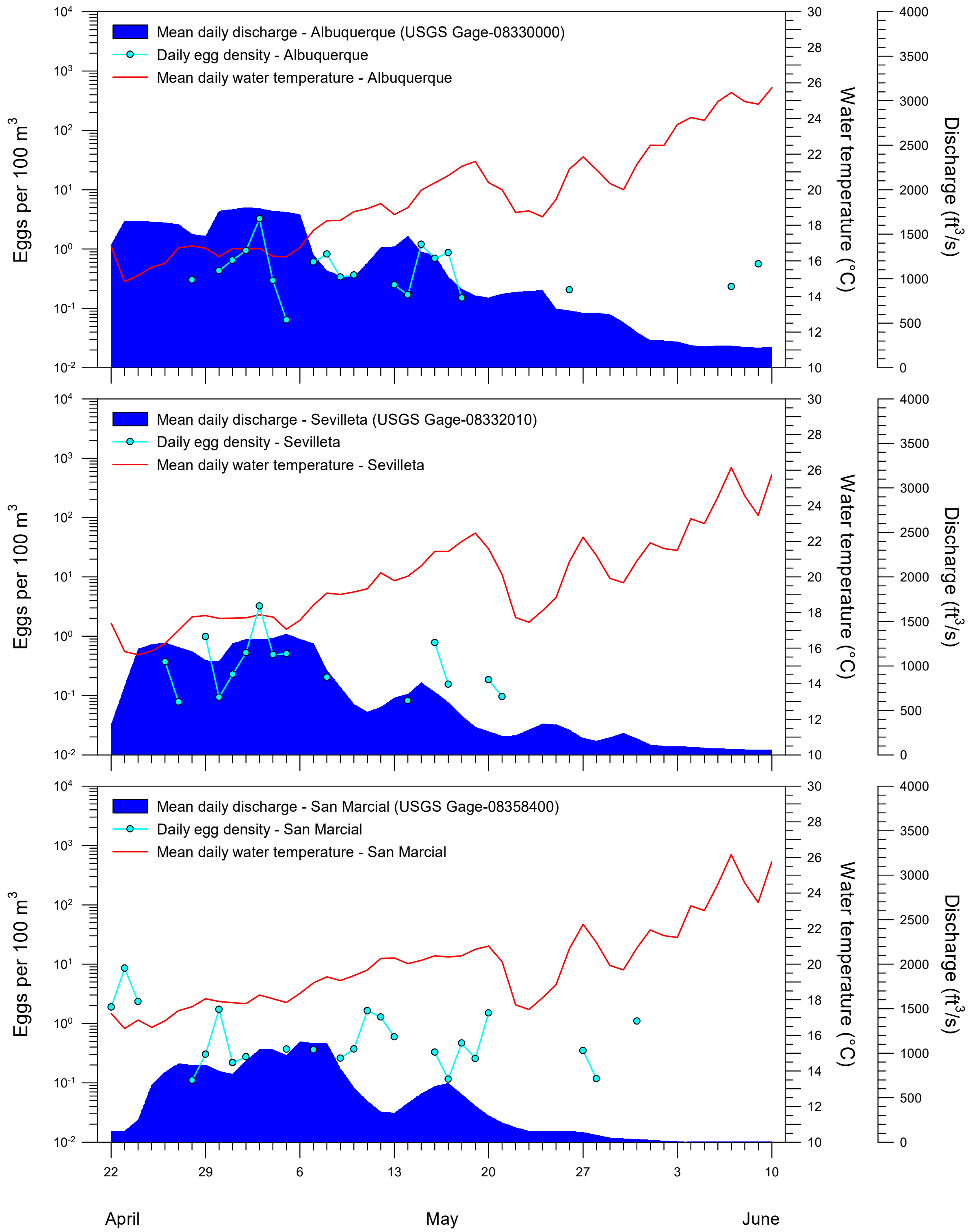


Figure 3. Mean daily discharge, daily egg density, and mean daily water temperature, by site and date, during 2022 (see Table 1 for egg abundance data).

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
2021	49	34	15	69.4	12,627
2022	48	20	28	41.7	166

[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
2021	45	26	19	57.8	4,428
2022	48	15	33	31.3	76

[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	48.6	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
2021	50	31	19	62.0	9,813
2022	50	23	27	46.0	331

[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).

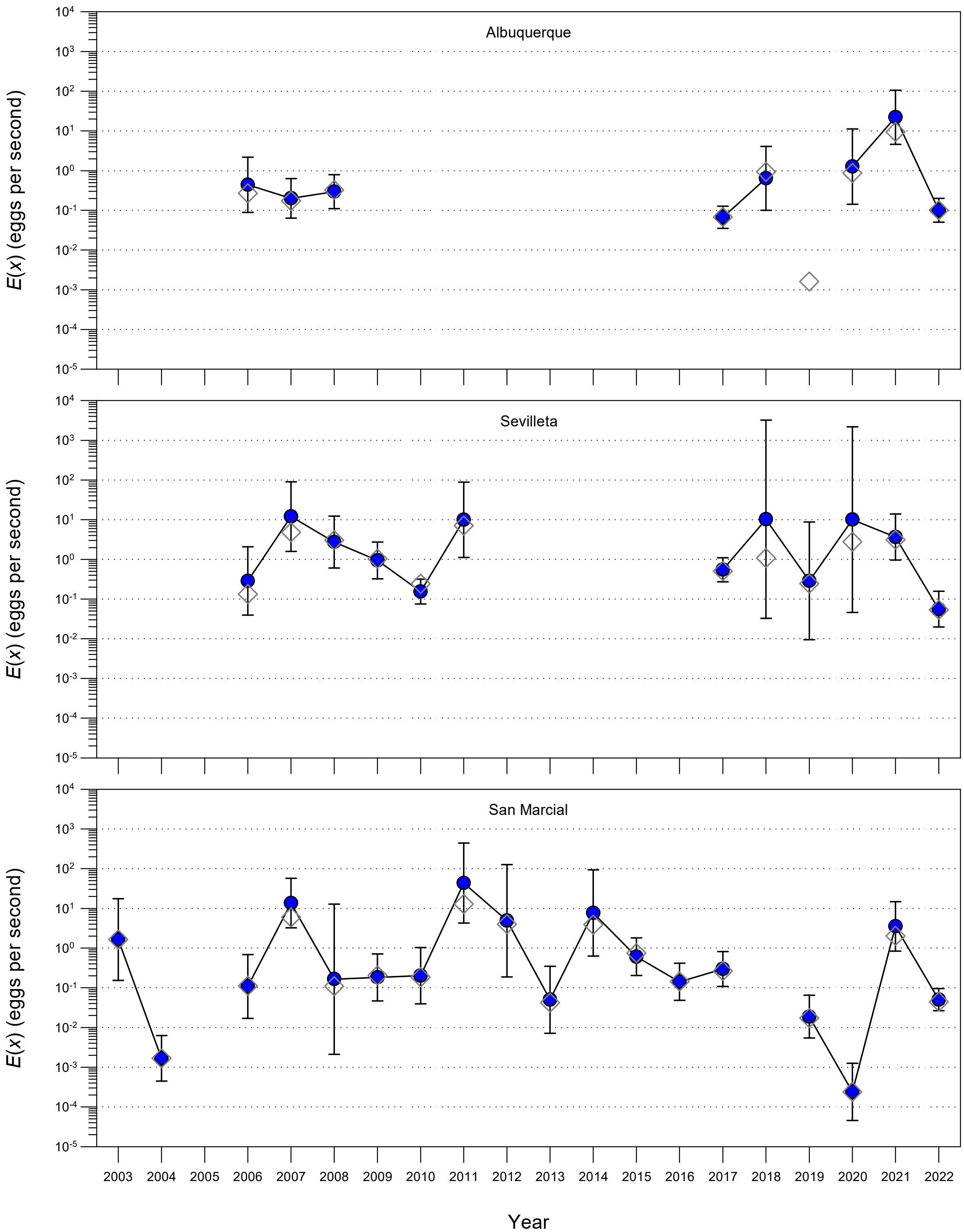


Figure 4. Rio Grande Silvery Minnow egg-passage rates (estimated using 22 April to 10 June data) across sites and years. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated.

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.

Year[1]	Albuquerque[1]	Sevilleta[2]	San Marcial[3,4]	All Sites
2003			1.64 (0.15–17.55)	1.64 (0.15–17.55)
2004			$1.66 \cdot 10^{-3}$ ($4.43 \cdot 10^{-4}$–0.01)	$1.66 \cdot 10^{-3}$ ($4.43 \cdot 10^{-4}$–0.01)
2005				
2006	0.44 (0.09–2.18)	0.29 (0.04–2.09)	0.11 (0.02–0.69)	0.32 (0.10–1.03)
2007	0.20 (0.06–0.63)	12.02 (1.60–90.14)	13.59 (3.25–56.82)	8.33 (2.91–23.83)
2008	0.30 (0.11–0.79)	2.73 (0.60–12.37)	0.16 ($2.10 \cdot 10^{-3}$–12.89)	0.81 (0.30–2.19)
2009		0.95 (0.33–2.74)	0.18 (0.05–0.71)	0.68 (0.23–2.02)
2010		0.15 (0.08–0.32)	0.20 (0.04–1.04)	0.17 (0.08–0.37)
2011		9.97 (1.12–88.49)	43.37 (4.29–438.84)	23.16 (4.61–116.44)
2012			4.89 (0.19–127.42)	4.89 (0.19–127.42)
2013			0.05 (0.01–0.35)	0.05 (0.01–0.35)
2014			7.64 (0.63–93.15)	7.64 (0.63–93.15)
2015			0.61 (0.20–1.81)	0.61 (0.20–1.81)
2016			0.14 (0.05–0.42)	0.14 (0.05–0.42)
2017	0.07 (0.04–0.13)	0.55 (0.28–1.10)	0.30 (0.11–0.82)	0.29 (0.18–0.47)
2018	0.64 (0.10–4.08)	10.21 (0.03–$3.21 \cdot 10^{3}$)		2.46 (0.21–28.71)
2019	-	0.29 (0.01–8.73)	0.02 (0.01–0.06)	0.05 (0.01–0.24)
2020	1.26 (0.14–11.22)	10.04 (0.05–$2.17 \cdot 10^{3}$)	$2.39 \cdot 10^{-4}$ ($4.58 \cdot 10^{-5}$–$1.25 \cdot 10^{-3}$)	2.87 (0.19–42.30)
2021	22.06 (4.61–105.62)	3.67 (0.97–13.95)	3.52 (0.84–14.69)	8.21 (3.37–19.98)
2022	0.10 (0.05–0.20)	0.06 (0.02–0.16)	0.05 (0.03–0.10)	0.07 (0.04–0.11)

[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).

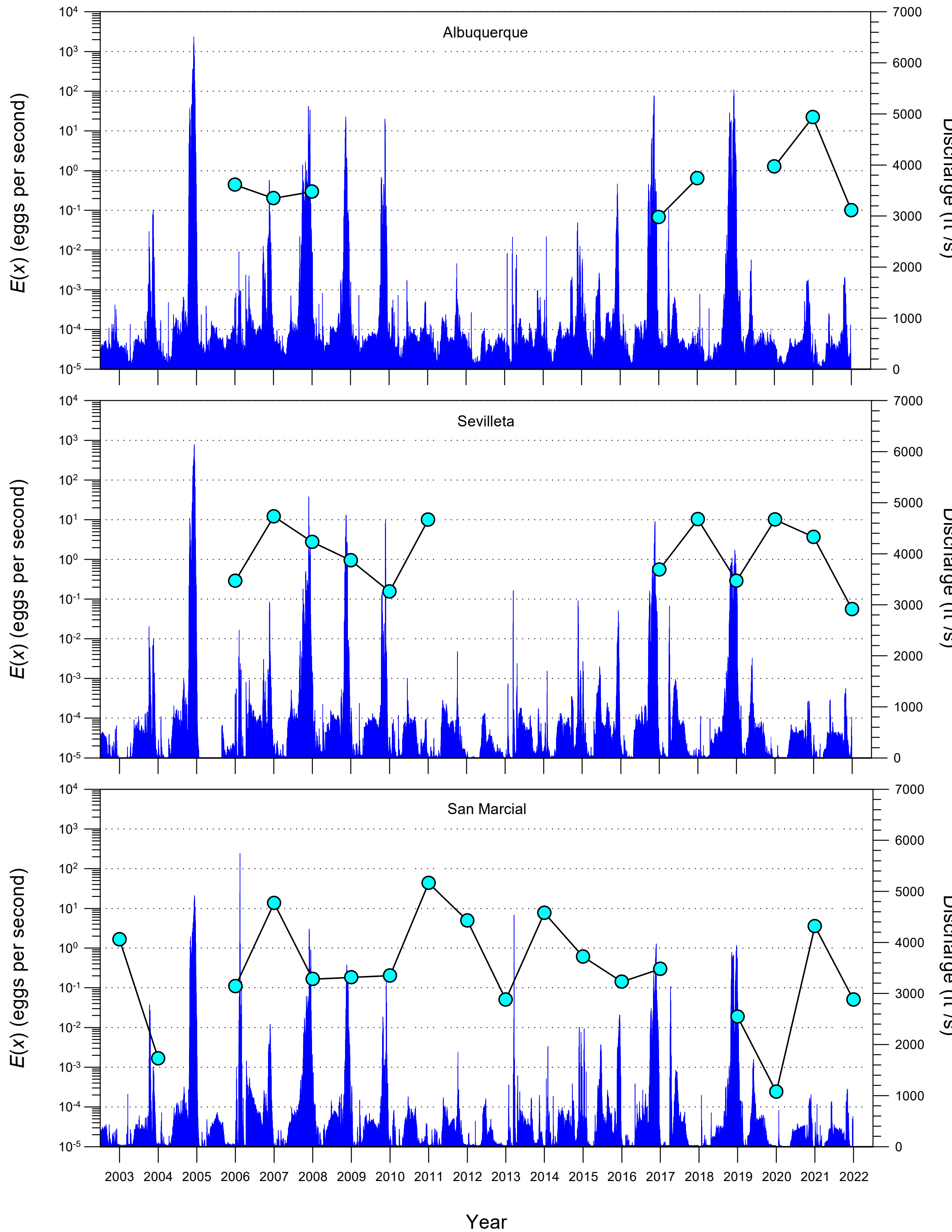


Figure 5. Rio Grande Silvery Minnow egg-passage rates (estimated using 22 April to 10 June data), and mean daily discharge data (Albuquerque, Bosque/Bernardo, and San Marcial gages [2003-01-01 to 2022-06-30]), across sites and years.

Ecological Relationships

Spawning cues (2003–2022)

Logistic regression modeling of Rio Grande Silvery Minnow daily egg presence-absence data from all sites (2003–2022) revealed strong associations with the percentage change in mean daily discharge (i.e., independent of flow magnitude) just prior to egg collection (G^2 = 64.20 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 0 to 5,360 ft^3/s. The probability of collecting eggs (i.e., daily egg-occurrence probability) ranged from 0.21 (Δ discharge = –50%) to 0.40 (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 0.80, whereas the occurrence probability was 0.96 during a 200% increase in flow. The occurrence probability (O_p) can be computed, based on the intercept (β_0 = –0.4191) and slope (β_1 = 0.0183) of the logistic regression (2003–2022), using the formula: $O_p = \exp(\beta_0 + (\beta_1 \cdot \Delta)) / (1 + \exp(\beta_0 + (\beta_1 \cdot \Delta)))$.

In contrast to the robust discharge relationship, daily egg presence-absence data from all sites (2003–2022) revealed a very weak association with mean daily water temperature during the study period ($G^2 = 8.41 \cdot 10^{-3}$ and P = 0.93). The egg occurrence probability decreased negligibly from 0.403 at a minimum observed temperature of 13°C to 0.397 at a maximum observed temperature of 27°C. This weak relationship also resulted in considerable uncertainty in the estimated probabilities (i.e., confidence intervals could not be computed), so we did not illustrate these nonsignificant results.

Spawning dynamics (2003–2022)

Rio Grande Silvery Minnow egg-passage rates ($E(x)$; estimated using data from all sites [22 April to 10 June; 2003–2022]) revealed notable differences across years (Figure 7). Passage rates were lowest in 2004 ($1.66 \cdot 10^{-3}$) and highest in 2011 ($2.32 \cdot 10^{1}$). 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 ($7.64 \cdot 10^{0}$) to 2016 ($1.42 \cdot 10^{-1}$). The 2022 passage rate ($6.89 \cdot 10^{-2}$) was lower ($P < 0.05$) than in 2021 ($8.21 \cdot 10^{0}$). Combining a plot of $E(x)$ values and mean daily discharge data (2003–2022) revealed a long-term recurrent pattern of reduced passage rates during years with higher spring flows (Figure 8). Values of $E(x)$ decreased with maximum discharge, number of days with discharge exceeding a threshold value, estimated acres of inundation, and mean daily discharge (Figure 9).

Annual egg-occurrence probabilities (δ) and annual lognormal egg-passage rates (μ), estimated from the year model (δ[Year] μ[Year]), were also modestly associated with hydrological metrics across years (2003–2022). Values of δ generally decreased with higher spring flows (Figures 10 and 11), particularly at the highest flows. However, values of μ generally increased with higher spring flows (Figures 12 and 13).

Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using data from all sites, revealed that variation in both δ and μ was moderately predicted by changes in hydrological metrics across years (2003–2022; Table 6). The top ecological model (δ[ABQ>3,000+*R*] μ[ABQ>1,000+R]) received 25.9% of the AIC_c weight (w_i) out of the 224 models considered. The top δ covariate (ABQ>3,000) accounted for 13.5% of the deviance (P = 0.12) explained by the δ(Year) model over the δ(.) model. Similarly, we found no significant effects for ABQmean (5.7%), ABQ>2,000 (5.2%), Inundation (4.0%), ABQmax (1.8%), or ABQ>1,000 (0.0%). In contrast, the top μ covariate (ABQ>1,000) accounted for 23.6% of the deviance ($P < 0.05$) explained by the μ(Year) model over the μ(.) model. Similarly, we found significant effects ($P < 0.05$) for ABQmax (23.1%), ABQmean (22.5%), Inundation (20.8%), ABQ>3,000 (20.1%), and ABQ>2,000 (18.1%). In summary, we found that low and truncated spring flows were associated with higher estimated egg-occurrence probabilities (δ), and that high and prolonged spring flows were associated with lower estimated egg-passage rates ($E(x)$).

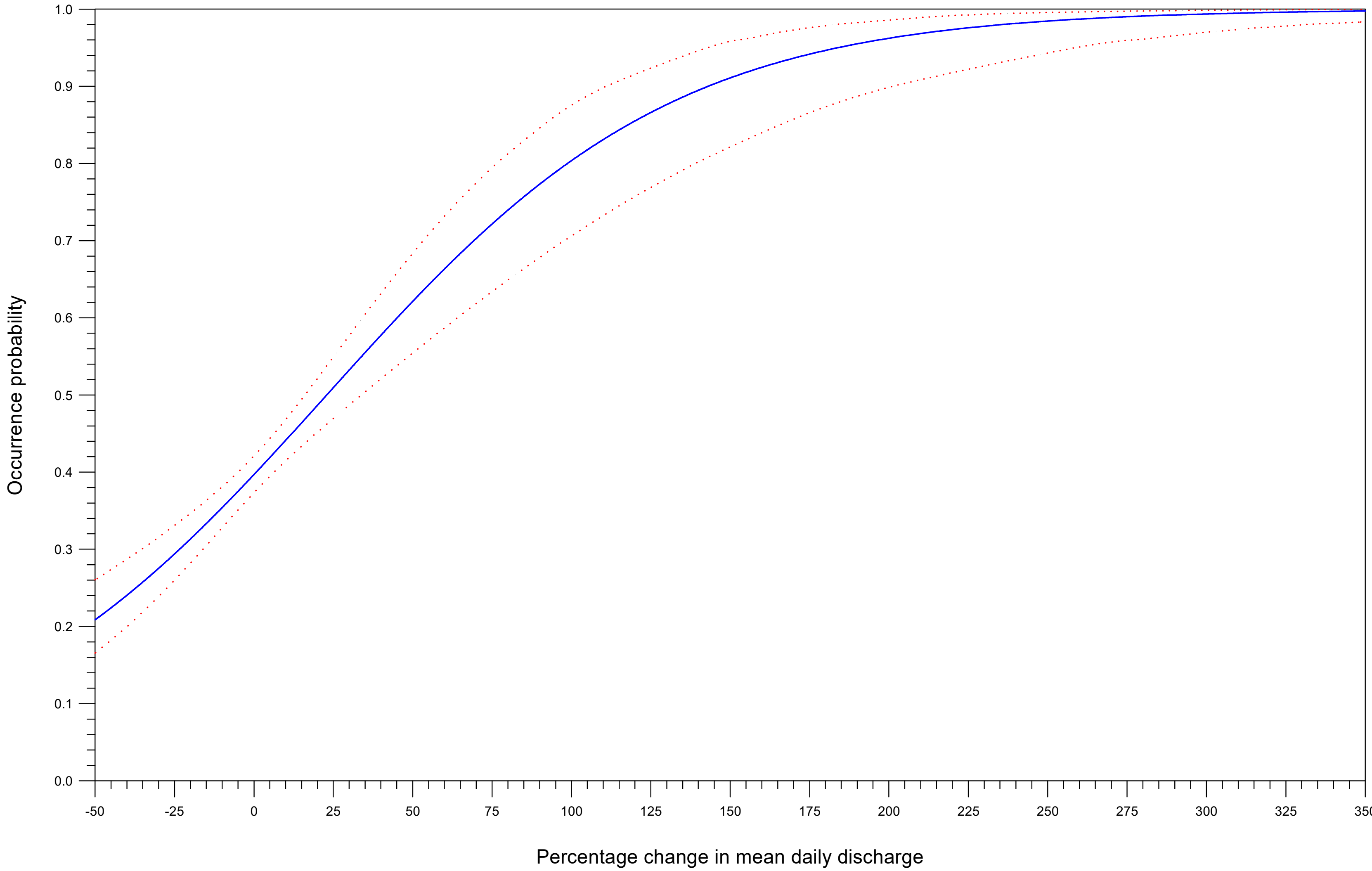


Figure 6. Logistic regression plot, using data from all sites (22 April to 10 June; 2003–2022), illustrating Rio Grande Silvery Minnow daily egg-occurrence probability as a function of the percentage change in mean daily discharge taken from the nearest upstream gaging station. Logistic regression line (solid) and 95% confidence intervals (dotted) are illustrated.

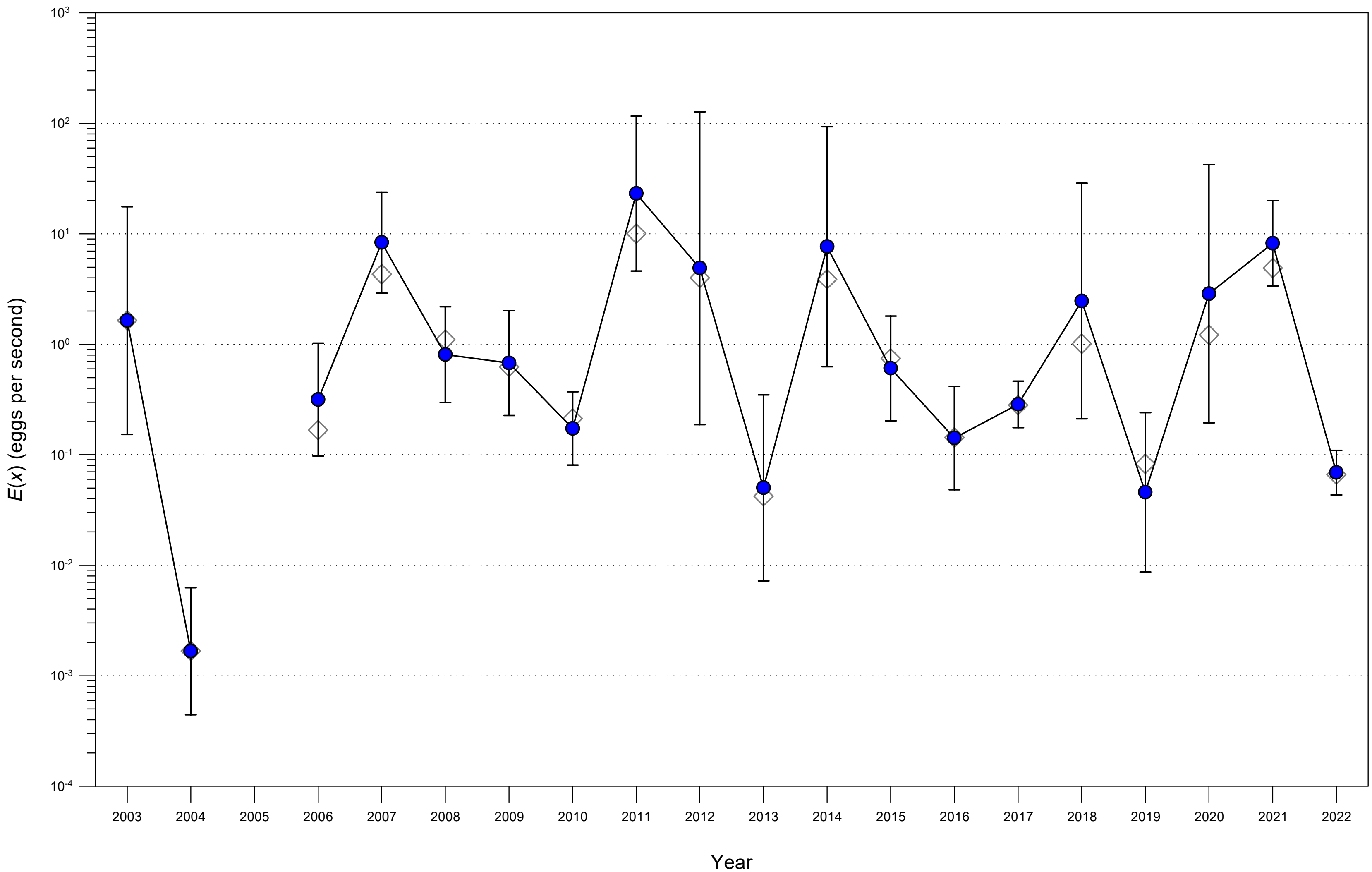


Figure 7. Rio Grande Silvery Minnow egg-passage rates (estimated using data from all sites [22 April to 10 June]) across years. Sampling did not occur in 2005. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated.

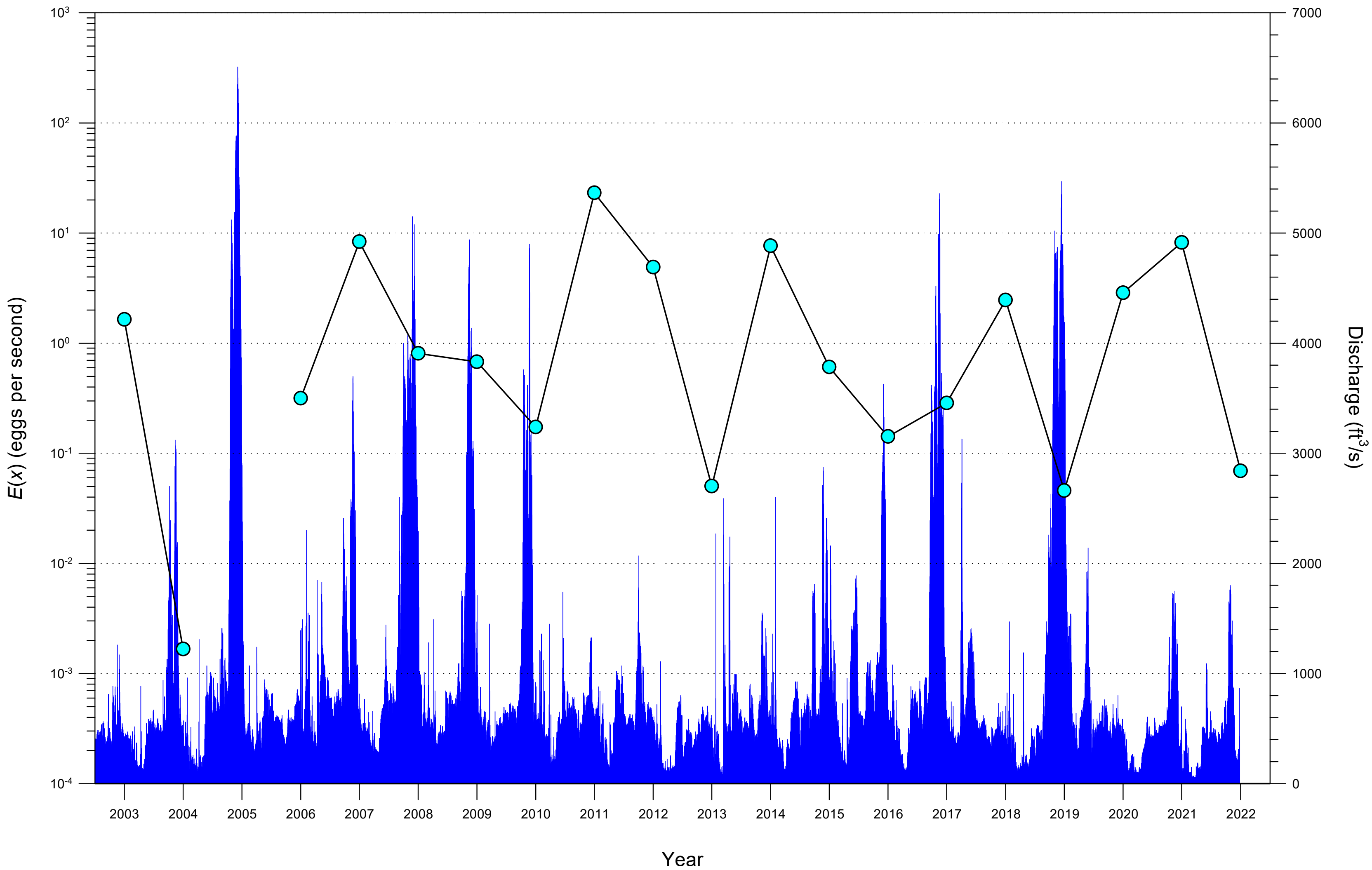


Figure 8. Rio Grande Silvery Minnow egg-passage rates (estimated using data from all sites [22 April to 10 June]), and mean daily discharge data from the Albuquerque Gage (2003-01-01 to 2022-06-30), across years. Sampling did not occur in 2005.

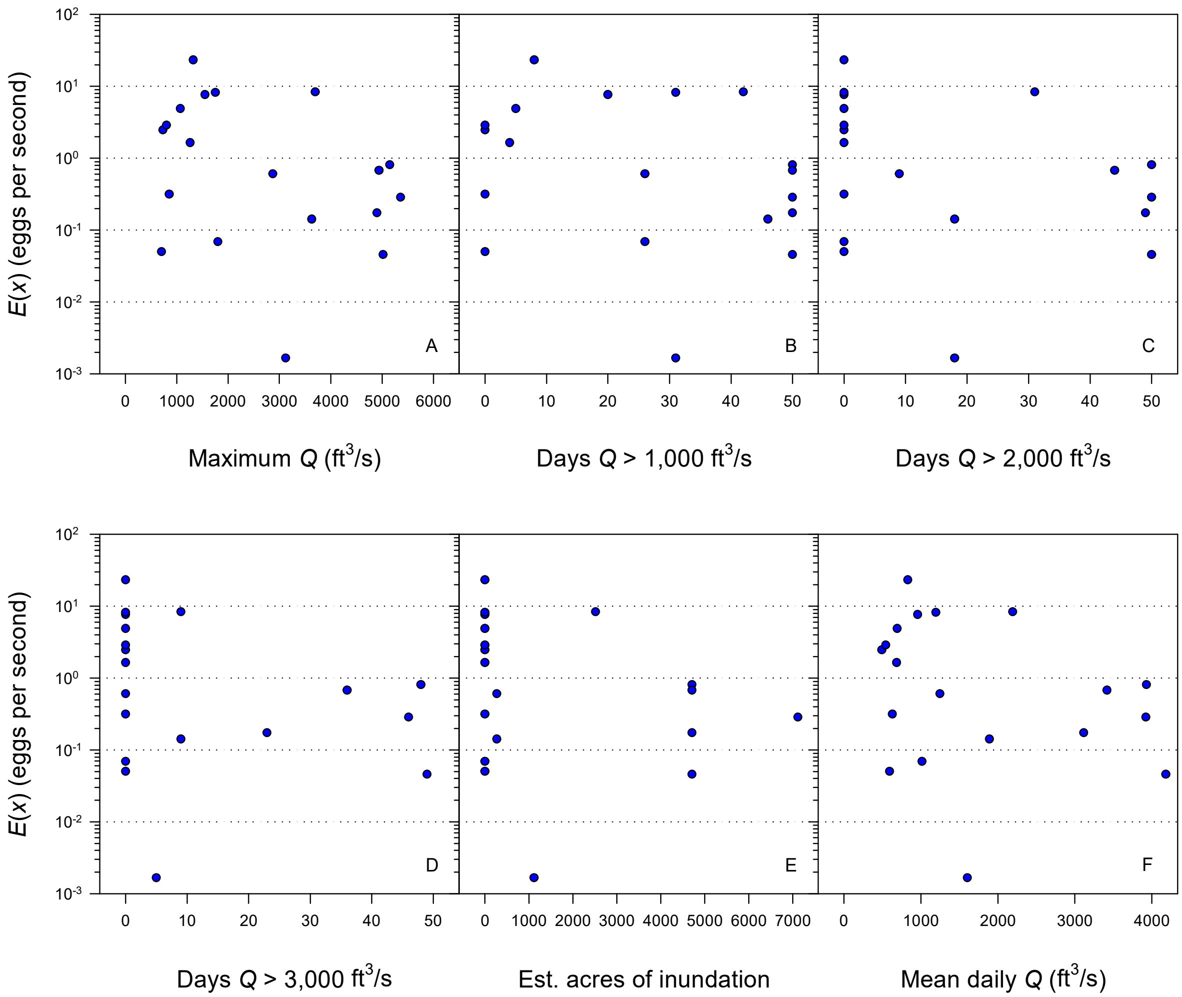


Figure 9. Bivariate plots of Rio Grande Silvery Minnow egg-passage rates (estimated using data from all sites [22 April to 10 June; 2003–2022]) and Albuquerque Gage data.

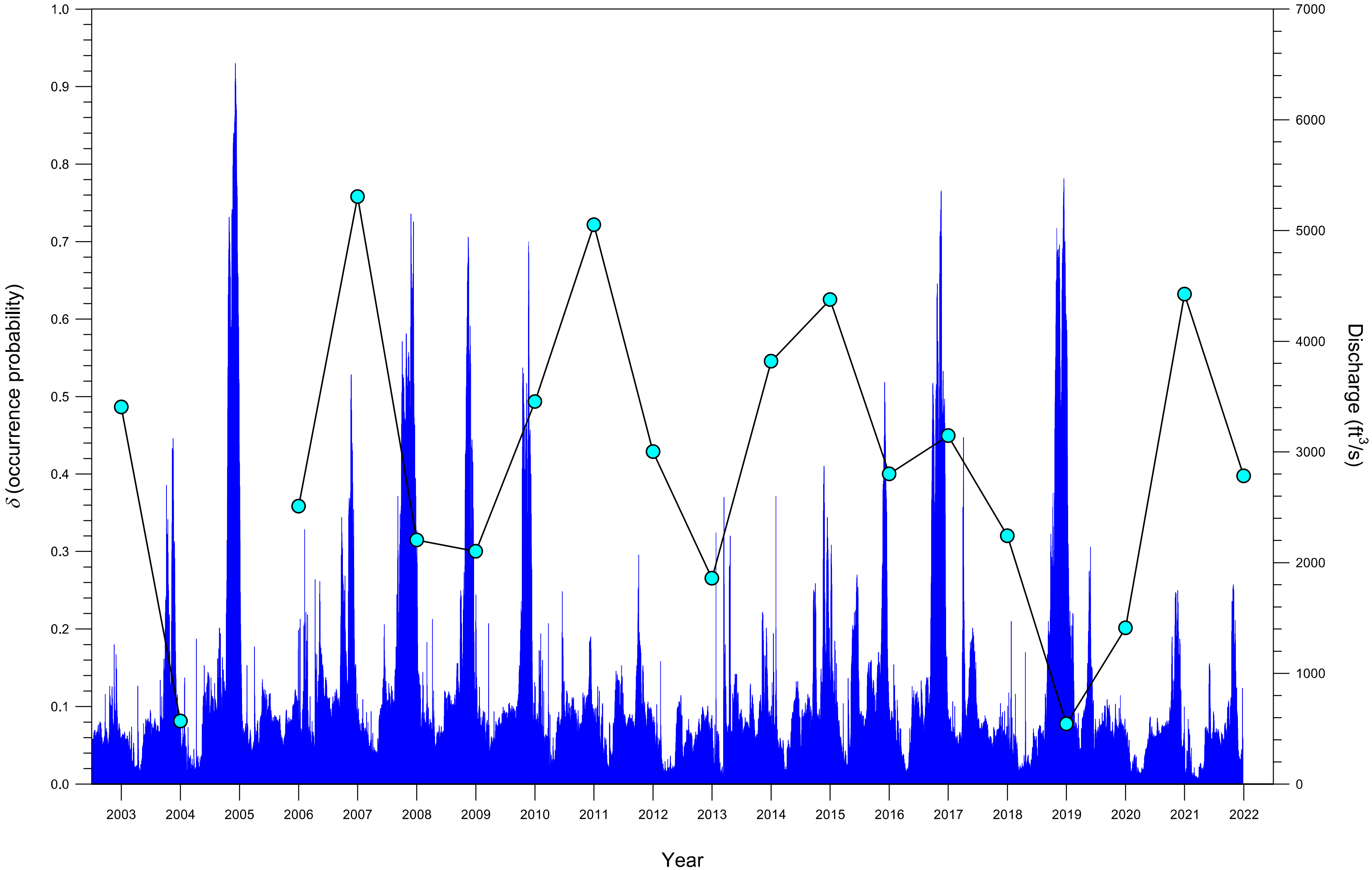


Figure 10. Rio Grande Silvery Minnow egg-occurrence probabilities (estimated using data from all sites [22 April to 10 June]), and mean daily discharge data from the Albuquerque Gage (2003-01-01 to 2022-06-30), across years. Sampling did not occur in 2005.

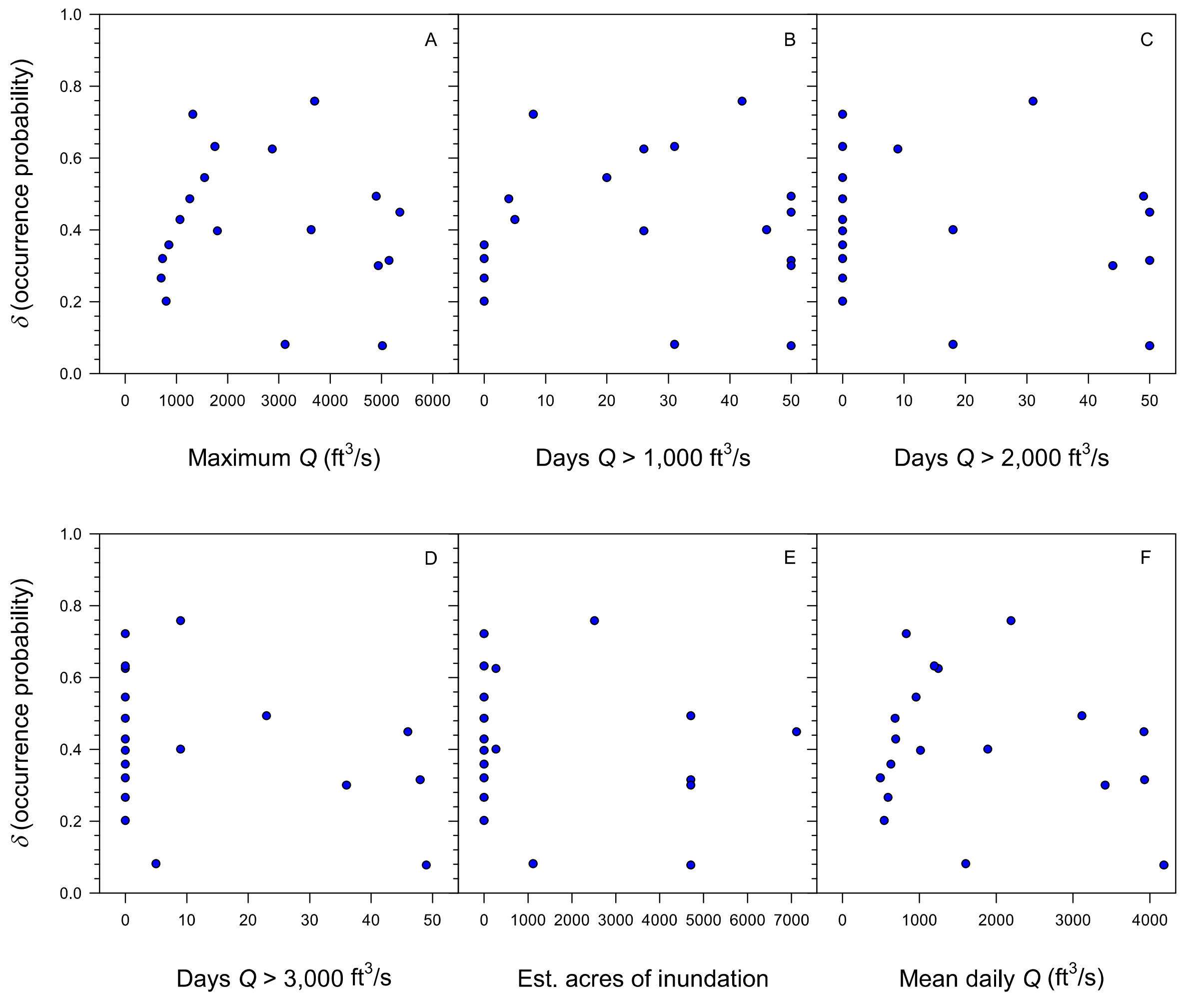


Figure 11. Bivariate plots of Rio Grande Silvery Minnow egg-occurrence probabilities (estimated using data from all sites [22 April to 10 June; 2003–2022]) and Albuquerque Gage data.

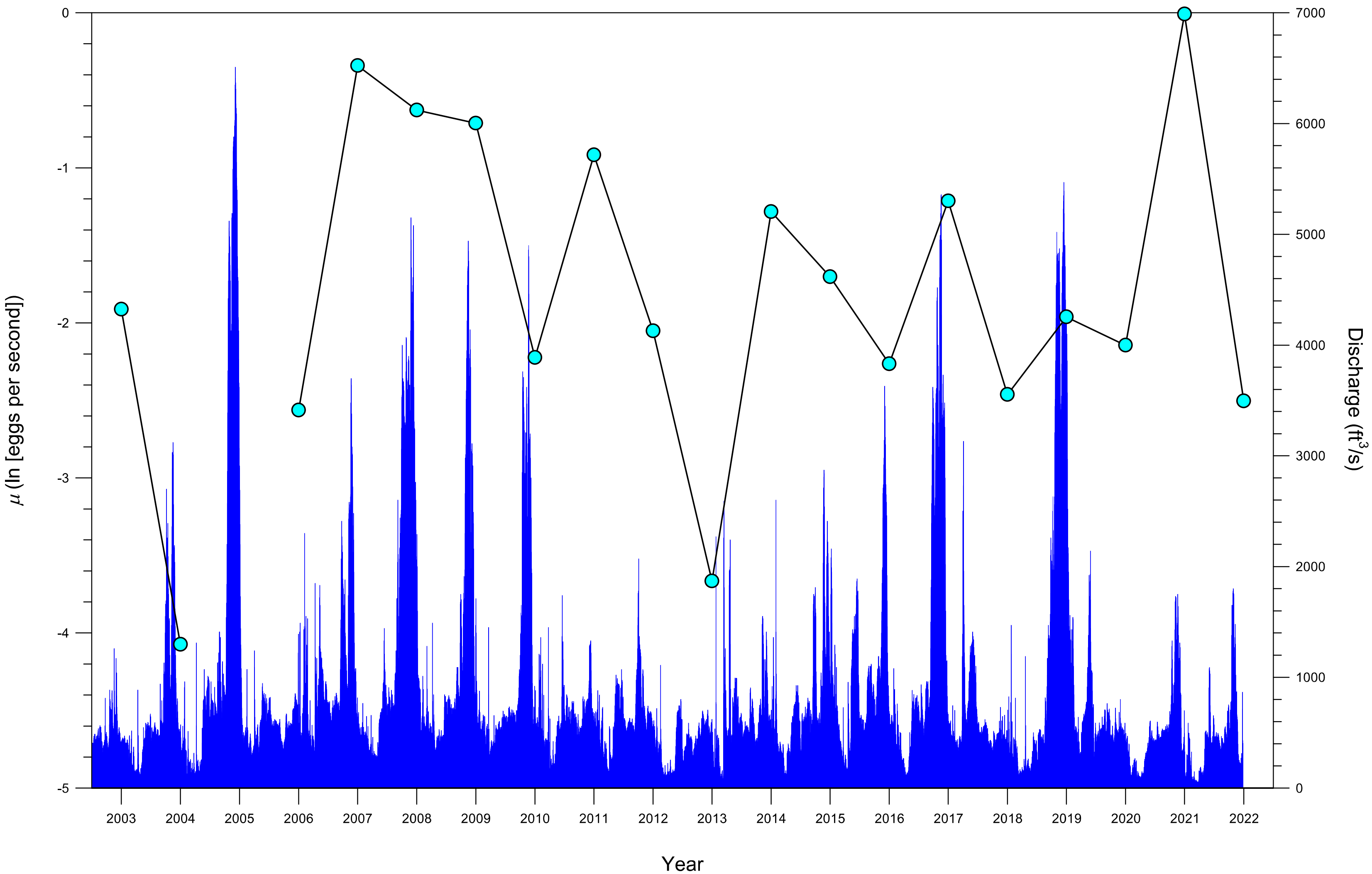


Figure 12. Rio Grande Silvery Minnow lognormal egg-passage rates (estimated using data from all sites [22 April to 10 June]), and mean daily discharge data from the Albuquerque Gage (2003-01-01 to 2022-06-30), across years. Sampling did not occur in 2005.

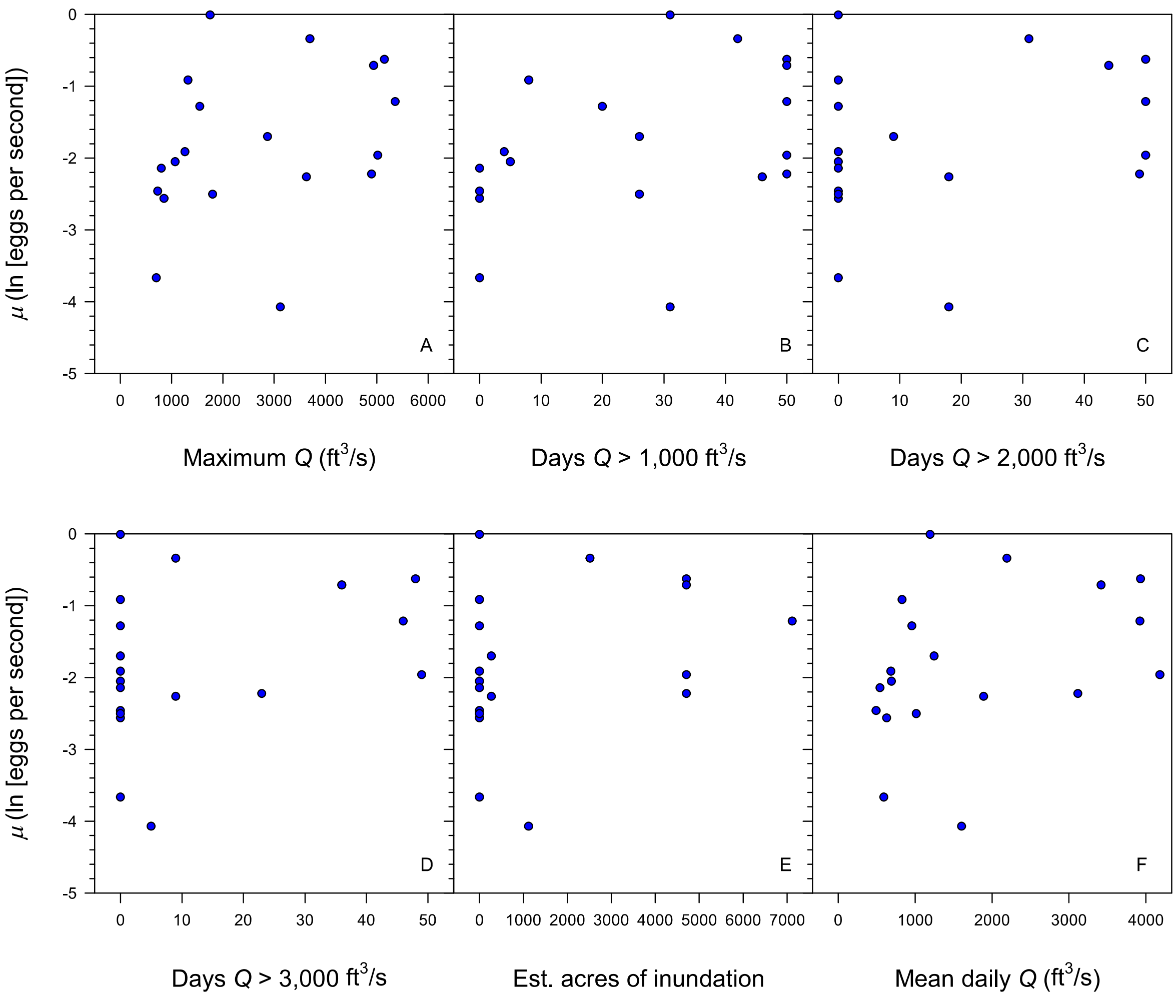


Figure 13. Bivariate plots of Rio Grande Silvery Minnow lognormal egg-passage rates (estimated using data from all sites [22 April to 10 June; 2003–2022]) and Albuquerque Gage data.

Table 6. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using data from all sites (22 April to 10 June; 2003–2022).

Model[1]	**logLike**[2]	**K**[3]	**AIC$_c$**[4]	***w_i***[4]
δ(ABQ>3,000+*R*) μ(ABQ>1,000+*R*)	3,869.69	9	3,887.80	0.2588
δ(ABQ>3,000+*R*) μ(ABQmax+*R*)	3,870.76	9	3,888.86	0.1522
δ(*R*) μ(ABQ>1,000+*R*)	3,874.34	8	3,890.43	0.0696
δ(ABQmean+*R*) μ(ABQ>1,000+*R*)	3,872.33	9	3,890.43	0.0694
δ(ABQ>3,000+*R*) μ(ABQmean+*R*)	3,873.25	9	3,891.36	0.0438
δ(ABQ>2,000+*R*) μ(ABQ>1,000+*R*)	3,873.32	9	3,891.43	0.0422
δ(Inundation+*R*) μ(ABQ>1,000+*R*)	3,873.36	9	3,891.47	0.0414
δ(ABQmean+*R*) μ(ABQmax+*R*)	3,873.43	9	3,891.54	0.0400
δ(*R*) μ(ABQmax+*R*)	3,875.56	8	3,891.65	0.0378
δ(ABQmax+*R*) μ(ABQ>1,000+*R*)	3,873.99	9	3,892.10	0.0302

[1] = Models included all δ and μ combinations of null effects (.), random effects (*R*), year (2003–2022), and hydrological metrics (with and without *R*) from Albuquerque (ABQ: USGS Gage-08330000).

[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, 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 numerous pelagic-spawning cyprinids, whose reproductive propagules often drift downstream of instream barriers or into unsuitable riverine/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 (1993–2021) 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. 2022). 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 and larvae. The closure of Cochiti Dam resulted in the vastly reduced passage of fine sediments, which has progressively contributed to channel degradation, armoring, and narrowing (Lagasse 1980; Massong et al. 2006). Cumulatively, these modifications have effectively severed the historical abiotic/biotic exchange between the river and its floodplain (e.g., decreased ecosystem productivity and reduced propagule retention) over substantial portions of the Middle Rio Grande (Massong et al. 2006; Adair 2016). While arroyos, backwaters, and other nursery habitats may result in some 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. 2022).

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 drifting fish 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 produces 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 its 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 rapidly increasing 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). However, we found that the probability of collecting eggs (i.e., daily egg-occurrence probability) was only weakly related to mean daily water temperature across a wide range of values (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 revealed that the mortality rates of eggs and larvae were 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). 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, and water quality) and biotic (e.g., food availability, competition, and 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 increase its 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 a suitable range of water temperatures. During years with high spring runoff, these environmental conditions synergistically result in the inundation of productive 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. 2022). 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; Krabbenhoft et al. 2014), 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 because of changes in ambient temperature (i.e., affecting the rate of snowmelt) or because of short-term precipitation events. The young that are produced because 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 low, truncated, and fluctuating spring flows. These periodic spawning 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 within all three reaches. 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. 2022). 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. 2022). It appears that the environmental conditions that immediately follow spawning (e.g., magnitude and duration of flow) should ideally result in the seasonal inundation 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 stability and persistence of these habitats is essential for ensuring the successful recruitment and survival 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 (2003–2022) 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 [δ] vs. passage rate [μ]) 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 δ, non-constant σ in the lognormal distribution, or additional variation around δ and μ 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 eggs collected from multiple MECs to obtain a daily total for each site. The variation of 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 increase the probability of detecting eggs across sites and days.

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 short-term, 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

Although reproductive monitoring at the three sites revealed very similar trends in egg passage rates over time (2003–2022), there were a few notable differences. For example, the 2007 egg passage rate was significantly lower ($P < 0.05$) at Albuquerque than at Sevilleta or San Marcial. The Sevilleta and San Marcial sites also exhibited large changes in egg passage rates from 2006 to 2008, whereas passage rates at Albuquerque remained relatively unchanged during that period. These site-specific patterns haven't persisted in a predictable manner, however, throughout the study (2003–2022).

While we've observed several additional minor disparities across the sampling sites in recent years (2018–2020), a close examination of these data suggests that the unusual trends were caused primarily by the periodic lack of spawning across the three reaches. For example, we were only able to reliably estimate the egg passage rate and number of eggs transported downstream from two sites in both 2018 (Albuquerque and Sevilleta) and 2019 (Sevilleta and San Marcial). In fact, eggs were only captured on a single day between 22 April and 10 June (i.e., precluding mixture-model estimation of σ) at San Marcial in 2018 and Albuquerque in 2019. 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. River flows were consistently low at San Marcial in 2020 (i.e., often < 30 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 because portions of the river were dry.

The egg passage rates at all three sites were significantly lower in 2022 than in 2021, perhaps caused by the lack of flow-related spawning cues in 2022. In 2021, there was a relatively weak spring runoff that began in late April and persisted into early June. Although there was a similarly weak spring runoff in 2022, it both started and ended several weeks earlier than in 2021. It is possible that Rio Grande

Silvery Minnow egg-passage rates were lower in 2022 because flows were generally declining, with no substantial flow spikes, from late April to early June. Additionally, flows had declined precipitously by mid-May at all three sampling sites in 2022, which effectively truncated the spawning season. In contrast, egg passage rates were notably elevated following multiple flow spikes from mid-May to early June in 2021. Thus, the combination of unusually brief and steadily declining spring flows in 2022 could explain why egg passage rates were notably lower than in 2021.

Interestingly, we found no significant differences in egg passage rates among the three sites in either 2021 or 2022. This further suggests that recent pronounced differences (e.g., 2018 and 2020) across reaches were likely the result of exceptionally unusual flow/spawning conditions (i.e., low flows and river drying), as opposed to a shift in the consistent passage-rate trends that we've observed over time (2003–2022). Egg passage rates typically increased or decreased concurrently, and often significantly, within all three reaches across years. It appears that notable, range-wide changes in spring flows across years (e.g., low vs. high, truncated vs. prolonged, and fluctuating vs. stable) affected Rio Grande Silvery Minnow passage-rate trends similarly across all sampling reaches. Thus, we assessed the long-term ecological relationships in this study using the full dataset from all three reaches.

Ecological Relationships

Prolonged and elevated spring flows result in overbank flooding of vegetated areas and the formation of inundated habitats within the river channel (e.g., 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. 2022).

Based on the long-term reproductive monitoring data from all sites (2003–2022), we found that low, truncated, and fluctuating spring flows were associated with higher estimated egg-occurrence probabilities (δ), whereas high, prolonged, and stable spring flows were associated with lower estimated egg-passage rates ($E(x)$). Although low egg-passage rates 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 occurrence probabilities and passage rates (i.e., reduced downstream transport), which likely reflected a higher retention of eggs in low-velocity floodplain habitats. In contrast, years with low and fluctuating flows were often associated with increased occurrence probabilities and passage rates (i.e., increased downstream transport). These changes in downstream transport rates are likely caused by disparities in habitat complexity during higher (i.e., floodplain inundation) and lower (i.e., non-braided channel) flows across years, which differentially affect drifting egg transport efficiencies (Dudley and Platania 2007; Widmer et al. 2012). Differences in the timing, duration, frequency, and magnitude of spawning over time, and the subsequent retention/recruitment of eggs and larvae in productive nursery habitats, might also partially explain the increased autumnal density of juvenile Rio Grande Silvery Minnow in years with elevated and prolonged spring flows (Dudley et al. 2022).

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 positively 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 newly hatched fish require about one month to progress through the early larval phases (Platania 1995), the stability and persistence of these nursery habitats is essential during this initial period (ca. May–June). The current conservation status and long-term recovery of Rio Grande Silvery Minnow appear strongly dependent on reliably ensuring sufficient seasonal flow, habitat conditions, and river connectivity that will promote the successful spawning, recruitment, and survival of this imperiled species.

ACKNOWLEDGMENTS

We thank David T. Camak, Tyler D. Damron, Joshua M. Lopez-Binder, Alexis J. Schroeder, Ashley T. Willis, and Soren Winter (ASIR) for their assistance with the field, laboratory, and data-entry aspects of this project. We extend a special thanks to Aaron C. Wedemeyer (ASIR) for serving as the field crew leader and maintenance manager of this project. Donald A. Helfrich (ASIR) skillfully 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, granted us access to our Albuquerque sampling site. The Sevilleta National Wildlife Refuge, with the assistance of Nancy J. Spencer-Morris, provided us access to our Sevilleta sampling site. The U.S. Bureau of Reclamation (USBR), through the assistance of Brian Skornia, Christopher Torres, and Susan Woods, facilitated access to our San Marcial sampling site. Joel D. Lusk and Mary B. Maestas (USBR) assisted with all technical and contract administration aspects of this study. Joel D. Lusk and Raul Sanchez (USBR), along with Andrew T. Dean and Daniel B. Fenner (U.S. Fish and Wildlife Service), 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 TE001623-5). 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 USBR, and its Albuquerque Area Office and Salt Lake City Regional Office administered all funds (Contract 140R4021C0007: Requisition 0040571030).

LITERATURE CITED

Adair, J.B.M. 2016. Reconstructing the historical Albuquerque reach of the Middle Rio Grande to evaluate the influence of river engineering on floodplain inundation. M.S. thesis, Civil Engineering, University of New Mexico, Albuquerque, New Mexico, USA.

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 103:1033–1044.

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. https://doi.org/10.13140/RG.2.1.1874.8324

Dudley, R.K., and S.P. Platania. 1999. Imitating the physical properties of drifting semibuoyant fish (Cyprinidae) eggs with artificial eggs. Journal of Freshwater Ecology 14:423–430.

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. https://doi.org/10.13140/RG.2.1.2808.7200

Dudley, R.K., S.P. Platania, and G.C. White. 2022. Rio Grande Silvery Minnow population monitoring during 2021. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. https://doi.org/10.13140/RG.2.2.14952.55041

Dudley, R.K., T.O. Robbins, S.P. Platania, and G.C. White. 2021. Rio Grande Silvery Minnow reproductive monitoring during 2021. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. https://doi.org/10.13140/RG.2.2.15457.58722

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.

JMP. 2021. Version 16.2 for Macintosh. 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).

Krabbenhoft, T.J., S.P. Platania, and T.F. Turner. 2014. Interannual variation in reproductive phenology in a riverine fish assemblage: implications for predicting the effects of climate change and altered flow regimes. Freshwater Biology 59:1744–1754.

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 Corp. 2018. TidbiT v2 Temp (UTBI-001) Manual. Onset Computer Corp., 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.

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.H. Brandenburg, and R.K. Dudley. 2020. 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. 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.

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

SAS. 2022. Version 9.4 for Windows. 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.

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 exceptionally large values, particularly when unusually 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 μ 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 (δ) 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, δ = probability of a nonzero value, and where μ and σ 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 δ is estimated. When only one $x > 0$ is observed, only δ and μ 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 2021) to obtain the maximum likelihood estimates of δ, μ, and σ 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 δ is the logit link (i.e., reverse logit specified as the expit function), for μ is the identity link, and for σ 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 μ and σ. Conversely, we reasoned that the covariates best related to the egg passage rate $(\mu \text{ and } \sigma)$ might be quite different than covariates best related to the occurrence probability (δ).

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 $(\sigma_{\delta}^{2} \text{ and } \sigma_{\mu}^{2})$ are estimated from the data, using PROC NLMIXED to numerically integrate out the random effect in the log-likelihood function. When both δ and μ 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 $\text{SD}(E(x))$, are generated from PROC NLMIXED using these equations:

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

Confidence intervals, based on α = 0.05, are obtained for $E(x)$ by using a log transformation to maintain LCI > 0:

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

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 via the delta method using PROC NLMIXED. Annual $E(x)$ values 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 the egg passage-rate dynamics of Rio Grande Silvery Minnow across years. This is because we estimate, and individually analyze, both the egg occurrence probability (based on δ) and egg passage rate (based on μ and σ). Additionally, diverse environmental covariates are used to model the key parameters (δ and μ), which collectively lend insight into the fundamental, yet complex, egg drift dynamics of Rio Grande Silvery Minnow over time.

APPENDIX B (Statistical Assumptions)

Table B1. 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 spatial or temporal 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 spatial or temporal 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 spatial or temporal 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 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 spatial or temporal differences in egg passage rates.	Low: Eggs were preserved whenever high densities precluded accurate field counts. 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.
Species absence represented samples with no individuals of a particular species (i.e., none were present in the sampled mesohabitats).	This would reduce our ability to detect meaningful spatial or temporal differences in egg passage rates.	Low: We sampled intensively at all sites and have broad experience in identifying all drifting fish eggs to species in the Rio Grande.	Two MECs were sampled for four hours per day at each site. Biologists with extensive experience, in both egg identification and MEC sampling, were present on all intensive sampling efforts.
Species detection probability was reasonably similar over time and space.	This would reduce our ability to detect meaningful spatial or temporal differences in egg passage rates.	Low: We routinely detected remarkably large spatial or temporal differences in egg passage rates.	Monitoring was highly standardized to ensure similar MEC sampling effort across sites and years.

Table B1. 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**
Nonzero data fit a lognormal distribution reasonably well.	This would reduce our ability to detect meaningful spatial or temporal differences in egg passage rates.	Low: Goodness-of-fit tests failed to reject the lognormal distribution for nonzero data.	Distributions were fit with two parameters (i.e., 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 egg drift dynamics and environmental covariates across years.	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 2022, as part of the
Rio Grande Silvery Minnow Reproductive Monitoring Program
(Any blanks in this database output indicate null data)

Rio Grande Silvery Minnow Reproductive Monitoring
April 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-001**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 22 April 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Dudley, R.K. Effort: 896.7 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV22-001**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 22 April 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,403.4 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM22-001**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 22 April 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,278.0 m³

Family	**Species**	**Total**
76	*Hybognathus amarus*	24

Rio Grande Silvery Minnow Reproductive Monitoring
April 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-002**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 23 April 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 863.1 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-002**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 23 April 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,339.0 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-002**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 23 April 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,571.8 m³

Family	Species	Total
76	*Hybognathus amarus*	134

Rio Grande Silvery Minnow Reproductive Monitoring
April 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-003**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 24 April 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 909.7 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-003**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 24 April 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 0.0 m³

Family	Species	Total

Not Sampled - Sampling Not Safe

New Mexico: Socorro County, Rio Grande Drainage **SAM22-003**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 24 April 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,634.4 m³

Family	Species	Total
76	*Hybognathus amarus*	38

Rio Grande Silvery Minnow Reproductive Monitoring
April 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-004**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 25 April 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Willis, A.T. Effort: 745.0 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV22-004**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 25 April 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Effort: 0.0 m³

Family	**Species**	**Total**

Not Sampled - Sampling Not Safe

New Mexico: Socorro County, Rio Grande Drainage **SAM22-004**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 25 April 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,164.3 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
April 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-005**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 26 April 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Dudley, R.K. Effort: 1,277.6 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-005**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 26 April 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Winter, S. Effort: 1,084.1 m³

Family	Species	Total
76	*Hybognathus amarus*	4

New Mexico: Socorro County, Rio Grande Drainage **SAM22-005**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 26 April 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Platania, S.P. Effort: 928.0 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
April 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-006**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 27 April 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Dudley, R.K. Effort: 1,028.7 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV22-006**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 27 April 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 1,289.8 m³

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

New Mexico: Socorro County, Rio Grande Drainage **SAM22-006**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 27 April 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 930.1 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
April 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-007**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 28 April 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Dudley, R.K. Effort: 1,325.9 m³

Family	Species	Total
76	*Hybognathus amarus*	4

New Mexico: Socorro County, Rio Grande Drainage **SEV22-007**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 28 April 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Platania, S.P. Effort: 1,297.7 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-007**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 28 April 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 910.9 m³

Family	Species	Total
76	*Hybognathus amarus*	1

Rio Grande Silvery Minnow Reproductive Monitoring
April 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-008**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 29 April 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Platania, S.P. Effort: 1,339.4 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-008**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 29 April 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 919.6 m³

Family	Species	Total
76	*Hybognathus amarus*	9

New Mexico: Socorro County, Rio Grande Drainage **SAM22-008**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 29 April 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 665.2 m³

Family	Species	Total
76	*Hybognathus amarus*	2

Rio Grande Silvery Minnow Reproductive Monitoring
April 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-009**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 30 April 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 1,390.7 m³

Family	Species	Total
76	*Hybognathus amarus*	6

New Mexico: Socorro County, Rio Grande Drainage **SEV22-009**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 30 April 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,070.1 m³

Family	Species	Total
76	*Hybognathus amarus*	1

New Mexico: Socorro County, Rio Grande Drainage **SAM22-009**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 30 April 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Camak, D.T. Effort: 1,744.8 m³

Family	Species	Total
76	*Hybognathus amarus*	30

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-010**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 01 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 1,388.1 m³

Family	Species	Total
76	*Hybognathus amarus*	9

New Mexico: Socorro County, Rio Grande Drainage **SEV22-010**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 01 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 882.1 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SAM22-010**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 01 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,380.2 m³

Family	Species	Total
76	*Hybognathus amarus*	3

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-011**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 02 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Camak, D.T.; Lopez-Binder, J.; Wedemeyer, A.C. Effort: 1,588.3 m³

Family	**Species**	**Total**
76	*Hybognathus amarus*	15

New Mexico: Socorro County, Rio Grande Drainage **SEV22-011**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 02 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 761.6 m³

Family	**Species**	**Total**
76	*Hybognathus amarus*	4

New Mexico: Socorro County, Rio Grande Drainage **SAM22-011**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 02 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,101.5 m³

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

Rio Grande Silvery Minnow Reproductive Monitoring

May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-012**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 03 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,425.9 m³

Family	Species	Total
76	*Hybognathus amarus*	46
76	*Platygobio gracilis*	1

New Mexico: Socorro County, Rio Grande Drainage **SEV22-012**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 03 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Platania, S.P. Effort: 807.3 m³

Family	Species	Total
76	*Hybognathus amarus*	26

New Mexico: Socorro County, Rio Grande Drainage **SAM22-012**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 03 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 904.8 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring

May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-013**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 04 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,691.8 m³

Family	Species	Total
76	*Hybognathus amarus*	5

New Mexico: Socorro County, Rio Grande Drainage **SEV22-013**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 04 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 1,022.6 m³

Family	Species	Total
76	*Hybognathus amarus*	5

New Mexico: Socorro County, Rio Grande Drainage **SAM22-013**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 04 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,339.7 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring

May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-014**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 05 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,572.3 m³

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

New Mexico: Socorro County, Rio Grande Drainage **SEV22-014**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 05 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Platania, S.P. Effort: 989.1 m³

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

New Mexico: Socorro County, Rio Grande Drainage **SAM22-014**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 05 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,910.8 m³

Family	**Species**	**Total**
76	*Hybognathus amarus*	7

Rio Grande Silvery Minnow Reproductive Monitoring

May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-015**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 06 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,713.3 m³

Family	Species	Total
76	*Platygobio gracilis*	1

New Mexico: Socorro County, Rio Grande Drainage **SEV22-015**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 06 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,042.0 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-015**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 06 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Platania, S.P. Effort: 1,622.9 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-016**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 07 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Wedemeyer, A.C. Effort: 1,329.7 m³

Family	Species	Total
76	*Cyprinus carpio*	3
76	*Hybognathus amarus*	8

New Mexico: Socorro County, Rio Grande Drainage **SEV22-016**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 07 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,196.3 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-016**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 07 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Camak, D.T. Effort: 1,118.3 m³

Family	Species	Total
76	*Hybognathus amarus*	4

Rio Grande Silvery Minnow Reproductive Monitoring

May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-017**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 08 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Platania, S.P. Effort: 1,335.4 m³

Family	Species	Total
76	*Hybognathus amarus*	11

New Mexico: Socorro County, Rio Grande Drainage **SEV22-017**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 08 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 987.5 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SAM22-017**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 08 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,521.9 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-018**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 09 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 892.3 m³

Family	Species	Total
76	*Hybognathus amarus*	3

New Mexico: Socorro County, Rio Grande Drainage **SEV22-018**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 09 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 954.0 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-018**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 09 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 774.9 m³

Family	Species	Total
76	*Hybognathus amarus*	2

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-019**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 10 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 825.0 m³

Family	Species	Total
76	*Hybognathus amarus*	3

New Mexico: Socorro County, Rio Grande Drainage **SEV22-019**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 10 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 1,208.2 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-019**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 10 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 811.5 m³

Family	Species	Total
76	*Hybognathus amarus*	3

Rio Grande Silvery Minnow Reproductive Monitoring

May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-020**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 11 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 899.8 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-020**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 11 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 1,327.1 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-020**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 11 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Dudley, R.K. Effort: 797.7 m³

Family	Species	Total
76	*Hybognathus amarus*	13

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-021**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 12 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,217.0 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV22-021**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 12 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 1,261.3 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM22-021**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 12 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Dudley, R.K. Effort: 1,018.6 m³

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

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-022**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 13 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,206.7 m³

Family	Species	Total
76	*Hybognathus amarus*	3

New Mexico: Socorro County, Rio Grande Drainage **SEV22-022**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 13 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,444.3 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-022**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 13 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Camak, D.T. Effort: 846.9 m³

Family	Species	Total
76	*Hybognathus amarus*	5

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-023**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 14 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 1,180.6 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SEV22-023**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 14 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,226.3 m³

Family	Species	Total
76	*Hybognathus amarus*	1

New Mexico: Socorro County, Rio Grande Drainage **SAM22-023**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 14 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Camak, D.T. Effort: 1,025.7 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-024**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 15 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 1,173.7 m³

Family	Species	Total
76	*Hybognathus amarus*	14

New Mexico: Socorro County, Rio Grande Drainage **SEV22-024**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 15 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,439.8 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-024**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 15 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,073.4 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-025**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 16 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,438.4 m³

Family	Species	Total
76	*Hybognathus amarus*	10

New Mexico: Socorro County, Rio Grande Drainage **SEV22-025**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 16 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,410.8 m³

Family	Species	Total
76	*Hybognathus amarus*	11

New Mexico: Socorro County, Rio Grande Drainage **SAM22-025**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 16 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 915.7 m³

Family	Species	Total
76	*Hybognathus amarus*	3

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-026**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 17 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,385.9 m³

Family	Species	Total
76	*Hybognathus amarus*	12
76	*Platygobio gracilis*	2

New Mexico: Socorro County, Rio Grande Drainage **SEV22-026**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 17 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,298.2 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SAM22-026**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 17 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 875.0 m³

Family	Species	Total
76	*Hybognathus amarus*	1

Rio Grande Silvery Minnow Reproductive Monitoring

May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-027**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 18 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,333.6 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SEV22-027**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 18 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 1,273.7 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-027**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 18 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 858.7 m³

Family	Species	Total
76	*Hybognathus amarus*	4

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-028**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 19 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,442.5 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-028**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 19 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 1,147.2 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-028**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 19 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 785.3 m³

Family	Species	Total
76	*Hybognathus amarus*	2

Rio Grande Silvery Minnow Reproductive Monitoring

May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-029**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 20 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,165.2 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-029**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 20 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,087.8 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SAM22-029**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 20 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 1,268.3 m³

Family	Species	Total
76	*Hybognathus amarus*	19

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-030**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 21 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 1,250.2 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-030**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 21 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,049.5 m³

Family	Species	Total
76	*Hybognathus amarus*	1

New Mexico: Socorro County, Rio Grande Drainage **SAM22-030**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 21 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 945.5 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring

May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-031**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 22 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 1,264.2 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV22-031**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 22 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 721.3 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM22-031**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 22 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,081.4 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-032**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 23 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,264.4 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV22-032**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 23 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 943.3 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM22-032**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 23 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 994.1 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring

May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-033**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 24 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,107.5 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV22-033**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 24 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,062.9 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM22-033**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 24 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,304.2 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-034**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 25 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Effort: 0.0 m³

Family	Species	Total

Not Sampled - Sampling Not Feasible

New Mexico: Socorro County, Rio Grande Drainage **SEV22-034**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 25 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 1,182.2 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-034**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 25 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 1,205.3 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-035**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 26 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Wedemeyer, A.C. Effort: 1,462.6 m³

Family	Species	Total
76	*Hybognathus amarus*	3

New Mexico: Socorro County, Rio Grande Drainage **SEV22-035**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 26 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 1,048.5 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-035**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 26 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 972.7 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-036**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 27 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Wedemeyer, A.C. Effort: 1,183.2 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-036**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 27 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 678.1 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-036**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 27 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 1,153.7 m³

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

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-037**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 28 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 1,291.4 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-037**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 28 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 742.1 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-037**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 28 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 859.3 m³

Family	Species	Total
76	*Hybognathus amarus*	1

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-038**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 29 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 1,318.6 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-038**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 29 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 489.5 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-038**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 29 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 724.3 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-039**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 30 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Effort: 0.0 m³

Family	Species	Total

Not Sampled - Sampling Not Feasible

New Mexico: Socorro County, Rio Grande Drainage **SEV22-039**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 30 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 1,002.3 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-039**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 30 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,500.7 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-040**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 31 May 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,217.9 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-040**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 31 May 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T.; Willis, A.T. Effort: 844.1 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-040**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 31 May 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,377.7 m³

Family	Species	Total
76	*Hybognathus amarus*	15

Rio Grande Silvery Minnow Reproductive Monitoring
June 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-041**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 01 June 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Wedemeyer, A.C. Effort: 1,333.1 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV22-041**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 01 June 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 642.9 m³

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

New Mexico: Socorro County, Rio Grande Drainage **SAM22-041**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 01 June 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 1,153.7 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
June 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-042**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 02 June 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Platania, S.P. Effort: 1,329.4 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-042**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 02 June 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 510.3 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-042**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 02 June 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 781.6 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
June 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-043**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 03 June 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Camak, D.T. Effort: 1,514.2 m³

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

New Mexico: Socorro County, Rio Grande Drainage **SEV22-043**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 03 June 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 190.0 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM22-043**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 03 June 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 864.2 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
June 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-044**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 04 June 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 1,270.4 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV22-044**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 04 June 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 183.1 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM22-044**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 04 June 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 488.1 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
June 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-045**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 05 June 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Schroeder, A.J. Effort: 1,180.2 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV22-045**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 05 June 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 334.5 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM22-045**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 05 June 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 221.3 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
June 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-046**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 06 June 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Camak, D.T. Effort: 1,411.3 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV22-046**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 06 June 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 225.3 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM22-046**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 06 June 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 50.9 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
June 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-047**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 07 June 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Damron, T.D. Effort: 859.4 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SEV22-047**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 07 June 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 626.0 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-047**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 07 June 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 99.5 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
June 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-048**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 08 June 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,315.3 m³

Family	Species	Total
76	*Platygobio gracilis*	1

New Mexico: Socorro County, Rio Grande Drainage **SEV22-048**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 08 June 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 474.2 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-048**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 08 June 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 197.0 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
June 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-049**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 09 June 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,250.3 m³

Family	Species	Total
76	*Hybognathus amarus*	7

New Mexico: Socorro County, Rio Grande Drainage **SEV22-049**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 09 June 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Camak, D.T. Effort: 317.0 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-049**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 09 June 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 486.8 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring

June 2022

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ22-050**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 10 June 2022
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13N Quad: Albuquerque West
Collector(s): Lopez-Binder, J. Effort: 1,053.3 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV22-050**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 10 June 2022
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13N Quad: La Joya
Collector(s): Willis, A.T. Effort: 429.6 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM22-050**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 10 June 2022
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13N Quad: Paraje Well
Collector(s): Winter, S. Effort: 148.7 m³

Family	Species	Total