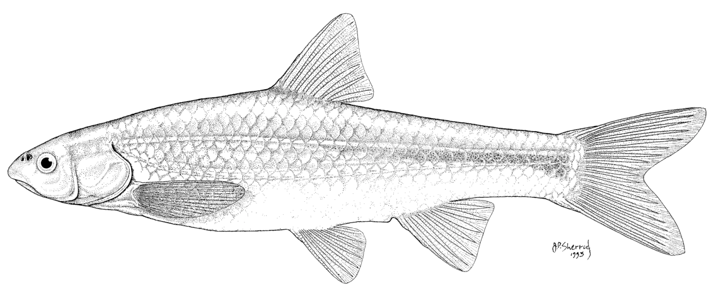
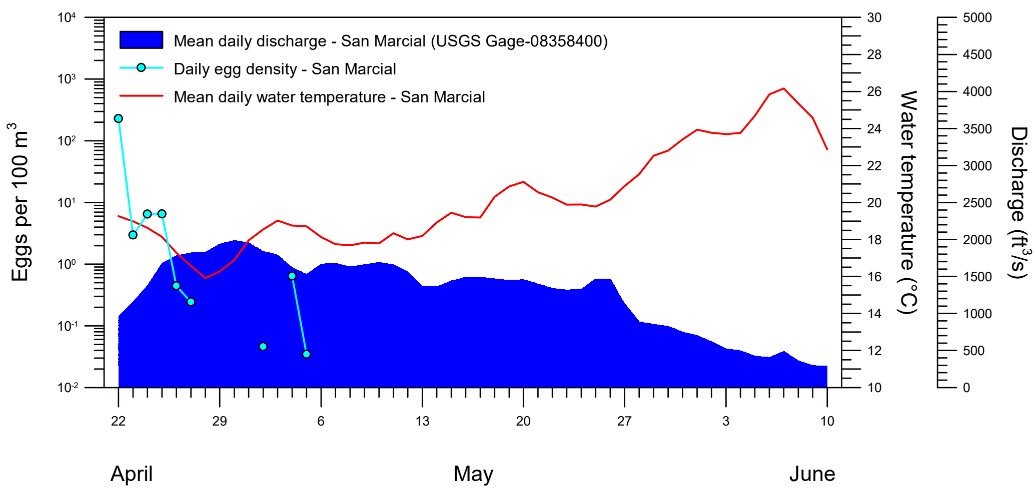
Rio Grande Silvery Minnow Reproductive Monitoring during 2024

A U.S. Bureau of Reclamation Funded Research Program





Final Report
30 October 2024

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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 imperiled 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 developing successful strategies for its long-term recovery.

Systematic reproductive monitoring of Rio Grande Silvery Minnow has been conducted annually since 2001. Multiple studies have demonstrated mid-April to mid-June as the primary period of spawning activity. The 2024 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 2024.

In 2024 (i.e., 22 April to 10 June), we collected drifting eggs from three fish species. All eggs (n = 4,586) were immediately identified in the field as Common Carp (n = 19), Rio Grande Silvery Minnow (n = 4,566), or Flathead Chub (n = 1). We caught the most Rio Grande Silvery Minnow eggs at San Marcial (n = 4,138), followed by Albuquerque (n = 344), and Sevilleta (n = 84). Based on the total sampling effort across all sites (ca. 600 h), we collected about 7.61 eggs/h for this species in 2024.

Reproductive monitoring of Rio Grande Silvery Minnow was reinitiated at the Albuquerque and Sevilleta sites in 2017, which allowed for comparisons of estimated egg-passage rates ($E(x)$; eggs per second) across reaches. These passage rates, which accounted for differences in mean daily discharge, were similar at Albuquerque, Sevilleta, and San Marcial in 2024 ($2.76 \cdot 10^{-1}$, $1.41 \cdot 10^{-1}$, and $1.74 \cdot 10^{0}$, respectively). We roughly estimated that about $1.19 \cdot 10^{6}$ eggs, $6.08 \cdot 10^{5}$ eggs, and $7.52 \cdot 10^{6}$ eggs were transported downstream of Albuquerque, Sevilleta, and San Marcial, respectively, during 2024.

Long-term spawning patterns and trends were based on all available data across sites and years (2003–2024). 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 0.79, 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 weak and nonsignificant association with mean daily water temperature.

Annual egg-passage rates, which were estimated using data from all sites (2003–2024), revealed notable differences across years. Passage rates were lowest in 2004 ($1.66 \cdot 10^{-3}$) and highest in 2011 ($2.32 \cdot 10^{1}$). There was a steady increase in passage rates from 2019 to 2021, followed by a decline in 2022. Passage rates increased again from 2022 ($6.89 \cdot 10^{-2}$) to 2024 ($3.12 \cdot 10^{-1}$).

Changes in egg-occurrence probabilities and egg-passage rates, using data from all sites, were moderately predicted by differences in seasonal river flows across years (2003–2024). Out of 224 ecological models considered, we found that the top two models, which represented elevated flows during spring, were most informative (ca. 71% of cumulative model weight) in explaining why some years had lower passage rates (i.e., reduced downstream transport) than others. Overall, we found that egg-occurrence probabilities were higher during years with low and truncated spring flows, whereas egg-passage rates were lower during years with high and prolonged spring flows. Additionally, data collected in 2024 further supported the overall trends and insights provided by these long-term ecological models.

Although many drifting fish eggs have been displaced into downstream reaches of the Middle Rio Grande during this study (2003–2024), some are retained every year in upstream reaches. The proportion of individuals successfully retained and recruited upstream is likely related to the seasonal availability of shallow, low-velocity habitats. These warm, productive habitats are also particularly important for accelerating the growth and development of early life phases. The availability and persistence of these nursery habitats are essential during peak spawning season (ca. mid-April to mid-June), as larval fish require about one month to successfully progress through their vulnerable early

developmental phases. The long-term recovery of Rio Grande Silvery Minnow appears strongly contingent upon reliably ensuring adequate seasonal flow and habitat conditions that will promote the successful survival and recruitment of this endangered species.

INTRODUCTION

The natural flow and sediment regimes of the Rio Grande between Cochiti Dam and Elephant Butte Reservoir (Middle Rio Grande) have been progressively altered for over 100 years (e.g., reduced peak flows, prolonged low flows, and diminished sediment supplies), which have cumulatively led to substantial incision, narrowing, and armoring of the river channel (Lagasse 1980; Massong et al. 2006; Mortensen et al. 2024). 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 mobile sand/silt 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 leuciscids (minnows) that were endemic to this drainage (Platania and Altenbach 1998; Propst 1999). However, many of the endemic pelagic-spawning minnows 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, *Alburnops orca* and Rio Grande Bluntnose Shiner, *Alburnops 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 minnow in the Middle Rio Grande (Bestgen and Platania 1991; Platania 1991) and is federally protected as an endangered species (USFWS 1994).

This group of imperiled pelagic-spawning minnows 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 season typically starts following rapid gonadal development in adults (i.e., related to increased temperature/photoperiod) during late spring (Platania and Altenbach 1996; Archdeacon et al. 2020). Distinct spawning events are generally associated with increases in discharge, such as spring runoff, summer rainstorms, or managed water releases (Valdez et al. 2019; Dudley et al. 2023). 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, studies using Visible Implant Elastomer (VIE) marked (Platania et al. 2020) and Passive Integrated Transponder (PIT) tagged (Chavez et al. 2024) individuals documented maximum upstream movements of about 25 km and 50 km, respectively.

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 2024. Ongoing and uninterrupted reproductive monitoring (ca. mid-April to mid-June) is also required to satisfy key aspects of USFWS's Biological Opinion (USFWS 2016).

The primary objective of the Rio Grande Silvery Minnow Reproductive Monitoring Program is to use daily egg data 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 Cochiti Dam and 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 numerous collecting localities in the Middle Rio Grande from 1996 to 2024. Given the downstream drift of eggs, long-term systematic sampling (2001–2024) has consistently been conducted near the terminus of the San Acacia Reach (San Marcial [UTM: 305552 E; 3711984 N; Zone 13; 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). From 2017 to 2024, two additional gates 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; Zone 13; 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; Zone 13; NAD83]) was in the same area that was consistently sampled from 2006 to 2011. These two additional sites allowed for a more detailed assessment of spatial spawning patterns over time.

Discharge patterns, throughout the Middle Rio Grande, were notably different between 2023 and 2024 (Figure 2). In 2023, spring runoff flows were unusually high from mid-April until late June. In contrast, there was a less robust spring runoff in 2024 that began in late April but noticeably declined by late May. In 2023 and 2024, 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). 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 typical, albeit higher, in 2023 and atypical (i.e., earlier and lower) in 2024. All mean-daily discharge data presented in this report are provisional and subject to change.

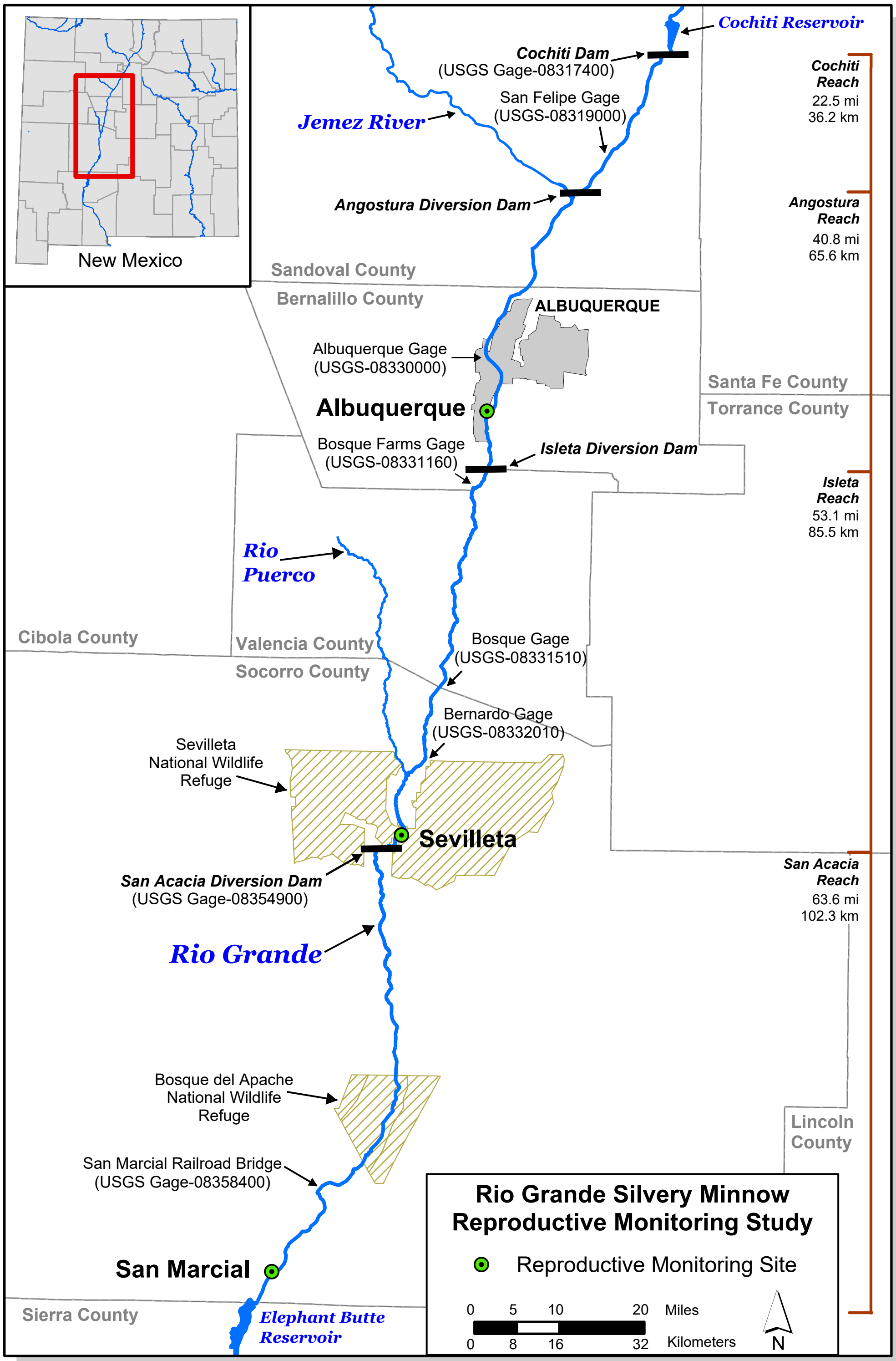

Figure 1. Map of the study area and sampling sites for the Rio Grande Silvery Minnow reproductive monitoring study.

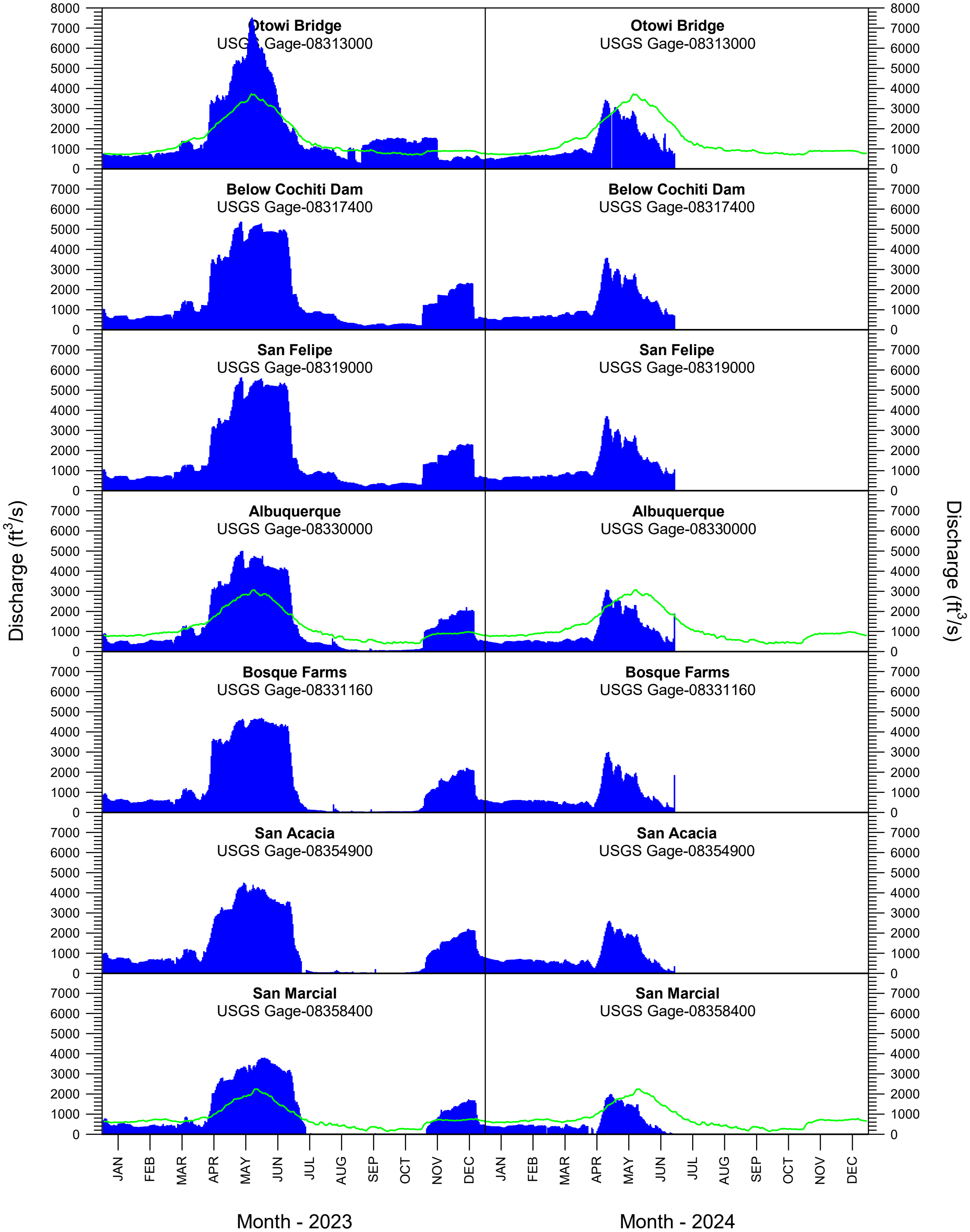

Figure 2. Rio Grande mean-daily discharge, by USGS gaging station, from 1 January 2023 to 30 June 2024. Green lines are the average mean-daily discharges across years (1973–2023).

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 nearly identical (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 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 had concluded.

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: $P_e = ((D / 100) \cdot Q)$. Values of Q were taken from the nearest upstream gaging station for the three sampling sites (i.e., Albuquerque: USGS Gage-08330000, Sevilleta: USGS Gage-08331510 [Bosque] and USGS Gage-08332010 [Bernardo], and San Marcial: USGS Gage-08358400). At Sevilleta, we used USGS Gage-08331510 (2006–2011) and USGS Gage-08332010 (2003–2005 and 2012–2024) 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 2024 (e.g., collecting additional eggs solely for captive propagation or documenting peak-spawning events at night) were excluded from subsequent statistical analyses. We also felt it was more reasonable to combine all available data across sites (Albuquerque, Sevilleta, San Marcial) and years (2003–2024), 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 (2003–2024), 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 two days to 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 (2003–2024), changed as a function of mean daily water temperature taken at each site. The associated 95% confidence intervals of the regression lines were constructed using inverse predictions (JMP 2024) of discharge or temperature across the range of modeled occurrence probabilities. The likelihood ratio chi-squared statistic (G^2; JMP 2024) was calculated to evaluate whether the fitted model (i.e., based on discharge or temperature) was significantly different ($P < 0.05$) from a model with equal occurrence probabilities across the range of modeled discharges or temperatures.

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 (2003–2024), from all sampling sites, were analyzed using PROC NLMIXED (Nonlinear Mixed Models; SAS 2024). 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 estimated, 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 varied across Year and were assessed for 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). Fixed-effects models for each covariate were generalized linear models with the corresponding link functions. These fixed effects assume that variation in the dataset is explained by the covariates (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; Burnham and Anderson 2002] corrected for finite sample sizes) were generated to assess the relative fit of data to various mixture models. 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 likelihood 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 (2024)

During 2024, all eggs (n = 4,586) were immediately identified in the field as Common Carp (n = 19), Rio Grande Silvery Minnow (n = 4,566), or Flathead Chub (n = 1). We retained and transferred a portion of the live Rio Grande Silvery Minnow eggs (n = 503) to the Albuquerque Biological Park. All remaining eggs, from all species, were released back into the river immediately downstream of each MEC sampling location. Common Carp and Rio Grande Silvery Minnow eggs were collected during April, May, and June. In contrast, a single Flathead Chub egg was collected during May.

Spatial Spawning Patterns

Simple patterns (2024)

Sampling at the Albuquerque, Sevilleta, and San Marcial sites in 2024 was conducted from 22 April to 10 June, with additional sampling on 11 and 12 June at Albuquerque (Appendix C). The cumulative volume of water sampled was highest at San Marcial, followed by Albuquerque and Sevilleta (107,724.3 m^3, 68,413.1 m^3, and 35,843.4 m^3, respectively). Rio Grande Silvery Minnow eggs were collected from all three sampling sites (Table 1 and Figure 3). We caught the most eggs at San Marcial (n = 4,138), followed by Albuquerque (n = 344), and Sevilleta (n = 84). Based on the total sampling effort across all sites (ca. 600 h), we collected about 7.61 eggs/h in 2024. Although the timing, duration, frequency, and magnitude of spawning varied across sites, the highest numbers of eggs were typically collected during elevated flows that occurred from late April to late May. Rio Grande Silvery Minnow eggs were collected across a broad range of mean daily water temperatures (ca. 15–20°C).

Complex patterns (2003–2024)

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 could not be estimated in 2023, however, as only a single nonzero value was recorded (i.e., precluding mixture-model estimation of σ). The passage rates at Albuquerque, Sevilleta, and San Marcial were similar in 2024 ($2.76 \cdot 10^{-1}$, $1.41 \cdot 10^{-1}$, and $1.74 \cdot 10^{0}$, respectively). Naïve passage-rate estimates (i.e., unmodeled), calculated using the method of moments, and model-estimated passage rates ($E(x)$) were similar across years. Additionally, we roughly estimated ($E(x)_{50d}$) that about $1.19 \cdot 10^{6}$ eggs, $6.08 \cdot 10^{5}$ eggs, and $7.52 \cdot 10^{6}$ eggs were transported downstream of Albuquerque, Sevilleta, and San Marcial, respectively, during the 2024 sampling season (i.e., 22 April to 10 June).

Table 1. Rio Grande Silvery Minnow egg abundance, by date and site, during 2024. Blank cells indicate days when it was not safe or feasible to sample at a site.

Sampling Date	**Albuquerque**	**Sevilleta**	**San Marcial**
22-Apr-24	2	12	3,848
23-Apr-24	0	15	59
24-Apr-24	0	24	112
25-Apr-24	22	21	84
26-Apr-24	5	3	10
27-Apr-24	0	0	6
28-Apr-24	0		0
29-Apr-24	0	0	0
30-Apr-24	3	0	0
1-May-24	5	0	0
2-May-24	12	0	1
3-May-24	2	0	0
4-May-24	2	0	17
5-May-24	4	0	1
6-May-24	3	0	0
7-May-24	1	0	0
8-May-24	0	0	0
9-May-24	0	1	0
10-May-24	3	0	0
11-May-24	3	3	0
12-May-24	2	1	0
13-May-24	0	0	0
14-May-24	0	0	0
15-May-24	8	0	0
16-May-24	1	2	0
17-May-24	59	0	0
18-May-24	20	2	0
19-May-24	1	0	0
20-May-24	7	0	0
21-May-24	3	0	0
22-May-24	4	0	0
23-May-24	2	0	0
24-May-24	71	0	0
25-May-24	57	0	0
26-May-24	11	0	0
27-May-24	5	0	0
28-May-24	0	0	0
29-May-24	0	0	0
30-May-24	0	0	0
31-May-24	0	0	0
1-Jun-24	0	0	0
2-Jun-24	0	0	0
3-Jun-24	0	0	0
4-Jun-24	0	0	0
5-Jun-24	0	0	0
6-Jun-24	0	0	0
7-Jun-24	0	0	0
8-Jun-24	0	0	0
9-Jun-24	0	0	0
10-Jun-24	0	0	0
11-Jun-24	0	0	0
12-Jun-24	26	0	0
Total (eggs)	**344**	**84**	**4,138**

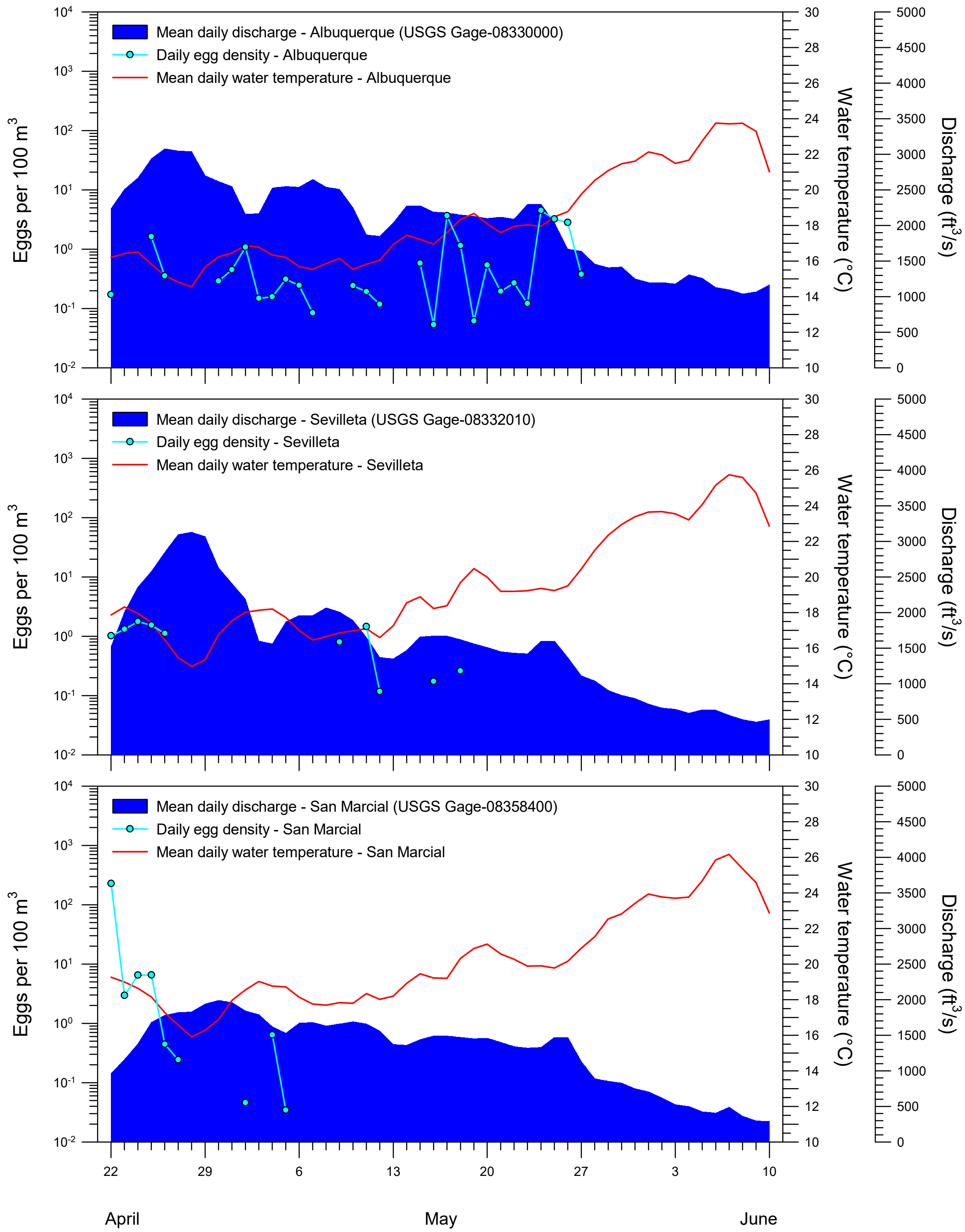

Figure 3. Mean daily discharge, daily egg density, and mean daily water temperature, by site and date, during 2024.

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
2023	50	0	50	0.0	0
2024	50	27	23	54.0	318

[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
2023	47	0	47	0.0	0
2024	49	10	39	20.4	84

[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
2023	50	1	49	2.0	1
2024	50	9	41	18.0	4,138

[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).

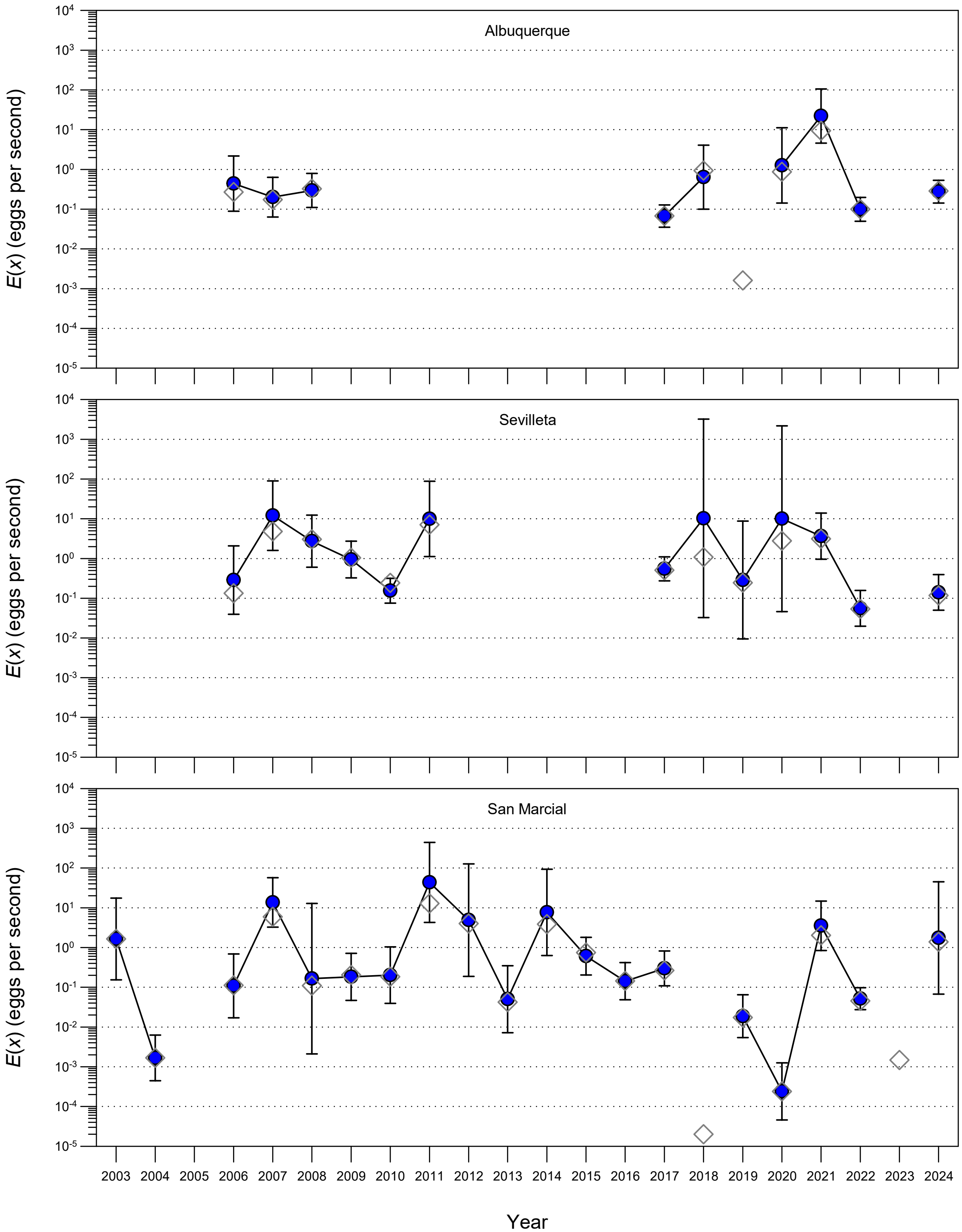

Figure 4. Rio Grande Silvery Minnow egg-passage rates (estimated using 22 April to 10 June data) across sites and years. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated.

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 estimated, as only a single nonzero value was recorded.

Year[1]	Albuquerque[1]	Sevilleta[2]	San Marcial[3]	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–$3.21 \cdot 10^{3}$)	-	1.73 (0.14–20.92)
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)
2023	0.00	0.00	-	-
2024	0.28 (0.14–0.53)	0.14 (0.05–0.40)	1.74 (0.07–45.15)	0.31 (0.15–0.63)

[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.

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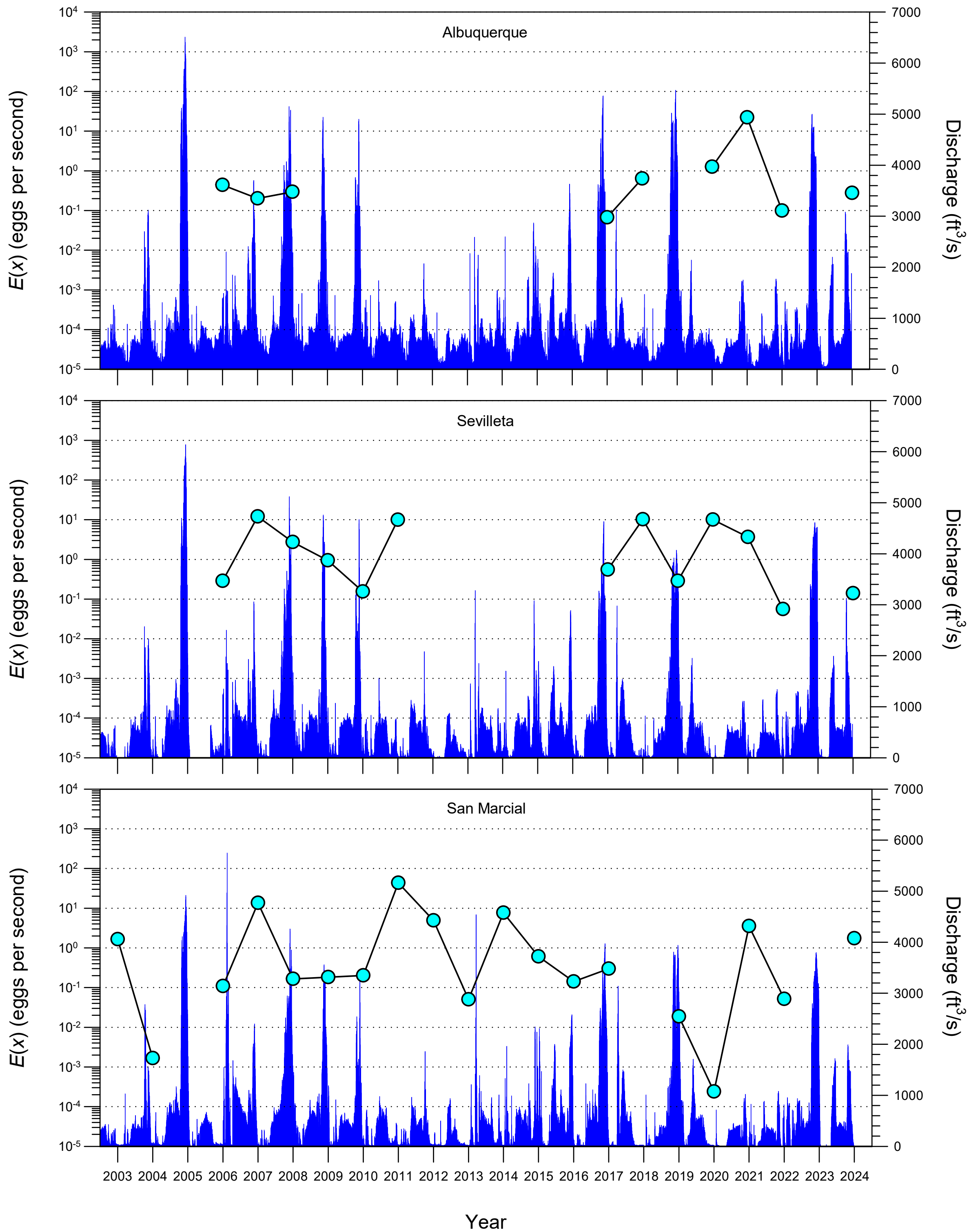

Figure 5. Rio Grande Silvery Minnow egg-passage rates (estimated using 22 April to 10 June data), and mean daily discharge data (Albuquerque, Bosque/Bernardo, and San Marcial gages [2003-01-01 to 2024-06-30]), across sites and years.

Ecological Relationships

Spawning cues (2003–2024)

Logistic regression modeling of Rio Grande Silvery Minnow daily egg presence-absence data from all sites (2003–2024) revealed strong associations with the percentage change in mean daily discharge (i.e., independent of flow magnitude) just prior to egg collection ($G^2 = 75.02$ and $P < 0.001$; Figure 6). Flows used to calculate the percentage change in discharge (∆), 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 0.17 (∆ discharge = –50%) to 0.35 (∆ discharge = 0%) during periods of declining or stable flows, respectively. The occurrence probability increased rapidly up to about a 100% increase in flow, but then began to level off. The occurrence probability during a 100% increase in flow was 0.79, whereas the occurrence probability was 0.96 during a 200% increase in flow. The occurrence probability (O_p) can be computed, based on the intercept ($\beta_0 = -0.6130$) and slope ($\beta_1 = 0.0196$) of the logistic regression (2003–2024), 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 (2003–2024) revealed a weak association with mean daily water temperature ($G^2 = 0.01$ and $P = 0.92$). The egg occurrence probability decreased slightly from 0.36 at a minimum observed temperature of 12°C to 0.35 at a maximum observed temperature of 27°C. This weak relationship also resulted in considerable uncertainty for these occurrence probabilities (i.e., confidence intervals could not be estimated), so we did not illustrate these nonsignificant results.

Spawning dynamics (2003–2024)

Rio Grande Silvery Minnow egg-passage rates ($E(x)$; estimated using data from all sites [22 April to 10 June; 2003–2024]) 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 increase ($P < 0.05$) in passage rates from 2019 to 2021, followed by a decline ($P < 0.05$) in 2022. Passage rates increased again ($P < 0.05$) from 2022 ($6.89 \cdot 10^{-2}$) to 2024 ($3.12 \cdot 10^{-1}$). Combining a plot of $E(x)$ values and mean daily discharge data (2003–2024) 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 lognormal egg-passage rates (μ), estimated from the year model (δ[Year] μ[Year]), were modestly associated with hydrological metrics across years (2003–2024). Values of δ generally decreased with higher spring flows (Figures 10 and 11), particularly at the highest flows. However, values of μ increased slightly 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 (2003–2024; Table 6). The top ecological model (δ[Year] μ[ABQ>1,000+R]) received 37.6% of the AIC_c weight (w_i) out of the 224 models considered. The top δ covariate (ABQ>3,000) accounted for 18.9% of the deviance ($P = 0.06$) explained by the δ(Year) model over the δ(.) model. Similarly, we found no significant effects for ABQmean (11.2%), ABQ>2,000 (10.0%), Inundation (6.4%), ABQmax (4.4%), or ABQ>1,000 (0.9%). In contrast, the top μ covariate (ABQ>1,000) accounted for 26.7% 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 (23.8%), ABQmean (23.1%), ABQ>2,000 (20.4%), Inundation (17.9%), and ABQ>3,000 (17.7%). Overall, 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 ($E(x)$). Additionally, data collected in 2024 further supported the overall trends and insights provided by these long-term ecological models.

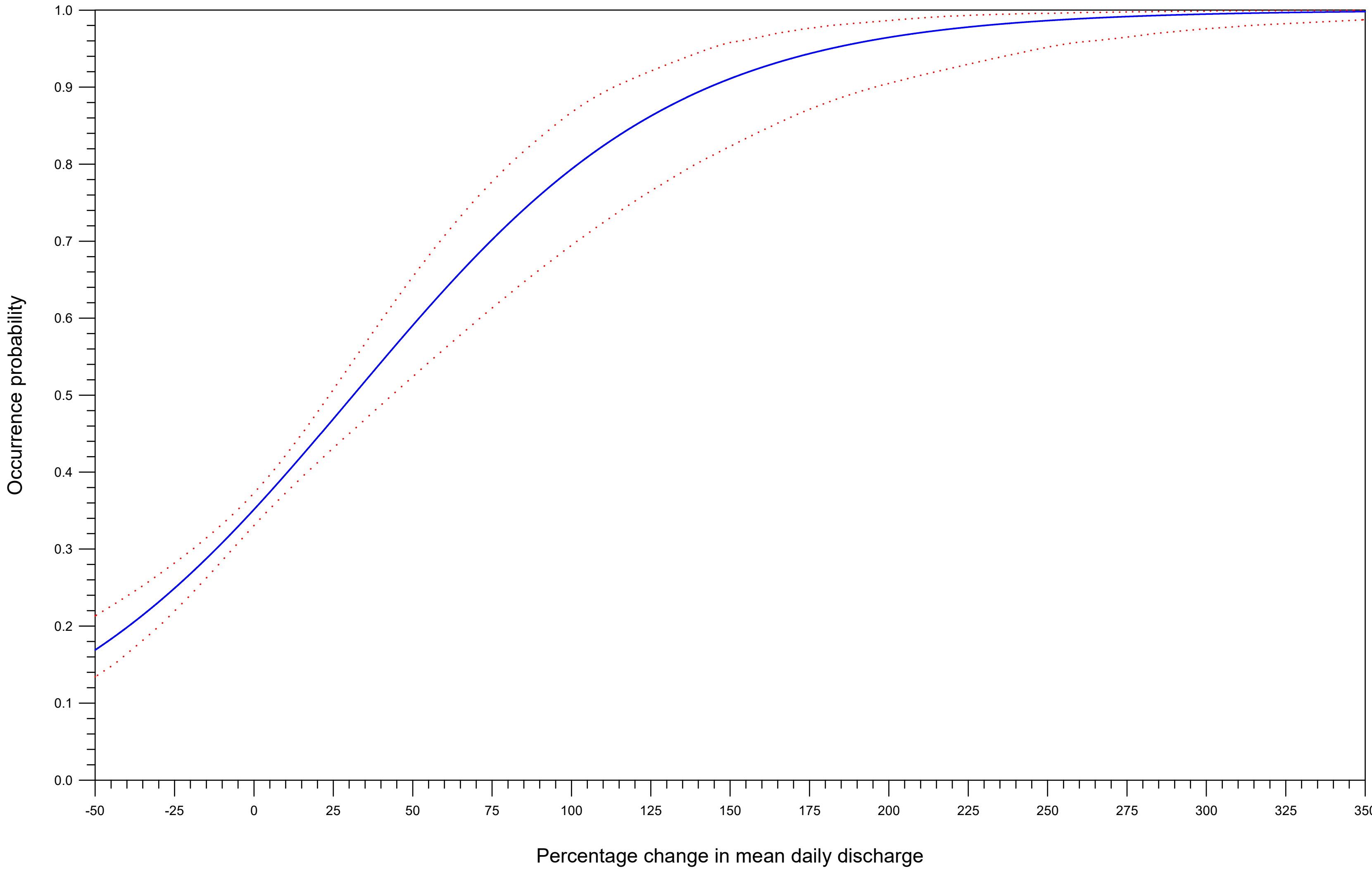

Figure 6. Logistic regression plot, using data from all sites (22 April to 10 June; 2003–2024), illustrating Rio Grande Silvery Minnow daily egg-occurrence probability as a function of the percentage change in mean daily discharge taken from the nearest upstream gaging station. Logistic regression line (solid) and 95% confidence intervals (dotted) are illustrated.

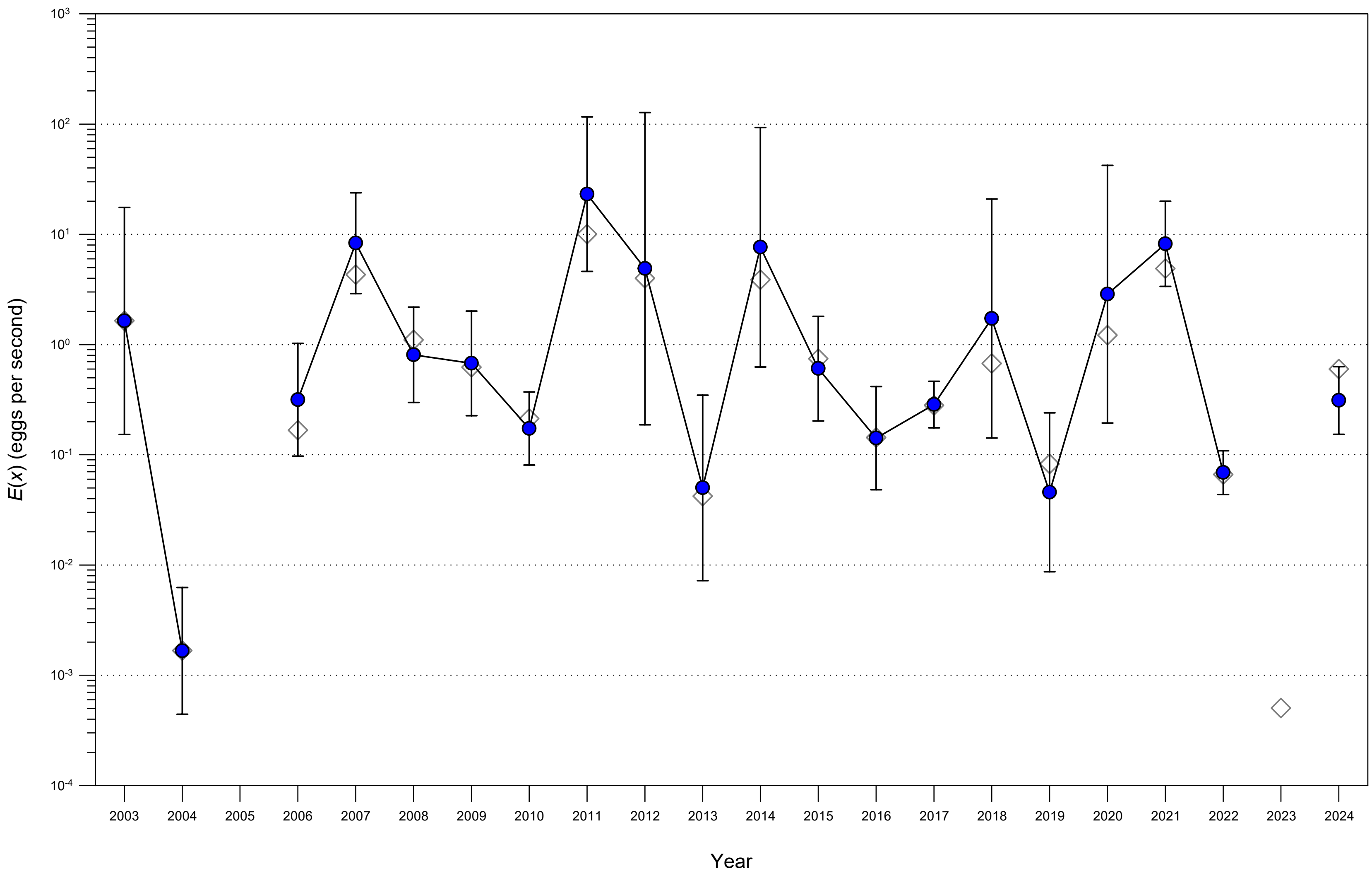

Figure 7. Rio Grande Silvery Minnow egg-passage rates (estimated using data from all sites [22 April to 10 June]) across years. Sampling did not occur in 2005, and egg-passage rate could not be estimated for 2023. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated.

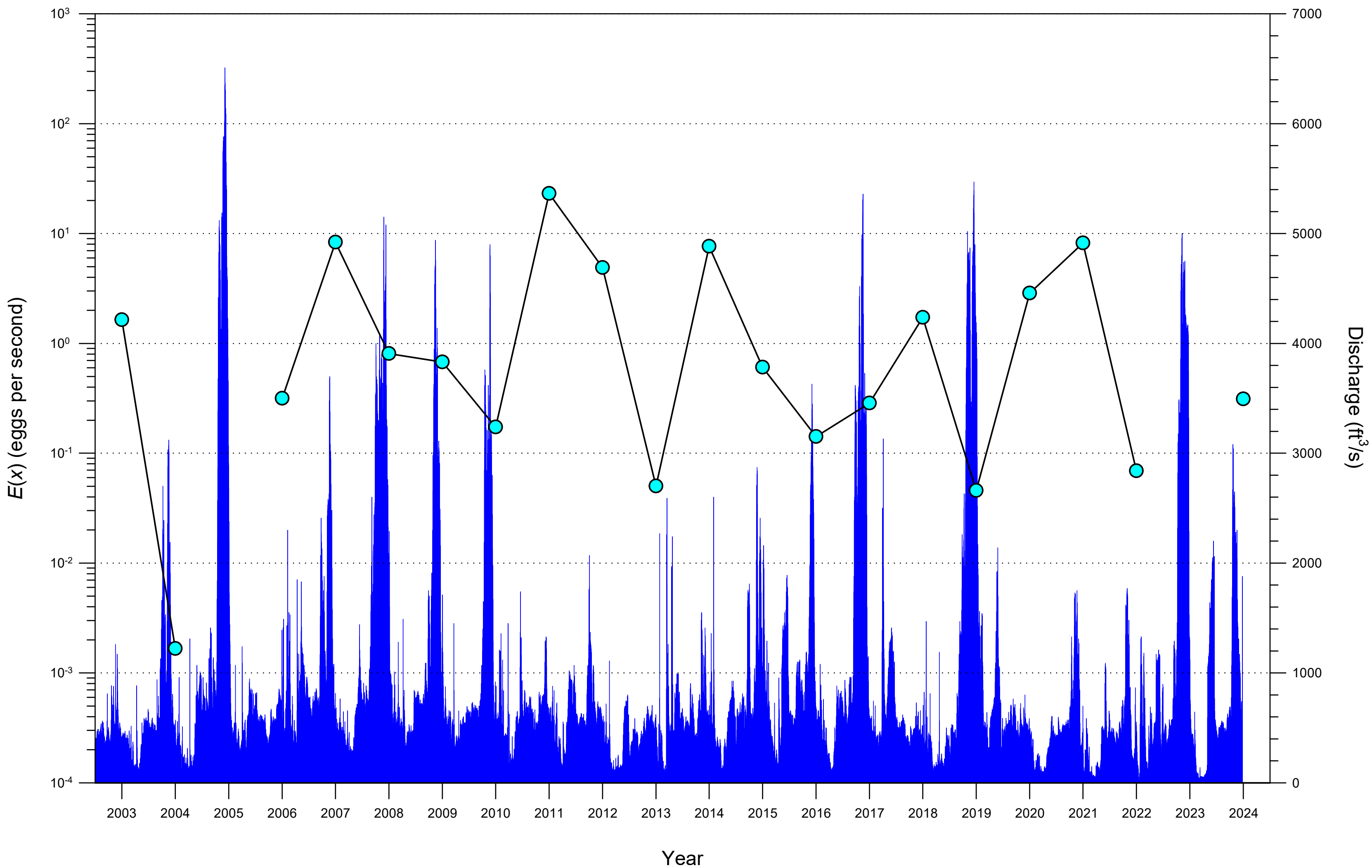

Figure 8. Rio Grande Silvery Minnow egg-passage rates (estimated using data from all sites [22 April to 10 June]) and mean daily discharge data from the Albuquerque Gage (2003-01-01 to 2024-06-30) across years. Sampling did not occur in 2005, and egg-passage rate could not be estimated for 2023.

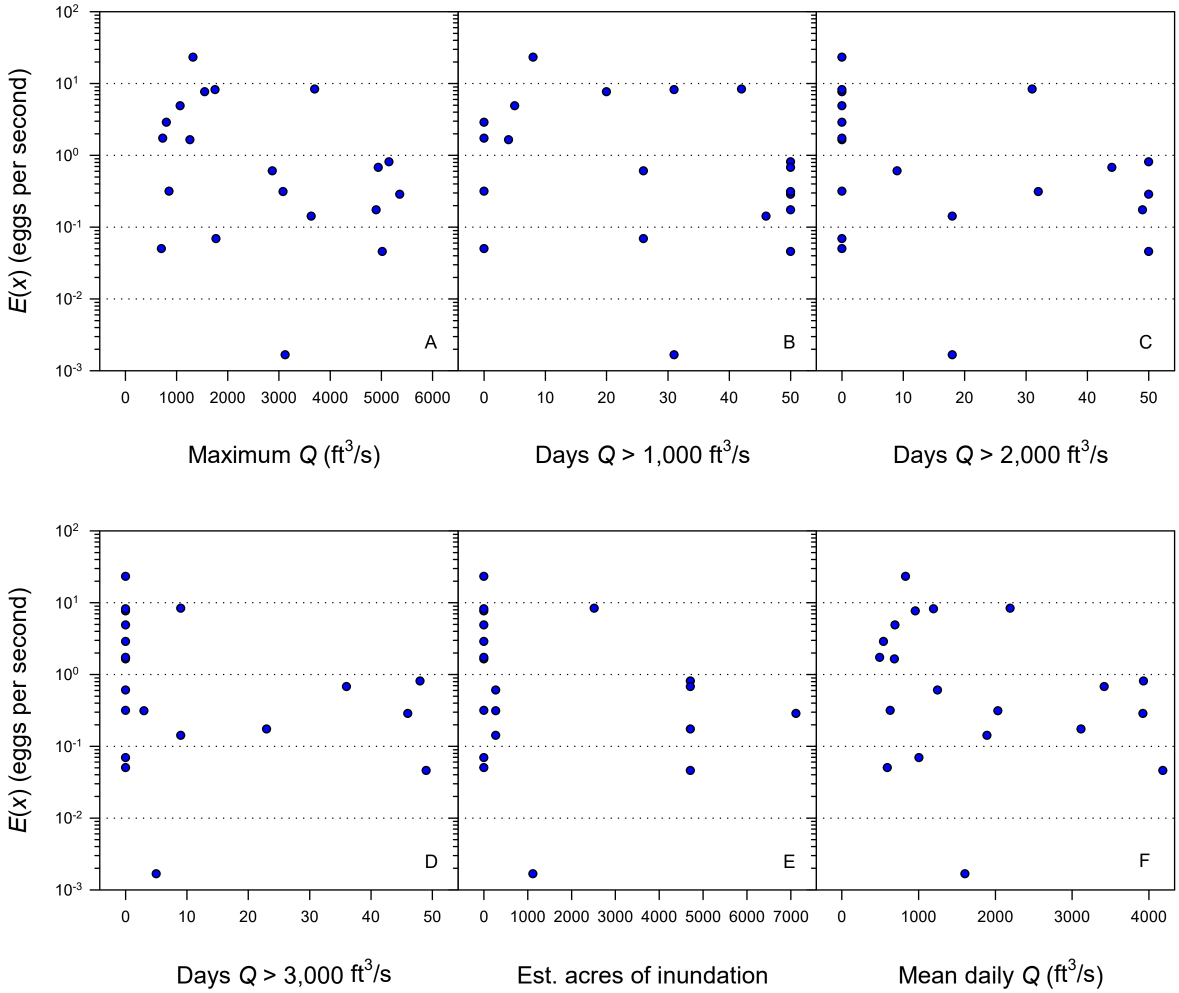

Figure 9. Bivariate plots of Rio Grande Silvery Minnow egg-passage rates (estimated using data from all sites [22 April to 10 June; 2003–2024]) and Albuquerque Gage data.

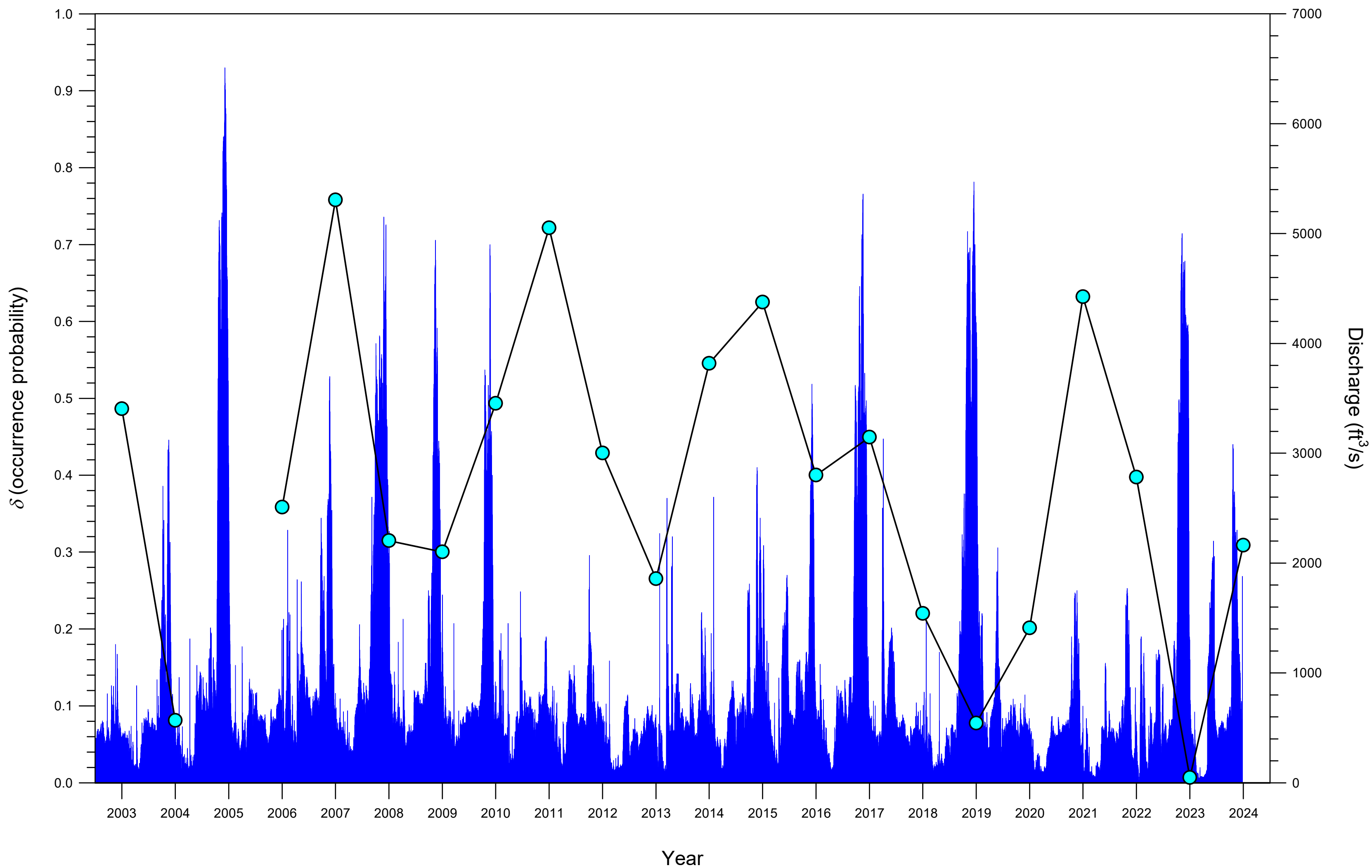

Figure 10. Rio Grande Silvery Minnow egg-occurrence probabilities (estimated using data from all sites [22 April to 10 June]) and mean daily discharge data from the Albuquerque Gage (2003-01-01 to 2024-06-30) across years. Sampling did not occur in 2005.

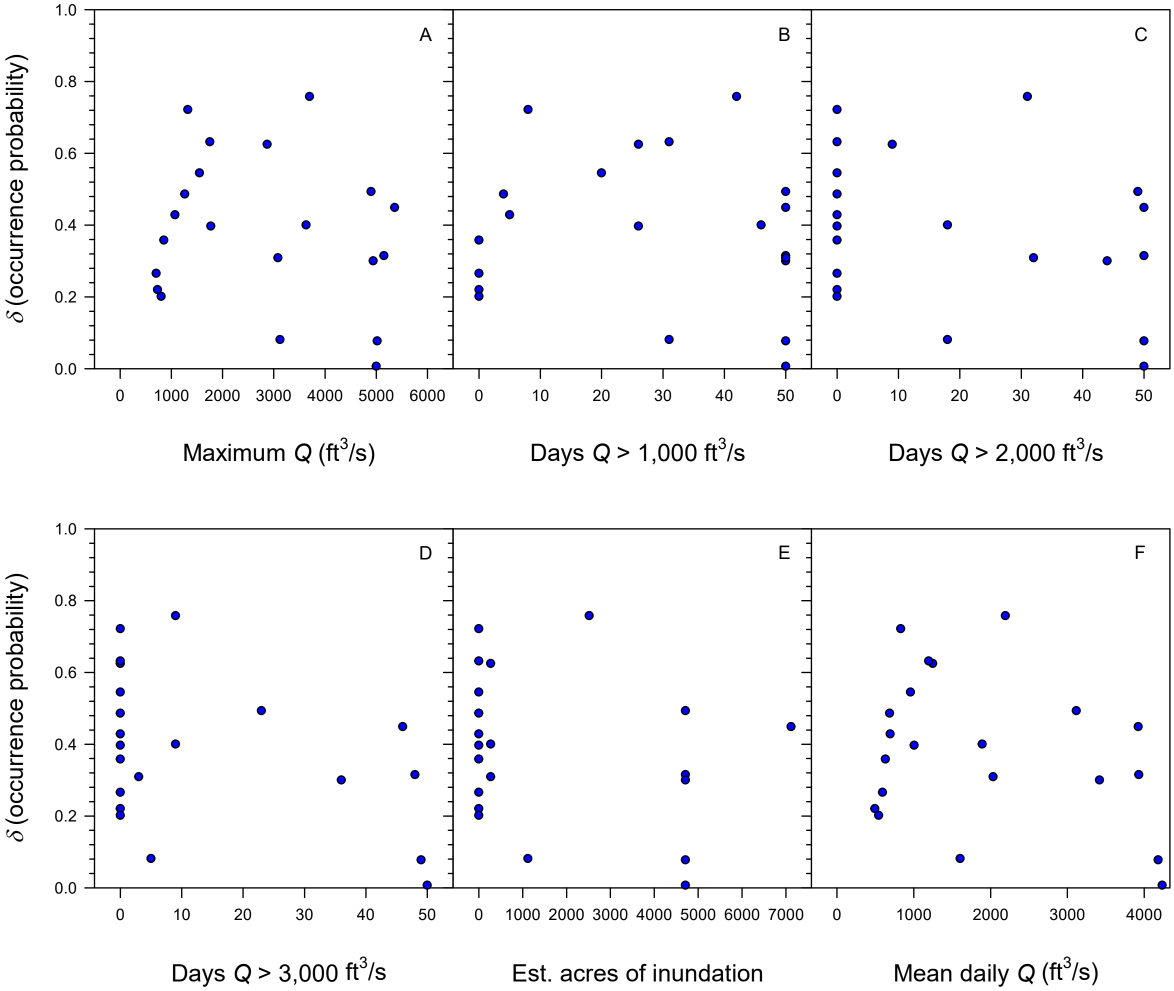

Figure 11. Bivariate plots of Rio Grande Silvery Minnow egg-occurrence probabilities (estimated using data from all sites [22 April to 10 June; 2003–2024]) and Albuquerque Gage data.

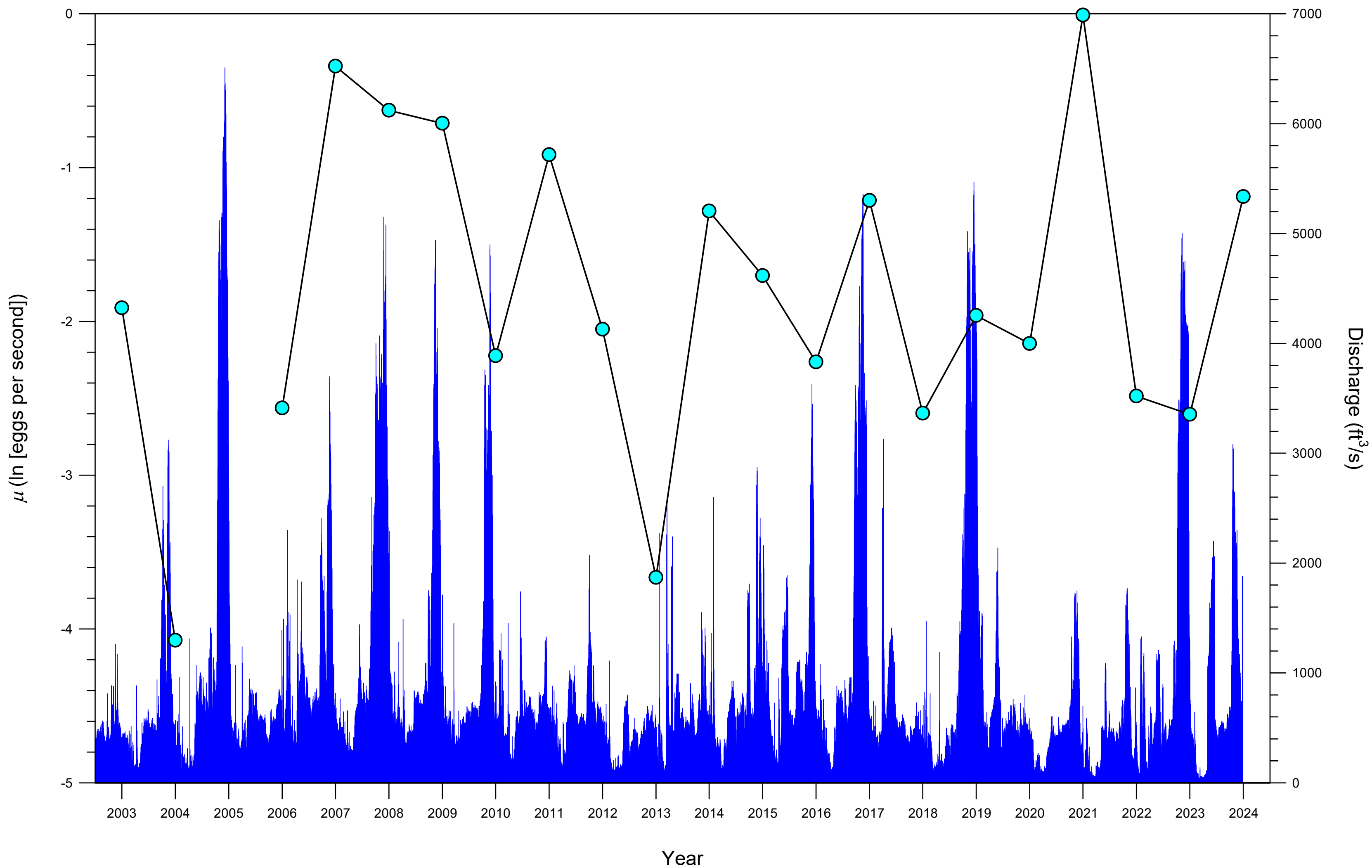

Figure 12. Rio Grande Silvery Minnow lognormal egg-passage rates (estimated using data from all sites [22 April to 10 June]) and mean daily discharge data from the Albuquerque Gage (2003-01-01 to 2024-06-30) across years. Sampling did not occur in 2005.

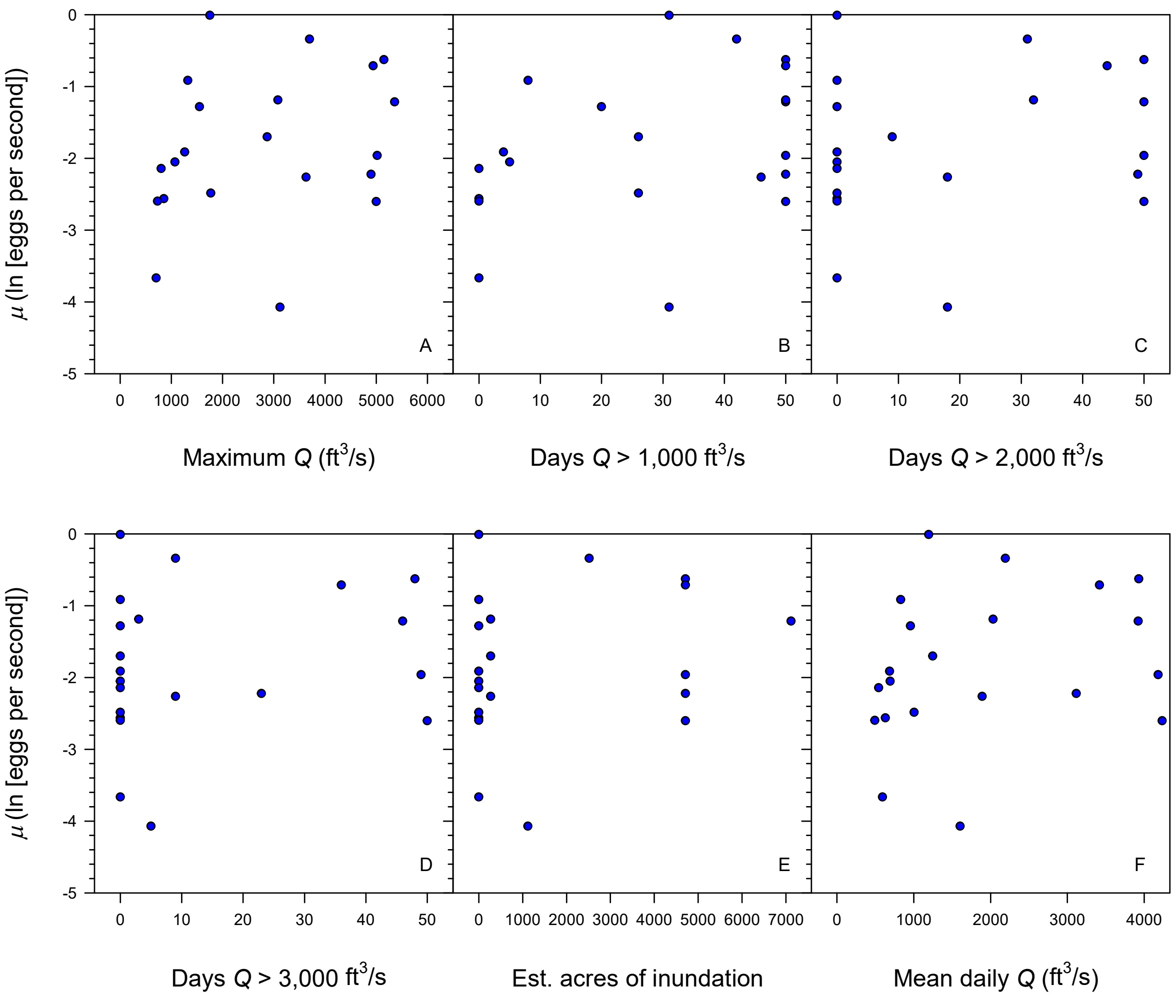

Figure 13. Bivariate plots of Rio Grande Silvery Minnow lognormal egg-passage rates (estimated using data from all sites [22 April to 10 June; 2003–2024]) and Albuquerque Gage data.

Table 6. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using data from all sites (22 April to 10 June; 2003–2024).

Model[1]	**logLike**[2]	**K**[3]	**AIC$_c$**[4]	**w_i**[4]
δ(Year) μ(ABQ>1,000+*R*)	4,137.79	26	4,226.86	0.3759
δ(ABQ>3,000+*R*) μ(ABQ>1,000+*R*)	4,209.03	9	4,227.12	0.3299
δ(ABQmean+*R*) μ(ABQ>1,000+*R*)	4,211.15	9	4,229.24	0.1142
δ(ABQ>2,000+*R*) μ(ABQ>1,000+*R*)	4,213.08	9	4,231.17	0.0436
δ(*R*) μ(ABQ>1,000+*R*)	4,215.60	8	4,231.67	0.0338
δ(Inundation+*R*) μ(ABQ>1,000+*R*)	4,213.97	9	4,232.06	0.0279
δ(ABQmax+*R*) μ(ABQ>1,000+*R*)	4,214.46	9	4,232.55	0.0218
δ(ABQ>1,000+*R*) μ(ABQ>1,000+*R*)	4,214.94	9	4,233.03	0.0172
δ(ABQ>3,000+*R*) μ(ABQmax+*R*)	4,215.75	9	4,233.84	0.0115
δ(Year) μ(ABQmax+*R*)	4,145.53	26	4,234.60	0.0078

[1] = Models included all δ and μ combinations of null effects (.), random effects (*R*), year (2003–2024), 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

Dams, reservoirs, and their operations have profoundly impacted the distribution and abundance of native fishes within the Great Plains and desert rivers of North America for over 100 years (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). Endemic pelagic-spawning minnows, with drifting propagules, have declined precipitously throughout these regions following extensive river fragmentation, flow regulation, and habitat loss (Dudley and Platania 2007; Hoagstrom 2015; Worthington et al. 2018). The downstream transport of eggs and larvae into unsuitable habitats, along with the deleterious 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 (1993–2023) demonstrated that densities of juvenile Rio Grande Silvery Minnow were consistently highest in the southern reaches (i.e., Isleta and San Acacia) of the Middle Rio Grande (Dudley et al. 2024), which could be explained by the cumulative displacement of propagules (drifting eggs and larvae) past instream barriers (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 incision, narrowing, and armoring (Lagasse 1980; Massong et al. 2006; Mortensen et al. 2024). 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; Mortensen et al. 2024). While shoreline pools, backwaters, arroyo confluences, 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 and often warmer mesohabitats are relatively rare (Braun et al. 2015). 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. 2024).

Fish Egg Identification

As Rio Grande Silvery Minnow is the only extant species remaining within the original reproductive guild of pelagic-spawning minnows 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 different 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 adhere to the chorion), have an opaque perivitelline space, and the resulting embryos become pigmented 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 those from pelagic-spawning fishes, 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, its eggs are nonadhesive, and its 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 it senses (e.g., vision, olfaction, and lateral line) these altered aquatic-habitat and water-quality conditions.

Although rapidly increasing discharge appears to cue distinct spawning events for Rio Grande Silvery Minnow, water temperature seems to cue the initiation of their spawning season. 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). Colder water temperatures (e.g., during autumn or winter) are not suitable for either robust gonadal development or successful spawning (Platania 2000; 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. 12–27°C) from April to June. 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 answer 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, 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). 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, during spring and summer, is likely affected by both abiotic (e.g., discharge, 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. 2024). Further, the survival and recruitment of individuals spawned during spring is likely higher than those spawned during summer because of reduced competition for food resources from later spawning species (Pease et al. 2006; Krabbenhoft et al. 2014).

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 hot ambient conditions and low flows, likely reduce the hatching success of eggs and survival rate of larvae (Platania 2000). In addition to elevated water temperatures and declining water quality (Van Horn et al. 2022), negative biotic interactions (e.g., competition, predation, and parasitism) also presumably increase as aquatic habitats contract or become isolated during critically low summer flows.

Based on data from all reaches over time, the downstream transport of eggs was typically highest during years with low and truncated spring flows. These periodic spawning events appear to have been triggered by reach-specific flow conditions. For example, the highest densities of eggs typically coincided with briefly elevated flows within each reach. 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. 2024). 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. 2024). 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 availability and persistence of these habitats are 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 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 (2003–2024) 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 generalized linear covariate models). 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.

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. 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 and Temporal Spawning Patterns

Although reproductive monitoring at the three sites revealed similar trends in egg passage rates over time (2003–2024), 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 have not persisted in a predictable manner, however, throughout the study (2003–2024).

While we have observed several additional minor disparities across the sampling sites in recent years (2018–2020), a close examination of those 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 persistently low at San Marcial in 2018 and 2020 (i.e., often < 25 ft^3/s), however, which resulted in reduced flow connectivity, elevated water temperatures, and weak spawning cues in the San Acacia Reach during those years.

Additionally, there were no significant differences in egg passage rates among the three sites from 2021 to 2024. 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 have observed over time (2003–2024). 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 flow characteristics across years (e.g., low vs. high and truncated vs. prolonged) affected egg 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.

This collective long-term dataset (2003–2024) enabled a robust evaluation of spawning and flow patterns over time. Although the annual addition of new data progressively strengthened these ecological analyses, some years supported specific models more than others. For example, egg passage rates were more variable at lower flows (ca. three orders of magnitude) than at higher flows (ca. one order of magnitude). Several extreme passage rates (e.g., 2011, 2013, 2014, and 2022) occurred over a relatively narrow range of low flows, which contributed to overall model uncertainty. In contrast, high flow years (e.g., 2008–2010, 2017, 2019, and 2023) consistently coincided with relatively low passage rates. In 2024, flow metrics were higher and spawning metrics were lower, as compared to their long-term averages (2003–2024). Overall, data collected in 2024 further supported the overall trends and insights provided by our long-term ecological models.

Ecological Relationships

Prolonged and elevated spring flows result in extensive overbank flooding 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 survival and recruitment of many endemic freshwater fishes (Welcomme 1979; Junk et al. 1989; Matthews 1998). In contrast, persistently low flows during spring and summer typically result in recruitment failure for sensitive species, such as pelagic-spawning minnows (Perkin et al. 2019; Archdeacon et al. 2020). Similar processes are likely reducing the survivorship of early life phases of Rio Grande Silvery Minnow during extended droughts (Pease et al. 2006; Turner et al. 2010; Hoagstrom and Turner 2013; Archdeacon et al. 2020; Dudley et al. 2024).

Based on the long-term reproductive monitoring data from all sites (2003–2024), we found that low and truncated spring flows were associated with higher estimated egg-occurrence probabilities (δ), whereas high and prolonged 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, 2019, and 2023) typically had the lowest occurrence probabilities and passage rates (i.e., reduced downstream transport), which likely reflected a higher retention of eggs in shallow, low-velocity floodplain habitats. In contrast, years with low and truncated flows were often associated with increased occurrence probabilities and passage rates (i.e., increased downstream transport). These differences in downstream transport rates across years were likely caused by changes in habitat complexity during higher flows (i.e., extensive floodplain inundation) vs. lower flows (i.e., narrow/incised channel structure), 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 nursery habitats, could also explain the increased autumnal density of juvenile Rio Grande Silvery Minnow in years with elevated and prolonged spring flows (Dudley et al. 2024).

Conclusions and Implications

Although many drifting fish eggs, and presumably larvae, are annually displaced into downstream reaches of the Middle Rio Grande, some of these propagules are retained every year in upstream reaches (Dudley and Platania 2007; Widmer et al. 2012). The proportion of individuals successfully retained and recruited upstream is likely related to the seasonal availability of shallow, low-velocity habitats. These warm, productive habitats are also particularly important for accelerating the growth and development of early life phases (Dudley and Platania 2007; Widmer et al. 2012; Medley and Shirey 2013; Gonzales et al. 2014; Valdez et al. 2019). The availability and persistence of these nursery habitats are essential during peak spawning season (ca. mid-April to mid-June [Archdeacon et al. 2024]), as larval fish require about one month to successfully progress through their early developmental phases (Platania 1995). The long-term recovery of Rio Grande Silvery Minnow appears strongly contingent upon reliably ensuring adequate seasonal flow and habitat conditions that will promote the successful survival and recruitment of this endangered species.

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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 2024) 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. The logit link maintains δ on a 0–1 scale, the identity link maintains μ between –infinity and +infinity, and the log link maintains σ greater than zero. 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; Burnham and Anderson 2002] corrected for finite sample sizes).

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

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

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

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

where LCI is the lower 95% confidence interval, UCI is the upper 95% confidence interval, and the standard error $\text{SE}\left(E(x)\right)$ 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, meaningful environmental covariates are used to model the key parameters (δ and μ), which collectively lend insight into the fundamental, yet complex, long-term egg drift dynamics of Rio Grande Silvery Minnow.

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: Sites were adequately spaced, so that eggs could hatch before reaching the next site. Eggs were preserved whenever high densities precluded accurate field counts.	Eggs that were not preserved or retained were released back into the river immediately downstream of each 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 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 efforts 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 2024, 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 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-001**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 22 April 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Platania, S.P. Effort: 1,165.5 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SEV24-001**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 22 April 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Damron, T.D. Effort: 1,183.8 m³

Family	Species	Total
76	*Hybognathus amarus*	12

New Mexico: Socorro County, Rio Grande Drainage **SAM24-001**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 22 April 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,689.7 m³

Family	Species	Total
76	*Hybognathus amarus*	3,848

Rio Grande Silvery Minnow Reproductive Monitoring
April 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-002**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 23 April 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Platania, S.P. Effort: 1,173.8 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV24-002**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 23 April 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R.; Damron, T.D. Effort: 1,148.1 m³

Family	Species	Total
76	*Hybognathus amarus*	15

New Mexico: Socorro County, Rio Grande Drainage **SAM24-002**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 23 April 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,997.6 m³

Family	Species	Total
76	*Hybognathus amarus*	59

Rio Grande Silvery Minnow Reproductive Monitoring
April 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-003**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 24 April 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Damron, T.D. Effort: 1,108.4 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV24-003**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 24 April 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 1,359.3 m³

Family	Species	Total
76	*Hybognathus amarus*	24

New Mexico: Socorro County, Rio Grande Drainage **SAM24-003**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 24 April 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,727.4 m³

Family	Species	Total
76	*Hybognathus amarus*	112

Rio Grande Silvery Minnow Reproductive Monitoring
April 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-004**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 25 April 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Damron, T.D. Effort: 1,354.1 m³

Family	Species	Total
76	*Hybognathus amarus*	22

New Mexico: Socorro County, Rio Grande Drainage **SEV24-004**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 25 April 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 1,370.4 m³

Family	Species	Total
76	*Hybognathus amarus*	21

New Mexico: Socorro County, Rio Grande Drainage **SAM24-004**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 25 April 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,290.0 m³

Family	Species	Total
76	*Hybognathus amarus*	84

Rio Grande Silvery Minnow Reproductive Monitoring
April 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-005**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 26 April 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Braun, E.R. Effort: 1,405.2 m³

Family	Species	Total
76	*Hybognathus amarus*	5

New Mexico: Socorro County, Rio Grande Drainage **SEV24-005**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 26 April 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Damron, T.D. Effort: 269.1 m³

Family	Species	Total
76	*Hybognathus amarus*	3

New Mexico: Socorro County, Rio Grande Drainage **SAM24-005**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 26 April 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,256.0 m³

Family	Species	Total
76	*Hybognathus amarus*	10

Rio Grande Silvery Minnow Reproductive Monitoring
April 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-006**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 27 April 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Platania, S.P. Effort: 1,311.2 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV24-006**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 27 April 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 284.5 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-006**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 27 April 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 2,473.7 m³

Family	Species	Total
76	*Hybognathus amarus*	6

Rio Grande Silvery Minnow Reproductive Monitoring
April 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-007**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 28 April 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Braun, E.R. Effort: 1,320.2 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV24-007**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 28 April 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 0.0 m³

Family	**Species**	**Total**

Not Sampled - Sampling Not Safe
(Rainstorms: Hazardous Dirt Roads)

New Mexico: Socorro County, Rio Grande Drainage **SAM24-007**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 28 April 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 2,494.4 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
April 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-008**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 29 April 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Platania, S.P. Effort: 1,251.0 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV24-008**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 29 April 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 686.9 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-008**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 29 April 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,165.5 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
April 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-009**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 30 April 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Urioste, A.D. Effort: 1,032.6 m³

Family	Species	Total
76	*Hybognathus amarus*	3

New Mexico: Socorro County, Rio Grande Drainage **SEV24-009**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 30 April 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Chavez, M.J. Effort: 634.9 m³

Family	Species	Total
76	*Cyprinus carpio*	1

New Mexico: Socorro County, Rio Grande Drainage **SAM24-009**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 30 April 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,480.6 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-010**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 01 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,105.9 m³

Family	Species	Total
76	*Hybognathus amarus*	5

New Mexico: Socorro County, Rio Grande Drainage **SEV24-010**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 01 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 293.7 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-010**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 01 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,394.6 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-011**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 02 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,106.9 m³

Family	Species	Total
76	*Hybognathus amarus*	12

New Mexico: Socorro County, Rio Grande Drainage **SEV24-011**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 02 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 214.6 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-011**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 02 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 2,182.5 m³

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

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-012**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 03 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,345.9 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SEV24-012**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 03 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 363.8 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-012**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 03 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,449.9 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-013**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 04 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Platania, S.P. Effort: 1,264.9 m^3

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SEV24-013**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 04 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Winter, S. Effort: 371.8 m^3

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-013**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 04 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 2,674.9 m^3

Family	Species	Total
76	*Hybognathus amarus*	17

Rio Grande Silvery Minnow Reproductive Monitoring

May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-014**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 05 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Platania, S.P. Effort: 1,282.1 m³

Family	Species	Total
76	*Hybognathus amarus*	4

New Mexico: Socorro County, Rio Grande Drainage **SEV24-014**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 05 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 299.9 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-014**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 05 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 2,909.0 m³

Family	Species	Total
76	*Hybognathus amarus*	1

Rio Grande Silvery Minnow Reproductive Monitoring

May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-015**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 06 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Farrington, M.A. Effort: 1,216.6 m³

Family	Species	Total
76	*Hybognathus amarus*	3

New Mexico: Socorro County, Rio Grande Drainage **SEV24-015**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 06 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 414.4 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-015**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 06 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,169.3 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-016**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 07 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Braun, E.R. Effort: 1,179.2 m³

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

New Mexico: Socorro County, Rio Grande Drainage **SEV24-016**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 07 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 434.5 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-016**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 07 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,854.6 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-017**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 08 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Farrington, M.A. Effort: 1,140.0 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV24-017**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 08 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 373.1 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-017**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 08 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,749.1 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-018**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 09 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,249.4 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV24-018**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 09 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 125.6 m³

Family	Species	Total
76	*Hybognathus amarus*	1

New Mexico: Socorro County, Rio Grande Drainage **SAM24-018**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 09 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,290.0 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-019**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 10 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Damron, T.D.; Dunn, E.A. Effort: 1,235.2 m³

Family	Species	Total
76	*Hybognathus amarus*	3

New Mexico: Socorro County, Rio Grande Drainage **SEV24-019**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 10 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 422.5 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-019**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 10 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,569.9 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-020**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 11 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,558.3 m³

Family	Species	Total
76	*Hybognathus amarus*	3

New Mexico: Socorro County, Rio Grande Drainage **SEV24-020**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 11 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 206.6 m³

Family	Species	Total
76	*Hybognathus amarus*	3

New Mexico: Socorro County, Rio Grande Drainage **SAM24-020**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 11 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 2,930.6 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-021**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 12 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,689.7 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SEV24-021**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 12 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 859.2 m³

Family	Species	Total
76	*Hybognathus amarus*	1

New Mexico: Socorro County, Rio Grande Drainage **SAM24-021**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 12 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 2,697.7 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-022**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 13 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Urioste, A.D. Effort: 1,844.3 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV24-022**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 13 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 504.1 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-022**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 13 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,682.3 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-023**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 14 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Urioste, A.D. Effort: 1,428.0 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV24-023**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 14 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 737.9 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-023**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 14 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,494.3 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-024**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 15 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,372.5 m^3

Family	Species	Total
76	*Hybognathus amarus*	8

New Mexico: Socorro County, Rio Grande Drainage **SEV24-024**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 15 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 758.6 m^3

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-024**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 15 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,470.5 m^3

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring

May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-025**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 16 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Accardo, C.M.; Dunn, E.A. Effort: 1,870.1 m³

Family	Species	Total
76	*Hybognathus amarus*	1

New Mexico: Socorro County, Rio Grande Drainage **SEV24-025**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 16 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Damron, T.D. Effort: 1,153.7 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SAM24-025**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 16 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,503.9 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-026**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 17 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Accardo, C.M.; Dunn, E.A. Effort: 1,608.8 m³

Family	Species	Total
76	*Cyprinus carpio*	1
76	*Hybognathus amarus*	59

New Mexico: Socorro County, Rio Grande Drainage **SEV24-026**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 17 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Chavez, M.J. Effort: 1,510.8 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-026**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 17 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,445.3 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-027**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 18 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,733.0 m³

Family	**Species**	**Total**
76	*Hybognathus amarus*	20

New Mexico: Socorro County, Rio Grande Drainage **SEV24-027**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 18 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 771.4 m³

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

New Mexico: Socorro County, Rio Grande Drainage **SAM24-027**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 18 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 2,883.3 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-028**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 19 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,618.5 m³

Family	Species	Total
76	*Cyprinus carpio*	3
76	*Hybognathus amarus*	1

New Mexico: Socorro County, Rio Grande Drainage **SEV24-028**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 19 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 746.0 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-028**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 19 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 2,840.7 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-029**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 20 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dudley, R.K. Effort: 1,293.9 m³

Family	Species	Total
76	*Hybognathus amarus*	7

New Mexico: Socorro County, Rio Grande Drainage **SEV24-029**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 20 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 829.7 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-029**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 20 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,521.5 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-030**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 21 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Chavez, M.J. Effort: 1,540.3 m³

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

New Mexico: Socorro County, Rio Grande Drainage **SEV24-030**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 21 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Dudley, R.K. Effort: 1,465.0 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-030**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 21 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,038.6 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring

May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-031**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 22 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,481.3 m³

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

New Mexico: Socorro County, Rio Grande Drainage **SEV24-031**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 22 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 1,114.0 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-031**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 22 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,362.5 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-032**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 23 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,640.9 m³

Family	Species	Total
76	*Hybognathus amarus*	2

New Mexico: Socorro County, Rio Grande Drainage **SEV24-032**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 23 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 1,157.9 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-032**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 23 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,535.6 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-033**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 24 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,571.4 m³

Family	Species	Total
76	*Cyprinus carpio*	1
76	*Hybognathus amarus*	71

New Mexico: Socorro County, Rio Grande Drainage **SEV24-033**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 24 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 1,198.0 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-033**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 24 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,291.9 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-034**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 25 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,767.6 m³

Family	Species	Total
76	*Hybognathus amarus*	57

New Mexico: Socorro County, Rio Grande Drainage **SEV24-034**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 25 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 1,350.9 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-034**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 25 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 2,714.6 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-035**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 26 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 390.0 m³

Family	Species	Total
76	*Hybognathus amarus*	11

New Mexico: Socorro County, Rio Grande Drainage **SEV24-035**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 26 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Platania, S.P. Effort: 1,255.7 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-035**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 26 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 2,064.6 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-036**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 27 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Platania, S.P. Effort: 1,322.4 m³

Family	Species	Total
76	*Hybognathus amarus*	5

New Mexico: Socorro County, Rio Grande Drainage **SEV24-036**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 27 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Damron, T.D. Effort: 1,175.1 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-036**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 27 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,693.7 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring

May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-037**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 28 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Farrington, M.A. Effort: 1,321.3 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV24-037**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 28 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 1,110.8 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-037**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 28 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,658.2 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring

May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-038**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 29 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Farrington, M.A. Effort: 1,245.3 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV24-038**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 29 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 963.5 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-038**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 29 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Damron, T.D. Effort: 2,279.1 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-039**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 30 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dudley, R.K. Effort: 1,338.3 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV24-039**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 30 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Damron, T.D. Effort: 889.7 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-039**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 30 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 2,078.0 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
May 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-040**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 31 May 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Farrington, M.A. Effort: 952.5 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV24-040**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 31 May 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Damron, T.D. Effort: 785.5 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-040**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 31 May 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,814.6 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
June 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-041**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 01 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Platania, S.P. Effort: 1,280.1 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV24-041**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 01 June 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 780.0 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-041**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 01 June 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 1,421.3 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
June 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-042**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 02 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,357.1 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV24-042**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 02 June 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 757.1 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-042**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 02 June 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 1,398.4 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
June 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-043**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 03 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Accardo, C.M. Effort: 1,200.8 m³

Family	Species	Total
76	*Cyprinus carpio*	3

New Mexico: Socorro County, Rio Grande Drainage **SEV24-043**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 03 June 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 420.1 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-043**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 03 June 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 729.0 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
June 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-044**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 04 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Accardo, C.M. Effort: 893.4 m³

Family	Species	Total
76	*Cyprinus carpio*	5

New Mexico: Socorro County, Rio Grande Drainage **SEV24-044**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 04 June 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 635.1 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-044**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 04 June 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,449.7 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
June 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-045**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 05 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,328.6 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV24-045**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 05 June 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 534.4 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-045**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 05 June 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,227.7 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
June 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-046**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 06 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,679.4 m^3

Family	Species	Total
76	*Cyprinus carpio*	1

New Mexico: Socorro County, Rio Grande Drainage **SEV24-046**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 06 June 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 641.3 m^3

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-046**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 06 June 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,327.6 m^3

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
June 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-047**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 07 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,329.4 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV24-047**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 07 June 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Braun, E.R. Effort: 521.9 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-047**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 07 June 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 1,284.4 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
June 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-048**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 08 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,371.3 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV24-048**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 08 June 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 337.2 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-048**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 08 June 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Braun, E.R. Effort: 951.6 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring
June 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-049**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 09 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Dunn, E.A. Effort: 1,299.0 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SEV24-049**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 09 June 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 269.8 m³

Family	**Species**	**Total**

New Mexico: Socorro County, Rio Grande Drainage **SAM24-049**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 09 June 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Schroeder, A.J. Effort: 1,173.2 m³

Family	**Species**	**Total**

Rio Grande Silvery Minnow Reproductive Monitoring

June 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-050**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 10 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Accardo, C.M. Effort: 753.4 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SEV24-050**
Rio Grande, at Sevilleta NWR, just upstream of the Rio Salado confluence, San Acacia.
Site Number: 2 River Mile: 119.6 10 June 2024
UTM Easting: 330100 UTM Northing: 3794552 Zone: 13 Quad: La Joya
Collector(s): Willis Mascareñas, A.T. Effort: 151.6 m³

Family	Species	Total

New Mexico: Socorro County, Rio Grande Drainage **SAM24-050**
Rio Grande, ca. 4.8 mi upstream of the Sierra County boundary, San Marcial.
Site Number: 3 River Mile: 55.5 10 June 2024
UTM Easting: 305552 UTM Northing: 3711984 Zone: 13 Quad: Paraje Well
Collector(s): Winter, S. Effort: 941.2 m³

Family	Species	Total

Rio Grande Silvery Minnow Reproductive Monitoring
June 2024

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-051**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 11 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Accardo, C.M. Effort: 1,248.3 m³

Family	Species	Total
76	*Hybognathus amarus*	26

New Mexico: Bernalillo County, Rio Grande Drainage **ABQ24-052**
Rio Grande, just downstream of the Powerline Crossing, near S Diversion Canal confluence, Albuquerque.
Site Number: 1 River Mile: 176.4 12 June 2024
UTM Easting: 346277 UTM Northing: 3874723 Zone: 13 Quad: Albuquerque West
Collector(s): Accardo, C.M. Effort: 835.9 m³

Family	Species	Total