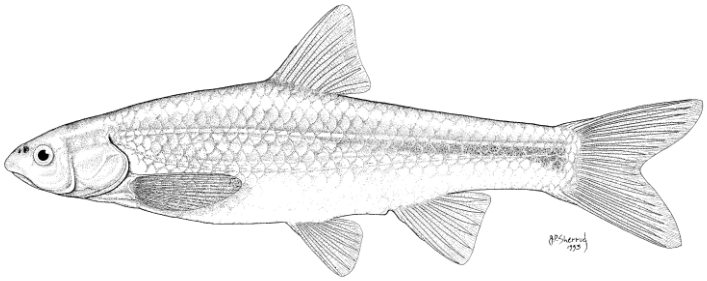
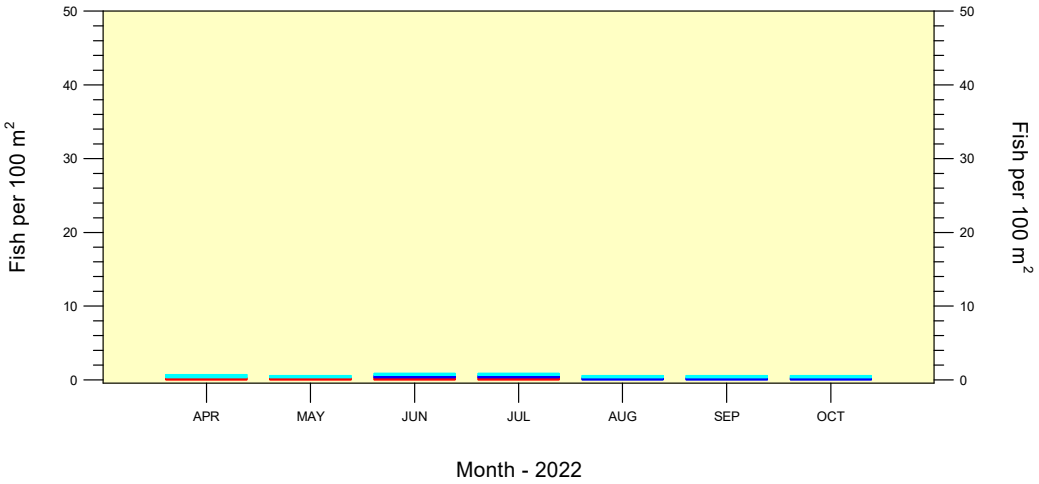
Rio Grande Silvery Minnow Population Monitoring during 2022

A U.S. Bureau of Reclamation Funded Research Program





Final Report
19 May 2023

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Final Report
19 May 2023

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EXECUTIVE SUMMARY

As part of the Rio Grande Silvery Minnow Population Monitoring Program, the status of this imperiled species and the associated Middle Rio Grande ichthyofaunal community has been systematically monitored since 1993. This effort is unique among ichthyofaunal research studies in the Middle Rio Grande, as it provides consistent sampling of fishes over a very long duration. Long-term sampling studies, like this one, also provide the data necessary to test and compare different ecological hypotheses. Our primary research objective is to evaluate how seasonal and annual changes in river flows affect the distribution and abundance of Rio Grande Silvery Minnow throughout its current range over time (1993–2022).

The annual occurrence and density of Rio Grande Silvery Minnow, during October, has fluctuated widely over the past three decades (1993–2022). Estimated densities ($E(x)$; fish per 100 m^2) were notably higher in 2016 and 2017, as compared with 2015, but then decreased dramatically from 2017 to 2018. Recent monitoring efforts revealed an 88.8% decrease in its density from 2019 (2.10) to 2020 (0.23), and its density had declined further by 2022 (0.08). While Rio Grande Silvery Minnow represented 8.61% of the fish community in 2019, it had decreased to only 0.68% by 2022.

Changes in the occurrence and density of Rio Grande Silvery Minnow were reliably predicted by seasonal differences in river flows across years (1993–2022). Further, our findings were consistent regardless of whether dry sites or additional sites were or were not included in the analyses. Out of 440 models considered, we found that the top three models, which represented extended high flows during spring, were crucial in explaining why some years had dramatically elevated densities of Rio Grande Silvery Minnow. In contrast, we found that extended low flows during summer were key to explaining reductions in the occurrence of this species across years. Thus, prolonged low flows during summer were most predictive of decreased occurrence and prolonged high flows during spring were most predictive of increased density of Rio Grande Silvery Minnow over time.

Additional analyses revealed that population trends in different mesohabitats (October [2002–2022]), or on different days during repeated sampling (November [2005–2022]), were comparable to population trends obtained from the long-term dataset (October [1993–2022]). These results indicate that the current sampling protocols are resulting in a reliable level of sampling precision and population trend consistency, especially when considering the substantial changes in the occurrence and density of Rio Grande Silvery Minnow over time. Additionally, Rio Grande Silvery Minnow population metrics were far more closely related to seasonal flow conditions across years than to local/regional sampling conditions (i.e., sampling occasions, mesohabitats, or reaches).

Site occupancy models, based on repeated sampling (November [2005–2022]), further revealed that Rio Grande Silvery Minnow occupancy probabilities decreased from 2019 (1.00) to 2020 (0.65), increased modestly in 2021 (0.81), but decreased markedly in 2022 (0.49). While estimated extinction probabilities were elevated during recent drought years (i.e., 2012–2014), they decreased substantially from 2014 to 2017, as seasonal river flows progressively improved. Likewise, estimated colonization probabilities increased considerably in recent years (2013–2017), as this species gradually repatriated multiple sites that had been previously unoccupied. However, these trends reversed in 2018 and 2020 following poor spring and summer flow conditions. While the long-term conservation status of Rio Grande Silvery Minnow improved from 2020 to 2021, its status again declined in 2022.

Pronounced changes in the occurrence and density of Rio Grande Silvery Minnow over the past three decades were closely related to the timing, duration, and magnitude of river flows during spring and summer. Prolonged and elevated spring flows result in extensive overbank flooding of vegetated areas and the formation of inundated habitats within the river channel (e.g., shoreline pools and backwaters). The unique early life history of this species ensures that its propagules (drifting eggs and larvae) are rapidly dispersed throughout these low-velocity, warm, and productive habitats when spring flows begin to rise. These conditions, combined with a protracted spring runoff, help ensure the inundation of these 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, the stability and persistence of these habitats is essential for ensuring the successful recruitment and survival of young to later life phases (i.e., metalarvae and juveniles).

Rio Grande Silvery Minnow was consistently most abundant in downstream reaches (i.e., Isleta and San Acacia) of the Middle Rio Grande. One explanation for this pattern is the cumulative downstream transport of propagules past instream barriers over time. Also, river channelization, habitat degradation, abandonment of the floodplain, and reductions in suspended sediments downstream of Cochiti Dam are likely limiting the number of appropriate habitats available for the successful retention and recruitment of early life phases, especially in the Cochiti and Angostura reaches. While it is evident that seasonally elevated flows, combined with habitat restoration, should lead to increased recruitment success, the long-term efficacy of those efforts will also depend on ensuring their utility and permanence by restoring a more dynamic flow regime and reestablishing river connectivity across fragmented reaches.

While extensive and diverse conservation-management efforts over the past three decades have provided protection against the extinction of Rio Grande Silvery Minnow, ongoing and planned efforts (e.g., restoring dynamic river flows, reconnecting fragmented reaches, and reestablishing a functional floodplain) should help to support resilient and self-sustaining populations of this imperiled species in the future. Unfortunately, both the occurrence and density of Rio Grande Silvery Minnow decreased in 2022, following an early/truncated spring runoff and poor summer flow conditions. Continued efforts to provide reasonable spring spawning and summer survival conditions will be essential for securing a self-sustaining wild population of this species in the Middle Rio Grande. Additionally, reestablishing resilient populations at other locations within its historical range would substantially help to further ensure its long-term persistence in the wild. Finally, future study of the relationships among aquatic species (i.e., from plankton to fish), instream habitats, and river flows should continue to elucidate key factors that regulate this complex ecosystem, which will be essential for developing and implementing successful strategies for the long-term recovery of Rio Grande Silvery Minnow.

INTRODUCTION

The negative effects of dam-related modifications on the native fishes of the Great Plains and American Southwest have been well documented (Stanford and Ward 1979; Cross et al. 1983, 1985; Cross and Moss 1987; Winston et al. 1991; Luttrell et al. 1999; Dudley and Platania 2007; Perkin et al. 2015; Worthington et al. 2018). River fragmentation, flow regulation, and habitat loss in these regions have led to the widespread decline or extirpation of several pelagic-spawning cyprinids, whose eggs and larvae often drift downstream of instream barriers or into unsuitable riverine/reservoir habitats (Dudley and Platania 2007; Hoagstrom 2015; Worthington et al. 2018). Many of the endemic pelagic-spawning cyprinids that historically occupied the Rio Grande Basin have been extirpated from large portions of their ranges (Speckled Chub, *Macrhybopsis aestivalis* and Rio Grande Shiner, *Notropis jemezanus*) or have become extinct (Phantom Shiner, *Notropis orca* and Rio Grande Bluntnose Shiner, *Notropis simus simus*) over the past century (Bestgen and Platania 1990; Platania and Altenbach 1998). Rio Grande Silvery Minnow, *Hybognathus amarus*, is the only extant pelagic-spawning cyprinid in the New Mexico portion of the Rio Grande (Bestgen and Platania 1991; Platania 1991).

As part of the Rio Grande Silvery Minnow Population Monitoring Program, data on Rio Grande Silvery Minnow and the associated ichthyofaunal community in the Middle Rio Grande (Rio Grande between Velarde and Elephant Butte Reservoir) have been gathered regularly since 1987. Platania (1993a) conducted the first comprehensive studies (1987–1992) to determine spatial and temporal changes in the Middle Rio Grande ichthyofaunal community and to provide resolution of species-specific habitat use patterns. An additional purpose of those initial studies was to provide information on the conservation status of Rio Grande Silvery Minnow. Sampling efforts during 1989 and 1990 revealed that the abundance of Rio Grande Silvery Minnow had declined markedly since 1987 (Platania 1993a). Based on previous samples, reduced numbers of individuals indicated a rapid decline of this species across its already reduced range. Rio Grande Silvery Minnow was listed as an endangered species primarily because there had been a 90–95% reduction in its historical range, and the remnant population in the Middle Rio Grande was threatened by several abiotic and biotic factors (USDOI 1994). Current threats to the persistence of Rio Grande Silvery Minnow have been identified, and a series of corrective actions have been proposed to help promote its future recovery (USFWS 2016).

Since 1993, the State of New Mexico, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and U.S. Fish and Wildlife Service have cooperated to fund numerous studies of the Middle Rio Grande ichthyofauna. Among those studies was the long-term systematic monitoring of the Middle Rio Grande fish community at numerous sites between Angostura Diversion Dam and Elephant Butte Reservoir. Population monitoring efforts have documented wide fluctuations (i.e., order of magnitude increases and decreases) in the densities of Rio Grande Silvery Minnow over the past three decades. The abundance of this species has decreased during years with low spring discharge combined with prolonged summer low-flow/drying conditions, but it has increased following years with extended high spring flows combined with minimal summer low-flow/drying conditions (Dudley et al. 2009; Archdeacon 2016; Dudley et al. 2022a). While Rio Grande Silvery Minnow has been the primary focus of long-term monitoring efforts and subsequent hypothesis testing, our research activities have also provided valuable information on the associated Middle Rio Grande fish community.

The primary objectives of the Rio Grande Silvery Minnow Population Monitoring Program are to assess interannual trends in the distribution and abundance of this species, at standardized sites throughout the Middle Rio Grande, and evaluate how those trends are affected by changes in seasonal and annual discharge patterns. Additional objectives include determining mesohabitat use patterns, assessing variation of density estimates based on repeated sampling, documenting changes in relative abundance among native and nonnative fishes, and evaluating changes in site occupancy status across years. Seasonal and spatial differences in the population structure and abundance of native and nonnative fishes are also examined across reaches and years. Our ongoing research should also aid natural resource managers in obtaining a more thorough understanding of the key factors that regulate the conservation status and population dynamics of Rio Grande Silvery Minnow, which will be essential for implementing effective strategies for the long-term recovery of this species.

STUDY AREA

The headwaters of the Rio Grande are in the San Juan Mountains of southern Colorado. The mainstem Rio Grande flows 750 km through New Mexico, draining an area of about 68,104 km^2 (excluding closed basins). The Rio Chama is the only major perennial tributary of the Rio Grande in New Mexico and confluences with it near the city of Española. Snowmelt from southern Colorado and northern New Mexico yields most of the water for the Rio Grande, but transmontane diversions from the San Juan River (Colorado River Basin) supplement flow by providing water in route to downstream municipalities. The highest flows in the Rio Grande, as measured at U.S. Geological Survey (USGS) gaging stations, generally occur shortly after spring snowmelt. In contrast, the lowest flows usually occur in late summer and early autumn prior to the cessation of irrigation season (October 31). Summer rainstorms periodically augment low flows in discrete reaches but do not ensure that the river channel will remain wetted in its entirety over time.

Several large dams on the Rio Chama and Rio Grande, along with numerous smaller diversion dams, regulate flow in the Middle Rio Grande. A complex system of ditches, drains, and conveyance channels provides water for agricultural and municipal purposes in the Rio Grande Valley. Cochiti Dam is the primary flood control structure that regulates discharge in the mainstem Middle Rio Grande. Cochiti Dam/Lake operations have led to notably lower peak flows, greatly reduced sediment supplies, and the progressive degradation, armoring, and narrowing of the river channel for up to 100 km downstream (Lagasse 1980; Massong et al. 2006). Additionally, river regulation, large levees, jetty jacks, and bank-stabilizing invasive vegetation have contributed to a dramatic reduction in seasonal floodplain habitats and river-floodplain connectivity over the past century (Adair 2016). While arroyos, backwaters, and other nursery habitats likely benefit native fishes (Porter and Massong 2004a, 2004b; Pease et al. 2006), these low velocity mesohabitats are relatively rare, particularly in incised sections of the river.

The study area (Figures 1 and 2) is a portion of the Middle Rio Grande, from Angostura Diversion Dam to the inflow of Elephant Butte Reservoir, which encompasses most of the current range of Rio Grande Silvery Minnow (i.e., below Cochiti Dam [although it is unknown if this species persists upstream of Angostura Diversion Dam] to the inflow of Elephant Butte Reservoir). The Cochiti Reach of the Rio Grande (Cochiti Dam to Angostura Diversion Dam) passes first through Cochiti Pueblo, then Santo Domingo Pueblo, and finally San Felipe Pueblo. The last comprehensive ichthyofaunal surveys of the Cochiti Reach documented low numbers of Rio Grande Silvery Minnow on Santo Domingo and San Felipe Pueblos (Platania 1995a) and its absence on Cochiti Pueblo (Platania 1993b). While our current study does not include sampling sites within these areas, or the Sandia or Isleta Pueblos, the U.S. Fish and Wildlife Service conducts ongoing fish monitoring efforts in some of these areas (Thomas P. Archdeacon, USFWS, pers. comm.).

Most of the standard sampling sites were selected from a list of nearly 100 Middle Rio Grande sites, which were monitored from 1987 to 1992 (Platania 1993a); these sites have been sampled consistently since 1993. Site locations were chosen based on spatial distribution, site accessibility, relative permanence of flow (or deep pools during drought), and the presence of reasonably suitable instream habitat. Although most sites have been consistently monitored over time, several localities were added (e.g., improving the spatial coverage within or among reaches [Dudley and Platania 1997b, 1999, 2002]) or removed (e.g., recognizing the loss of consistent land access [Dudley and Platania 1999]). Although our long-term population monitoring sites were not randomly selected, Archdeacon et al. (2015) found no meaningful differences in fish community composition or species-specific densities when using a random vs. nonrandom study design to sample fishes 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 were five standard sampling sites in the Angostura Reach (Angostura Diversion Dam to Isleta Diversion Dam), six sites in the Isleta Reach (Isleta Diversion Dam to San Acacia Diversion Dam), and nine sites in the San Acacia Reach (San Acacia Diversion Dam to Elephant Butte Reservoir). These 20 standard sampling sites (Appendix A [Table A1]) overlap the current documented range of Rio Grande Silvery Minnow and form the basis of the long-term monitoring efforts (1993–2022). In 2017, ten additional sampling sites were added to the study area. These sites were added to help fill in the largest sampling gaps between the standard sites, while ensuring that the sampling coverage remained spatially balanced within each reach. Also, all

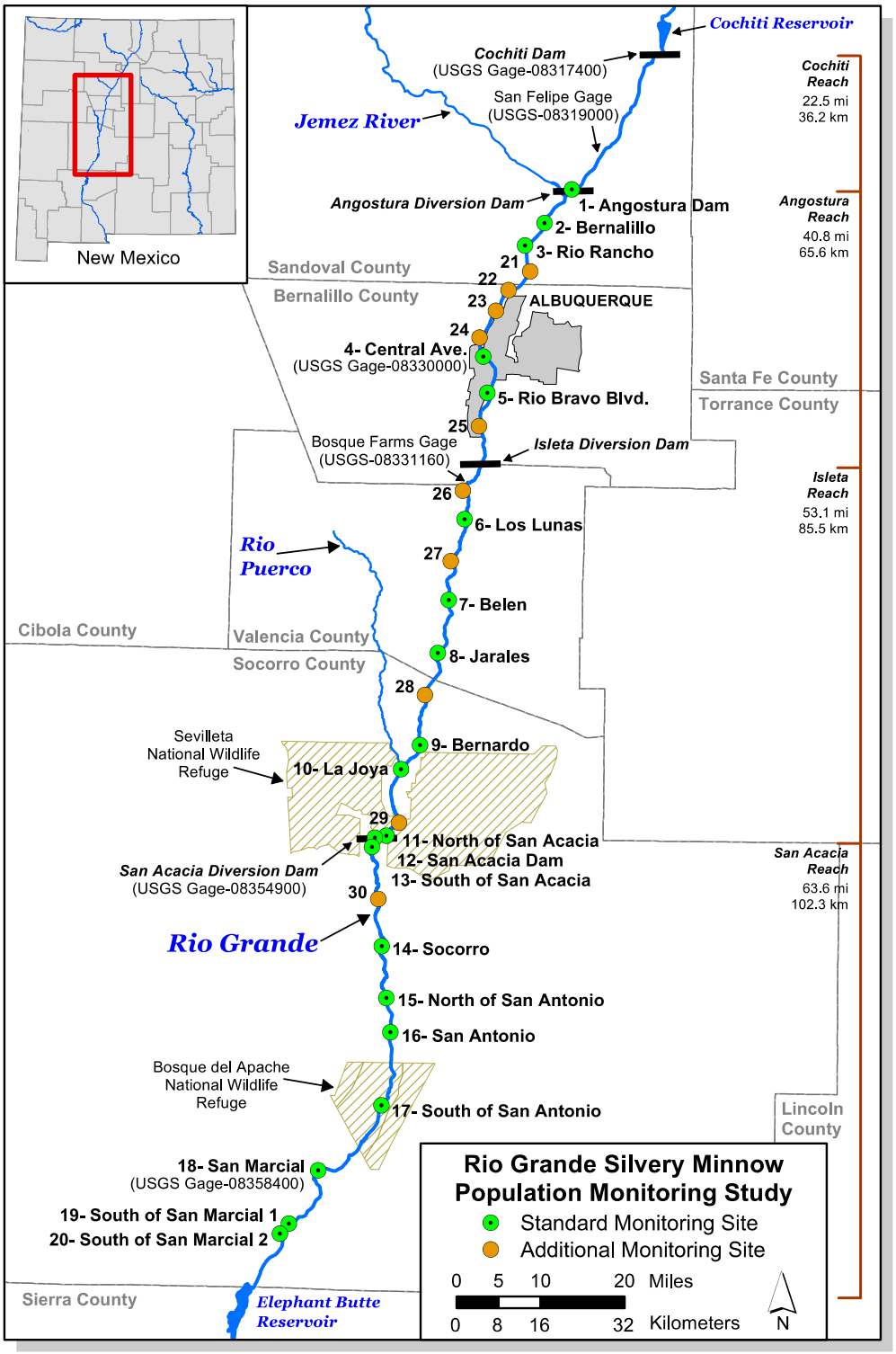

Figure 1. Map of the study area, standard sites, and additional sites for the Rio Grande Silvery Minnow population monitoring study. Site descriptions are provided in Appendix A.

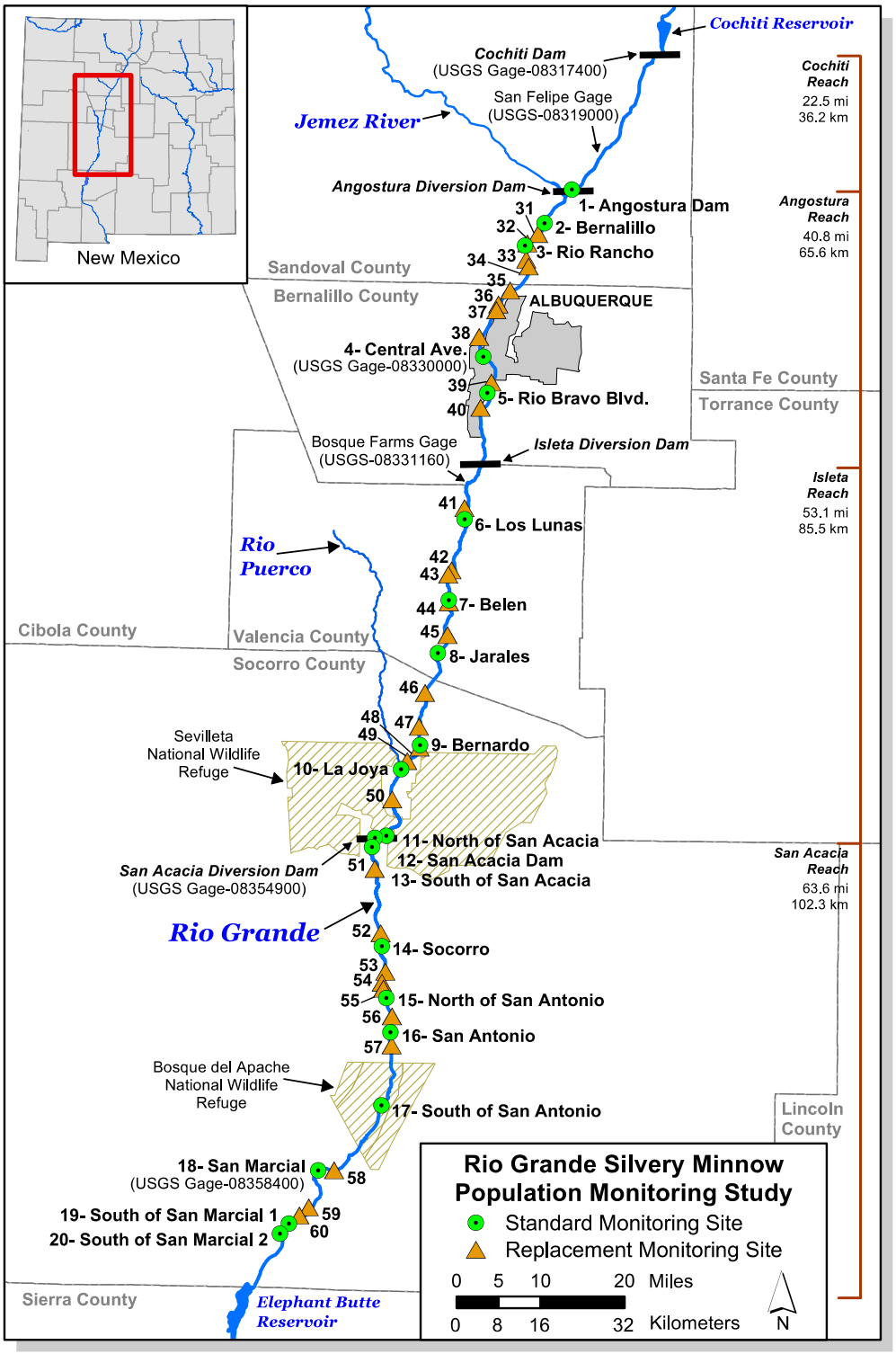

Figure 2. Map of the study area, standard sites, and replacement sites for the Rio Grande Silvery Minnow population monitoring study. Site descriptions are provided in Appendix A.

additional sites were in areas that did not present unreasonable safety or access issues. This same site-selection rationale has been consistently used for this project whenever additional sites were required to supplement the existing sampling coverage. To obtain a total of ten sites per reach, five sites were added to the Angostura Reach, four sites were added to the Isleta Reach, and one site was added to the San Acacia Reach (Figure 1; Appendix A [Table A2]).

Since 2017, replacement sites were also sampled whenever the river was dry at one of the standard/additional sampling sites (Figure 2; Appendix A [Table A3]). As these replacement sites were meant to supplement the established sampling sites during periods of river drying and had to satisfy an extensive list of selection criteria, all replacements were selected randomly using a spatially-balanced statistical design (GRTS; Stevens and Olsen 1999, 2003, 2004). Any candidate replacement site had to meet all selection criteria, established by the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program), prior to the initiation of sampling (i.e., located in a wetted area, located in a non-isolated stretch of river, located within the river channel, located in an area with > 0.5 miles of continuous river flow, located in an area that did not present unreasonable safety or access issues, located closest to the replaced dry site, located in the same reach as the replaced dry site, and located in an area where it would be likely to serve as a viable replacement over time).

Daily and seasonal discharge varied greatly during 2021 and 2022, especially in downstream reaches of the Middle Rio Grande (Figure 3). There was a general trend of lower flow in the San Acacia Reach (e.g., San Acacia: USGS Gage-08354900 and San Marcial: USGS Gage-08358400), as compared to upstream locations (e.g., San Felipe: USGS Gage-08319000 and Albuquerque: USGS Gage-08330000). In 2022, flows were relatively low throughout the study area, and there was a brief and somewhat early spring runoff. River flows began to peak by late April but declined rapidly to low levels by late May. Flows were persistently low from June through September, except for periodic increases from rainstorms. As compared to the generalized historical spring runoff (i.e., average mean-daily discharges since 1973 [Cochiti Dam operational]), there was a pronounced and prolonged summer drought event in 2021. Likewise, flows were typically low, except after periodic rainstorms, during the summer of 2022. All discharge data presented in this report are provisional and subject to change.

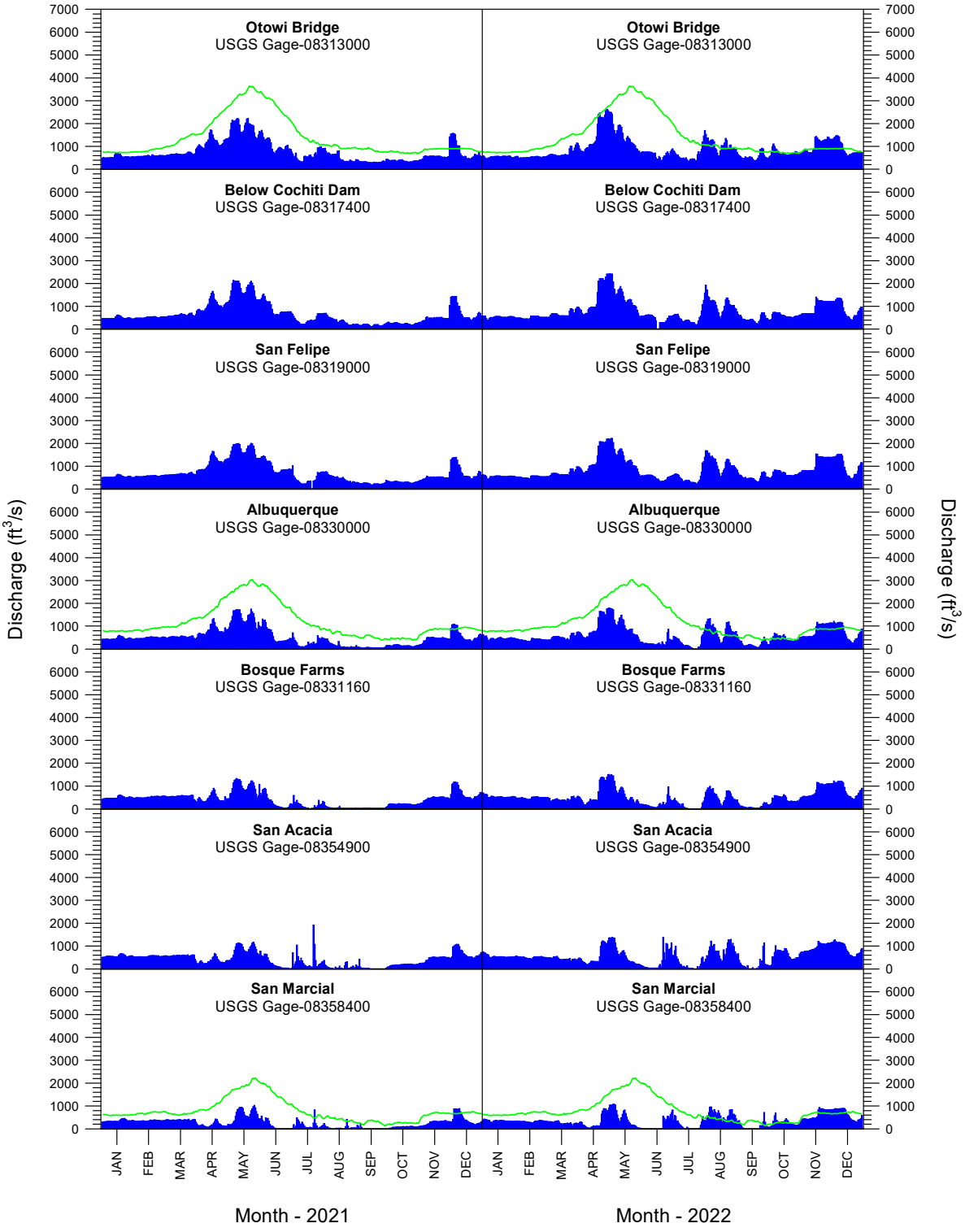

Figure 3. Rio Grande mean-daily discharge, by USGS gaging station, from 1 January 2020 to 31 December 2022. Green lines are the average mean-daily discharges across years (1973–2022).

METHODS

Sampling Protocols

This study was designed to monitor long-term trends in the abundance of Rio Grande Silvery Minnow, and the associated fish community, at 20 sampling sites throughout the Middle Rio Grande. Monthly sampling efforts, from April to October, have allowed for ongoing determination of general spatial and temporal changes in population structure and species abundance since 1993. Ten additional sites have been sampled in April and October since 2017. Repeated sampling, across multiple sampling occasions, was conducted during November to estimate site occupancy rates (Appendix B) and to characterize sampling variation. Continued and uninterrupted monitoring, from April to November, is also required to satisfy key aspects of USFWS's Biological Opinion (USFWS 2016).

Fish were collected with a 3.0 m x 1.8 m small-mesh (ca. 5 mm) seine in 18 discrete mesohabitats (< 15 m long). Runs were sampled four times at each site, as were shoreline pools (when available); backwaters, pools, and riffles were sampled two times (when available); any remaining samples were taken in shoreline runs. The sampling allocation was chosen so that common mesohabitats were sampled more frequently, rare mesohabitats were sampled less frequently, the total equaled 18 when all mesohabitats were available at a site, and so that sampling was spatially and temporally consistent. Additionally, a 1.2 m x 1.2 m fine-mesh (ca. 1 mm) seine was used to selectively sample shallow low-velocity mesohabitats for larval fish (two samples per site) from April to October. Seine hauls were spaced several meters apart to minimize disturbance of other mesohabitats during sampling. Mesohabitats with similar conditions, which did not exceed reasonable depths or velocities for efficient seining, were sampled regardless of flow conditions. Water quality metrics were recorded at each site (Appendix C [Table C1]), along with digital photographs of site and mesohabitat conditions.

We briefly handled fish for identification and enumeration purposes, kept them in a submerged small-mesh (ca. 5 mm) enclosure during sampling (i.e., to avoid recapture), and released them after sampling was completed. During repeated sampling, we identified and released fish back into sampled mesohabitats after each seine haul to avoid disturbing the site for subsequent repeated efforts. Scientific and common names (ordered phylogenetically) of fishes in this report follow Page et al. (2013; Table 1).

We further examined Rio Grande Silvery Minnow for the presence of Visible Implant Elastomer (VIE) tags (i.e., stocked fish) and recorded the colors and anatomical locations of all tags. Individuals with VIE tags matching known batches of Passive Integrated Transponder (PIT) tagged fish were scanned using handheld PIT tag readers to obtain their unique hexadecimal codes. All individuals (i.e., wild and stocked fish) were also measured (standard length [mm]; individual measurements or a length range for large collections) and identified to age-class (based on age-length relationships by sampling month [Dudley et al. 2009; Horwitz et al. 2018]). Standard length was measured because of its wide acceptance in taxonomic studies, and because it is reliable even when the caudal fin is malformed or damaged (Jennings et al. 2012). While field measurements of Rio Grande Silvery Minnow total length (TL) are generally less reliable than standard length (SL), TL can be derived from SL based on a highly predictable relationship (TL = 1.203(SL) + 2.454; R^2 = 0.99; n = 257; Horwitz et al. 2018).

Analytical Considerations

Fish that were too small to be accurately identified in the field (i.e., larvae or recently transformed juveniles) were fixed in formalin and returned to the laboratory for further processing and identification. Laboratory personnel, with extensive larval fish identification experience, identified all preserved specimens using stereomicroscopes with transmitted light bases and polarized light filters. We determined the developmental phase of all Rio Grande Silvery Minnow to definitively separate larval from non-larval individuals (e.g., recently transformed juveniles), which was required for subsequent analyses.

Density (catch-per-unit-effort [CPUE]) was estimated, for each site, by dividing the total number of individuals captured by the total area sampled, multiplied by 100 (i.e., fish per 100 m^2). Area was calculated by multiplying the seine width during sampling (larval = 1.0 m, regular = 2.5 m) by the haul length. Densities of larvae were based only on fine-mesh (ca. 1 mm) larval seine samples, and

Table 1. Scientific names, common names, and species codes of fishes collected in the Middle Rio Grande since 1993.

Scientific Name	Common Name	Species Code
Order Clupeiformes		
Family Clupeidae	**herrings**	
Dorosoma cepedianum	Gizzard Shad	(DORCEP)
Dorosoma petenense	Threadfin Shad	(DORPET)
Order Cypriniformes		
Family Cyprinidae	**carps and minnows**	
Campostoma anomalum	Central Stoneroller	(CAMANO)
Carassius auratus	Goldfish	(CARAUR)
Cyprinella lutrensis	Red Shiner[1]	(CYPLUT)
Cyprinus carpio	Common Carp[1]	(CYPCAR)
Gila pandora	Rio Grande Chub	(GILPAN)
Hybognathus amarus	Rio Grande Silvery Minnow[1]	(HYBAMA)
Notemigonus crysoleucas	Golden Shiner	(NOTCRY)
Pimephales promelas	Fathead Minnow[1]	(PIMPRO)
Pimephales vigilax	Bullhead Minnow	(PIMVIG)
Platygobio gracilis	Flathead Chub[1]	(PLAGRA)
Rhinichthys cataractae	Longnose Dace[1]	(RHICAT)
Family Catostomidae	**suckers**	
Carpiodes carpio	River Carpsucker[1]	(CARCAR)
Catostomus commersonii	White Sucker[1]	(CATCOM)
Ictiobus bubalus	Smallmouth Buffalo	(ICTBUB)
Order Siluriformes		
Family Ictaluridae	**North American catfishes**	
Ameiurus melas	Black Bullhead	(AMEMEL)
Ameiurus natalis	Yellow Bullhead	(AMENAT)
Ictalurus furcatus	Blue Catfish	(ICTFUR)
Ictalurus punctatus	Channel Catfish[1]	(ICTPUN)
Pylodictis olivaris	Flathead Catfish	(PYLOLI)
Family Loricariidae	**suckermouth armored catfishes**	
Pterygoplichthys disjunctivus	Vermiculated Sailfin Catfish	(PTEDIS)
Order Salmoniformes		
Family Salmonidae	**trouts and salmons**	
Oncorhynchus mykiss	Rainbow Trout	(ONCMYK)
Salmo trutta	Brown Trout	(SALTRU)

Table 1. Scientific names, common names, and species codes of fishes collected in the Middle Rio Grande since 1993 (continued).

Scientific Name	Common Name	Species Code
Order Cyprinodontiformes		
Family Poeciliidae	**livebearers**	
Gambusia affinis	Western Mosquitofish[1]	(GAMAFF)
Order Perciformes		
Family Moronidae	**temperate basses**	
Morone chrysops	White Bass	(MORCHR)
Morone saxatilis	Striped Bass	(MORSAX)
Family Centrarchidae	**sunfishes**	
Lepomis cyanellus	Green Sunfish	(LEPCYA)
Lepomis macrochirus	Bluegill	(LEPMAC)
Lepomis megalotis	Longear Sunfish	(LEPMEG)
Micropterus dolomieu	Smallmouth Bass	(MICDOL)
Micropterus salmoides	Largemouth Bass	(MICSAL)
Pomoxis annularis	White Crappie	(POMANN)
Pomoxis nigromaculatus	Black Crappie	(POMNIG)
Family Percidae	**perches and darters**	
Perca flavescens	Yellow Perch	(PERFLA)
Percina macrolepida	Bigscale Logperch	(PERMAC)
Sander vitreus	Walleye	(SANVIT)
Family Sciaenidae	**drums and croakers**	
Aplodinotus grunniens	Freshwater Drum	(APLGRU)

[1] = Focal taxa were typically the 10 most abundant species collected during October.

densities of age-0 and age-1+ fish were based only on small-mesh (ca. 5 mm) regular seine samples. Individuals with VIE tags were not included in subsequent statistical analyses of long-term population or occupancy trends. Samples from isolated pools were also not included in these analyses, as densities in these confined mesohabitats were often artificially elevated.

Statistical Analyses

Long-term analyses (1993–2022)

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 sampling-site density data during October (1993–2022), based on small-mesh regular seine samples, were analyzed using PROC NLMIXED (Nonlinear Mixed Models; SAS 2022). This advanced numerical optimization procedure was used to fit our long-term data to a mixture model, which comprised a binomial distribution (i.e., based on presence-absence data) and a lognormal distribution (i.e., based on natural logarithms of nonzero data). We implemented this robust ecological modeling approach to quantitatively assess the effects of environmental variables on long-term trends in the occurrence and density of Rio Grande Silvery Minnow. Logistic regression was used to estimate the annual probability that a site was occupied (i.e., occurrence probability), and a lognormal model was used to estimate the annual lognormal density based on occupied sites (Appendix D). Numerical optimization of the models provided four estimates (δ = estimated occurrence probability, μ = estimated lognormal density, σ = standard deviation of the estimated lognormal density, and $E(x)$ = estimated density [based on δ, μ, and σ]) for each year (i.e., based on the site-specific sampling data). 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 density estimates (i.e., unmodeled), calculated using the method of moments (Zar 2010), were also added as a reference to applicable figures. Analyses were conducted using four different versions of the dataset: (1) additional sites excluded and dry sites included, (2) additional sites and dry sites excluded, (3) additional sites and dry sites included, and (4) additional sites included and dry sites excluded.

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 densities. 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 October sampling-site density data (1993–2022) included various hydrological metrics based on data from Albuquerque (ABQ: USGS Gage-08330000) and San Marcial (SAN: USGS Gage-08358400). The upstream gage was chosen to represent prolonged high flows during spring, whereas the downstream gage was chosen to represent prolonged low flows during summer. Maximum daily discharge (ABQmax), 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), and mean daily discharge (ABQmean) were covariates that represented different spring runoff conditions (May–June). A modeled covariate (Inundation), that represented the total estimated inundation of the river floodplain, was based on an average of the five highest flow days in May (USACE 2010); models of recent conditions (2000–2009) were used to estimate inundation since 2010. Mean daily discharge (SANmean) and lower threshold discharge values (days < 200 [SAN<200] and < 100 [SAN<100] ft^3/s) were covariates that represented different low-flow conditions, and served as proxies for river drying, during irrigation season (March–October). Fixed-effects models for each covariate were generalized linear models with

the corresponding link function. These fixed effects assume that variation in the dataset is explained by the covariate (Appendix E [Table E1]). 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 (see 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] 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 logLike values explained by the environmental covariates, for both δ and μ models, and to assess whether that proportion was significantly different from zero ($P < 0.05$) based on an *F*-test (Skalski et al. 1993).

Kendall's *W* (Zar 2010) was used to test for the degree of concordance among the annual rank-abundance values of the 10 focal species, including Rio Grande Silvery Minnow, during October (1993–2022). This nonparametric statistical procedure was used to compute the *W* statistic, which ranges from zero (no concordance) to one (complete concordance). A chi-square statistic was calculated to evaluate whether the concordance (*W*) was significantly different from zero ($P < 0.05$).

Mesohabitat associations (2002–2022)

Rio Grande Silvery Minnow detailed density data during October (i.e., using mesohabitat-specific data from all sampling sites), have been consistently collected since 2002. Mesohabitats were simplified (i.e., combining main and side channel samples, coding debris piles as pools, and coding riffles as runs) and classified using channel-unit definitions (Armantrout 1998) for statistical analyses (backwaters [BW], pools [PO], runs [RU], shoreline pools [SHPO], and shoreline runs [SHRU]). The sampling unit for this analysis was mesohabitat (e.g., all shoreline-run samples combined for each site), whereas the sampling unit for the long-term analysis (1993–2022) was site (e.g., all mesohabitat samples combined for each site). Mesohabitat-specific density data from October (2002–2022) were analyzed using PROC NLMIXED, employing the same methods outlined previously, to generate parameter estimates and assess differences among models. Categorical covariates considered were Year, mesohabitat (Mesohabitat), and reach (Reach). Random-effects models (*R*) were also considered. Both additive and multiplicative effects were considered for single combinations of the year covariate for both Mesohabitat (e.g., Year+Mesohabitat and Year*Mesohabitat, respectively) and Reach.

Sampling variation (2005–2022)

Sampling variation was evaluated using Rio Grande Silvery Minnow sampling-site density data from repeated sampling at the 20 standard sites during November (2005–2022). For the repeated sampling effort, sites were sampled once per day for four days, using Population Monitoring Program sampling protocols. Additionally, all sampling locations were flagged on the first day, and repeated samples were taken at the same or similar locations on subsequent days. Sampling-site density data from November (2005–2022) were analyzed using PROC NLMIXED, employing the same methods outlined previously, to generate parameter estimates and assess differences among models. Categorical covariates considered were Year, Reach, and Occasion (i.e., 1st, 2nd, 3rd, and 4th day of sampling). Random-effects models (*R*) were also considered. Both additive and multiplicative effects were considered for single combinations of the year covariate for both Occasion (e.g., Year+Occasion and Year*Occasion, respectively) and Reach.

RESULTS

Rio Grande Silvery Minnow

Current population status

The abundance of Rio Grande Silvery Minnow (all age-classes combined), from April to October 2022, varied widely across reaches, sites, and months (Table 2). Densities of larval Rio Grande Silvery Minnow (non-larval fish excluded) increased following spring spawning, reaching their highest levels in June, but then rapidly declined by July (Figure 4). In 2022, larval individuals were collected in all three sampling reaches. Post-spawning densities of age-0 individuals (larval fish excluded) were highest in July but declined by August (Figure 5). Densities of marked and age-1+ individuals were relatively low in all three reaches throughout the year, and overall densities (i.e., age-0 and age-1+ combined) were highest in the San Acacia Reach (Figure 6).

Population trends (1993–2022)

Rio Grande Silvery Minnow densities ($E(x)$; estimated using October sampling-site data [1993–2022]) were generated from the year model (δ[Year] μ[Year]). Estimated densities were notably lower ($P < 0.05$) in 2018, as compared with 2017, but then increased dramatically ($P < 0.05$) from 2018 to 2019 (Figure 7). However, recent monitoring efforts revealed a substantial decrease (–88.8%) in the density of Rio Grande Silvery Minnow from 2019 ($E(x) = 2.10$) to 2020 ($E(x) = 0.23$), and its density had declined further by 2022 ($E(x) = 0.08$). Naïve density estimates (i.e., unmodeled), calculated using the method of moments, were very similar to model-estimated densities ($E(x)$). Combining a plot of $E(x)$ and mean daily discharge (1993–2022) revealed a long-term recurrent pattern of increased densities during years with high spring runoff and decreased densities during years with low spring runoff (Figure 8). Estimates of $E(x)$ increased with maximum discharge, number of days with discharge exceeding an upper threshold value, estimated inundation of the river floodplain, and mean daily discharge (Figure 9: A–G). In contrast, there were inverse relationships between estimates of $E(x)$ and the number of days with discharge below a lower threshold value (Figure 9: H–I).

The occurrence probability (δ) and the lognormal density (μ), estimated from the year model (δ[Year] μ[Year]), were also closely associated with hydrological metrics over time (1993–2022). Estimates of δ increased with higher spring flows but decreased with lower summer flows (Figures 10 and 11). Similar and consistent results were obtained for relationships between μ and the hydrological metrics (Figures 12 and 13).

Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates revealed that variation in both δ and μ was strongly predicted by changes in hydrological metrics across years (1993–2022; Table 3). The top ecological model (δ[Year] μ[ABQ>2,000+R]) received 38.9% of the AIC_c weight (w_i) out of the 440 models considered. The top δ covariate (SANmean) accounted for 67.5% of the deviance ($P < 0.001$) explained by the δ(Year) model over the δ(.) model. We also found significant effects ($P < 0.001$) for ABQmax (64.7%), ABQmean (64.0%), ABQ>2,000 (62.6%), ABQ>3,000 (56.9%), Inundation (56.5%), ABQ>1,000 (55.6%), SAN<200 (54.9%), and SAN<100 (47.5%). Further, the top μ covariate (ABQ>2,000) accounted for 41.6% of the deviance ($P < 0.001$) explained by the μ(Year) model over the μ(.) model. We also found significant effects ($P < 0.001$) for ABQmax (40.4%), ABQmean (36.6%), ABQ>1,000 (35.6%), ABQ>3,000 (35.4%), Inundation (32.6%), SANmean (32.5%), SAN<200 (26.7%), and SAN<100 (24.5%). The top three ecological models, which accounted for 90.7% of the cumulative w_i, were based on hydrological metrics representing elevated spring flows. Thus, prolonged low flows during summer were most predictive of decreased occurrence (δ) and prolonged high flows during spring were most predictive of increased density (μ and $E(x)$) of Rio Grande Silvery Minnow over time.

Table 2. Rio Grande Silvery Minnow abundance (all age-classes combined), by reach, site, and month, during 2022. Marked individuals are shown in parentheses, as a subset of the site-specific total. Blank cells indicate months when a site was not visited.

Reach	Site	Locality	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Angostura	1	Angostura Dam	0	0	0	0	2(0)	0	0	2
Angostura	2	Bernalillo	0	0	0	0	0	5(0)	0	5
Angostura	3	Rio Rancho	0	0	0	0	0	0	0	0
Angostura	21	Site 21	0						2(0)	2
Angostura	22	Site 22	0						1(0)	1
Angostura	23	Site 23	7(3)						2(0)	9
Angostura	24	Site 24	1(0)						7(0)	8
Angostura	4	Central Ave.	0	0	4(0)	12(0)	0	0	2(0)	18
Angostura	5	Rio Bravo Blvd.	1(0)	0	66(0)	6(0)	1(0)	2(0)	4(0)	80
Angostura	25	Site 25	0						2(0)	2
Angostura Totals			*9*	*0*	*70*	*18*	*3*	*7*	*20*	*127*
Isleta	26	Site 26	6(1)						2(0)	8
Isleta	6	Los Lunas	0	0	0	0	0	0	0	0
Isleta	27	Site 27							0	0
Isleta	7	Belen	0	1(0)	0	0	0	0	0	1
Isleta	8	Jarales	0	0	0	0	0	0	0	0
Isleta	28	Site 28	0						0	0
Isleta	9	Bernardo	0	0	1(1)	0	0	0	0	1
Isleta	10	La Joya	0	0	0	2(1)	0	0	0	2
Isleta	29	Site 29	0						0	0
Isleta	11	North of San Acacia	2(0)	0	27(0)	2(0)	1(0)	0	0	32
Isleta Totals			*8*	*1*	*28*	*4*	*1*	*0*	*2*	*44*
San Acacia	12	San Acacia Dam	46(5)	5(3)	10(0)	2(0)	0	0	0	63
San Acacia	13	South of San Acacia	2(1)	7(2)	0	12(0)	5(0)	0	0	26
San Acacia	30	Site 30	1(1)						3(0)	4
San Acacia	14	Socorro	0	2(1)	0	0	1(0)	1(0)	2(0)	6
San Acacia	15	North of San Antonio	4(0)	0	2(0)	0	1(0)	1(0)	0	8
San Acacia	16	San Antonio	1(0)	1(0)	2(0)	0	1(0)	0	0	5
San Acacia	17	South of San Antonio	2(0)	1(0)	1(0)	1(0)	1(0)	0	0	6
San Acacia	18	San Marcial	0	1(0)	1(0)	1(0)	0	0	0	3
San Acacia	19	South of San Marcial 1	0	1(0)	0	3(0)	0	0	0	4
San Acacia	20	South of San Marcial 2	0	0	0	0	0	0	0	0
San Acacia Totals			*56*	*18*	*16*	*19*	*9*	*2*	*5*	*125*
Monthly Totals			**73**	**19**	**114**	**41**	**13**	**9**	**27**	**296**

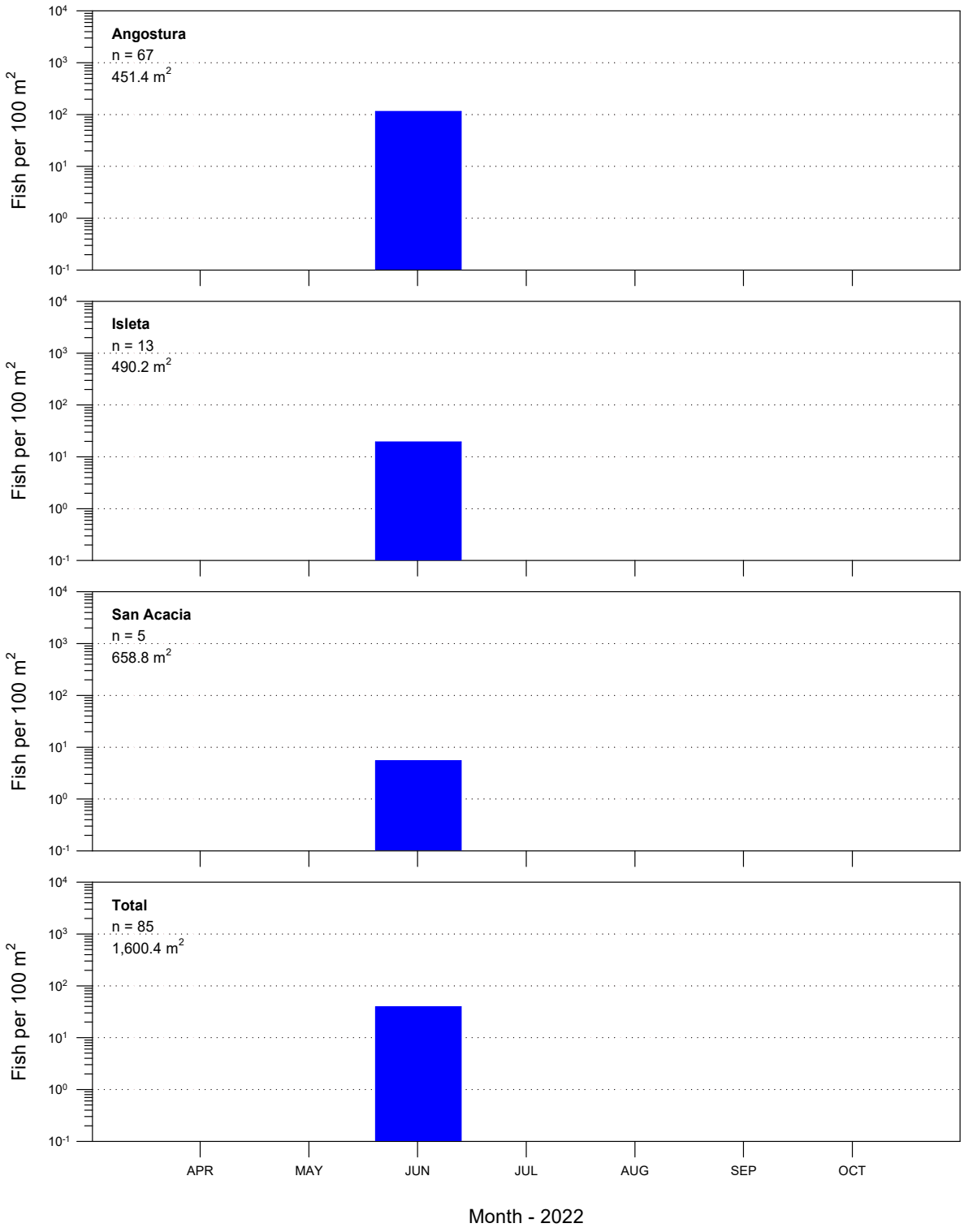

Figure 4. Rio Grande Silvery Minnow densities based on all sites (larval fish only [fine-mesh seine]; non-larval fish excluded), by reach and month, during 2022. The y-axis is logarithmic and larval sampling took place from April to October.

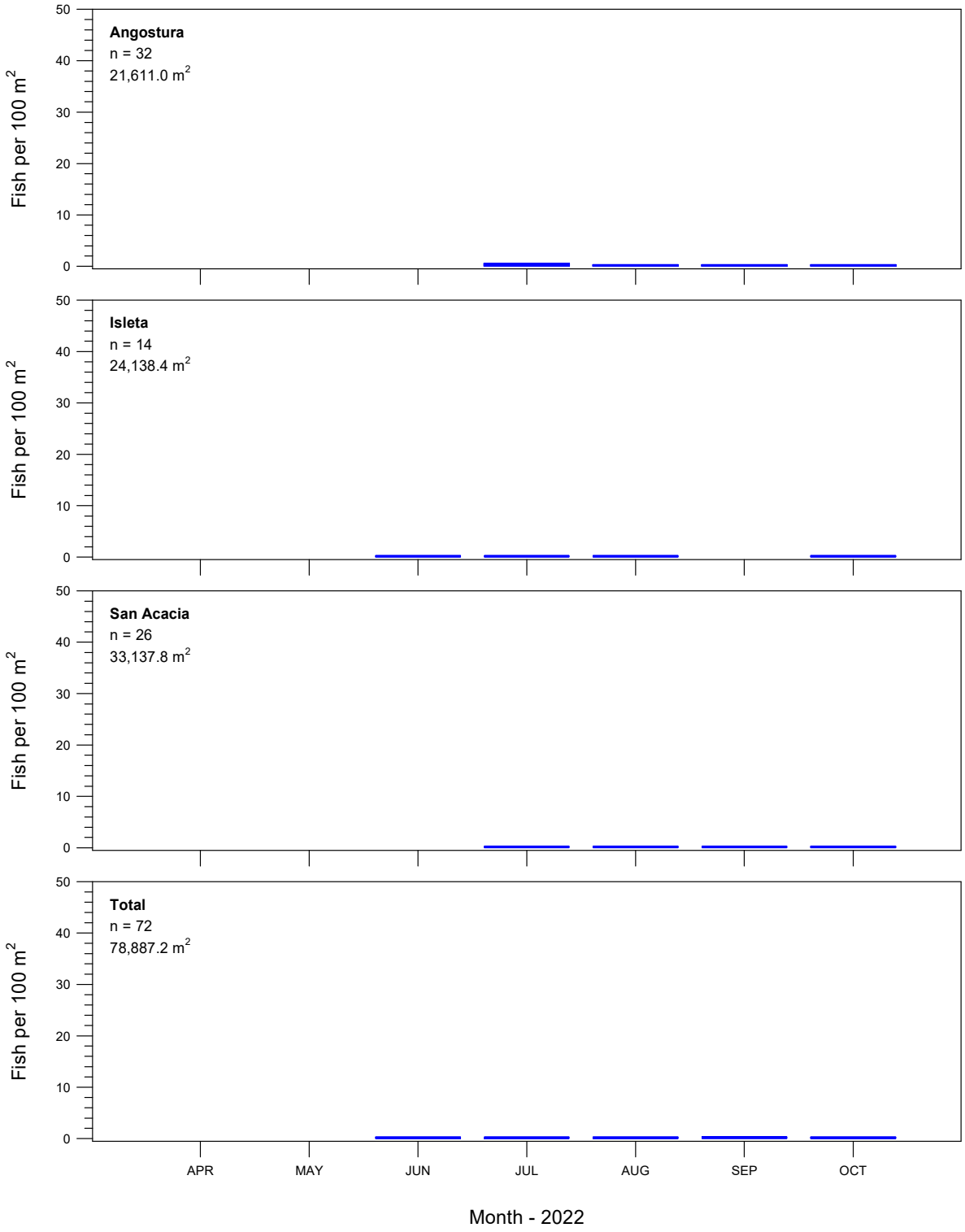

Figure 5. Rio Grande Silvery Minnow densities based on all sites (age-0 fish only [small-mesh seine]; larval fish excluded), by reach and month, during 2022. When present, marked (red) and unmarked (blue) individuals were included.

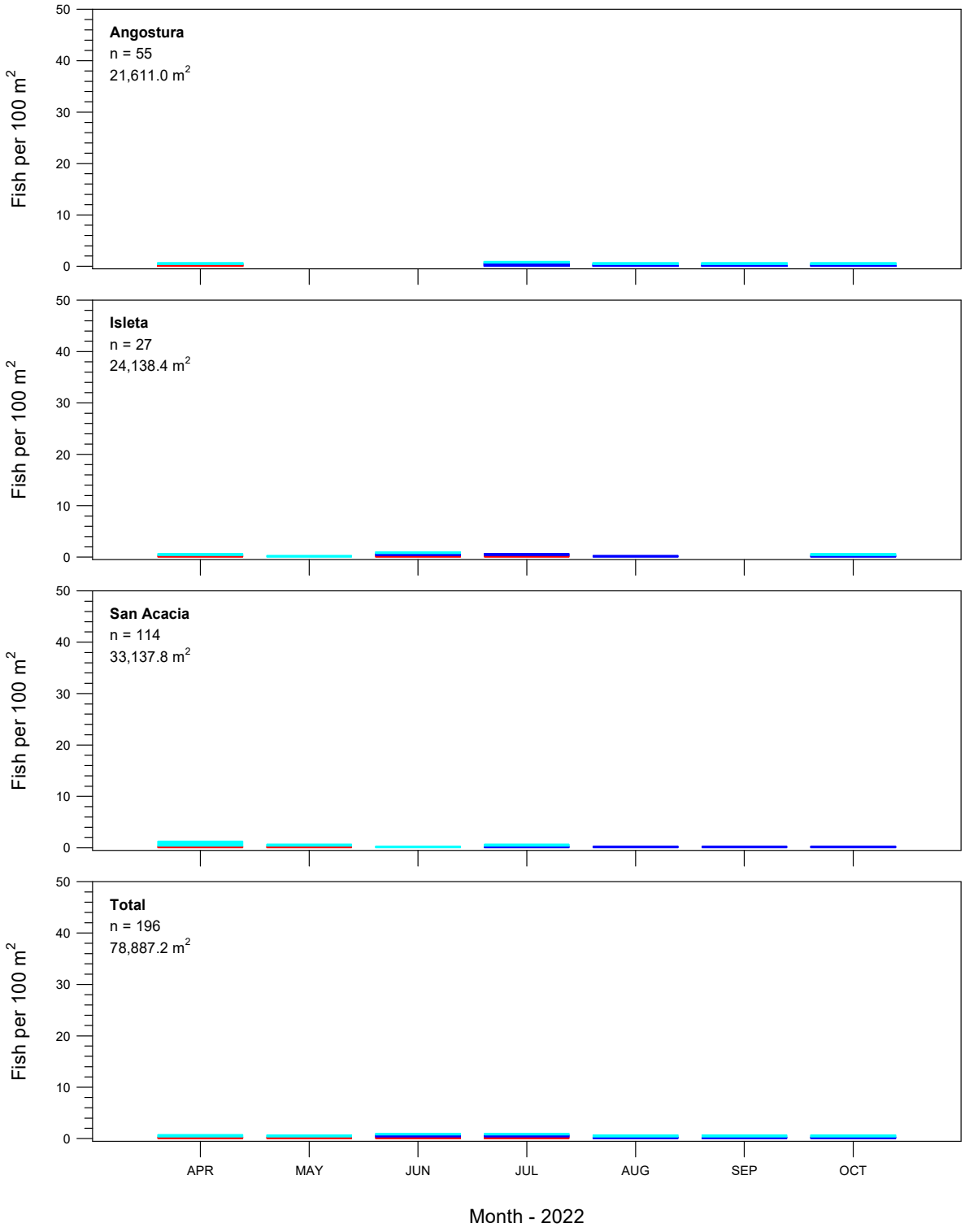

Figure 6. Rio Grande Silvery Minnow densities based on all sites (age-0 and age-1+ fish [small-mesh seine]; larval fish excluded), by reach and month, during 2022. When present, marked (red) and unmarked [(age-0 [blue] and age-1+ [cyan]) individuals were included.

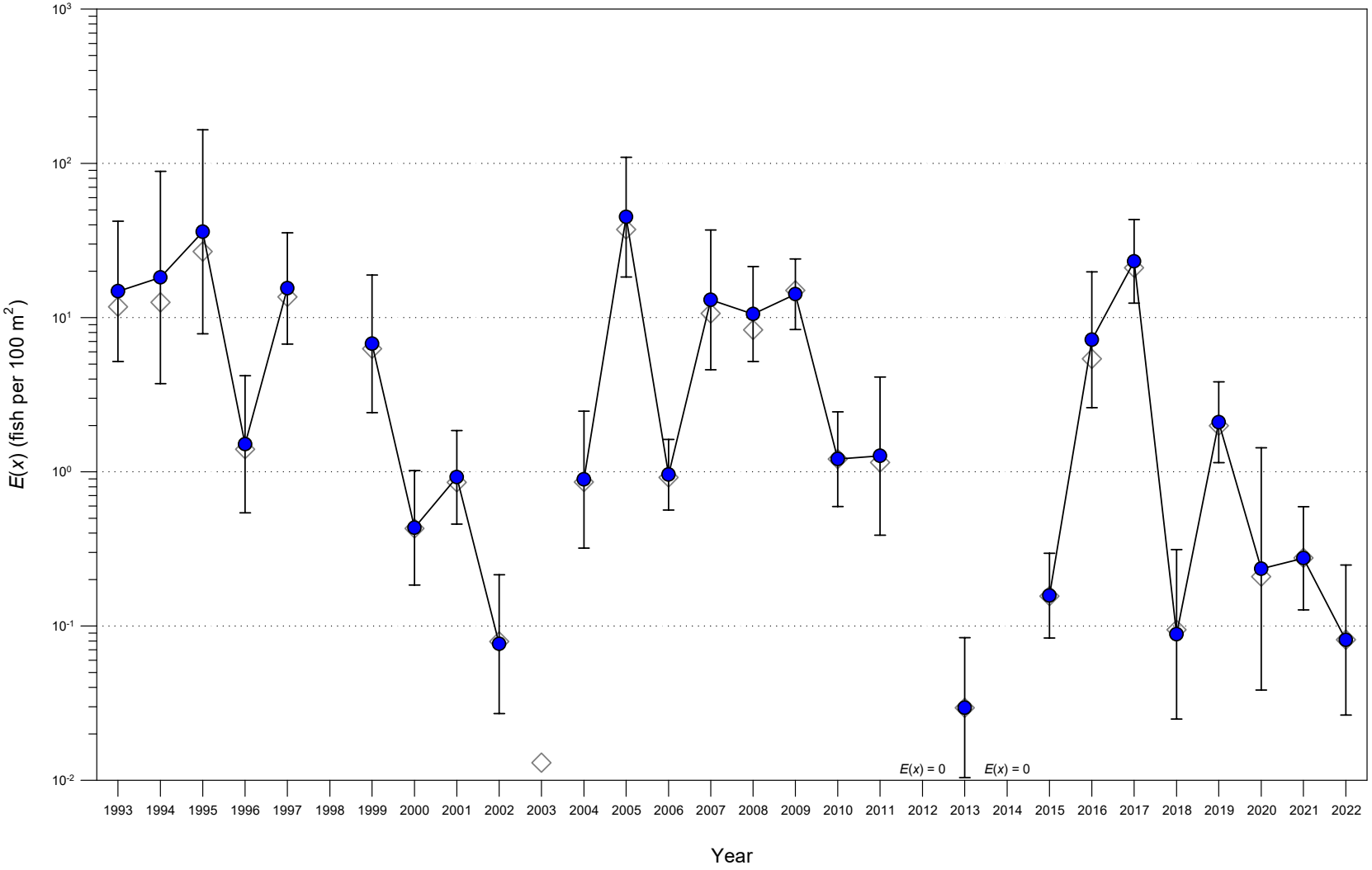

Figure 7. Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years (see Table 7). Sampling did not occur in 1998, and density could not be estimated for 2003. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated. Additional sites were excluded, and dry sites were included.

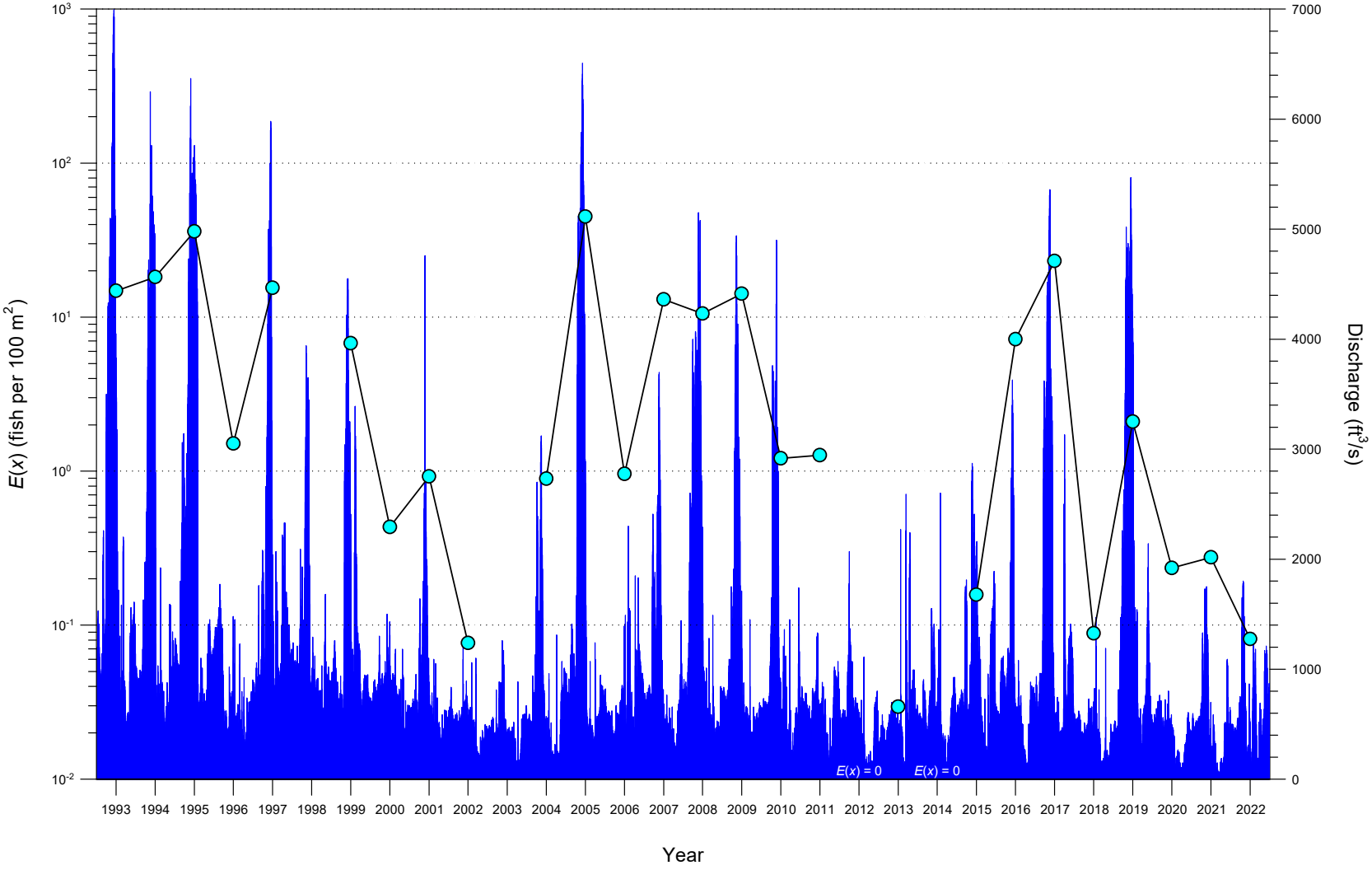

Figure 8. Rio Grande Silvery Minnow densities (estimated using October sampling-site data), and mean daily discharge data from the Albuquerque Gage (1993-01-01 to 2022-12-31), across years. Sampling did not occur in 1998, and density could not be estimated for 2003. Additional sites were excluded, and dry sites were included.

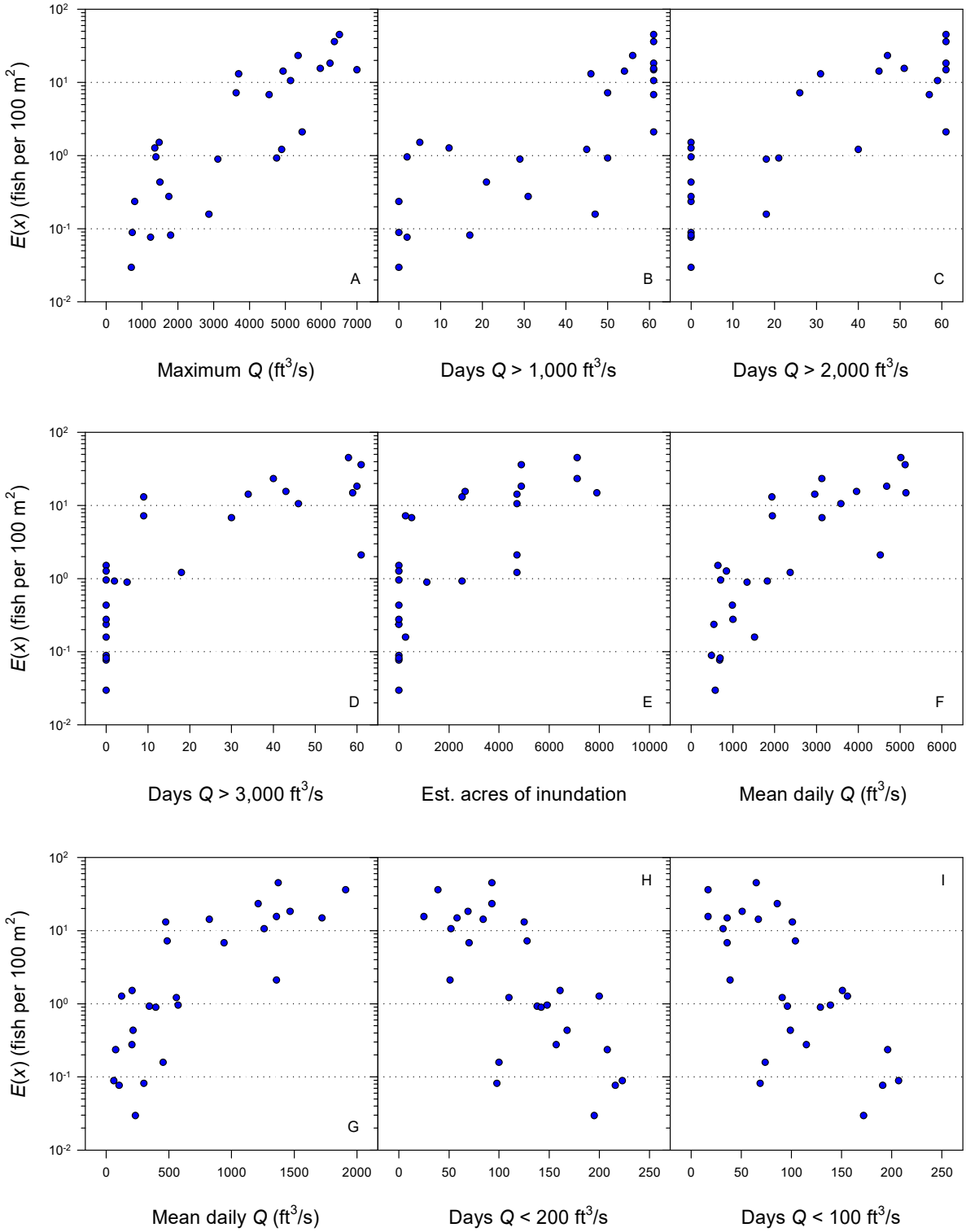

Figure 9. Bivariate plots of Rio Grande Silvery Minnow densities (estimated using October sampling-site data [1993–2022]), Albuquerque Gage data (A–F), and San Marcial Gage data (G–I). Additional sites were excluded, and dry sites were included.

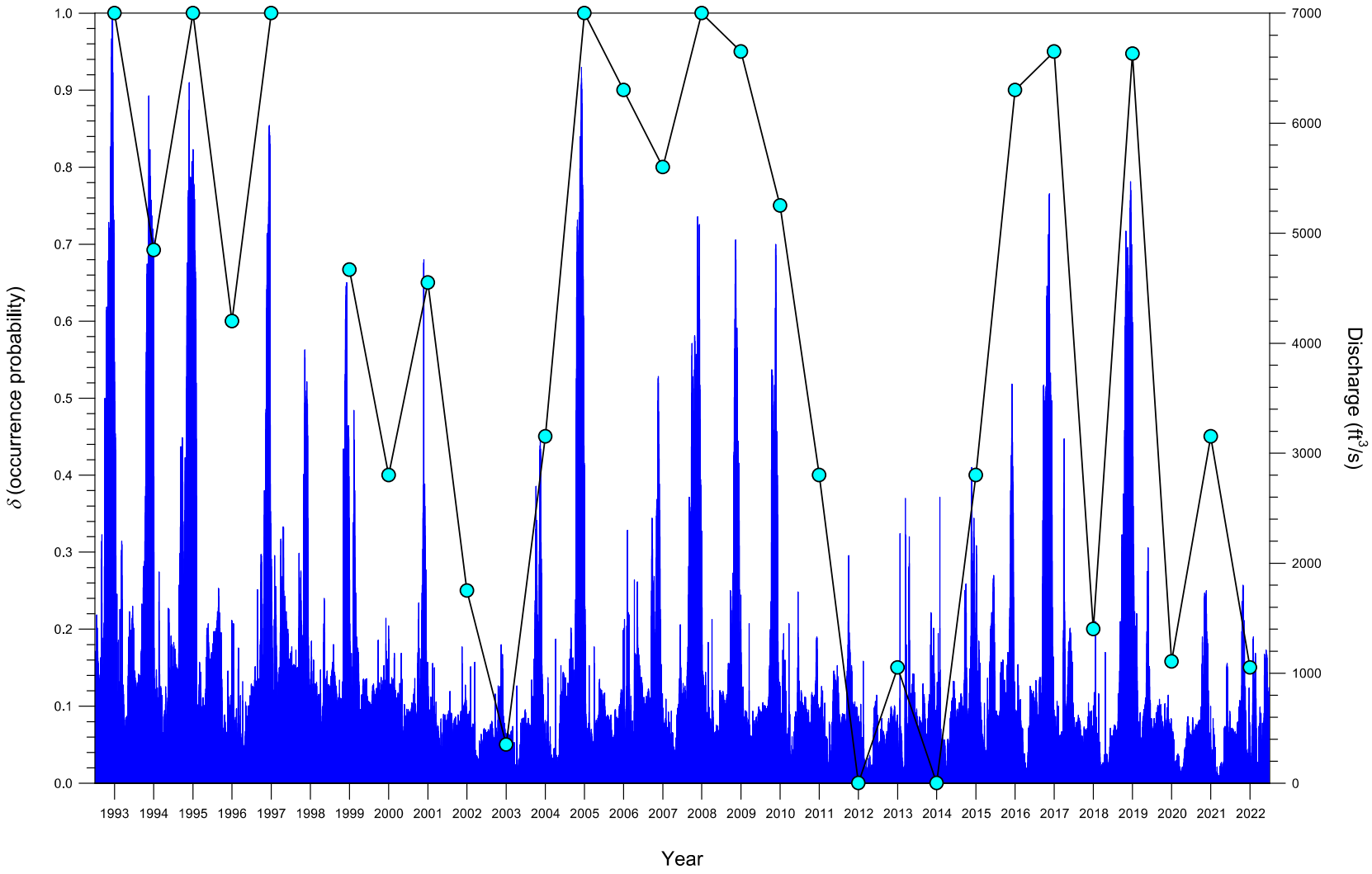

Figure 10. Rio Grande Silvery Minnow occurrence probabilities (estimated using October sampling-site data), and mean daily discharge data from the Albuquerque Gage (1993-01-01 to 2022-12-31), across years. Sampling did not occur in 1998. Additional sites were excluded, and dry sites were included.

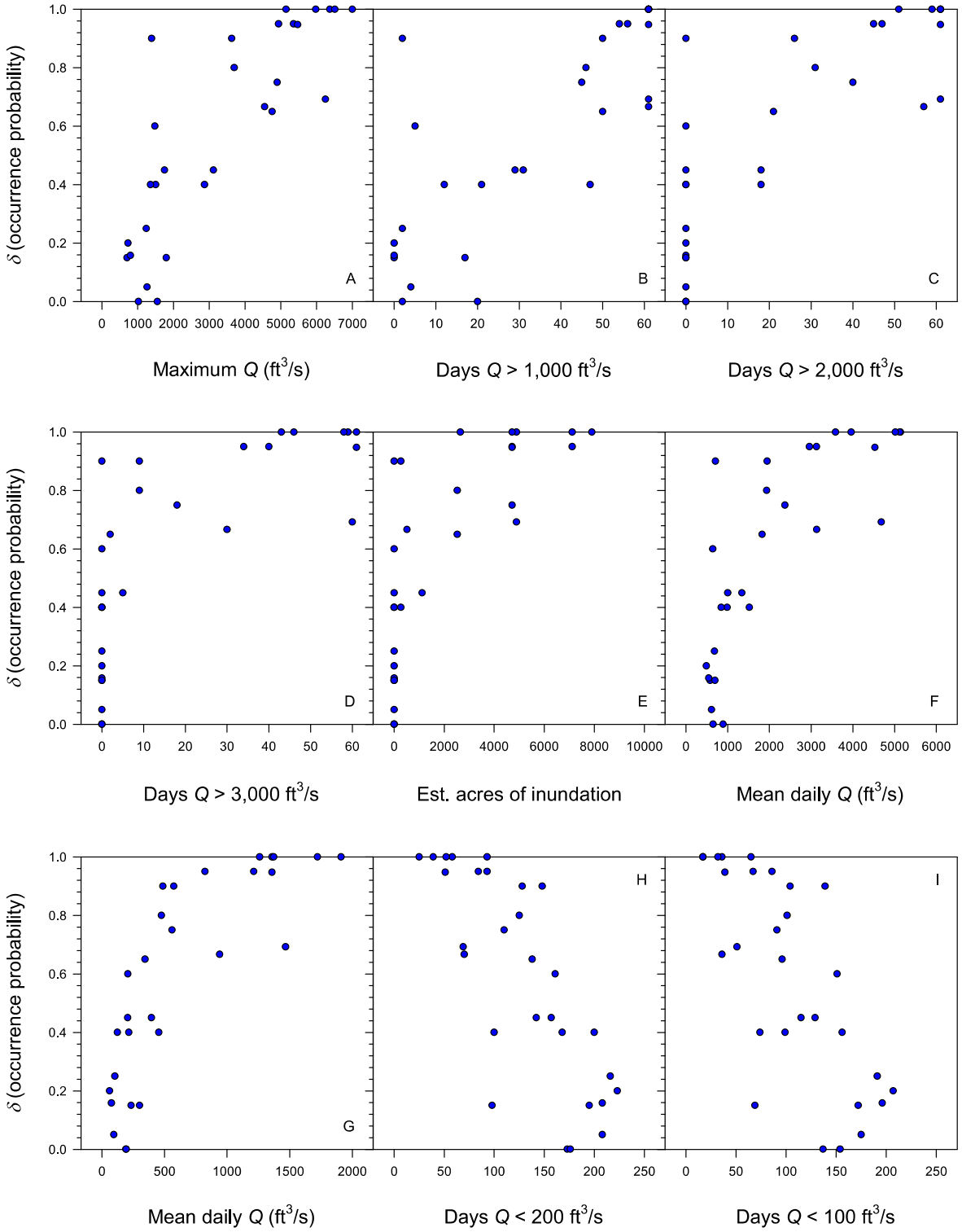

Figure 11. Bivariate plots of Rio Grande Silvery Minnow occurrence probabilities (estimated using October sampling-site data [1993–2022]), Albuquerque Gage data (A–F), and San Marcial Gage data (G–I). Additional sites were excluded, and dry sites were included.

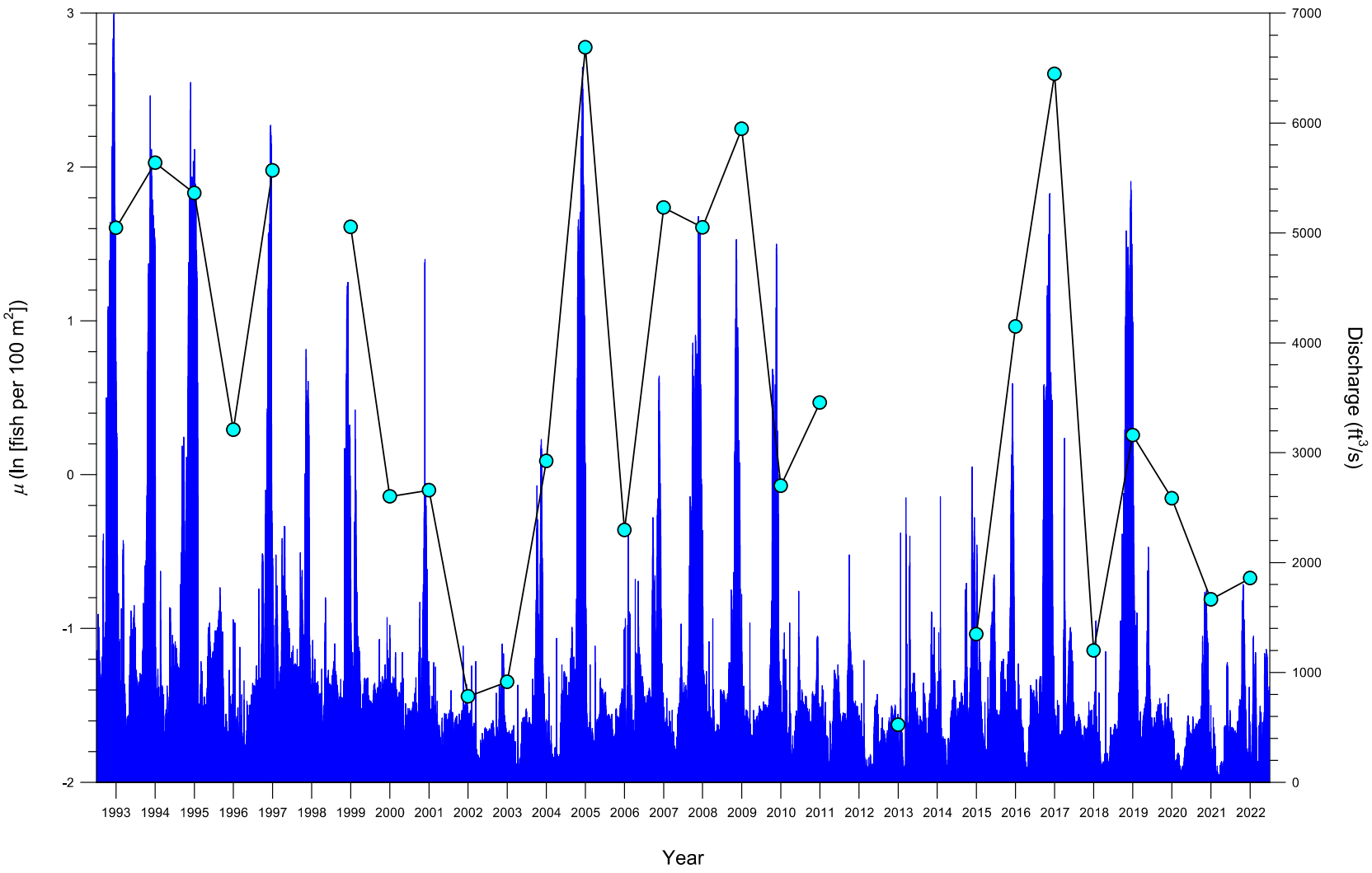

Figure 12. Rio Grande Silvery Minnow lognormal densities (estimated using October sampling-site data), and mean daily discharge data from the Albuquerque Gage (1993-01-01 to 2022-12-31), across years. Sampling did not occur in 1998, and lognormal density could not be estimated for 2012 or 2014 (i.e., all zero values). Additional sites were excluded, and dry sites were included.

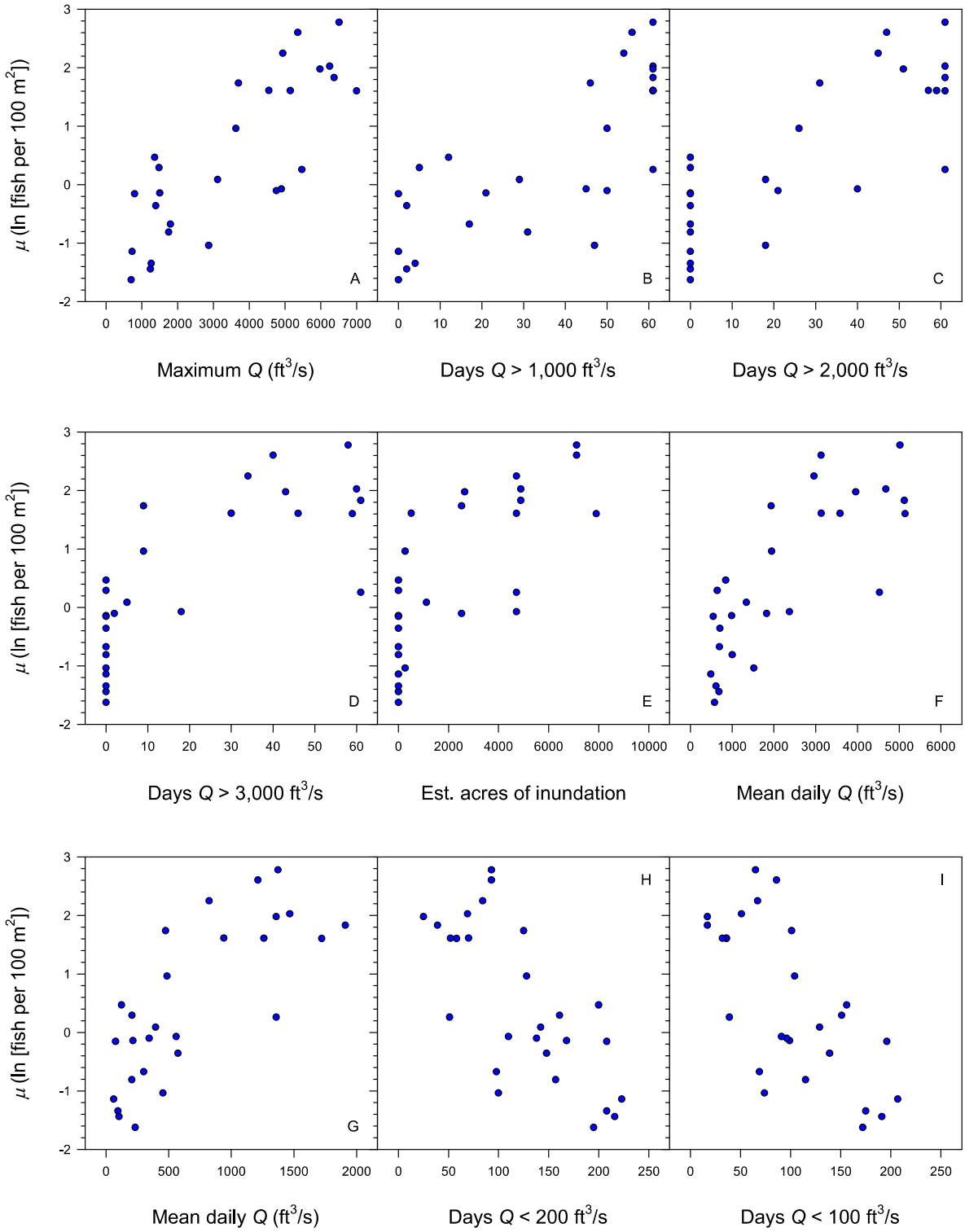

Figure 13. Bivariate plots of Rio Grande Silvery Minnow lognormal densities (estimated using October sampling-site data [1993–2022]), Albuquerque Gage data (A–F), and San Marcial Gage data (G–I). Additional sites were excluded, and dry sites were included.

Table 3. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2022). Additional sites were excluded, and dry sites were included.

Model[1]	**logLike**[2]	**K**[3]	**AIC$_c$**[4]	**w_i**[4]
δ(Year) μ(ABQ>2,000+*R*)	880.58	34	953.27	0.3885
δ(Year) μ(ABQmax+*R*)	880.87	34	953.55	0.3369
δ(Year) μ(ABQmean+*R*)	882.11	34	954.79	0.1812
δ(Year) μ(SANmean+*R*)	885.50	34	958.18	0.0333
δ(Year) μ(ABQ>3,000+*R*)	886.41	34	959.10	0.0210
δ(Year) μ(ABQ>1,000+*R*)	887.22	34	959.91	0.0140
δ(SANmean+*R*) μ(Year)	835.83	56	960.96	0.0083
δ(ABQmax+*R*) μ(Year)	837.63	56	962.76	0.0034
δ(SANmean+*R*) μ(ABQ>2,000+*R*)	945.30	9	963.64	0.0022
δ(ABQmean+*R*) μ(Year)	838.56	56	963.70	0.0021

[1] = Models included all δ and μ combinations of null effects (.), random effects (*R*), year (1993–2022), and hydrological metrics (with and without *R*) from Albuquerque (ABQ: USGS Gage-08330000) and San Marcial (SAN: USGS Gage-08358400).
[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).

Additionally, we evaluated the effects of excluding data from dry sites in a second analysis of Rio Grande Silvery Minnow estimated densities ($E(x)$). The estimated densities using this reduced dataset (Figure 14) were nearly identical to those using the standard long-term dataset (dry sites included). Similarly, generalized linear models of Rio Grande Silvery Minnow mixture-model estimates revealed that variation in both δ and μ was strongly predicted by changes in hydrological metrics when the dry sites were excluded (Table 4).

Similar analyses were conducted to evaluate the effects of including data from the additional sites (2017–2022). The estimated densities of Rio Grande Silvery Minnow using the additional sites (dry sites included) resulted in similar estimated densities (Figure 15), as compared to the dataset with the additional sites excluded (dry sites included). Likewise, the estimated densities using the additional sites (dry sites excluded) resulted in similar estimated densities (Figure 16), as compared to the dataset with the additional sites excluded (dry sites excluded). However, analyses that included additional sites revealed an increased AIC_c weight for the μ(Year) models (Tables 5 and 6). Also, the 95% confidence intervals for $E(x)$ were narrower (i.e., more precise) for both analyses when the additional sites were included, as compared to when they were excluded. A summary of the estimated densities across years (Table 7), was provided to facilitate long-term comparisons among all model combinations (i.e., additional sites [included/excluded] and dry sites [included/excluded]).

Mesohabitat associations (2002–2022)

Rio Grande Silvery Minnow densities ($E(x)$; estimated using October sampling-site data [2002–2022]) were generated from the year-mesohabitat model (δ[Year*Mesohabitat] μ[Year*Mesohabitat]). Interannual density trends for the five mesohabitats (BW, PO, RU, SHPO, and SHRU) were very similar over the study period (Figure 17). Densities increased dramatically in all mesohabitats from 2015 to 2017, but then swiftly declined from 2017 to 2018. There was another notable increase in densities across all mesohabitats from 2018 to 2019, followed by a dramatic decrease in 2020; densities remained low in 2021 and 2022. Densities in slack-water mesohabitats (BW, PO, and SHPO) were generally higher than densities in swift-water mesohabitats (RU and SHRU). These differences were quite pronounced in years with the highest densities of Rio Grande Silvery Minnow but were sometimes negligible in low-density years. Also, year-mesohabitat densities could not be estimated when only a single nonzero value was recorded (e.g., RU in 2015). While naïve density estimates were still illustrated in those instances, the lack of any illustrated values indicates year-mesohabitat combinations when no individuals were collected (e.g., RU in 2014).

Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates revealed that changes in its occurrence and density were reliably predicted by differences across years and mesohabitats, but much less so across reaches (Table 8). The top model (δ[Year+Mesohabitat] μ[Year+Mesohabitat]) effectively received all the AIC_c weight out of the 41 models considered. A comparison of AIC_c values revealed that year (δ[Year] μ[Year]; AIC_c = 2,840.92) was more informative in explaining changes in model parameter values over time as compared with mesohabitat (δ[Mesohabitat] μ[Mesohabitat]; AIC_c = 3,644.42) or reach (δ[Reach] μ[Reach]; AIC_c = 3,905.67). The mesohabitat model (δ[Mesohabitat] μ[Mesohabitat]) demonstrated that estimated densities in lower velocity mesohabitats (BW [29.33], PO [5.91], and SHPO [9.66]) were higher ($P < 0.05$) than densities in higher velocity mesohabitats (RU [1.04] and SHRU [3.03]).

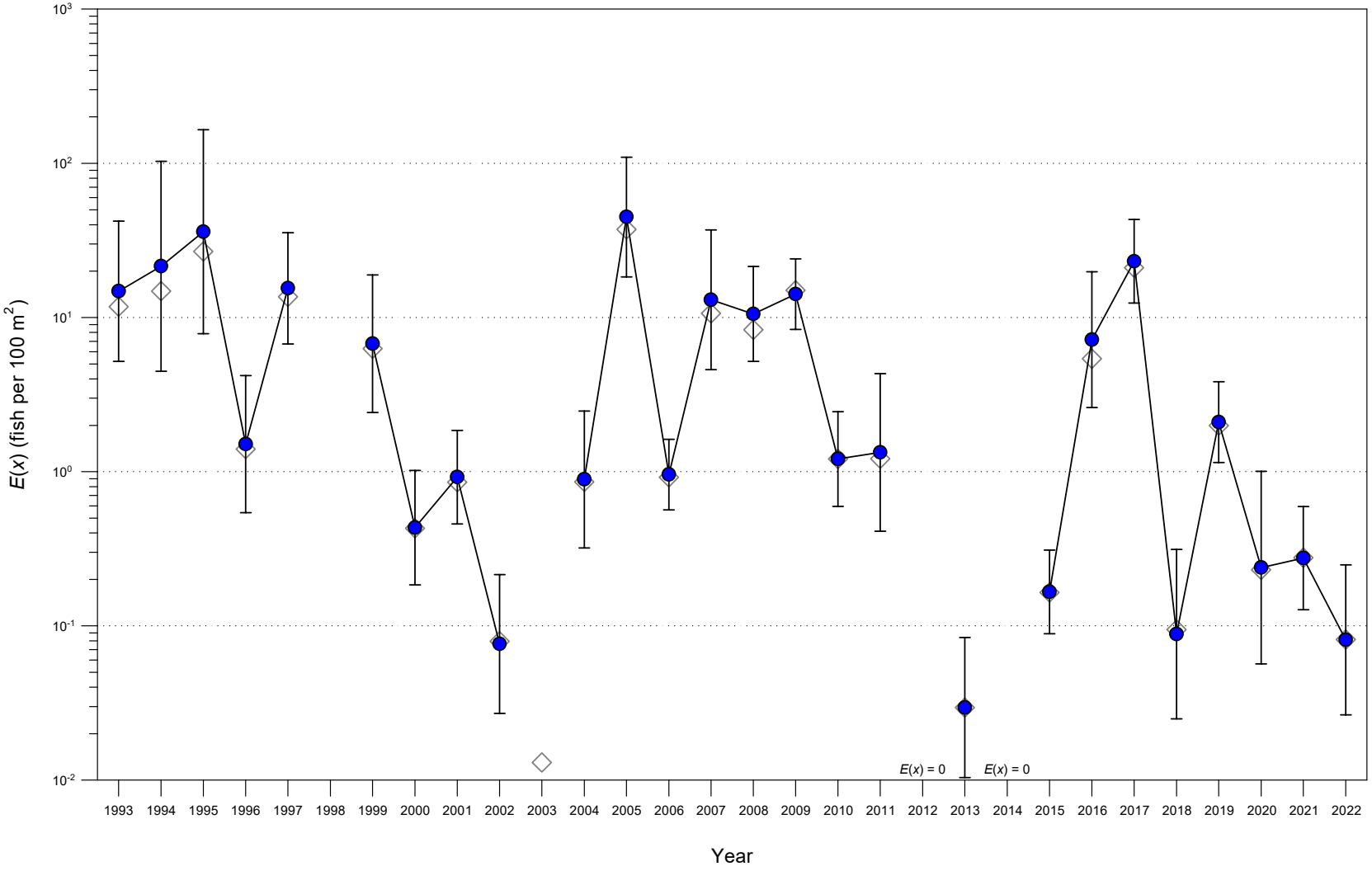

Figure 14. Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years (see Table 7). Sampling did not occur in 1998, and density could not be estimated for 2003. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated. Additional sites and dry sites were excluded.

Table 4. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2022). Additional sites and dry sites were excluded.

Model[1]	**logLike**[2]	**K**[3]	**AIC$_c$**[4]	**w_i**[4]
δ(Year) μ(ABQ>2,000+*R*)	876.25	34	949.02	0.3102
δ(Year) μ(ABQmax+*R*)	876.38	34	949.15	0.2910
δ(Year) μ(ABQmean+*R*)	877.82	34	950.59	0.1412
δ(SANmean+*R*) μ(Year)	826.79	56	952.17	0.0642
δ(SANmean+*R*) μ(ABQ>2,000+*R*)	934.62	9	952.97	0.0431
δ(Year) μ(SANmean+*R*)	881.24	34	954.01	0.0256
δ(Year) μ(ABQ>3,000+*R*)	882.33	34	955.10	0.0148
δ(SANmean+*R*) μ(ABQmean+*R*)	936.76	9	955.11	0.0148
δ(ABQmean+*R*) μ(Year)	829.90	56	955.29	0.0135
δ(ABQmax+*R*) μ(Year)	830.09	56	955.47	0.0123

[1] = Models included all δ and μ combinations of null effects (.), random effects (*R*), year (1993–2022), and hydrological metrics (with and without *R*) from Albuquerque (ABQ: USGS Gage-08330000) and San Marcial (SAN: USGS Gage-08358400).
[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).

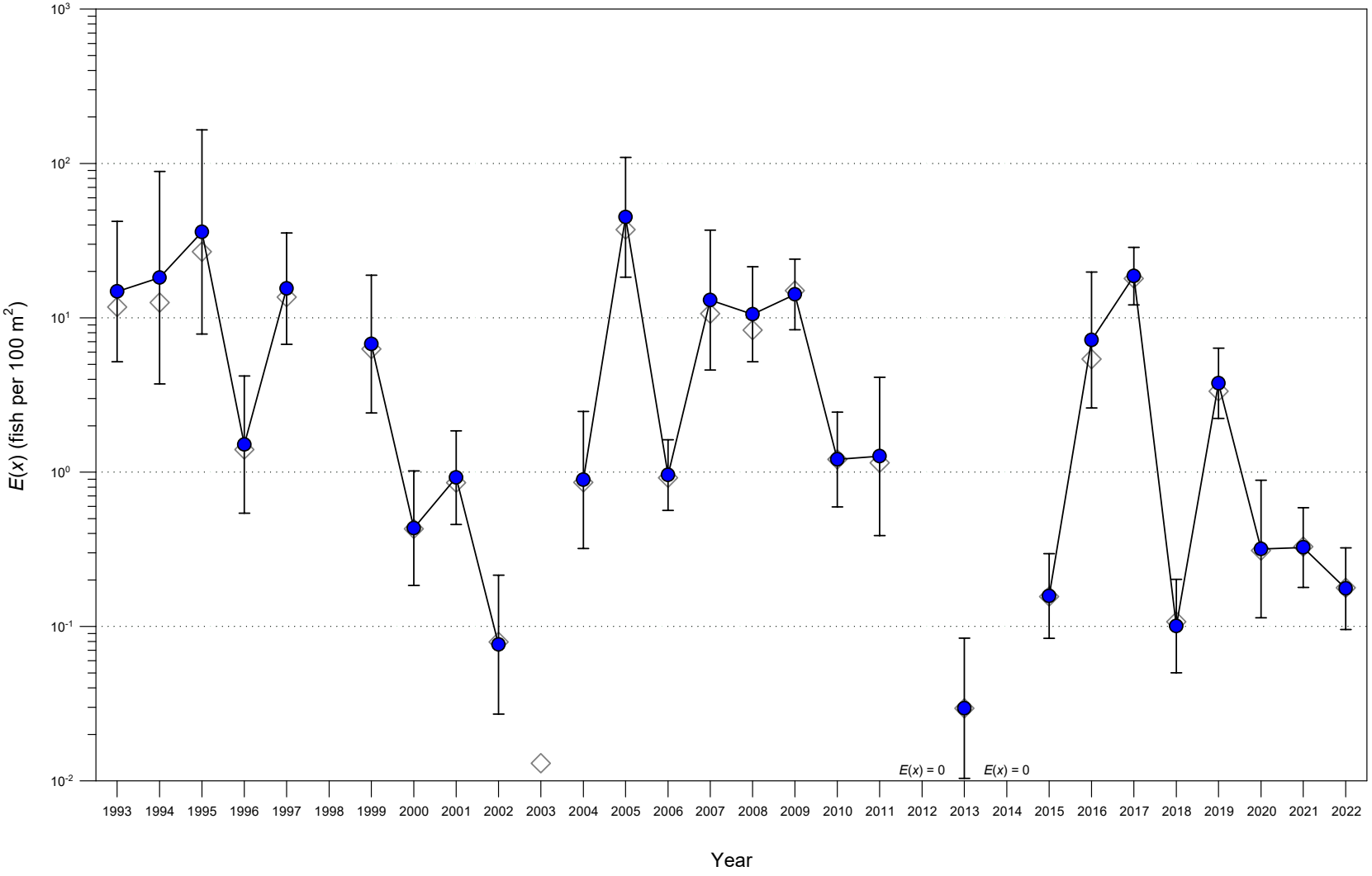

Figure 15. Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years (see Table 7). Sampling did not occur in 1998, and density could not be estimated for 2003. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated. Additional sites and dry sites were included.

Table 5. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2022). Additional sites and dry sites were included.

Model[1]	**logLike**[2]	**K**[3]	**AIC$_c$**[4]	***w$_i$***[4]
δ(SANmean+*R*) μ(Year)	929.66	56	1,053.36	0.2965
δ(Year) μ(ABQ>2,000+*R*)	981.58	34	1,053.77	0.2414
δ(Year) μ(ABQmax+*R*)	982.26	34	1,054.45	0.1715
δ(Year) μ(ABQmean+*R*)	983.23	34	1,055.42	0.1055
δ(ABQmax+*R*) μ(Year)	932.66	56	1,056.35	0.0664
δ(ABQmean+*R*) μ(Year)	933.15	56	1,056.84	0.0520
δ(ABQ>2,000+*R*) μ(Year)	934.78	56	1,058.48	0.0229
δ(ABQ>3,000+*R*) μ(Year)	936.46	56	1,060.15	0.0099
δ(Inundation+*R*) μ(Year)	936.91	56	1,060.60	0.0079
δ(SAN<200+*R*) μ(Year)	937.14	56	1,060.83	0.0071

[1] = Models included all δ and μ combinations of null effects (.), random effects (*R*), year (1993–2022), and hydrological metrics (with and without *R*) from Albuquerque (ABQ: USGS Gage-08330000) and San Marcial (SAN: USGS Gage-08358400).
[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).

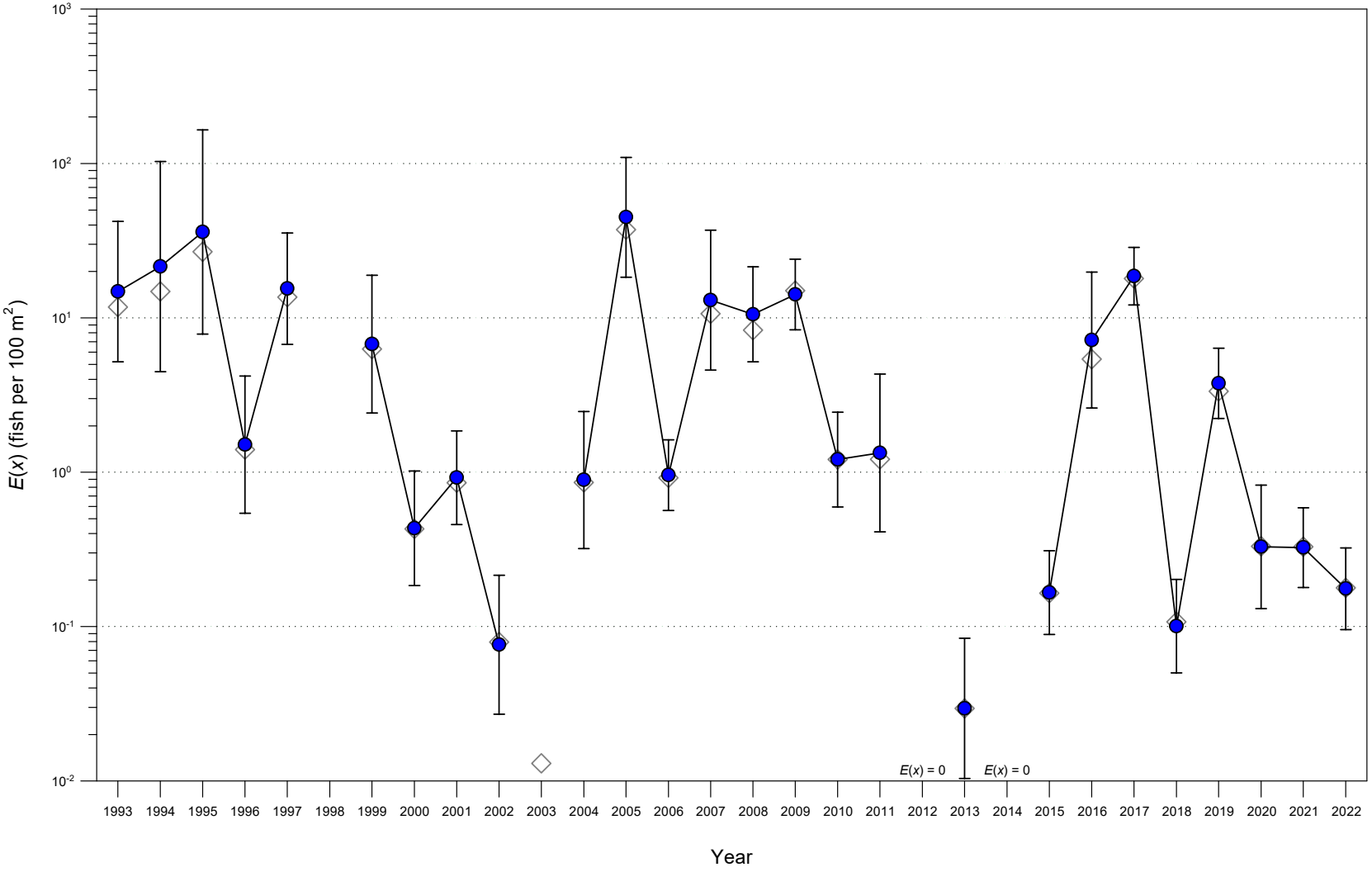

Figure 16. Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years (see Table 7). Sampling did not occur in 1998, and density could not be estimated for 2003. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated. Additional sites were included, and dry sites were excluded.

Table 6. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2022). Additional sites were included, and dry sites were excluded.

Model[1]	**logLike**[2]	**K**[3]	**AIC$_c$**[4]	**w_i**[4]
δ(SANmean+*R*) μ(Year)	923.16	56	1,047.05	0.6842
δ(ABQmean+*R*) μ(Year)	927.24	56	1,051.13	0.0890
δ(ABQmax+*R*) μ(Year)	927.98	56	1,051.86	0.0617
δ(Year) μ(ABQ>2,000+*R*)	980.11	34	1,052.37	0.0479
δ(Year) μ(ABQmax+*R*)	980.68	34	1,052.94	0.0361
δ(ABQ>2,000+*R*) μ(Year)	929.99	56	1,053.88	0.0226
δ(Year) μ(ABQmean+*R*)	981.84	34	1,054.09	0.0202
δ(ABQ>3,000+*R*) μ(Year)	930.64	56	1,054.53	0.0163
δ(Inundation+*R*) μ(Year)	932.73	56	1,056.62	0.0057
δ(SANmean+*R*) μ(ABQ>2,000+*R*)	1,038.74	9	1,057.05	0.0046

[1] = Models included all δ and μ combinations of null effects (.), random effects (*R*), year (1993–2022), and hydrological metrics (with and without *R*) from Albuquerque (ABQ: USGS Gage-08330000) and San Marcial (SAN: USGS Gage-08358400).
[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).

Table 7. Rio Grande Silvery Minnow densities *E*(*x*) and 95% confidence intervals (LCI–UCI), estimated using October sampling-site data, across years. Dashes (-) indicate instances when *E*(*x*) could not be estimated, as only a single nonzero value was recorded. Zeroes (0) indicate instances when zero values were recorded at all sites. All combinations of additional sites (included/excluded) and dry sites (included/excluded) are presented.

Year[1]	Add(N)Dry(Y)[2]	Add(N)Dry(N)[3]	Add(Y)Dry(Y)[4]	Add(Y)Dry(N)[5]
1993	14.81 (5.20–42.21)	14.81 (5.20–42.21)	14.81 (5.20–42.21)	14.81 (5.20–42.21)
1994	18.19 (3.73–88.72)	21.50 (4.49–103.08)	18.19 (3.73–88.72)	21.50 (4.49–103.08)
1995	36.01 (7.85–165.19)	36.01 (7.85–165.19)	36.01 (7.85–165.19)	36.01 (7.85–165.19)
1996	1.51 (0.54–4.20)	1.51 (0.54–4.20)	1.51 (0.54–4.20)	1.51 (0.54–4.20)
1997	15.48 (6.75–35.51)	15.48 (6.75–35.51)	15.48 (6.75–35.51)	15.48 (6.75–35.51)
1998				
1999	6.77 (2.42–18.91)	6.77 (2.42–18.91)	6.77 (2.42–18.91)	6.77 (2.42–18.91)
2000	0.43 (0.18–1.02)	0.43 (0.18–1.02)	0.43 (0.18–1.02)	0.43 (0.18–1.02)
2001	0.92 (0.46–1.85)	0.92 (0.46–1.85)	0.92 (0.46–1.85)	0.92 (0.46–1.85)
2002	0.08 (0.03–0.22)	0.08 (0.03–0.22)	0.08 (0.03–0.22)	0.08 (0.03–0.22)
2003	-	-	-	-
2004	0.89 (0.32–2.48)	0.89 (0.32–2.48)	0.89 (0.32–2.48)	0.89 (0.32–2.48)
2005	44.86 (18.34–109.73)	44.86 (18.34–109.73)	44.86 (18.34–109.73)	44.86 (18.34–109.73)
2006	0.96 (0.56–1.62)	0.96 (0.56–1.62)	0.96 (0.56–1.62)	0.96 (0.56–1.62)
2007	13.03 (4.59–37.02)	13.03 (4.59–37.02)	13.03 (4.59–37.02)	13.03 (4.59–37.02)
2008	10.55 (5.19–21.44)	10.55 (5.19–21.44)	10.55 (5.19–21.44)	10.55 (5.19–21.44)
2009	14.18 (8.37–24.03)	14.18 (8.37–24.03)	14.18 (8.37–24.03)	14.18 (8.37–24.03)
2010	1.21 (0.60–2.45)	1.21 (0.60–2.45)	1.21 (0.60–2.45)	1.21 (0.60–2.45)
2011	1.27 (0.39–4.13)	1.33 (0.41–4.33)	1.27 (0.39–4.13)	1.33 (0.41–4.33)
2012	0	0	0	0
2013	0.03 (0.01–0.08)	0.03 (0.01–0.08)	0.03 (0.01–0.08)	0.03 (0.01–0.08)
2014	0	0	0	0
2015	0.16 (0.08–0.30)	0.17 (0.09–0.31)	0.16 (0.08–0.30)	0.17 (0.09–0.31)
2016	7.18 (2.61–19.79)	7.18 (2.61–19.79)	7.18 (2.61–19.79)	7.18 (2.61–19.79)
2017	23.17 (12.41–43.24)	23.17 (12.41–43.24)	18.63 (12.13–28.62)	18.63 (12.13–28.62)
2018	0.09 (0.02–0.31)	0.09 (0.02–0.31)	0.10 (0.05–0.20)	0.10 (0.05–0.20)
2019	2.10 (1.15–3.84)	2.10 (1.15–3.84)	3.77 (2.23–6.37)	3.77 (2.23–6.37)
2020	0.23 (0.04–1.43)	0.24 (0.06–1.00)	0.32 (0.11–0.88)	0.33 (0.13–0.83)
2021	0.27 (0.13–0.59)	0.27 (0.13–0.59)	0.32 (0.18–0.59)	0.32 (0.18–0.59)
2022	0.08 (0.03–0.25)	0.08 (0.03–0.25)	0.18 (0.10–0.32)	0.18 (0.10–0.32)

[1] = Sampling did not occur in 1998.
[2] = Additional sites were excluded, and dry sites were included.
[3] = Additional sites and dry sites were excluded.
[4] = Additional sites and dry sites were included.
[5] = Additional sites were included, and dry sites were excluded.

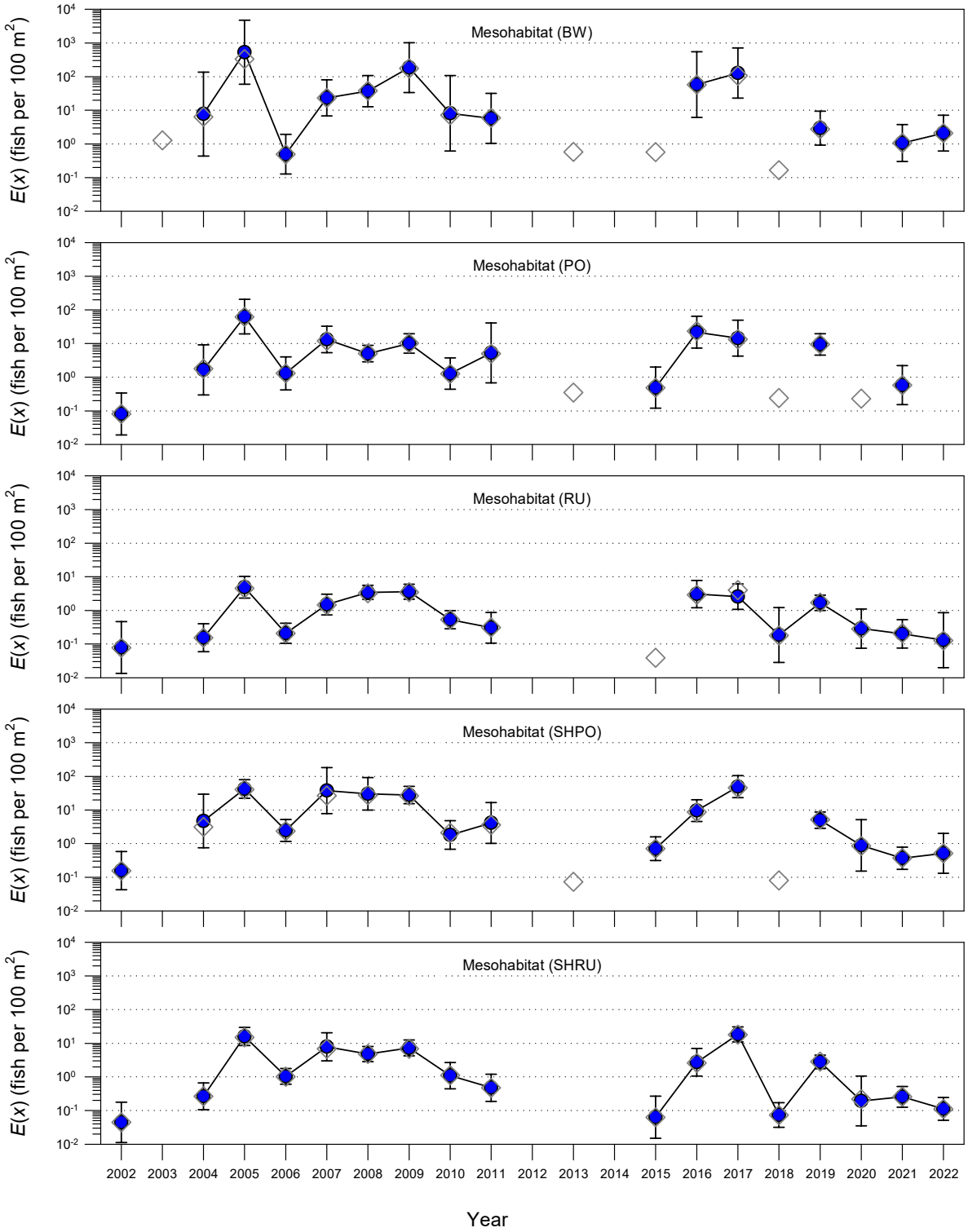

Figure 17. Rio Grande Silvery Minnow densities (estimated using October mesohabitat-specific data from all sites) across years. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated.

Table 8. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October mesohabitat-specific data from all sites (2002–2022).

Model[1]	**logLike**[2]	**K**[3]	**AIC$_c$**[4]	**w_i**[4]
δ(Year+Mesohabitat) μ(Year+Mesohabitat)	2,363.31	70	2,508.57	> 0.9999
δ(Year) μ(Year+Mesohabitat)	2,419.91	66	2,556.58	< 0.0001
δ(Year*Mesohabitat) μ(Year*Mesohabitat)	2,085.11	267	2,703.55	< 0.0001
δ(Year+Mesohabitat) μ(Mesohabitat)	2,655.56	35	2,726.86	< 0.0001
δ(Year) μ(Mesohabitat)	2,712.15	31	2,775.18	< 0.0001
δ(Year+Mesohabitat) μ(Year)	2,664.73	62	2,792.84	< 0.0001
δ(*R*) μ(Mesohabitat)	2,812.76	12	2,836.92	< 0.0001
δ(Year) μ(Year+Reach)	2,710.12	62	2,838.23	< 0.0001
δ(Year) μ(Year)	2,721.33	58	2,840.92	< 0.0001
δ(Year+Reach) μ(Year+Reach)	2,709.48	64	2,841.86	< 0.0001

[1] = Models included all δ and μ combinations of null effects (.), random effects (*R*), year (2002–2022), mesohabitat (backwater, pool, run, shoreline pool, and shoreline run), and reach (Angostura, Isleta, and San Acacia).
[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).

Sampling variation (2005–2022)

Rio Grande Silvery Minnow densities ($E(x)$; estimated using November sampling-site data [2005–2022]) were generated from the year-occasion model (δ[Year*Occasion] μ[Year*Occasion]). Interannual density trends for the sampling occasions (i.e., 1st, 2nd, 3rd, and 4th day of sampling) were very similar over the study period (Figure 18). While densities had dramatically increased ($P < 0.05$) for all sampling occasions from 2018 to 2019, there was a notable decrease ($P < 0.05$) in 2020; densities remained relatively low in 2021 and 2022. However, year-occasion densities could not be estimated when only a single nonzero value was recorded (e.g., 1st day in 2013). While naïve density estimates were still illustrated in those instances, the lack of any illustrated estimates indicates year-occasion combinations when no individuals were collected (e.g., 3rd day in 2013).

Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates revealed that changes in its occurrence and density were reliably predicted by differences across years and reaches, but much less so across sampling occasions (Table 9). The top model (δ[Year*Reach] μ[Year*Reach]) received nearly all the AIC_c weight out of the 41 models considered. A comparison of AIC_c values revealed that year (δ[Year] μ[Year]; AIC_c = 2,444.56) was more informative in explaining changes in model parameter values over time as compared with reach (δ[Reach] μ[Reach]; AIC_c = 3,808.07) or sampling occasion (δ[Occasion] μ[Occasion]; AIC_c = 3,848.67). Also, there were no significant differences in estimated densities across the four sampling occasions for any year (2005–2022).

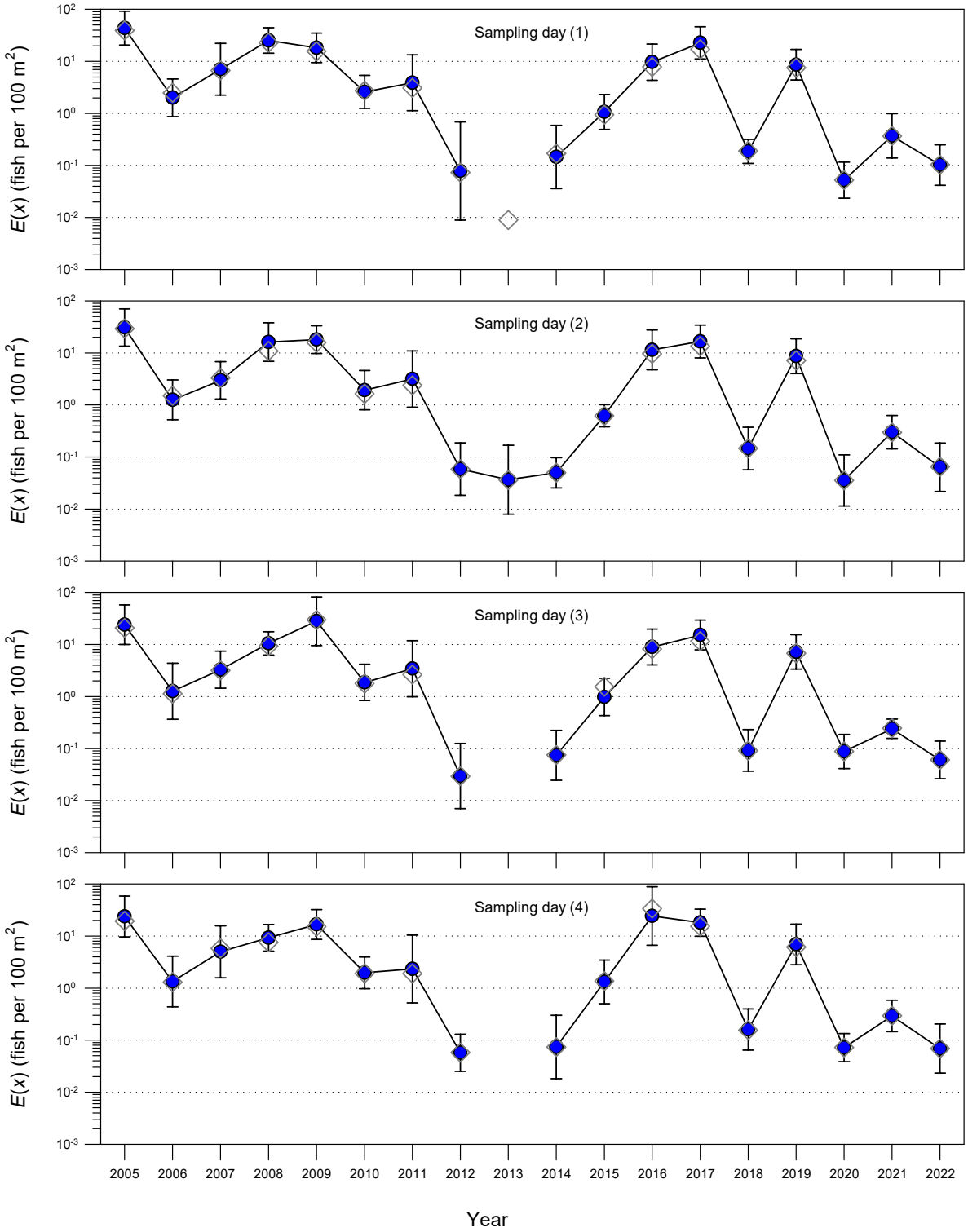

Figure 18. Rio Grande Silvery Minnow densities (estimated using November sampling-site data from all sites) across years. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated.

Table 9. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using November sampling-site data from all sites (2005–2022).

Model[1]	**logLike**[2]	**K**[3]	**AIC$_c$**[4]	**w_i**[4]
δ(Year*Reach) μ(Year*Reach)	1,802.02	156	2,152.32	> 0.9999
δ(Year+Reach) μ(Year+Reach)	2,246.03	60	2,371.36	< 0.0001
δ(Year) μ(Year+Reach)	2,273.82	58	2,394.79	< 0.0001
δ(Year+Reach) μ(Year)	2,304.46	56	2,421.09	< 0.0001
δ(Year) μ(Year)	2,332.26	54	2,444.56	< 0.0001
δ(Year) μ(Year+Occasion)	2,323.78	60	2,449.10	< 0.0001
δ(Year+Occasion) μ(Year)	2,331.40	57	2,450.19	< 0.0001
δ(Year+Occasion) μ(Year+Occasion)	2,322.92	63	2,454.79	< 0.0001
δ(*R*) μ(Year)	2,413.68	38	2,491.80	< 0.0001
δ(Year) μ(*R*)	2,533.55	21	2,576.21	< 0.0001

[1] = Models included all δ and μ combinations of null effects (.), random effects (*R*), year (2005–2022), sampling occasion (i.e., 1st, 2nd, 3rd, and 4th day of sampling), and reach (Angostura, Isleta, and San Acacia).

[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).

Fish Community

Population status (1993–2022)

The ichthyofaunal community in the Middle Rio Grande during 2022 was numerically dominated by cyprinids (Tables 10 and 11; Appendix F). The native ichthyofauna comprised 11 species (Gizzard Shad, Red Shiner, Rio Grande Silvery Minnow, Fathead Minnow, Flathead Chub, Longnose Dace, River Carpsucker, Smallmouth Buffalo, Blue Catfish, Flathead Catfish, and Bluegill). Red Shiner was the most abundant native species collected (n = 12,708), followed by Flathead Chub (n = 1,432), and Longnose Dace (n = 600). The nonnative ichthyofauna comprised 12 species. The most abundant nonnative species were Western Mosquitofish (n = 2,016), Channel Catfish (n = 1,326), and White Sucker (n = 378).

There were notable seasonal changes in the relative abundance of the 10 focal taxa from April to October 2022 (Figures 19 and 20). Densities of all fish species generally increased during summer. Rio Grande Silvery Minnow abundance was highest in April and July but had declined considerably by October. Other focal species typically reached their highest densities from June to August, following their respective spawning periods.

In addition to temporal variation in the relative abundance of fish species during 2022, there were also pronounced differences in the densities of species across reaches (Figure 21). Fathead Minnow, Flathead Chub, Longnose Dace, White Sucker, and Channel Catfish were most common in the Angostura Reach. Densities of Red Shiner, Common Carp, River Carpsucker, and Western Mosquitofish were highest in the Isleta Reach. Rio Grande Silvery Minnow was most common in the San Acacia Reach.

The abundance of the ten focal species, during October, has fluctuated markedly across years (Table 12). Several species, including Rio Grande Silvery Minnow, have periodically declined to very low numbers (< 10). In contrast, other species (e.g., Red Shiner and Western Mosquitofish) have never declined to fewer than 100 individuals. Different species also varied widely in their abundance trends over time, and it was not uncommon for several species to increase or decrease dramatically within one or two years. The annual abundance of Rio Grande Silvery Minnow was particularly volatile, fluctuating from a high of 3,939 in 2005 to a low of < 5 in multiple years (2003 and 2012–2014).

Rio Grande Silvery Minnow composed a higher fraction of the ichthyofaunal community, during October, from 2016 to 2017 than from 2018 to 2022 (Figure 22). Notable changes in the relative abundance of this species mirrored similar changes in its estimated occurrence and density over the study period (1993–2022). While Rio Grande Silvery Minnow represented 8.61% of the fish community in 2019, it had decreased to only 0.68% by 2022.

The magnitude of change in the relative abundance of Rio Grande Silvery Minnow was particularly evident when compared to other focal species across all study years (Table 13). Rio Grande Silvery Minnow had decreased from being the most common focal species in 2017 to being the least common by 2018. While its rank abundance improved dramatically from 2018 (10th) to 2019 (3rd), it again declined precipitously in 2020 (8th) and remained low in 2022 (7th). The coefficient of concordance (W = 0.67) for the ten focal species indicated high agreement among ranks over time (1993–2022; X^2 = 174.2; P < 0.001) despite marked changes in ranks for some species (e.g., Rio Grande Silvery Minnow, Longnose Dace, and River Carpsucker).

Table 10. Ichthyofaunal summary based on all sites (all age-classes combined), by species, during 2022. Marked and unmarked Rio Grande Silvery Minnow were included. Dashes (-) indicate species that were absent during sampling.

Family	Common Name	Residence Status[1]	Total Number of Individuals	Percent (%) of Total	Frequency of Occurrence[2]	% Frequency of Occurrence[2]
Clupeidae	Gizzard Shad	N	5	0.03	3	1.88
Clupeidae	Threadfin Shad	I	-	-	-	-
Cyprinidae	Central Stoneroller	I	-	-	-	-
Cyprinidae	Goldfish	I	-	-	-	-
Cyprinidae	Red Shiner	N	12,708	65.46	143	89.38
Cyprinidae	Common Carp	I	366	1.89	56	35.00
Cyprinidae	Rio Grande Chub	N	-	-	-	-
Cyprinidae	Rio Grande Silvery Minnow	N	296	1.52	59	36.88
Cyprinidae	Golden Shiner	I	1	0.01	1	0.63
Cyprinidae	Fathead Minnow	N	105	0.54	41	25.63
Cyprinidae	Bullhead Minnow	I	-	-	-	-
Cyprinidae	Flathead Chub	N	1,432	7.38	97	60.63
Cyprinidae	Longnose Dace	N	600	3.09	26	16.25
Catostomidae	River Carpsucker	N	94	0.48	30	18.75
Catostomidae	White Sucker	I	378	1.95	32	20.00
Catostomidae	Smallmouth Buffalo	N	1	0.01	1	0.63
Ictaluridae	Black Bullhead	I	2	0.01	1	0.63
Ictaluridae	Yellow Bullhead	I	40	0.21	18	11.25
Ictaluridae	Blue Catfish	N	7	0.04	3	1.88
Ictaluridae	Channel Catfish	I	1,326	6.83	87	54.38
Ictaluridae	Flathead Catfish	N	1	0.01	1	0.63
Loricariidae	Vermiculated Sailfin Catfish	I	-	-	-	-
Salmonidae	Rainbow Trout	I	-	-	-	-
Salmonidae	Brown Trout	I	-	-	-	-
Poeciliidae	Western Mosquitofish	I	2,016	10.38	100	62.50
Moronidae	White Bass	I	-	-	-	-
Moronidae	Striped Bass	I	-	-	-	-
Centrarchidae	Green Sunfish	I	8	0.04	3	1.88
Centrarchidae	Bluegill	N	1	0.01	1	0.63
Centrarchidae	Longear Sunfish	I	-	-	-	-
Centrarchidae	Smallmouth Bass	I	1	0.01	1	0.63
Centrarchidae	Largemouth Bass	I	5	0.03	5	3.13
Centrarchidae	White Crappie	I	17	0.09	7	4.38
Centrarchidae	Black Crappie	I	-	-	-	-
Percidae	Yellow Perch	I	-	-	-	-
Percidae	Bigscale Logperch	I	4	0.02	1	0.63
Percidae	Walleye	I	-	-	-	-
Sciaenidae	Freshwater Drum	N	-	-	-	-
Annual Total			**19,414**	**100.00**		

[1] = Native (N) or introduced (I) species (Sublette et al. 1990; Propst 1999)
[2] = Based on 160 samples

Table 11. Ichthyofaunal summary based on all sites (all age-classes combined), by species and month, during 2022. Marked and unmarked Rio Grande Silvery Minnow were included.

Family	Common Name	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Clupeidae	Gizzard Shad	0	2	1	2	0	0	0	5
Clupeidae	Threadfin Shad	0	0	0	0	0	0	0	0
Cyprinidae	Central Stoneroller	0	0	0	0	0	0	0	0
Cyprinidae	Goldfish	0	0	0	0	0	0	0	0
Cyprinidae	Red Shiner	4,500	1,097	1,683	1,484	887	876	2,181	12,708
Cyprinidae	Common Carp	8	3	260	24	6	50	15	366
Cyprinidae	Rio Grande Chub	0	0	0	0	0	0	0	0
Cyprinidae	Rio Grande Silvery Minnow	73	19	114	41	13	9	27	296
Cyprinidae	Golden Shiner	0	0	0	0	0	0	1	1
Cyprinidae	Fathead Minnow	28	1	19	16	3	10	28	105
Cyprinidae	Bullhead Minnow	0	0	0	0	0	0	0	0
Cyprinidae	Flathead Chub	168	84	229	324	119	123	385	1,432
Cyprinidae	Longnose Dace	31	30	109	65	129	49	187	600
Catostomidae	River Carpsucker	8	2	54	22	0	3	5	94
Catostomidae	White Sucker	1	166	168	34	7	1	1	378
Catostomidae	Smallmouth Buffalo	0	1	0	0	0	0	0	1
Ictaluridae	Black Bullhead	0	0	0	2	0	0	0	2
Ictaluridae	Yellow Bullhead	0	0	1	16	5	10	8	40
Ictaluridae	Blue Catfish	0	0	4	3	0	0	0	7
Ictaluridae	Channel Catfish	24	17	0	169	505	135	476	1,326
Ictaluridae	Flathead Catfish	0	0	0	0	0	1	0	1
Loricariidae	Vermiculated Sailfin Catfish	0	0	0	0	0	0	0	0
Salmonidae	Rainbow Trout	0	0	0	0	0	0	0	0
Salmonidae	Brown Trout	0	0	0	0	0	0	0	0
Poeciliidae	Western Mosquitofish	228	10	109	175	127	713	654	2,016
Moronidae	White Bass	0	0	0	0	0	0	0	0
Moronidae	Striped Bass	0	0	0	0	0	0	0	0
Centrarchidae	Green Sunfish	0	0	4	4	0	0	0	8
Centrarchidae	Bluegill	0	0	0	0	1	0	0	1
Centrarchidae	Longear Sunfish	0	0	0	0	0	0	0	0
Centrarchidae	Smallmouth Bass	0	0	0	0	1	0	0	1
Centrarchidae	Largemouth Bass	0	0	1	2	0	1	1	5
Centrarchidae	White Crappie	13	2	2	0	0	0	0	17
Centrarchidae	Black Crappie	0	0	0	0	0	0	0	0
Percidae	Yellow Perch	0	0	0	0	0	0	0	0
Percidae	Bigscale Logperch	0	0	4	0	0	0	0	4
Percidae	Walleye	0	0	0	0	0	0	0	0
Sciaenidae	Freshwater Drum	0	0	0	0	0	0	0	0
Monthly Totals		**5,082**	**1,434**	**2,762**	**2,383**	**1,803**	**1,981**	**3,969**	**19,414**

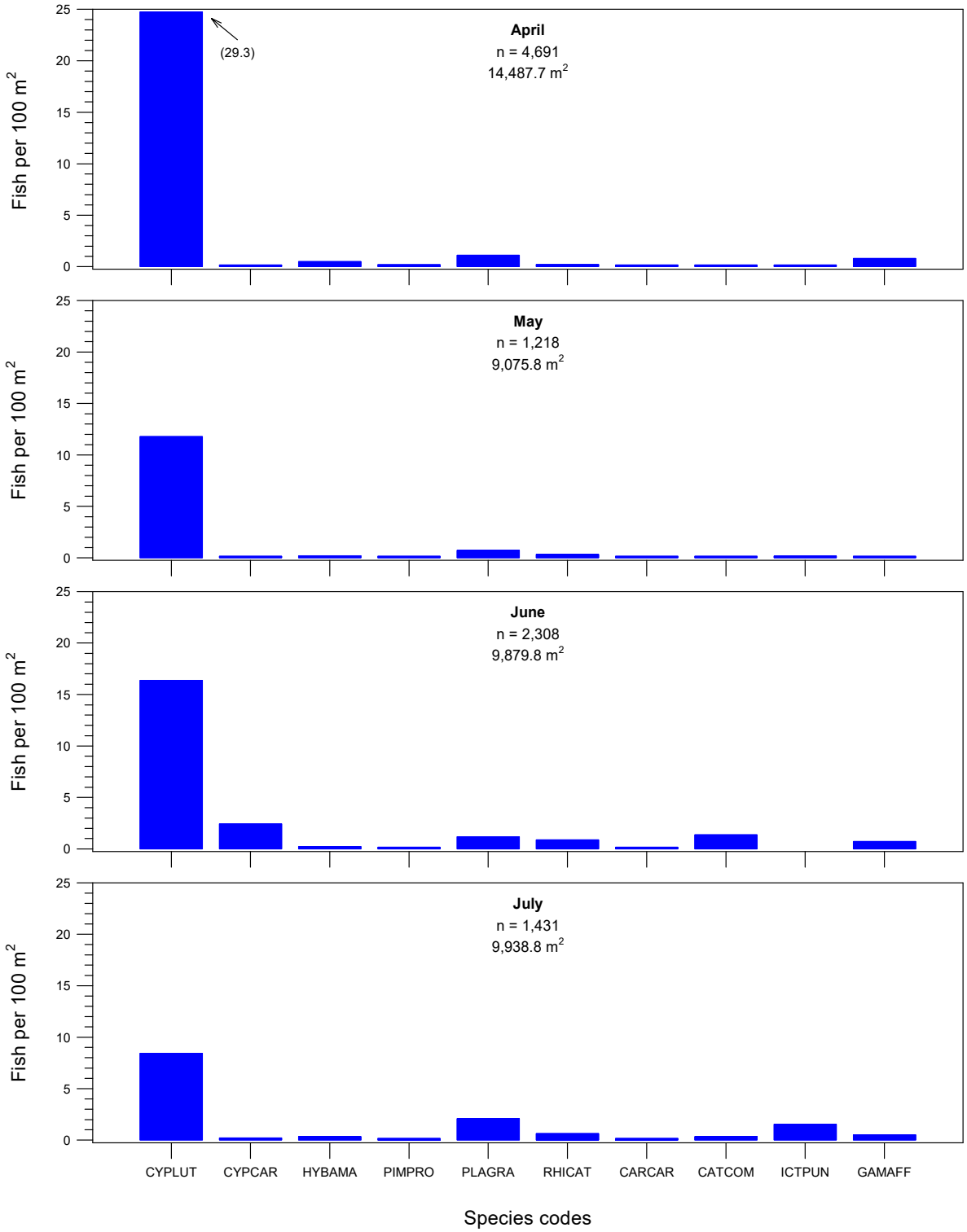

Figure 19. Fish densities based on all sites (age-0 and age-1+ fish [small-mesh seine]; larval fish excluded), by month and focal taxa, from April to July 2022.

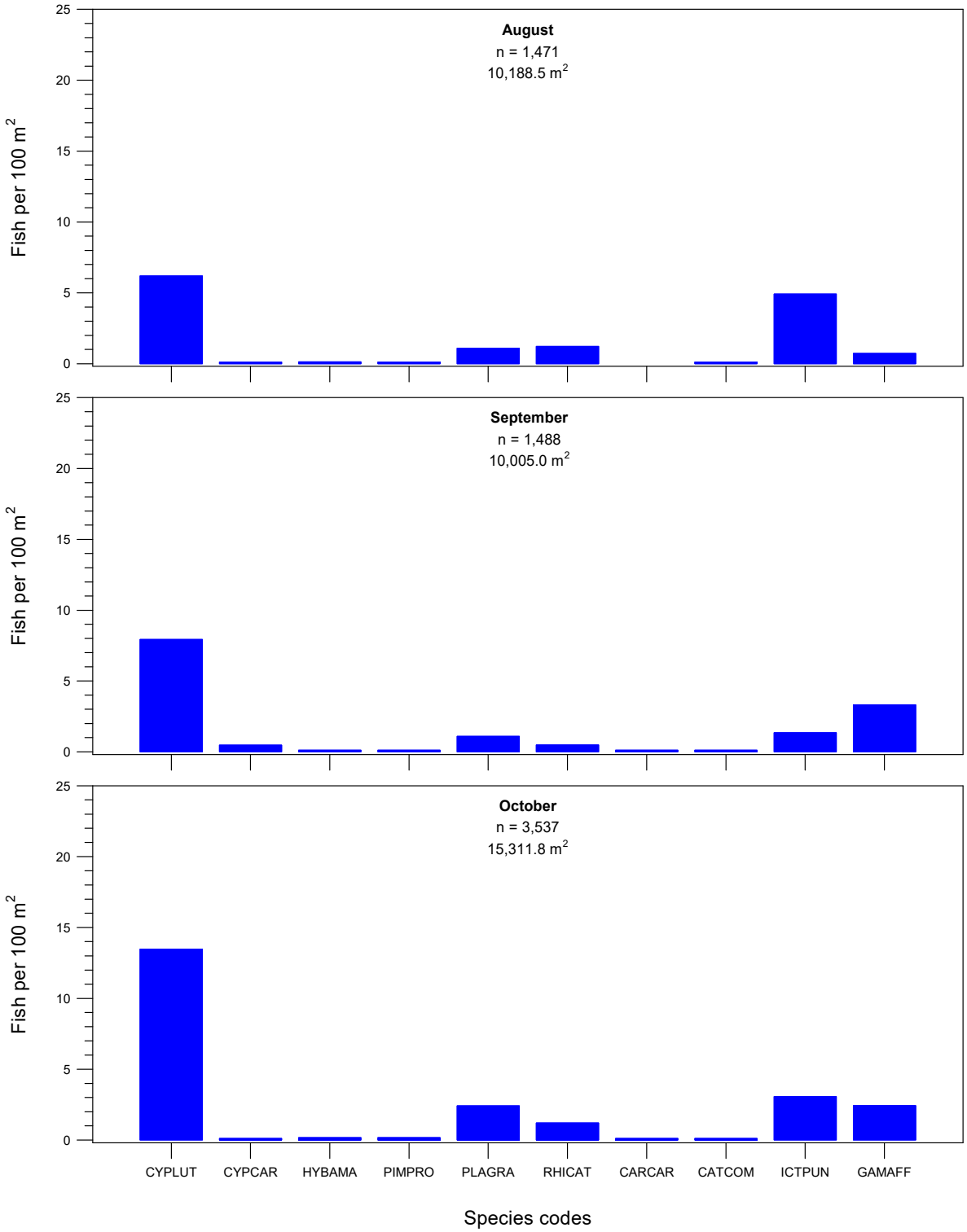

Figure 20. Fish densities based on all sites (age-0 and age-1+ fish [small-mesh seine]; larval fish excluded), by month and focal taxa, from August to October 2022.

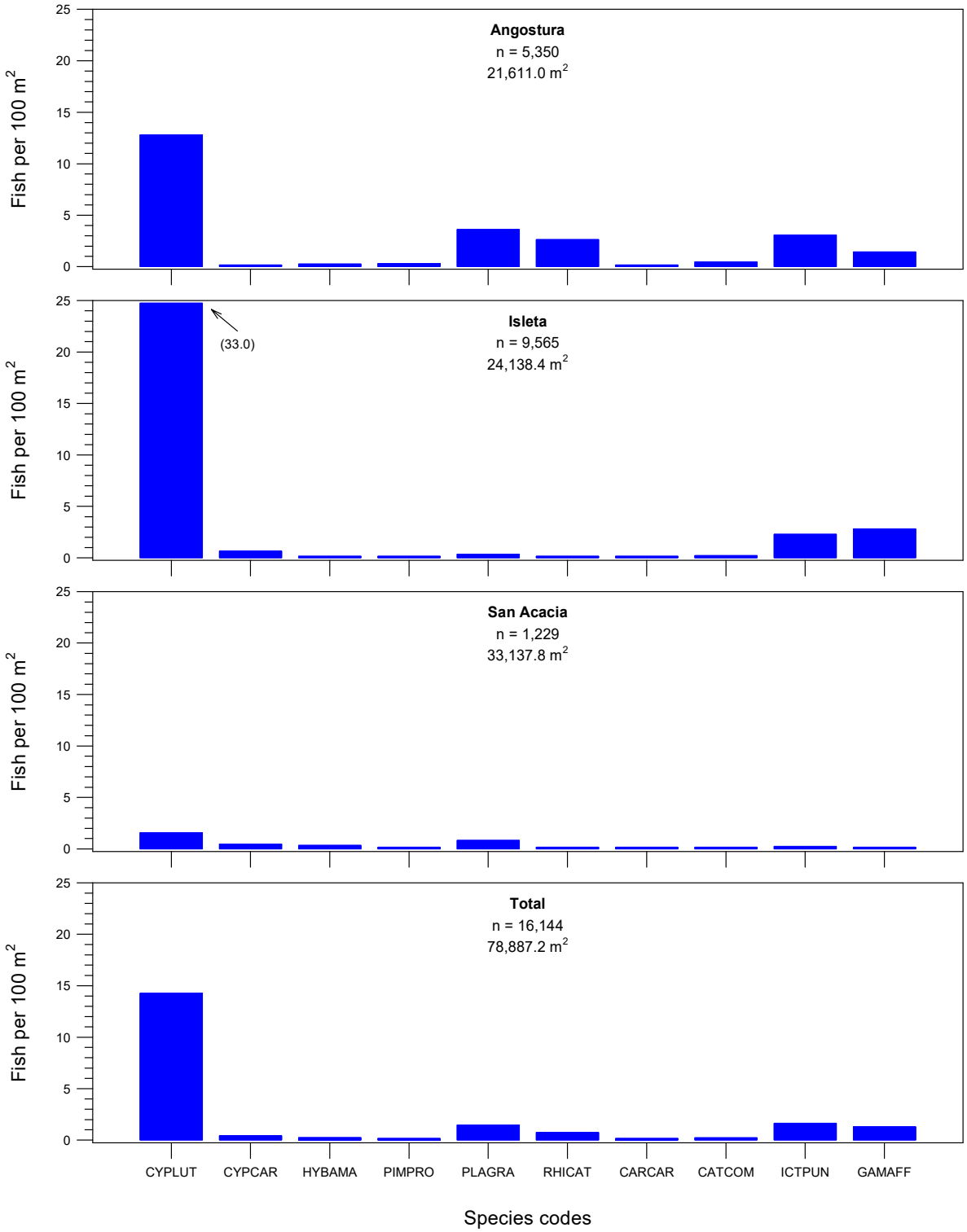

Figure 21. Fish densities based on all sites (age-0 and age-1+ fish [small-mesh seine]; larval fish excluded), by reach and focal taxa, from April to October 2022.

Table 12. Fish abundance based on all sites during October, by year and focal taxa, from 1993 to 2022. Sampling did not occur in 1998.

	Species Codes									
Year	**CYPLUT**	**CYPCAR**	**HYBAMA**	**PIMPRO**	**PLAGRA**	**RHICAT**	**CARCAR**	**CATCOM**	**ICTPUN**	**GAMAFF**
1993	3,585	24	939	315	297	11	322	48	174	185
1994	1,091	26	906	131	139	58	108	27	465	122
1995	510	13	1,292	97	308	35	29	71	170	142
1996	1,994	43	956	396	295	46	316	38	386	869
1997	724	18	606	82	196	54	100	70	257	351
1998										
1999	1,522	11	412	63	259	60	180	11	74	297
2000	7,511	13	37	399	48	53	251	78	313	2,443
2001	5,769	88	112	740	158	53	284	21	242	3,984
2002	8,054	25	11	1,564	126	198	150	43	253	1,843
2003	5,042	25	2	757	126	31	123	24	38	2,508
2004	3,436	7	78	447	194	24	42	5	60	781
2005	399	47	3,939	115	61	32	2	2	48	829
2006	1,669	1	162	76	204	23	3	3	160	192
2007	5,287	6	1,166	129	543	55	142	19	174	557
2008	1,635	41	868	114	239	29	18	12	82	745
2009	2,314	2	1,835	144	210	16	60	20	321	811
2010	2,518	6	137	54	503	41	15	4	162	489
2011	3,121	16	118	44	122	28	79	17	64	430
2012	5,272	84	0	154	781	28	73	19	184	1,237
2013	3,265	6	3	307	127	317	7	25	218	959
2014	1,506	8	0	52	215	58	12	2	167	338
2015	690	6	16	18	169	68	12	0	129	639
2016	1,574	37	584	18	183	39	9	2	135	206
2017	2,631	102	2,867	44	300	69	24	26	1,126	810
2018	6,552	55	17	188	662	179	298	20	338	1,920
2019	3,327	96	517	51	483	167	4	8	383	919
2020	14,003	37	51	363	619	47	405	74	120	3,522
2021	4,889	7	49	68	287	246	7	5	155	1,561
2022	2,181	15	27	28	385	187	5	1	476	654

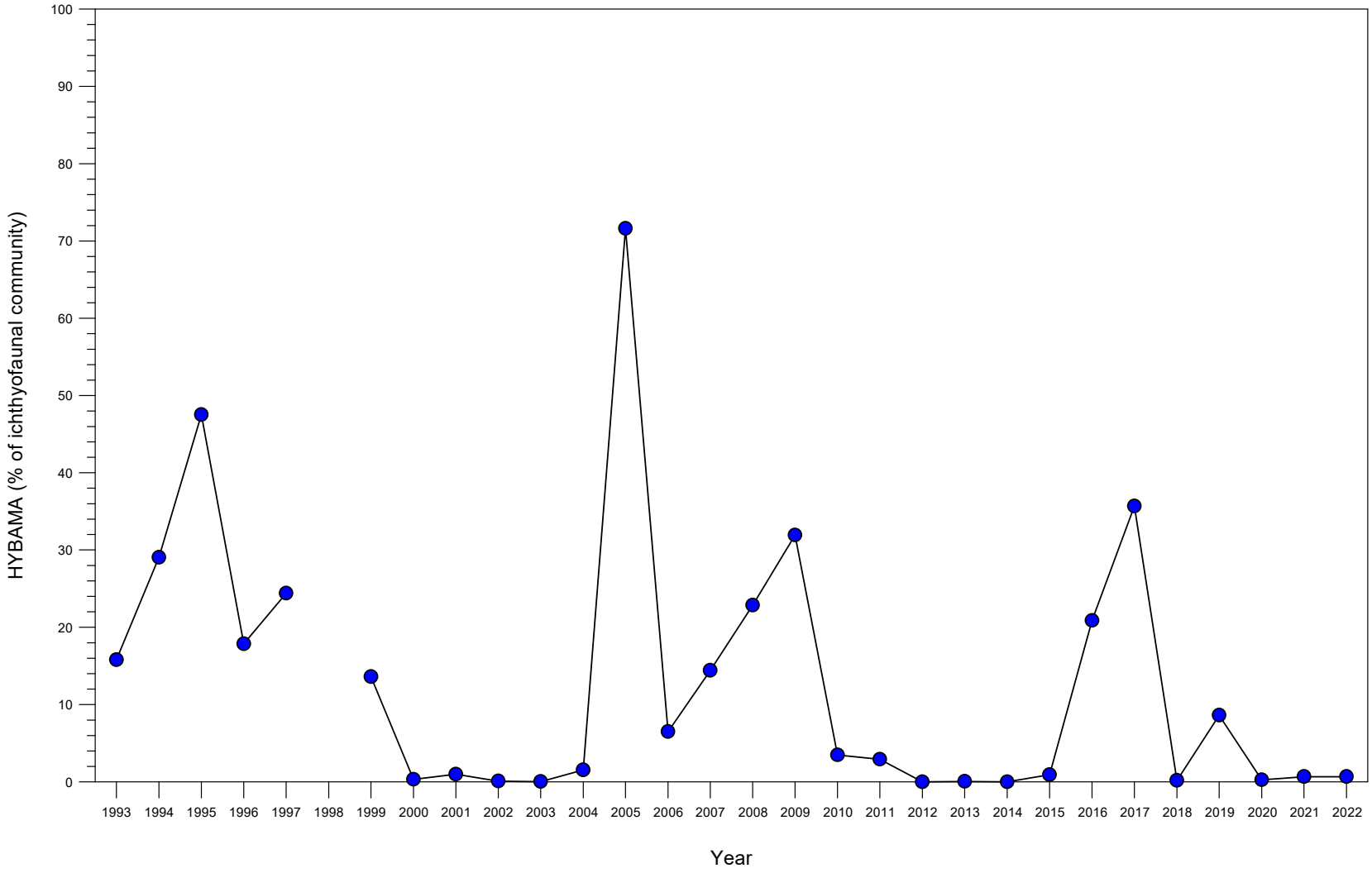

Figure 22. Relative abundance of Rio Grande Silvery Minnow as a percentage of the ichthyofaunal community, based on all sites during October, across years. Sampling did not occur in 1998.

Table 13. Fish rank-abundance based on all sites during October, by year and focal taxa, from 1993 to 2022. Sampling did not occur in 1998.

	Species Codes									
Year	**CYPLUT**	**CYPCAR**	**HYBAMA**	**PIMPRO**	**PLAGRA**	**RHICAT**	**CARCAR**	**CATCOM**	**ICTPUN**	**GAMAFF**
1993	1	9	2	4	5	10	3	8	7	6
1994	1	10	2	5	4	8	7	9	3	6
1995	2	10	1	6	3	8	9	7	4	5
1996	1	9	2	4	7	8	6	10	5	3
1997	1	10	2	7	5	9	6	8	4	3
1998										
1999	1	9.5	2	7	4	8	5	9.5	6	3
2000	1	10	9	3	8	7	5	6	4	2
2001	1	8	7	3	6	9	4	10	5	2
2002	1	9	10	3	7	5	6	8	4	2
2003	1	8	10	3	4	7	5	9	6	2
2004	1	9	5	3	4	8	7	10	6	2
2005	3	7	1	4	5	8	9.5	9.5	6	2
2006	1	10	4	6	2	7	8.5	8.5	5	3
2007	1	10	2	7	4	8	6	9	5	3
2008	1	7	2	5	4	8	9	10	6	3
2009	1	10	2	6	5	9	7	8	4	3
2010	1	9	5	6	2	7	8	10	4	3
2011	1	10	4	7	3	8	5	9	6	2
2012	1	6	10	5	3	8	7	9	4	2
2013	1	9	10	4	6	3	8	7	5	2
2014	1	8	10	6	3	5	7	9	4	2
2015	1	9	7	6	3	5	8	10	4	2
2016	1	7	2	8	4	6	9	10	5	3
2017	2	6	1	8	5	7	10	9	3	4
2018	1	8	10	6	3	7	5	9	4	2
2019	1	7	3	8	4	6	10	9	5	2
2020	1	10	8	5	3	9	4	7	6	2
2021	1	8.5	7	6	3	4	8.5	10	5	2
2022	1	8	7	6	4	5	9	10	3	2

DISCUSSION

Research Goals and Objectives

The population status of Rio Grande Silvery Minnow, and the associated Middle Rio Grande ichthyofaunal community, has been systematically monitored since 1993. This effort is unique among ichthyofaunal research studies in the Middle Rio Grande, as it provides consistent sampling of fishes over a very long duration. Determining changes in fish population trends is best accomplished by analyzing the suite of available data over the full study period. Long-term sampling studies also provide the data necessary to test specific ecological hypotheses. While this study was initially designed to monitor the long-term population trends of fish species in the Middle Rio Grande, its scope has expanded to address some of the evolving data needs of natural resource managers. Examples of key study components that have been added over time include: (1) evaluating the influence of river flows on population fluctuations, (2) determining mesohabitat use patterns, (3) assessing variation of density estimates based on repeated sampling, (4) documenting changes in relative abundance among native and nonnative fishes, and (5) evaluating changes in site occupancy status across years. The primary objectives of the Rio Grande Silvery Minnow Population Monitoring Program are to assess interannual trends in the abundance of this imperiled species, at standardized sites throughout the Middle Rio Grande, and evaluate how those trends are affected by changes in annual discharge patterns over time.

Population Trends vs. Population Estimates

While the primary purpose of this study was to estimate fish population trends over time using a density index (i.e., CPUE), there are important distinctions between estimating population trends vs. estimating population size. Both the accuracy and precision of population size estimates, based on mark-recapture or multiple-pass sampling techniques, are likely to be better than estimates based on a density index (Otis et al. 1978). However, the practical budgetary constraints of agencies, charged with the long-term monitoring of imperiled species, often preclude the utilization of more statistically-robust sampling techniques (e.g., mark-recapture or multiple-pass studies). Despite these challenges, density indices have repeatedly been shown to be appropriate for assessing population trends and can be a practical and cost-effective approach for long-term monitoring studies (Johnson 2008; Al-Chokhachy et al. 2009; Cao et al. 2016; Crane and Kapuscinski 2018).

Statistical analyses revealed a close relationship between Rio Grande Silvery Minnow population trends (2008–2011) obtained from the population-monitoring and population-estimation studies (Dudley et al. 2012). Despite similarities in population trends obtained from these two studies, each study has its own unique objectives that address different research needs. Systematic population monitoring provides an assessment of recruitment success within years, a basis for comparing changes in recruitment success across years, and timely information about the status of the species during periods of reduced abundance. Additionally, this dataset has been used to assess seasonal survivorship rates (e.g., Dudley et al. 2009) and could be used to evaluate the effectiveness of future adaptive-management activities on both native and nonnative fishes. In contrast, the population estimation study was more narrowly focused to provide statistically-robust population estimates of Rio Grande Silvery Minnow across years. For assessing population changes over time, that study generally resulted in a higher degree of precision and accuracy, as compared to the population monitoring study (Dudley et al. 2012). Further, the substantial methodological differences between these studies (e.g., multiple-pass sampling with enclosures [estimation] vs. single-pass sampling without enclosures [monitoring]) meant that any population size estimate generated from population monitoring data would be biased. While density estimates generated from the population monitoring study should not be used to derive population size estimates, they have proven to be a reliable index of Rio Grande Silvery Minnow population trends over time (Dudley et al. 2012).

Analytical Considerations

The mixture models used to estimate Rio Grande Silvery Minnow densities (1993–2022) employed two separate statistical components, an approach that is particularly effective for modeling zero-inflated ecological data (White 1978; Welsh et al. 1996; Fletcher et al. 2005; Martin et al. 2005). Logistic regression was used to estimate the annual probability that a site was occupied, and a lognormal model was used to estimate the annual lognormal density based on occupied sites. The two processes (i.e., occurrence [δ] vs. density [μ]) that generated $E(x)$ were clearly separated when using the mixture-model approach. Also, it was unnecessary to add some arbitrary positive constant onto observations of zero values, as is commonly done for simple linear regression models using log-transformed data. Further, our approach fully accounts for over-dispersion (e.g., extra-binomial variation around δ, non-constant σ in the lognormal distribution, or additional variation around δ and μ for the linear covariate model). Thus, we have produced estimates using a robust, yet highly flexible, approach that avoids many assumptions typically required for traditional statistical analyses (Appendix E [Table E1]).

For our analyses, we reasoned that capture probabilities were likely similar across sampling sites and years. As mark-recapture or multiple-pass data were not collected as part of this study, this premise cannot be directly evaluated. However, it seems highly unlikely that pronounced downward density trends were caused by low capture efficiencies, as our methods have remained consistent to ensure that comparable mesohabitats (i.e., depths and velocities) were sampled across different sites and annual flow conditions. As an example, a substantial decline (> 90%) in density between years (e.g., 1995–1996, 1999–2000, 2001–2002, 2005–2006, 2009–2010, and 2017–2018) would require a seemingly unreasonable decrease (> 90%) in capture probability (e.g., 0.5 to 0.01) between those years. Additionally, seining has been shown to be quite effective and reliable in sand-bottomed rivers, such as the Rio Grande, where habitat complexity is relatively low (Rabeni et al. 2009). Thus, it seems more reasonable that any differences in capture efficiencies across sites or years would tend to average out because of the substantial sampling effort required for this study. Additionally, Archdeacon et al. (2020b) found that taking 20 hauls at 20 sites (200-m long), which matched the sampling effort of our study, would yield a robust sampling regime for Rio Grande Silvery Minnow. Further, environmental conditions during October (e.g., water temperatures, flows, depths, velocities, and turbidities) have been quite stable and suitable for efficient sampling as compared to other times of the year (i.e., spring runoff or summer monsoons), making it an ideal time of year for evaluating long-term trends in the occurrence and density of Rio Grande Silvery Minnow. We have also maintained a steadfast consistency in our crew leaders, training procedures, and sampling protocols over the past three decades. Finally, we found that population trends in different mesohabitats (October [2002–2022]), or on different days during repeated sampling (November [2005–2022]), were remarkably like population trends obtained from the long-term dataset (October [1993–2022]).

Although we used frequentist statistical methods (i.e., mixture models and generalized linear models) to analyze the long-term data in our study, we also thoroughly evaluated the merits of the Bayesian method of statistical inference. Frequentist and Bayesian approaches both use the same general analytical framework (i.e., parametric likelihood models supplemented with linear covariate models) to generate parameter estimates and make ecological inferences from the data. However, Bayesian techniques rely on subjective assumptions about prior distributions, and require additional Markov chain Monte Carlo (MCMC) statistical analyses to obtain model estimates (Burnham and Anderson 2002). Therefore, conducting Bayesian analyses based on a non-hierarchical framework, as was used in our study, will not result in different conclusions, but does raise the issues of including subjective data and interpreting additional statistical results. While Bayesian hierarchical modeling has recently been applied to a portion of our dataset (1993–2017) for reach-specific analyses (Walsworth and Budy 2021), using informative priors to substitute for sparse reach-specific data seems contrary to objective long-term monitoring. Thus, we have used frequentist statistical modeling to rigorously analyze trends in the occurrence and density of Rio Grande Silvery Minnow and evaluate how those trends were affected by environmental changes over time (1993–2022).

Additional, Dry, and Replacement Sites

Based on recommendations by Hubert et al. (2016) and the Collaborative Program, we conducted statistical analyses using four different datasets: (1) additional sites excluded and dry sites included, (2) additional sites and dry sites excluded, (3) additional sites and dry sites included, and (4) additional sites included and dry sites excluded. Replacement sites were also sampled (i.e., since 2017) and used as surrogates within any analyses where dry sites were excluded. While these four analyses were based on different versions of the long-term dataset (1993–2022), our estimated densities of Rio Grande Silvery Minnow were reasonably consistent regardless of whether additional/dry sites were or were not included. However, we found that analyses that included additional sites had an increased AIC_c weight on the μ(Year) models. This difference was likely caused by the increased effective sample size of these analyses (i.e., more samples since 2017), which coincided with widely disparate estimates of μ from 2017 to 2022.

While we have included these additional-site analyses for comparative purposes, they should not be used to make inferences regarding long-term ecological relationships. Only the analyses based on the long-term monitoring data (i.e., additional sites excluded and dry sites included) should be used to make these inferences, as the number and spatial distribution of sites have remained consistent over time. In contrast, the additional-site analyses include a recent 50% increase in the number of sampling sites, which are most concentrated in the Angostura Reach and least concentrated in the San Acacia Reach. This altered, and spatially biased, distribution of sampling renders the additional-site analyses unsuitable for long-term inference of range-wide ecological changes, as a spatially-balanced sampling design (1993–2016) was combined with a spatially-unbalanced sampling design (2017–2022). Over time, however, the additional-site sampling design will become more suitable and robust for estimating reach-specific densities and assessing reach-specific ecological relationships.

Despite these limitations, we found that the 95% confidence intervals of estimated densities were consistently narrower when the additional sites were included in the analyses, which allowed for more robust comparisons of densities across recent years (i.e., since 2017). In contrast, the densities of Rio Grande Silvery Minnow were uniformly low throughout the study area during years characterized by low flows and dry sampling sites. Thus, the removal of dry-site data from the analyses did not meaningfully change our interpretation of the long-term population trends or ecological relationships.

While these extra analyses demonstrated the consistency of our research findings using four different datasets, the exclusion of data from dry sampling sites may yield biased results, particularly in years with extensive river drying. Consider the following hypothetical example: In year one, fish occupy the 20 standard sites with an estimated density of 10. In year two, fish occupy only 10 standard sites (e.g., the lower half of the study area dried). However, the estimated density at the wetted sites (i.e., 10 standard sites plus 10 replacement sites) might still be 10. It seems problematic to ignore the data from dry sites, as that would lead to an ecological model that is unchanged between years one and two (i.e., occurrence = 1.0 and density = 10 for both years). Instead, the inclusion of data from dry sites would lead to more realistic estimates (i.e., occurrence = 0.5 and density = 5 in year two). Similarly, a population estimate, based on this same scenario, would also show a 50% decline between years one and two because of the absence of fish in the lower half of the study area. We find it more reasonable that zeros at dry sites are true zeros (see Martin et al. [2005]), as there is a temporary loss of suitable habitat and the organism is truly absent, and we conclude that only the long-term monitoring data (i.e., all standard sites included) should form the basis of any inference regarding the long-term ecological relationships of Rio Grande Silvery Minnow.

Sampling Precision and Timing

Over the past three decades, there have been remarkable changes (e.g., over three orders of magnitude [> 100,000% increase or > 99.9% decrease]) in the densities of Rio Grande Silvery Minnow. Despite these substantial changes, the relative precision of estimated densities was adequate to frequently detect significant increases or decreases across years. Further, analyses of sampling variation across days (based on repeated sampling during November [2005–2022]) revealed that sampling occasion and reach were far less informative in explaining changes in the density of Rio Grande Silvery

Minnow over time as compared with year. These repeated-sampling analyses also generated population trends that were remarkably like those obtained from the long-term October density data (1993–2022). Thus, the current sampling protocols are resulting in a reliable level of sampling precision and population trend consistency, especially when considering the substantial changes in the occurrence and density of Rio Grande Silvery Minnow over time.

While October and November sampling efforts revealed very similar trends in the estimated densities of Rio Grande Silvery Minnow over time (2005–2022), its densities tended to be somewhat higher in November than in October. One possible explanation for this pattern could be the tendency of Rio Grande Silvery Minnow to congregate more in deeper and lower velocity habitats when water temperatures are cooler (Dudley and Platania 1997a). November repeated-sampling data were particularly useful during years when this species was very rare (e.g., 2012–2014), as these data provided another metric by which to assess subtle changes in its occurrence and density during periods of low abundance. For example, the November repeated-sampling efforts (i.e., sites sampled four times) yielded at least some individuals each year from 2012 to 2014, whereas the October sampling efforts (i.e., sites sampled once) yielded no individuals in 2012 or 2014. Further, the November data are even more powerful when considered collectively as part of the site occupancy study (2005–2022; Appendix B), as those analyses provide a robust long-term assessment of the conservation status of Rio Grande Silvery Minnow.

The timing of sampling also likely affected the accuracy of age-class designations, which were based on the standard length of Rio Grande Silvery Minnow. Although different age-classes (i.e., age-0, age-1, and age-2+) are presented in this report (e.g., Appendix F), those designations should be interpreted very cautiously. For example, the length-based distinctions between age-1 and age-2+ individuals are quite unclear across both reaches and seasons (Horwitz et al. 2018). While age-0 and age-1+ fish can be confidently distinguished following spawning until about July of each year, this length-based distinction becomes progressively less certain throughout the remainder of the year (e.g., Dudley and Platania 1996, 1997b; Horwitz et al. 2018). Mixture models were not constructed for different age-classes (e.g., age-0, age-1, or age-2+) because of the uncertainty in assigning age-class based strictly on standard length, particularly during autumn when the lengths of individuals broadly overlapped across reaches and annual cohorts (e.g., Dudley and Platania 1996, 1997b; Horwitz et al. 2018).

Mesohabitat Associations

A qualitative examination of the mesohabitats occupied by Rio Grande Silvery Minnow was conducted to obtain general information on the habitat-use patterns of this species. While the physical locations of mesohabitats shift around considerably over time, established sampling protocols for this study ensured that similar mesohabitats (i.e., depths and velocities) were sampled across years. We sampled a wide variety of mesohabitats to ensure balanced monitoring of the ichthyofaunal community and all life phases of Rio Grande Silvery Minnow. Population trends in the five different mesohabitats (BW, PO, RU, SHPO, SHRU) were quite similar over the study period (2002–2022), despite notable differences in the estimated densities of Rio Grande Silvery Minnow among mesohabitats. Densities were typically highest in lower velocity mesohabitats and lowest in higher velocity mesohabitats. General mesohabitat-use patterns observed during this study were comparable to those documented during past studies (e.g., Dudley and Platania 1997a).

Encouragingly, the population trends generated from the mesohabitat-specific density data (2002–2022) and sampling-site density data (1993–2022) were remarkably consistent even though they were measured on two widely different spatial scales. While either mesohabitat-specific or sampling-site density data can be used to evaluate population trends since 2002, any evaluation from 1993 to 2001 is solely dependent on sampling-site density data. As the sampling-site density data have been collected over a much longer period (1993–2022), they are more appropriate than the mesohabitat-specific density data for modeling the effects of different seasonal flow patterns (e.g., increased spring runoff or decreased summer flows) on the October occurrence and density of Rio Grande Silvery Minnow.

Spatial Distribution Patterns

Sampling efforts during October (1993–2022) indicated that the highest densities of juvenile Rio Grande Silvery Minnow were nearly always in the Isleta and San Acacia reaches. This pattern has persisted over time even though all three reaches have been regularly augmented with large numbers of hatchery-reared fish since 2002 (Archdeacon 2023). The few exceptions to this pattern have occurred in years when flows in the San Acacia Reach were unusually low during spring and summer (e.g., 2002 and 2012) or following notable augmentation efforts and improved flow conditions in the Angostura Reach (e.g., 2019).

One explanation for this pattern of increasing densities in downstream reaches is the cumulative longitudinal transport of drifting eggs and larvae past instream barriers over time (Dudley and Platania 2007). Although it is unknown how far Rio Grande Silvery Minnow might disperse back upstream if unimpeded, VIE-marked adults dispersed over 25 km upstream to the base of San Acacia Diversion Dam within a few months (Platania et al. 2020). In addition to downstream dispersal past diversion dams, river channelization, habitat degradation, abandonment of the floodplain, and reductions in suspended sediments (Lagasse 1980; Massong et al. 2006) are likely limiting the number of appropriate habitats available for the successful retention and recruitment of early life phases. Further, it is evident that seasonal inundation of side-channel and floodplain habitats, combined with extensive restoration of aquatic habitat complexity, should lead to increased propagule retention and recruitment success for Rio Grande Silvery Minnow and other pelagophils in Southwestern rivers (Dudley and Platania 2007; Widmer et al. 2012; Medley and Shirey 2013; Gonzales et al. 2014; Valdez et al. 2019; Dudley et al. 2022b). However, the long-term efficacy of these management and restoration efforts will also depend on ensuring their utility and permanence by restoring a more dynamic flow regime and reestablishing river connectivity across fragmented reaches (Dudley and Platania 2007).

Additionally, we have analyzed larval and non-larval fish data separately since 2016 (i.e., based on developmental phases), to examine the seasonal patterns of distribution and abundance more closely for Rio Grande Silvery Minnow. While nearly all larvae have been collected during June or July, we have occasionally collected a few metalarvae during August. The late larval developmental phase of these individuals suggests that they were likely spawned in late June or early July, but a targeted study (i.e., otolith examination) would be required to precisely determine the timing of spawning or the subsequent age-growth relationship.

Although larval densities of Rio Grande Silvery Minnow were similarly elevated in all three reaches following spring spawning from 2016 to 2022, densities of age-0 fish (non-larval) were often lower in the Angostura Reach throughout the summer and autumn. Densities of age-0 fish (non-larval) generally peaked somewhat later, and subsequently remained higher, in the San Acacia Reach than in the two upstream reaches. These findings seem to suggest that: (1) survival of young was relatively lower in the Angostura Reach than in the two downstream reaches, (2) young were progressively dispersing downstream, either passively or actively, during the spring and summer, or (3) these patterns were caused by some combination of the first two factors. However, these seasonal reach-specific patterns were based only on recent data (i.e., since 2016), do not account for variation across sites within a reach (i.e., no confidence intervals), and could change over time depending on annual spring and summer flow conditions. Thus, potential differences in recent reach-specific densities of Rio Grande Silvery Minnow should be interpreted cautiously.

Long-Term Ecological Relationships

There were notable changes in the relative and rank abundance of Middle Rio Grande fish species over time (1993–2022). Several species (e.g., Rio Grande Silvery Minnow, Longnose Dace, and River Carpsucker) changed dramatically in rank abundance across years. However, the overall rank abundance of fishes remained remarkably consistent over time. The dynamic changes in species rank abundance could indicate that key environmental conditions are controlling species-specific abundance over time. It is likely that changes in the timing, magnitude, and duration of flows could be an important factor leading to the observed spatiotemporal differences in fish species abundance. For this study, an intense and focused effort was made to elucidate possible flow patterns that could account for the

variation observed in the occurrence and density of Rio Grande Silvery Minnow across years. However, additional study would help further determine those environmental factors that most influence the spatial and temporal patterns of occurrence and density for other Middle Rio Grande fish species (Hoagstrom et al. 2010).

Comparison of changes in Rio Grande Silvery Minnow occurrence and density during October (1993–2022) with hydrological metrics revealed several strong ecological relationships. Elevated and prolonged flows during the spawning/rearing season (i.e., primarily May–June) were closely related to the increased occurrence and density of Rio Grande Silvery Minnow. In contrast, extended low flows during summer were consistently related to its decreased occurrence and density. Modeling these distinct population responses (occurrence vs. density) provided valuable insights into long-term population trends for this species. While these hydrological metrics were not chosen to provide detailed assessments of seasonal flows across sites or reaches, our analyses indicated that elevated and extended spring flows were most predictive of range-wide increases in the occurrence and density of this species over time. Comparable findings, using portions of our dataset and a Bayesian modeling framework (Walsworth and Budy 2021 [Data: 1993–2017]; Yackulic et al. 2022 [Data: 2002–2018]), further support the ecological insights from our long-term population monitoring study (1993–2022). Similarly, higher numbers of young Rio Grande Silvery Minnow, collected in isolated pools during periodic river-drying events from June to October (2009–2015), were associated with elevated mean May discharge during the same year (Archdeacon 2016). In contrast, prolonged low flows during spring and summer reduce juvenile/adult survival rates, which could negatively impact long-term population persistence (Dudley et al. 2009; Archdeacon and Reale 2020; Hatch et al. 2020; Dudley et al. 2022a).

Prolonged and elevated spring flows result in overbank flooding of vegetated areas and the formation of inundated habitats within the river channel (e.g., shoreline pools and backwaters). These shallow low-velocity habitats, which typically increase in number and extent during spring runoff, are essential for the successful recruitment of larvae for many freshwater fishes throughout the world (Welcomme 1979; Junk et al. 1989; Matthews 1998). In the absence of adequate spring flows (e.g., during extended droughts), however, pelagic-spawning cyprinids appear to be particularly susceptible to recruitment failure (Perkin et al. 2019). It is likely that similar processes are also affecting the survival and recruitment of native fishes in the Middle Rio Grande, including early life phases of Rio Grande Silvery Minnow (Pease et al. 2006; Turner et al. 2010; Hoagstrom and Turner 2013; Archdeacon et al. 2020a; Dudley et al. 2022b).

Years with elevated and extended spring flows typically had the lowest occurrence probabilities and passage rates (i.e., low downstream transport) of Rio Grande Silvery Minnow eggs. (Dudley et al. 2022b). In contrast, years with lower and more variable flows were often associated with increased occurrence probabilities and passage rates (i.e., high downstream transport). These differences in downstream transport rates are likely caused by disparities in habitat complexity during higher (i.e., floodplain inundation) and lower (i.e., non-braided channel) flows across years, which differentially affect drifting egg transport efficiencies (Dudley and Platania 2007; Widmer et al. 2012). High sustained flows also result in the inundation of productive nursery habitats, which are crucial for the retention and survival of early life phases of this species in the Middle Rio Grande (Dudley and Platania 1997a; Magaña 2012; Medley and Shirey 2013; Hutson et al. 2018; Valdez et al. 2019; Dudley et al. 2022b). Further, individuals spawned during spring probably have a higher survivorship than those spawned during summer, as there would likely be reduced competition from other larval fishes for food resources (Pease et al. 2006; Krabbenhoft et al. 2014), which become widely available shortly after the initial inundation of floodplain habitats (Junk et al. 1989).

Although short-term floodplain inundation, based on five-day peak flows in May (USACE 2010), was related to the elevated occurrence and density of Rio Grande Silvery Minnow, this relationship was considerably weaker than relationships with long-term elevated flows (i.e., May–June). As growth from the egg phase through the vulnerable early larval phases (i.e., protolarvae and mesolarvae) requires about one month (Platania 1995b), the seasonal inundation and persistence of nursery habitats is essential for ensuring the successful recruitment and survival of young to later life phases (i.e., metalarvae and juveniles). Additional research on the early life history of Rio Grande Silvery Minnow (e.g., collecting drifting eggs and drifting larvae concurrently during spring and summer) would help to elucidate these complex ecological relationships, while also potentially providing valuable management insights.

Conclusions and Implications

Despite recurring and sometimes sustained declines in the occurrence and density of Rio Grande Silvery Minnow following periods of poor spring runoff and prolonged low flows during summer (e.g., 2002–2003 and 2012–2014), it is encouraging that this species has rebounded relatively quickly following consecutive years with improved spawning and recruitment conditions (e.g., 2004–2005 and 2015–2017). Similarly, the genetic effective population size of this species was very low during the drought years of the early 2000s (Alò and Turner 2005) but increased in subsequent years following improved seasonal flow conditions, intense augmentation efforts, and the implementation of a robust propagation management plan (Osborne et al. 2012; Osborne et al. 2022). Based on autumn–winter sampling, there was a progressive decrease in the genetic effective population size of Rio Grande Silvery Minnow from 2016–2017 to 2020–2021, followed by a modest increase in 2021–2022 (Osborne et al. 2022). These rising and falling trends in genetic diversity generally reflect the underlying trends in population dynamics that we have documented in our study of this species over the past three decades. However, exceptionally low levels of genetic diversity, combined with periods of vastly reduced occurrence and density, continue to threaten the long-term persistence of Rio Grande Silvery Minnow.

While extensive and diverse management efforts over the past three decades have provided protection against the extinction of Rio Grande Silvery Minnow, ongoing and planned efforts (e.g., restoring dynamic river flows, reconnecting fragmented reaches, and reestablishing a functional floodplain) should help to support resilient and self-sustaining populations of this imperiled species in the future. Unfortunately, both the occurrence and density of Rio Grande Silvery Minnow decreased in 2022, following an early/truncated spring runoff and poor summer flow conditions. Continued efforts to provide reasonable spring spawning and summer survival conditions will be essential for securing a self-sustaining wild population of this species in the Middle Rio Grande. Additionally, reestablishing resilient populations at other locations within its historical range would substantially help to further ensure its long-term persistence in the wild. Finally, future study of the relationships among aquatic species (i.e., from plankton to fish), instream habitats, and river flows should continue to elucidate key factors that regulate this complex ecosystem, which will be essential for developing and implementing successful strategies for the long-term recovery of Rio Grande Silvery Minnow.

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APPENDIX A (Sampling Sites)

Middle Rio Grande Fish Sampling Sites

Table A1. Sampling reaches and standard sites for population monitoring of Rio Grande Silvery Minnow in the Middle Rio Grande.

Reach and Site	Locality
Angostura Reach	
1	New Mexico, Sandoval County, Rio Grande, just downstream of Angostura Diversion Dam, Algodones. River Mile: 209.9; UTM Easting: 363665; UTM Northing: 3916331; Zone: 13; Datum: NAD83
2	New Mexico, Sandoval County, Rio Grande, at US HWY 550 bridge crossing, Bernalillo. River Mile: 203.9; UTM Easting: 358457; UTM Northing: 3909887; Zone: 13; Datum: NAD83
3	New Mexico, Sandoval County, Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho. River Mile: 199.9; UTM Easting: 354728; UTM Northing: 3905587; Zone: 13; Datum: NAD83
4	New Mexico, Bernalillo County, Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque. River Mile: 183.4; UTM Easting: 346719; UTM Northing: 3884331; Zone: 13; Datum: NAD83
5	New Mexico, Bernalillo County, Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque. River Mile: 178.4; UTM Easting: 347468; UTM Northing: 3877400; Zone: 13; Datum: NAD83
Isleta Reach	
6	New Mexico, Valencia County, Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas. River Mile: 161.7; UTM Easting: 343149; UTM Northing: 3853187; Zone: 13; Datum: NAD83
7	New Mexico, Valencia County, Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen. River Mile: 150.8; UTM Easting: 340105; UTM Northing: 3837722; Zone: 13; Datum: NAD83
8	New Mexico, Valencia County, Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales. River Mile: 143.2; UTM Easting: 338020; UTM Northing: 3827545; Zone: 13; Datum: NAD83
9	New Mexico, Socorro County, Rio Grande, at US HWY 60 bridge crossing, Bernardo. River Mile: 130.6; UTM Easting: 334578; UTM Northing: 3809921; Zone: 13; Datum: NAD83
10	New Mexico, Socorro County, Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo. River Mile: 126.8; UTM Easting: 330946; UTM Northing: 3805307; Zone: 13; Datum: NAD83
11	New Mexico, Socorro County, Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia. River Mile: 117.3; UTM Easting: 328152; UTM Northing: 3792564; Zone: 13; Datum: NAD83

Table A1. Sampling reaches and standard sites for population monitoring of Rio Grande Silvery Minnow in the Middle Rio Grande (continued).

Reach and Site	Locality
San Acacia Reach	
12	New Mexico, Socorro County, Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia. River Mile: 115.6; UTM Easting: 325960; UTM Northing: 3792182; Zone: 13; Datum: NAD83
13	New Mexico, Socorro County, Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia. River Mile: 114.1; UTM Easting: 325390; UTM Northing: 3790397; Zone: 13; Datum: NAD83
14	New Mexico, Socorro County, Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro. River Mile: 99.6; UTM Easting: 327231; UTM Northing: 3771432; Zone: 13; Datum: NAD83
15	New Mexico, Socorro County, Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio. River Mile: 92.0; UTM Easting: 328151; UTM Northing: 3761487; Zone: 13; Datum: NAD83
16	New Mexico, Socorro County, Rio Grande, at US HWY 380 bridge crossing, San Antonio. River Mile: 87.8; UTM Easting: 328907; UTM Northing: 3754926; Zone: 13; Datum: NAD83
17	New Mexico, Socorro County, Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio. River Mile: 79.0; UTM Easting: 327219; UTM Northing: 3740906; Zone: 13; Datum: NAD83
18	New Mexico, Socorro County, Rio Grande, at San Marcial Railroad bridge crossing, San Marcial. River Mile: 68.3; UTM Easting: 315091; UTM Northing: 3728487; Zone: 13; Datum: NAD83
19	New Mexico, Socorro County, Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial. River Mile: 60.1; UTM Easting: 309441; UTM Northing: 3718309; Zone: 13; Datum: NAD83
20	New Mexico, Socorro County, Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial. River Mile: 58.5; UTM Easting: 307767; UTM Northing: 3716360; Zone: 13; Datum: NAD83

Table A2. Sampling reaches and additional sites for population monitoring of Rio Grande Silvery Minnow in the Middle Rio Grande.

Reach and Site	Locality
Angostura Reach	
21	New Mexico, Sandoval County, Rio Grande, ca. 4.4 miles upstream of Alameda Blvd. (NM State Hwy. 528) bridge crossing, Corrales. River Mile: 196.6; UTM Easting: 355531; UTM Northing: 3900626; Zone: 13; Datum: NAD83
22	New Mexico, Sandoval County, Rio Grande, ca. 1.1 miles upstream of Alameda Blvd. (NM State Hwy. 528) bridge crossing, Corrales. River Mile: 193.1; UTM Easting: 351562; UTM Northing: 3897190; Zone: 13; Datum: NAD83
23	New Mexico, Bernalillo County, Rio Grande, ca. 1.0 miles downstream of Paseo del Norte Blvd. (NM State Hwy. 423) bridge crossing Albuquerque. River Mile: 190.0; UTM Easting: 349214; UTM Northing: 3893063; Zone: 13; Datum: NAD83
24	New Mexico, Bernalillo County, Rio Grande, ca. 1.1 miles upstream of I-40 bridge crossing, Albuquerque. River Mile: 186.1; UTM Easting: 346011; UTM Northing: 3887973; Zone: 13; Datum: NAD83
25	New Mexico, Bernalillo County, Rio Grande, ca. 1.5 miles upstream of I-25 bridge crossing, Isleta. River Mile: 174.0; UTM Easting: 345900; UTM Northing: 3870990; Zone: 13; Datum: NAD83
Isleta Reach	
26	New Mexico, Valencia County, Rio Grande, ca. 4.1 miles upstream of NM State Hwy. 6 bridge crossing, Los Lunas. River Mile: 165.2; UTM Easting: 342799; UTM Northing: 3858637; Zone: 13; Datum: NAD83
27	New Mexico, Valencia County, Rio Grande, ca. 6.2 miles upstream of NM State Hwy. 309 bridge crossing, Belen. River Mile: 156.0; UTM Easting: 340647; UTM Northing: 3845146; Zone: 13; Datum: NAD83
28	New Mexico, Socorro County, Rio Grande, ca. 6.3 miles upstream of US Hwy. 60 bridge crossing, Bernardo. River Mile: 137.1; UTM Easting: 335554; UTM Northing: 3819543; Zone: 13; Datum: NAD83
29	New Mexico, Socorro County, Rio Grande, ca. 1.5 miles upstream of confluence with the Rio Salado, San Acacia. River Mile: 120.1; UTM Easting: 330498; UTM Northing: 3795053; Zone: 13; Datum: NAD83
San Acacia Reach	
30	New Mexico, Socorro County, Rio Grande, ca. 2.6 miles upstream of Pueblitos Rd. bridge crossing, Escondida. River Mile: 107.1; UTM Easting: 326303; UTM Northing: 3781123; Zone: 13; Datum: NAD83

Table A3. Sampling reaches and replacement sites for population monitoring of Rio Grande Silvery Minnow in the Middle Rio Grande.

Reach and Site	Locality
Isleta Reach	
44	New Mexico, Valencia County, Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen. River Mile: 150.5; UTM Easting: 340084; UTM Northing: 3837308; Zone: 13; Datum: NAD83
San Acacia Reach	
51	New Mexico, Socorro County, Rio Grande, ca. 5.0 mi downstream of San Acacia Diversion Dam, San Acacia. River Mile: 110.8; UTM Easting: 325855; UTM Northing: 3786216; Zone: 13; Datum: NAD83
52	New Mexico, Socorro County, Rio Grande, ca. 2.2 mi. downstream of Pueblitos Rd. bridge crossing, Escondida. River Mile: 101.7; UTM Easting: 327091; UTM Northing: 3773950; Zone: 13; Datum: NAD83
53	New Mexico, Socorro County, Rio Grande, ca. 3.1 mi downstream of the Socorro Low Flow Conveyance Channel bridge crossing, Socorro. River Mile: 96.0; UTM Easting: 327928; UTM Northing: 3766570; Zone: 13; Datum: NAD83
54	New Mexico, Socorro County, Rio Grande, ca. 4.7 mi. downstream of Socorro LFCC bridge crossing, Socorro. River Mile: 94.2; UTM Easting: 327288; UTM Northing: 3764453; Zone: 13; Datum: NAD83
56	New Mexico, Socorro County, Rio Grande, ca. 2.1 miles upstream of San Antonio bridge crossing, San Antonio. River Mile: 89.3; UTM Easting: 329188; UTM Northing: 3758027; Zone: 13; Datum: NAD83
58	New Mexico, Socorro County, Rio Grande, ca. 1.8 mi. upstream of San Marcial Railroad bridge crossing, San Marcial. River Mile: 70.1; UTM Easting: 318083; UTM Northing: 3728535; Zone: 13; Datum: NAD83
59	New Mexico, Socorro County, Rio Grande, ca. 5.1 mi. downstream of San Marcial Railroad bridge crossing, San Marcial. River Mile: 63.3; UTM Easting: 313269; UTM Northing: 3721434; Zone: 13; Datum: NAD83
60	New Mexico, Socorro County, Rio Grande, ca. 6.4 mi. downstream of San Marcial Railroad bridge crossing, San Marcial. River Mile: 61.8; UTM Easting: 311422; UTM Northing: 3719873; Zone: 13; Datum: NAD83

APPENDIX B (Rio Grande Silvery Minnow Site Occupancy)

INTRODUCTION

The Rio Grande Silvery Minnow site occupancy study was initiated because of our insights from statistical analyses of its estimated densities across multiple sampling days. This extensive dataset provided an opportunity to further study the site occupancy patterns of this imperiled species over time (2005–2022). The site occupancy dataset was based on repeated-sampling efforts at our 20 long-term monitoring sites during November. While the first few years of sampling yielded only preliminary results and relatively simplistic models, this study now includes a series of robust occupancy models that generate annual estimates of the occupancy, extinction, colonization, and detection probabilities for Rio Grande Silvery Minnow. Although these estimates are based on data collected at numerous sampling sites and are indicative of range-wide trends, they are not absolute measurements of conservation status (i.e., extinction probability refers to loss of the species from individual sites [extirpation] vs. complete loss of the species from the wild [extinction]). Further, these long-term conservation status assessments are dependent on the ongoing and consistent monitoring of Rio Grande Silvery Minnow, as part of the November repeated-sampling efforts (2005–2022).

Techniques to estimate the presence-absence and abundance of organisms, which do not require full site depletion or mark-recapture of individuals, have been shown to be reliable for a variety of species (see Royle and Nichols 2003). Statistical methods have been developed that account for the inherent heterogeneity of population abundance across sites. Presence-absence data provide crucial information for estimating the probabilities that underlie spatial patterns of species abundance in the environment (MacKenzie et al. 2003). In other words, the absence of a species during sampling does not necessarily mean that the species is truly absent from the area (MacKenzie et al. 2002; Finley et al. 2005; White 2005).

By fully incorporating these complexities into our site occupancy models, we have generated robust estimates of the occupancy, extinction, colonization, and detection probabilities for Rio Grande Silvery Minnow over time (2005–2022). Our site occupancy analyses also complement and enhance the ecological insights provided by the long-term population monitoring study (1993–2022). In contrast to the population monitoring study, which documents trends over multiple intervals (i.e., monthly and annual) for the entire ichthyofaunal community, this study provides targeted estimates of Rio Grande Silvery Minnow site occupancy rates across years. The primary objectives of this study are to evaluate annual changes in the occupancy, extinction, colonization, and detection probabilities for Rio Grande Silvery Minnow and assess the dynamic conservation status of this imperiled species over time.

METHODS

Repeated sampling data from population monitoring efforts (multi-day sampling efforts during November [2005–2022]) were used to generate estimates of site occupancy rates based on methods developed by MacKenzie et al. (2002, 2003, 2006). This study was conducted using the same sampling protocols and 20 standard sites established for the long-term population monitoring study. In our study, mesohabitats were sampled at the same locations on subsequent days, except in rare cases (e.g., location moved slightly because of increased water velocity). Developing site occupancy rates for Rio Grande Silvery Minnow enabled assessment of the likelihood of detecting its presence or absence (i.e., detection probability) based on the encounter history. The encounter history of wild Rio Grande Silvery Minnow at the sampling sites was based on the four repeated-sampling efforts. For example, an encounter history of 1101 at a particular site meant that individuals were collected on days one, two, and four but not on day three. A higher proportion of presence encounters indicated that individuals were more consistently detected at the site over time.

We constructed a multiyear statistical model, based on patterns of occupancy (Appendix D), to better understand Rio Grande Silvery Minnow population dynamics and conservation status over time. Site occupancy was the proportion of sites occupied relative to those surveyed. The estimated occupancy probability for each site was based on the raw site-occupancy data and the estimated detection probability (and its associated variance). In this way, the occupancy probability was appropriately corrected based on the detection probability (MacKenzie et al. 2006). Increased consistency across days (either 0000 or 1111) will result in a site occupancy model with results that more closely match those obtained from the original estimate of site occupancy probability based on a single survey. We reasoned that sampling sites were large enough (ca. 200 m) that it was unlikely that a site would change in status from occupied to unoccupied across sequential days. Additional assumptions included that there could be no false detections, that there could be sites where the species was present but undetected, and that species detection at any site was independent of species detection at other sites (Appendix E [Table E2]). The encounter history data from the sampling sites allowed for a robust-design model of occupancy (MacKenzie et al. 2003), based on annual sampling efforts, to estimate the probability of occupancy (psi, ψ), the probability of extinction at occupied sites (epsilon, ε), the probability of colonization at unoccupied sites (gamma, γ), and the probability of detection (p).

Site occupancy models were constructed, using Program MARK (White and Burnham 1999), with year (Year) and sampling occasion (Occasion) as covariates. Models were not constructed for different age-classes (e.g., age-0, age-1, or age-2+) because of the uncertainty in assigning age-class based strictly on standard length, particularly during autumn when the lengths of individuals broadly overlapped across reaches and annual cohorts (e.g., Dudley and Platania 1996, 1997; Horwitz et al. 2018). Different models were considered that allowed detection probabilities to vary by site and reach. Likewise, the occupancy probability was allowed to vary by reach. Akaike's information criterion (Akaike 1973), corrected for finite sample sizes (AIC_c), was used to select the most parsimonious site occupancy model based on the encounter history data. Models were not averaged because some annual parameter estimates had a standard error of zero. Annual estimates of the occupancy, extinction, colonization, and detection probabilities were generated based on the year model (i.e., ψ[.] ε[Year] γ[Year] p[Year]). Associated measures of sampling variance, and confidence intervals, were generated for all model parameter estimates, following the methods of MacKenzie et al. (2006).

RESULTS

Multiyear models, based on patterns of site occupancy, were developed for Rio Grande Silvery Minnow using long-term (2005–2022) sampling-site data (Table B1). The top AIC_c model (AIC_c weight = 62.9%) had constant occupancy (ψ) and colonization (γ) probabilities, but extinction (ε) and detection probabilities (p) that varied across years. The second and third ranked models had detection probabilities and colonization/detection probabilities that varied across years, respectively. Models that included sampling occasion (e.g., ψ(.) ε(.) γ(.) p(Year*Occasion)) received essentially no AIC_c weight (< 0.01%), indicating that the day of sampling was not informative in explaining variation in detection probability over time.

Estimates of occupancy probability (ψ) were consistently elevated from 2015 to 2017, but then decreased from 2017 to 2018 (Figure B1). While the occupancy probability was 1.00 in 2019, it had decreased to 0.49 by 2022. There was, however, increased uncertainty in occupancy probabilities (i.e., broad confidence intervals) during years when individuals were absent from many sites over multiple sampling days (e.g., 2018, 2020, and 2022). The progressive decline, or rebound, of occupancy probabilities typically unfolded slowly over several years. Further, these occupancy patterns coincided closely with the underlying hydrological patterns of the Middle Rio Grande over time (2005–2022; Figure B2). Consecutive years with low spring and summer flows (e.g., 2012–2014) were associated with the lowest estimates of occupancy probability. In contrast, years with high flows (e.g., 2017 and 2019) often had the highest estimates of occupancy probability.

Estimates of extinction probability (ε) were consistently low from 2006 to 2010, progressively increased from 2010 to 2013, and remained elevated in 2014 (Figure B3). However, so few sites were occupied from 2012 to 2014 that there were not many sites left where the species status could change from present to absent (or vice versa), which led to uncertain estimates during this period. While the extinction probability decreased from 0.35 in 2020 to 0.07 in 2021, it increased to 0.53 in 2022.

Estimated colonization probabilities (γ) were generally highest following extended periods of elevated extinction probabilities. While the colonization probability was relatively low from 2006 to 2013, it steadily increased from 2013 to 2017, as individuals were progressively detected at sites that were unoccupied in 2013. As all 20 sites were occupied in 2019, the colonization probability declined to zero in 2020 (i.e., no further colonization possible). The colonization probability was 0.60 in 2021 and was very similar (0.58) in 2022.

The transition between elevated extinction and colonization probabilities mirrored patterns observed for occupancy probabilities over time. Extinction probabilities were typically highest during low flow periods (i.e., droughts) that persisted over several years (Figure B4). In contrast, colonization probabilities often peaked when extended high flows, during spring and summer, persisted over several years. While the long-term conservation status of Rio Grande Silvery Minnow improved from 2020 to 2021, its status again declined in 2022.

Table B1. Site occupancy models for Rio Grande Silvery Minnow, using November sampling-site data (2005–2022).

Site Occupancy Models[1]	logLike[2]	K[3]	AIC_c[4]	w_i[4]
ψ(.) ε(Year) γ(.) *p*(Year)	947.57	37	1,030.30	0.6290
ψ(.) ε(.) γ(.) *p*(Year)	986.63	21	1,031.36	0.3705
ψ(.) ε(.) γ(Year) *p*(Year)	969.11	34	1,044.43	0.0005
ψ(.) ε(Year) γ(Year) *p*(Year)	925.48	53	1,050.19	< 0.0001
ψ(.) ε(.) γ(.) *p*(Year*Occasion)	934.88	75	1,125.02	< 0.0001
ψ(.) ε(Year) γ(.) *p*(Year*Occasion)	892.88	91	1,137.36	< 0.0001
ψ(.) ε(.) γ(Year) *p*(Year*Occasion)	916.85	91	1,161.32	< 0.0001
ψ(.) ε(Year) γ(Year) *p*(Year*Occasion)	867.33	107	1,173.05	< 0.0001
ψ(.) ε(Year) γ(.) *p*(.)	1,256.85	20	1,299.33	< 0.0001
ψ(.) ε(Year) γ(Year) *p*(.)	1,223.26	36	1,303.51	< 0.0001

[1] = Models included all ε, γ, and p combinations of null effects (.) and year (2005–2022), along with a multiplicative effect (year and sampling occasion [i.e., 1st, 2nd, 3rd, or 4th day of sampling]) for detection probability.
[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).

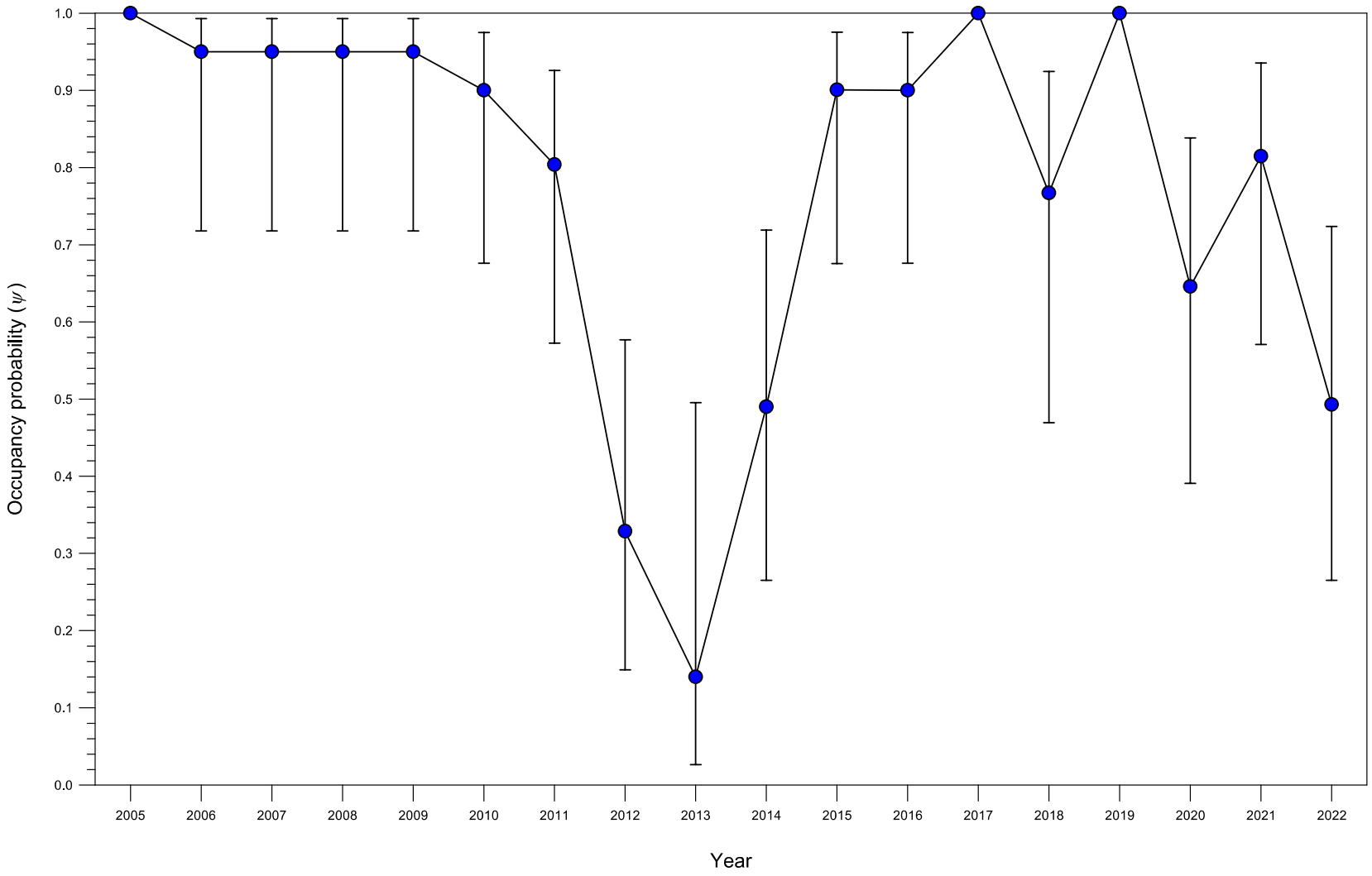

Figure B1. Rio Grande Silvery Minnow occupancy probabilities (estimated using November sampling-site data) across years. Modeled estimates (circles) and 95% confidence intervals (bars) are illustrated.

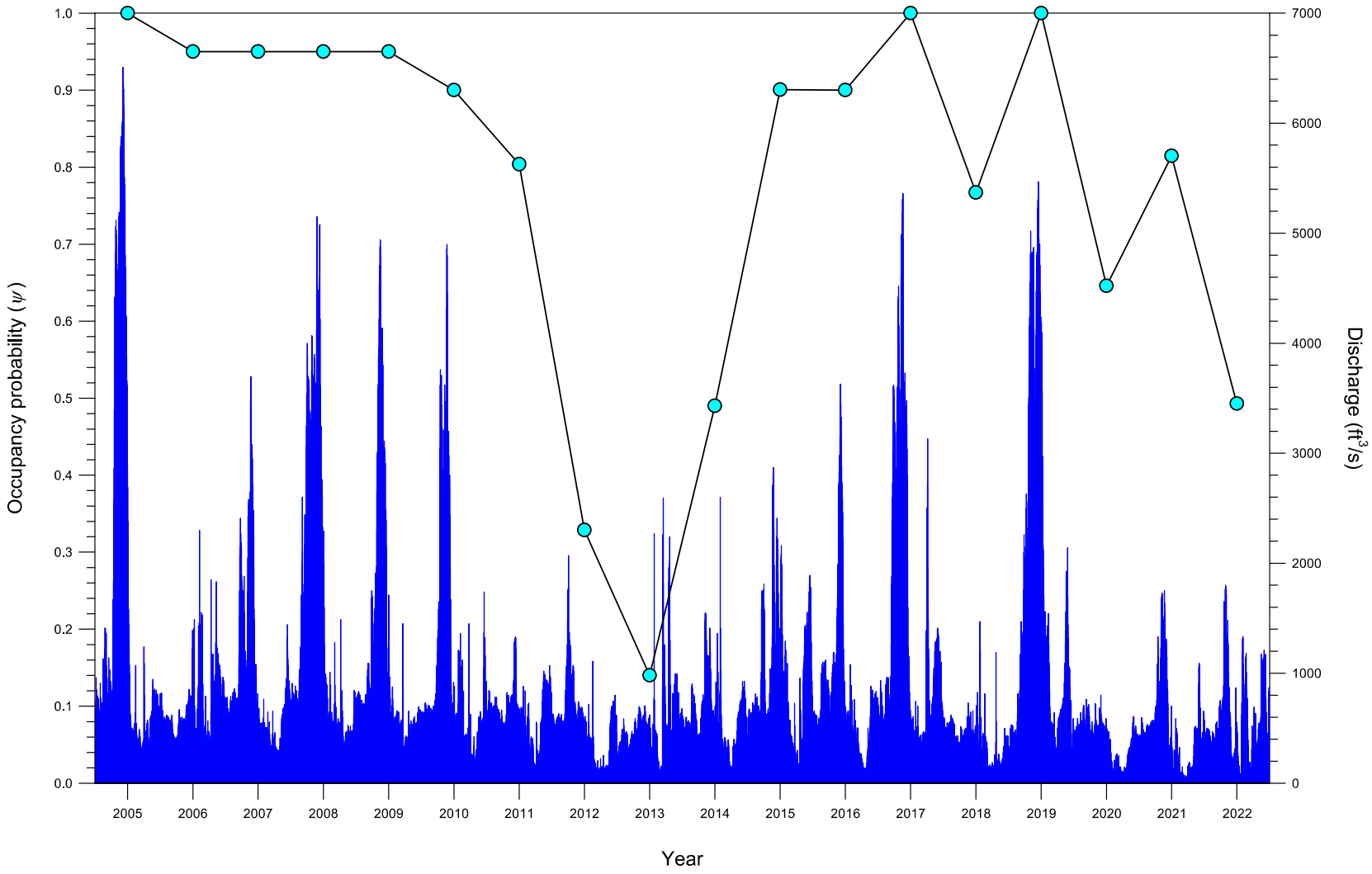

Figure B2. Rio Grande Silvery Minnow occupancy probabilities (estimated using November sampling-site data), and mean daily discharge data from the Albuquerque Gage (2005-01-01 to 2022-12-31), across years.

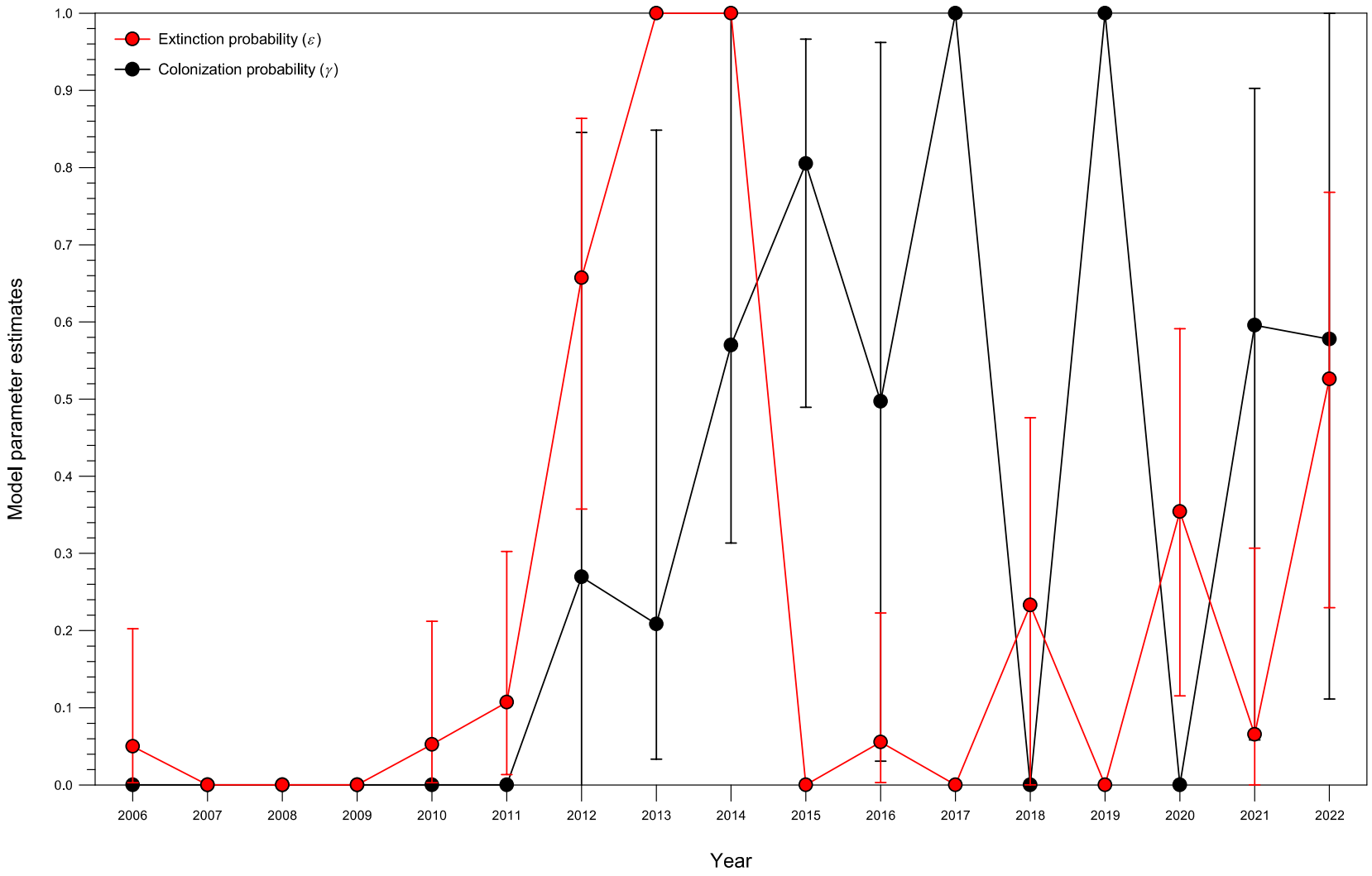

Figure B3. Rio Grande Silvery Minnow extinction/colonization probabilities (estimated using November sampling-site data) across years. Modeled estimates (symbols) and 95% confidence intervals (bars) are illustrated.

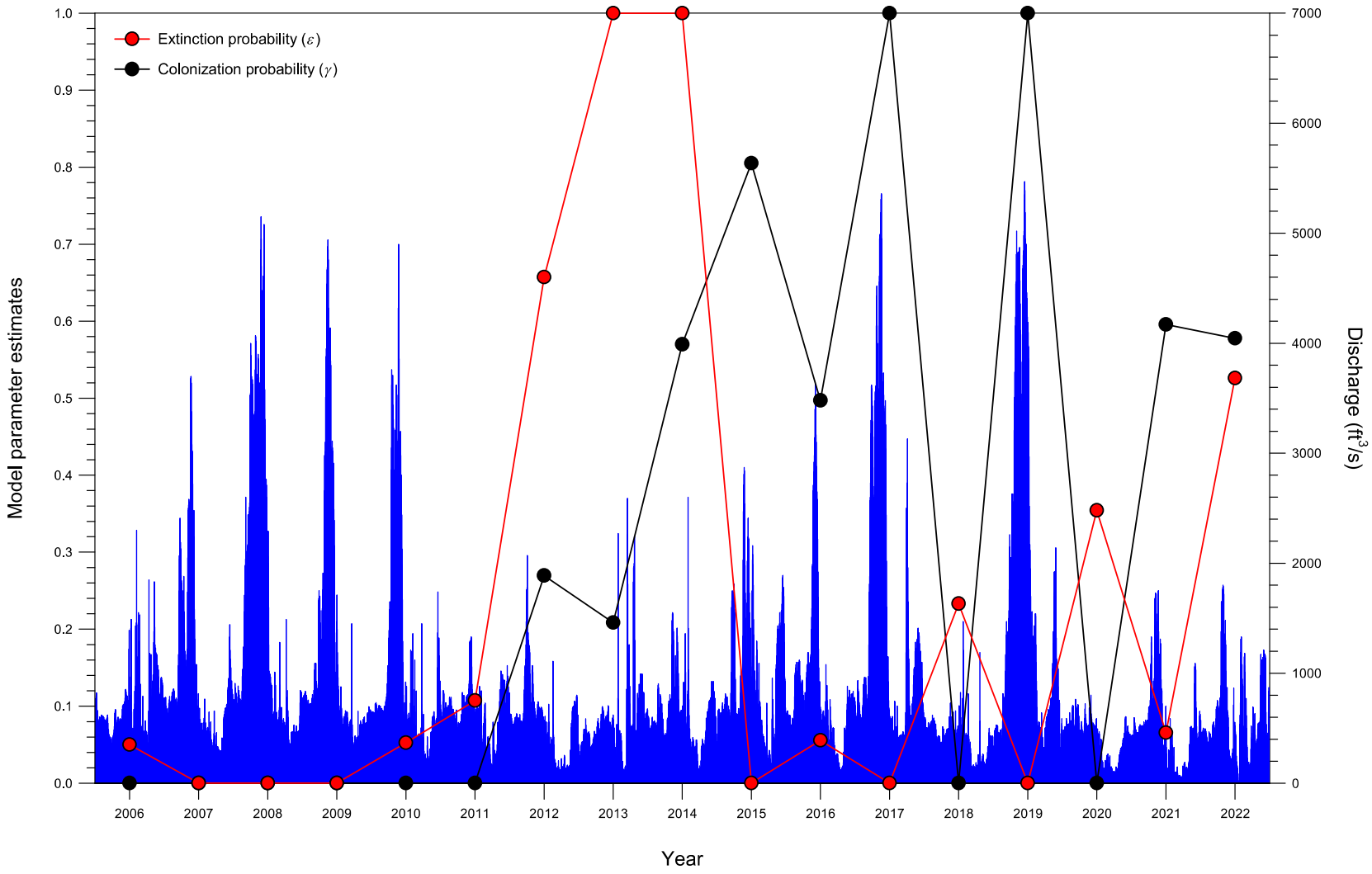

Figure B4. Rio Grande Silvery Minnow extinction/colonization probabilities (estimated using November sampling-site data), and mean daily discharge data from the Albuquerque Gage (2006-01-01 to 2022-12-31), across years.

DISCUSSION

There are numerous benefits to documenting long-term trends in site occupancy rates, particularly for rare species like Rio Grande Silvery Minnow, which may be difficult to detect using traditional single-survey monitoring efforts. From 2005 to 2022, we estimated the occupancy, extinction, colonization, and detection probabilities for Rio Grande Silvery Minnow based on repeated sampling efforts in November. By evaluating trends in these probabilities over time, we were able to assess the changing conservation status of this imperiled species across a wide range of environmental conditions (e.g., high spring flows vs. low summer flows).

While detection probability was estimated for the site occupancy analyses, it was not possible to generate an estimate of capture probability (i.e., a related but separate concept) for Rio Grande Silvery Minnow from either the detection probability or from the underlying repeated-sampling dataset. Also, there was strong positive covariance between detection and occupancy probability, so we chose to illustrate occupancy probability because it was more relevant, accurate, and meaningful. One established method for estimating the capture probability of individuals would be to conduct removal sampling using instream enclosures (e.g., Dudley et al. 2012), but this would require substantial fieldwork outside of the current objectives of this study. Additionally, we found a close statistical relationship between Rio Grande Silvery Minnow population trends (2008–2011) obtained from the population-monitoring and population-estimation studies (Dudley et al. 2012). Thus, it seems highly unlikely that fluctuating capture efficiencies, or detection probabilities, would meaningfully influence long-term density or occupancy trends. Further, our established and statistically-robust monitoring and occupancy studies have both proven essential for assessing the long-term population dynamics and conservation status of Rio Grande Silvery Minnow across a broad range of fish densities and fluctuating environmental conditions.

Our multiyear statistical models illustrated that occupancy, extinction, and colonization probabilities generally had larger confidence intervals during years when this species was rare, as compared to when it was abundant. While the sampling design for this study matched that of the long-term population monitoring study, the 20 sites were sampled four times per month for the site occupancy study vs. once per month for the population monitoring study. Although the site-occupancy sampling intensity seemed appropriate during periods of modest occurrence and density, the ability to precisely estimate site occupancy rates was reduced during periods of very low occurrence and density (e.g., drought years [2012–2014]). During periods of extreme rarity, however, we were still able to reliably estimate site occupancy probabilities and their associated confidence intervals. While occupancy probabilities decreased substantially from 2019 to 2020, there was a rebound in 2021, followed by a marked decline in 2022. These recent occupancy trends, even when Rio Grande Silvery Minnow was rare, appeared closely related to fluctuating hydrological conditions across years (i.e., occupancy was highest following high flows and lowest following low flows).

Extinction probabilities reached some of their highest levels, and colonization probabilities reached some of their lowest levels, during an extended drought (2012–2014) in the Middle Rio Grande. This pronounced extinction/colonization pattern was likely indicative of the exceptionally low spring and summer flows that characterized that period. While the improved spring and summer flows of 2017 and 2019 apparently led to increased colonization probabilities and decreased extinction probabilities, these trends again reversed in 2020 following poor spring and summer flow conditions. Similarly, the brief and somewhat early spring runoff of 2022, as compared with 2021, coincided with a marked increase in the extinction probability and a slight decrease in the colonization probability for this imperiled species.

The current conservation status of Rio Grande Silvery Minnow could change dramatically, however, if there are consecutive years of persistently low flows during the crucial spring-spawning and summer-survival periods. Further, site occupancy rates can change rapidly across years (e.g., 2011–2015 and 2019–2022) depending on unforeseen changes in seasonal flow conditions. Thus, the occupancy, extinction, and colonization probabilities for Rio Grande Silvery Minnow should be viewed as an analysis of historical data as opposed to a prediction of future trends.

The site occupancy results can also be used in combination with the population monitoring results to provide a more robust understanding of the dynamic conservation status of Rio Grande Silvery Minnow over time. Specifically, the extinction probability is a particularly valuable metric by which to assess the vulnerability of the Middle Rio Grande population during extended periods of poor flow conditions,

decreasing numbers of individuals, and declining occupancy probabilities. Consistently high extinction probabilities, particularly when accompanied by low colonization/occupancy probabilities and reduced densities (e.g., 2012–2014), indicate severe and imminent threats to the long-term persistence of Rio Grande Silvery Minnow in the wild.

Although the combined results of the site-occupancy and population-monitoring studies should facilitate a more comprehensive assessment of the conservation status of Rio Grande Silvery Minnow, an increase in sampling effort (e.g., more sites or more samples per site) would increase both the accuracy and precision of the resulting estimates. The strength of inference will ultimately be strongly dependent on these fundamental aspects of the overall study design (Burnham and Anderson 2002; MacKenzie et al. 2006). However, we found that hypothetically doubling the number of sampling sites, as compared to doubling the sampling effort within existing sites, was much more effective in increasing the precision of Rio Grande Silvery Minnow population estimates (Dudley et al. 2012).

Despite the inherent challenges of monitoring rare species, our site occupancy study has provided statistically-robust estimates of the long-term occupancy probability for Rio Grande Silvery Minnow, even during periods of unusually low abundance (e.g., 2012–2014). Although the site-occupancy/population-monitoring sites were not randomly selected, Archdeacon et al. (2015) found no meaningful differences in fish community composition or species-specific densities when using a random vs. nonrandom study design to sample fishes in the Middle Rio Grande. Finally, it is apparent that the synergistic combination of the site-occupancy and population-monitoring studies, despite practical limitations of extensively modifying the existing study designs, has vastly improved our ability to accurately discern trends in the occurrence and density of Rio Grande Silvery Minnow over the past three decades.

It is well established that simply having large numbers of individuals is inadequate to ensure the long-term persistence of a species in the wild (Groom et al. 2006). This is particularly true for short-lived and highly-fecund species, such as Rio Grande Silvery Minnow. The dramatic population fluctuations of this species, often within a short duration, underscore the need to ensure the presence of individuals over a broad geographical range. Different seasonal flow conditions have resulted in substantial changes in the occurrence and density of Rio Grande Silvery Minnow over time (Archdeacon 2016; Dudley et al. 2022). For example, poor spring runoff may inhibit spawning and limit recruitment to such a degree that its densities decline several orders of magnitude within a single year (Dudley et al. 2022). 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. The short life span of this species means that, following extended periods of poor recruitment or survival, the population is inadequately buffered by surviving members of older age-classes (Horwitz et al. 2018; Archdeacon and Reale 2020; Hatch et al. 2020; Dudley et al. 2022). Thus, the establishment of resilient populations of Rio Grande Silvery Minnow, at multiple locations within its current and historical range, would substantially help to ensure its long-term persistence in the wild.

Although the success of this study will be evaluated annually, insight into the efficacy of estimating occupancy, extinction, and colonization probabilities for Rio Grande Silvery Minnow will require a long-term commitment to consistent and systematic monitoring. Data from future monitoring efforts will provide valuable information that will supplement current site-occupancy analyses and facilitate accurate assessments of the conservation status of this imperiled species over time. Ultimately, insights gained from the site-occupancy and population-monitoring studies can collectively be used to objectively evaluate progress towards achieving the long-term recovery of Rio Grande Silvery Minnow.

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APPENDIX C (Water Quality Summary)

Table C1. Water quality statistics based on standard sites (April to October), by reach and site, during 2022.

Reach (Site & Locality)	Water Quality Measurements[1]: Mean (Standard Error) Sec.	Temp.	Sal.	D.O.	Con. T.	Con. S.	pH
Angostura Reach							
1 Angostura Dam	25 (7.4)	19 (2.1)	0.1 (< 0.1)	6.9 (0.7)	248.3 (18.6)	280.3 (15.1)	8 (0.3)
2 Bernalillo	11.9 (2.6)	20.4 (2.1)	0.1 (< 0.1)	6.8 (0.9)	253.3 (11.7)	272.9 (9.7)	8 (0.3)
3 Rio Rancho	11.3 (2.5)	21.1 (2.1)	0.1 (< 0.1)	6.7 (0.7)	261.1 (12.7)	283.1 (7.9)	8.2 (0.1)
4 Central Ave.	9.1 (2.1)	19.3 (2.3)	0.1 (< 0.1)	6.9 (0.7)	258.4 (11.8)	289.6 (5.7)	7.8 (0.3)
5 Rio Bravo Blvd.	10.4 (2)	18.7 (2)	0.1 (< 0.1)	6.8 (0.8)	253.9 (11.6)	289.9 (5.1)	8 (0.3)
Isleta Reach							
6 Los Lunas	7.9 (2.5)	24.8 (2.1)	0.2 (< 0.1)	6 (0.6)	391.3 (26.6)	391.7 (19.5)	7.9 (0.3)
7 Belen	6.3 (1.8)	24.6 (2.1)	0.2 (< 0.1)	6.1 (0.6)	403.9 (49.6)	403.7 (40.9)	7.9 (0.3)
8 Jarales	7.4 (2)	22.1 (1.9)	0.2 (< 0.1)	6.4 (0.7)	425.7 (70.9)	444 (64.9)	7.9 (0.3)
9 Bernardo	6.9 (2)	21.7 (1.7)	0.2 (< 0.1)	6.5 (0.7)	383.6 (28.2)	402.4 (21)	8 (0.3)
10 La Joya	6.1 (1.9)	20.6 (1.6)	0.2 (< 0.1)	6.4 (0.7)	393.6 (30.3)	425 (20.7)	8 (0.3)
11 North of San Acacia	4.4 (1.8)	23.6 (1.9)	0.3 (0.1)	5.8 (0.5)	652.1 (125.6)	651.7 (106.1)	8 (0.2)
San Acacia Reach							
12 San Acacia Dam	4.1 (1.7)	22.6 (1.8)	0.3 (0.1)	6.4 (0.7)	635.1 (126.8)	645 (107.1)	8.1 (0.2)
13 South of San Acacia	4.4 (1.8)	21.8 (1.9)	0.3 (< 0.1)	6.5 (0.8)	606.4 (112.7)	626.3 (95.5)	8 (0.2)
14 Socorro	4.3 (1.6)	21.5 (1.6)	0.3 (0.1)	6.5 (0.8)	599.9 (119.2)	626.6 (106.1)	8 (0.2)
15 North of San Antonio	3.9 (1.3)	20.5 (1.5)	0.3 (0.1)	6.8 (0.9)	596.4 (129.5)	632.1 (117.5)	8.2 (0.2)
16 San Antonio	2.3 (0.9)	25.5 (1.7)	0.3 (0.1)	6.1 (0.6)	630.7 (122.4)	609.4 (103.1)	8.2 (0.2)
17 South of San Antonio	2.3 (0.9)	24.6 (1.7)	0.3 (< 0.1)	6.2 (0.6)	608.4 (108.1)	599.3 (89.7)	8.1 (0.2)
18 San Marcial	2.1 (1)	22.5 (1.6)	0.3 (< 0.1)	6.3 (0.6)	507.4 (58.9)	526.6 (47.2)	8.1 (0.2)
19 South of San Marcial 1	2 (1)	21.7 (1.6)	0.3 (< 0.1)	6.2 (0.7)	509.1 (59.6)	537.3 (49.6)	8.1 (0.2)
20 South of San Marcial 2	1.6 (0.8)	21 (1.5)	0.3 (< 0.1)	6.1 (0.7)	503.6 (56.2)	539.3 (47.5)	7.9 (0.2)

[1] = Water quality descriptions were based on USGS definitions (i.e., National field manual for the collection of water-quality data):
Sec. = Secchi depth (cm); Disk with black and white quadrants for measuring water clarity
Temp. = Water temperature (°C); Accurate measurements taken to compute other water quality parameters
Sal. = Salinity (ppt); Concentration of dissolved salts in the water
D.O. = Dissolved oxygen (mg/l); Concentration of dissolved oxygen in the water
Con. T. = True conductivity (μS/cm); Electrical conductance of the water
Con. S. = Specific conductance (μS/cm); Con. T. corrected for water temperature
pH = pH; Concentration of hydrogen ions in the water

APPENDIX D (Statistical Methods)

POPULATION MONITORING

Density data, for Rio Grande Silvery Minnow, comprise either zeros (i.e., fish not detected) or positive (nonzero) values (i.e., fish detected) at each of the 20 standard sites. The nonzero data range widely across sites and can include exceptionally large values, particularly when a sampling site contains an unusually high density of fish. 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 site 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 = fish density at a site, 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 month is then the sum of the log-likelihoods from all sampling sites:

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

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 2022) 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 fish density $(\mu \text{ and } \sigma)$ might be quite different than covariates best related to the occurrence probability (δ).

In addition, random effects are considered by year:

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

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

The estimated fish density $E(x)$, 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 $\alpha = 0.05$, are obtained for $E(x)$ by using a log transformation to maintain LCI > 0:

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

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

An essential benefit of our mixture-model approach is that the estimated parameters, and accompanying generalized linear models, provide direct and meaningful insight into key factors affecting the long-term population dynamics of Rio Grande Silvery Minnow. This is because we estimate, and individually analyze, both the occurrence probability (based on δ) and fish density (based on μ and σ). Additionally, diverse environmental covariates are used to model the key parameters (δ and μ), which collectively lend insight into the fundamental, yet complex, long-term ecological relationships of Rio Grande Silvery Minnow.

SITE OCCUPANCY

Site occupancy data, for Rio Grande Silvery Minnow, comprise values of either 1 (species detected during a site visit) or 0 (species not detected during a site visit). The sampling protocol consists of four sequential visits per year (primary occasions) to each of the 20 standard sites (secondary occasions). These repeated-sampling efforts are conducted annually during November.

The likelihood function is constructed based on the probability of observing each site's encounter histories (h_s), across the $t = 1, 2, \cdots, K$ years (primary occasions) and l_t site visits (secondary occasions), for each of the K primary occasions, following the methods of MacKenzie et al. (2003, 2006):

$$L(\psi_t, p_{jt} | h_1, h_2, \cdots, h_s) = \prod_1^s \Pr(h_s)$$

where the estimated parameters are ψ_t (probability a site is occupied in year t) and p_{jt} (probability of detection during visit j, $j = 1, 2, \cdots, l_t$, and year t). This model assumes closure within a site (i.e., if the site is occupied on the 1st visit in year t, the site remains occupied for the 2nd, 3rd, and 4th visits). Also, the model assumes that sites that are unoccupied in year t remain unoccupied during all four visits.

Because we are interested in modeling the probability of occupancy through time, as a function of the probability of extinction of occupied sites and the probability of colonization of unoccupied sites, we incorporate two new parameters: ε_t = probability an occupied site in year t is unoccupied by the species in year $t + 1$ (i.e., extinction); and γ_t = probability an unoccupied site in year t is occupied by the species in year $t + 1$ (i.e., colonization).

The likelihood is thus reparameterized following MacKenzie et al. (2003, 2006):

$$L(\psi_1, \varepsilon_t, \gamma_t, p_{jt} | h_1, h_2, \cdots, h_s) = \prod_1^s \Pr(h_s)$$

where matrix algebra is used to compute the transitions from occupied to unoccupied (i.e., extinction) and, conversely, from unoccupied to occupied (i.e., colonization).

Program MARK (White and Burnham 1999) is used to estimate the three key model parameters $(\psi_1,\ \varepsilon, \text{and } \gamma)$, based on the Robust Design Occupancy Estimation (RDOccupEG) statistical procedure. With this site occupancy model, estimates of ψ_t for the primary occasions $(t = 2, 3, \cdots, K)$ are obtained as derived parameters because only ψ_1 is in the likelihood. Confidence intervals, based on $\alpha = 0.05$, are obtained for ψ_t by using a logit transformation to maintain LCI ≥ 0 and UCI ≤ 1, where LCI is the lower 95% confidence interval and UCI is the upper 95% confidence interval. Additionally, profile-likelihood confidence intervals, based on $\alpha = 0.05$, are obtained for ε_t and γ_t by using the log-likelihood function to maintain LCI ≥ 0 and UCI ≤ 1. Annual parameter values $(\psi_t,\ \varepsilon_t, \text{or } \gamma_t)$ with non-overlapping 95% confidence intervals (LCI–UCI) are significantly different ($P < 0.05$).

A key benefit of our site occupancy approach is that the data only consist of values of 1 (species detected) or 0 (species not detected), which eliminates the uncertainty associated with occasionally wide-ranging fish densities. Additionally, simple patterns of species presence-absence are quite robust when considered over multiple site-sampling efforts across years. Most importantly, these analyses lend insight into the dynamic extinction and colonization processes that affect the long-term conservation status of Rio Grande Silvery Minnow.

APPENDIX E (Statistical Assumptions)

Table E1. Statistical assumptions, violation implications, violation risks, and mitigation precautions for Rio Grande Silvery Minnow population monitoring analyses.

Statistical assumptions	Violation implications	Violation risks	Mitigation precautions
Seine hauls composed a reasonably representative sample for each site.	This would reduce our ability to detect meaningful year-to-year differences in fish densities.	Low: All available mesohabitat types (e.g., backwaters, pools, and runs) were represented during site-specific sampling.	Monitoring was highly standardized (i.e., mesohabitat-specific sampling quotas) across sites and years.
Fish were sampled with similar effort over time and space.	This would reduce our ability to detect meaningful year-to-year differences in fish densities.	Low: Conditions during October (e.g., temperature, discharge, and turbidity) were suitable for efficient and standardized sampling across sites and years.	Monitoring was highly standardized (i.e., numbers and lengths of samples per site) across sites and years.
Fish were not recaptured during the same sampling effort.	This would reduce our ability to detect meaningful year-to-year differences in fish densities.	Negligible: Fish were not released back into the sampling site until the sampling efforts were completed.	All fish were kept in a submerged small-mesh enclosure during each sampling effort.
Species absence represented samples with no individuals of a particular species (i.e., none were present in the sampled mesohabitats or all mesohabitats were dry).	This would reduce our ability to detect meaningful year-to-year differences in fish densities.	Low: We sampled intensively at all sites and have broad experience in identifying all fish to species in the Rio Grande. We also walked the length of all dry sites to confirm the absence of any isolated pools.	Twenty seine hauls, across all available mesohabitats, were taken at each site. Biologists with extensive experience, in both fish identification and mesohabitat sampling, were present on all intensive sampling efforts.
Species detection probability was reasonably similar across sites.	This would reduce our ability to detect meaningful site-to-site and year-to-year differences in fish densities.	Low: We routinely detected remarkably large site-to-site differences in fish densities.	Past population estimation studies showed no site-to-site differences in detection probabilities. Monitoring was highly standardized across sites.
Species detection probability was reasonably similar across years.	This would reduce our ability to detect meaningful year-to-year differences in fish densities.	Low: We routinely detected remarkably large year-to-year differences in fish densities.	Past population estimation studies showed no year-to-year differences in detection probabilities. Monitoring was highly standardized across years.

Table E1. Statistical assumptions, violation implications, violation risks, and mitigation precautions for Rio Grande Silvery Minnow population 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 year-to-year differences in fish densities.	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 population 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.

Table E2. Statistical assumptions, violation implications, violation risks, and mitigation precautions for Rio Grande Silvery Minnow site occupancy analyses.

Statistical assumptions	**Violation implications**	**Violation risks**	**Mitigation precautions**
There were no false detections of the species.	This would result in an overestimation of the occupancy probability (ψ) in the site occupancy models.	Negligible: We have extensive experience in identifying all fish to species in the Rio Grande.	Biologists with extensive experience, in both fish identification and mesohabitat sampling, were present on all intensive sampling efforts.
Site-specific occupancy status did not change across sampling days (e.g., occupied to unoccupied or unoccupied to occupied).	This would change the interpretation of ψ from probability of occupancy to probability of use.	Low: Long sampling sites (ca. 200 m) made it unlikely that the occupancy status would change across days. All fish were immediately returned to their occupied mesohabitats (i.e., available for recapture on subsequent days).	Samples were taken on four consecutive sampling days, which yielded an extensive and robust dataset to detect any potential issues regarding unusual changes in site occupancy status over time.
Species detection probability was independent across sites.	This would result in an underestimation of the variance of ψ in the site occupancy models.	Low: Information was not transferred from day to day in the site occupancy models.	Relative to the lengths of individual sites (ca. 200 m), different sites were spaced very far apart from each other (i.e., many kilometers).
Species detection probability was reasonably similar across sites.	This would result in an underestimation of the variance of ψ, but only in the simplest site occupancy models.	Negligible: More complex and robust site-occupancy models, as were used and presented in this study, did not make this assumption.	For annual samples, we modeled species detection probability as a function of species density. We considered site heterogeneity in our multiyear site occupancy models.
Species detection probability was reasonably similar across years.	This would only be an assumption for site occupancy models with constant detection probability across years.	Negligible: Site occupancy models with constant detection probability across years never adequately fit the data.	We used AIC_c to discriminate against models that were either too simple or too complex.

APPENDIX F (Site-Specific Population Monitoring Data)

Site-specific data, collected in 2022, as part of the
Rio Grande Silvery Minnow Population Monitoring Program
(Any blanks in this database output indicate null data)

Rio Grande Silvery Minnow Population Monitoring
April 2022

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-018**
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9 07 April 2022
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13 USGS Quad: San Felipe Pueblo
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 499.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	1
76	*Platygobio gracilis*	3

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-019**
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9 07 April 2022
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13 USGS Quad: Bernalillo
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 492.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	11
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	34
76	*Rhinichthys cataractae*	9
81	*Catostomus commersonii*	1

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-020**
Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.
Site Number: 3 River Mile: 199.9 07 April 2022
UTM Easting: 354728 UTM Northing: 3905587 Zone: 13 USGS Quad: Bernalillo
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 540.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	55
76	*Pimephales promelas*	2
76	*Platygobio gracilis*	25

Rio Grande Silvery Minnow Population Monitoring
April 2022

NEW MEXICO: Sandoval County, RIO GRANDE Drainage **RKD22-030**
Rio Grande, ca. 4.5 mi upstream of Alameda Blvd. bridge crossing (NM State HWY 528), Corrales.
Site Number: 21 River Mile: 196.5 13 April 2022
UTM Easting: 355670 UTM Northing: 3900620 Zone: 13 USGS Quad: Alameda
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D. Effort: 489.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	3
76	*Platygobio gracilis*	44
76	*Rhinichthys cataractae*	19
81	*Carpiodes carpio*	1

NEW MEXICO: Sandoval County, RIO GRANDE Drainage **RKD22-029**
Rio Grande, ca. 1.0 mi upstream of Alameda Blvd. bridge crossing (NM State HWY 528), Corrales.
Site Number: 22 River Mile: 193.0 13 April 2022
UTM Easting: 351565 UTM Northing: 3897088 Zone: 13 USGS Quad: Los Griegos
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D. Effort: 497.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	35
76	*Platygobio gracilis*	18
76	*Rhinichthys cataractae*	2
212	*Gambusia affinis*	1

NEW MEXICO: Bernalillo County, RIO GRANDE Drainage **RKD22-028**
Rio Grande, ca. 1.2 mi downstream of Paseo del Norte Blvd. bridge crossing (NM State HWY 423), Albuquerque.
Site Number: 23 River Mile: 189.9 13 April 2022
UTM Easting: 349121 UTM Northing: 3893113 Zone: 13 USGS Quad: Los Griegos
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D. Effort: 489.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	176
76	*Hybognathus amarus**	7
76	*Pimephales promelas*	4
76	*Platygobio gracilis*	4
93	*Ictalurus punctatus*	1
212	*Gambusia affinis*	1

***Hybognathus amarus* (age-classes):**

age-0	
age-1	4
age-2+	3

Rio Grande Silvery Minnow Population Monitoring
April 2022

NEW MEXICO: Bernalillo County, RIO GRANDE Drainage **RKD22-027**
Rio Grande, ca. 1.1 mi upstream of US Interstate HWY I-40 bridge crossing, Albuquerque.
Site Number: 24 River Mile: 186.1 13 April 2022
UTM Easting: 346011 UTM Northing: 3887973 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D. Effort: 484.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	47
76	*Hybognathus amarus**	1
76	*Platygobio gracilis*	2

***Hybognathus amarus* (age-classes):**

age-0	
age-1	
age-2+	1

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-017**
Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.
Site Number: 4 River Mile: 183.4 07 April 2022
UTM Easting: 346719 UTM Northing: 3884331 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 519.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	65
76	*Platygobio gracilis*	4

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-016**
Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.
Site Number: 5 River Mile: 178.4 07 April 2022
UTM Easting: 347468 UTM Northing: 3877400 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 501.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	103
76	*Hybognathus amarus**	1
76	*Pimephales promelas*	8
76	*Platygobio gracilis*	3
93	*Ictalurus punctatus*	1

***Hybognathus amarus* (age-classes):**

age-0	
age-1	1
age-2+	

Rio Grande Silvery Minnow Population Monitoring
April 2022

NEW MEXICO: Bernalillo County, RIO GRANDE Drainage **RKD22-026**
Rio Grande, ca. 1.4 mi upstream of US Interstate HWY I-25 bridge crossing, Isleta.
Site Number: 25 River Mile: 174.0 25 April 2022
UTM Easting: 345874 UTM Northing: 3870990 Zone: 13 USGS Quad: Isleta
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T. Effort: 480.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	199
76	*Platygobio gracilis*	2
93	*Ictalurus punctatus*	7
212	*Gambusia affinis*	1

NEW MEXICO: Valencia County, RIO GRANDE Drainage **RKD22-025**
Rio Grande, ca. 4.1 mi upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 26 River Mile: 165.2 25 April 2022
UTM Easting: 342799 UTM Northing: 3858637 Zone: 13 USGS Quad: Los Lunas
Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T. Effort: 469.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	100
76	*Hybognathus amarus**	6
76	*Pimephales promelas*	2
76	*Platygobio gracilis*	1
81	*Carpiodes carpio*	2
212	*Gambusia affinis*	2

***Hybognathus amarus* (age-classes):**

age-0	
age-1	4
age-2+	2

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-015**
Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 6 River Mile: 161.7 06 April 2022
UTM Easting: 343149 UTM Northing: 3853187 Zone: 13 USGS Quad: Los Lunas
Collector(s): Dudley, R.K.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 490.6 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	285
93	*Ictalurus punctatus*	7
212	*Gambusia affinis*	18

Rio Grande Silvery Minnow Population Monitoring
April 2022

NEW MEXICO: Valencia County, RIO GRANDE Drainage **RKD22-024**
Rio Grande, ca. 6.5 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 27 River Mile: 156.0 25 April 2022
UTM Easting: 340512 UTM Northing: 3845124 Zone: 13 USGS Quad: Tome
Collector(s): Effort: sq. m

Family	Species	Total
	Sampling Not Safe	

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-014**
Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 7 River Mile: 150.8 06 April 2022
UTM Easting: 340105 UTM Northing: 3837722 Zone: 13 USGS Quad: Tome
Collector(s): Dudley, R.K.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 487.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	466
76	*Pimephales promelas*	1
81	*Carpiodes carpio*	2
93	*Ictalurus punctatus*	2
212	*Gambusia affinis*	1
294	*Pomoxis annularis*	5

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-013**
Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.
Site Number: 8 River Mile: 143.2 06 April 2022
UTM Easting: 338020 UTM Northing: 3827545 Zone: 13 USGS Quad: Veguita
Collector(s): Dudley, R.K.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 496.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	791
76	*Pimephales promelas*	2
93	*Ictalurus punctatus*	1
212	*Gambusia affinis*	49
294	*Pomoxis annularis*	1

Rio Grande Silvery Minnow Population Monitoring
April 2022

NEW MEXICO: Socorro County, RIO GRANDE Drainage **RKD22-023**
Rio Grande, ca. 3.8 mi downstream of NM State HWY 346 bridge crossing, Jarales.
Site Number: 28 River Mile: 137.0 11 April 2022
UTM Easting: 335506 UTM Northing: 3819543 Zone: 13 USGS Quad: Veguita
Collector(s): Farrington, M.A.; Urioste, A.D.; Damron, T.D. Effort: 503.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	556
76	*Platygobio gracilis*	1
93	*Ictalurus punctatus*	2
212	*Gambusia affinis*	51

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-012**
Rio Grande, at US HWY 60 bridge crossing, Bernardo.
Site Number: 9 River Mile: 130.6 06 April 2022
UTM Easting: 334578 UTM Northing: 3809921 Zone: 13 USGS Quad: Abeytas
Collector(s): Dudley, R.K.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 471.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	772
76	*Pimephales promelas*	4
81	*Carpiodes carpio*	1
212	*Gambusia affinis*	23
294	*Pomoxis annularis*	6

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-011**
Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.
Site Number: 10 River Mile: 126.8 06 April 2022
UTM Easting: 330946 UTM Northing: 3805307 Zone: 13 USGS Quad: Abeytas
Collector(s): Dudley, R.K.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 481.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	621
81	*Carpiodes carpio*	2
93	*Ictalurus punctatus*	2
212	*Gambusia affinis*	76
294	*Pomoxis annularis*	1

Rio Grande Silvery Minnow Population Monitoring
April 2022

NEW MEXICO: Socorro County, RIO GRANDE Drainage **RKD22-022**
Rio Grande, ca. 1.4 mi upstream of the Rio Salado confluence, San Acacia.
Site Number: 29 River Mile: 120.0 11 April 2022
UTM Easting: 330550 UTM Northing: 3795050 Zone: 13 USGS Quad: La Joya
Collector(s): Farrington, M.A.; Urioste, A.D.; Damron, T.D. Effort: 463.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	16
76	*Platygobio gracilis*	3

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-010**
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3 05 April 2022
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13 USGS Quad: La Joya
Collector(s): Dudley, R.K.; Farrington, M.A.; Damron, T.D. Effort: 581.1 sq. m

Family	Species	Total
76	*Hybognathus amarus**	2
76	*Platygobio gracilis*	3

***Hybognathus amarus* (age-classes):**

age-0	
age-1	2
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-009**
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6 05 April 2022
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13 USGS Quad: San Acacia
Collector(s): Dudley, R.K.; Farrington, M.A.; Damron, T.D. Effort: 470.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	20
76	*Hybognathus amarus**	46
76	*Pimephales promelas*	1

***Hybognathus amarus* (age-classes):**

age-0	
age-1	43
age-2+	3

Rio Grande Silvery Minnow Population Monitoring
April 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-008**
Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 13 River Mile: 114.1 05 April 2022
UTM Easting: 325390 UTM Northing: 3790397 Zone: 13 USGS Quad: Lemitar
Collector(s): Dudley, R.K.; Farrington, M.A.; Damron, T.D. Effort: 531.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	19
76	*Hybognathus amarus**	2
76	*Platygobio gracilis*	6
76	*Rhinichthys cataractae*	1
212	*Gambusia affinis*	1

***Hybognathus amarus* (age-classes):**

age-0	
age-1	2
age-2+	

NEW MEXICO: Socorro County, RIO GRANDE Drainage **RKD22-021**
Rio Grande, ca. 2.1 mi upstream of Pueblitos Rd. bridge crossing, Lemitar.
Site Number: 30 River Mile: 106.3 11 April 2022
UTM Easting: 326666 UTM Northing: 3780246 Zone: 13 USGS Quad: Lemitar
Collector(s): Farrington, M.A.; Urioste, A.D.; Damron, T.D. Effort: 496.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	25
76	*Hybognathus amarus**	1
76	*Platygobio gracilis*	6
212	*Gambusia affinis*	3

***Hybognathus amarus* (age-classes):**

age-0	
age-1	1
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-007**
Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.
Site Number: 14 River Mile: 99.6 05 April 2022
UTM Easting: 327231 UTM Northing: 3771432 Zone: 13 USGS Quad: Loma de las Canas
Collector(s): Dudley, R.K.; Farrington, M.A.; Damron, T.D. Effort: 572.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	10
76	*Platygobio gracilis*	1

Rio Grande Silvery Minnow Population Monitoring
April 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-006**
Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.
Site Number: 15 River Mile: 92.0 05 April 2022
UTM Easting: 328151 UTM Northing: 3761487 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Farrington, M.A.; Damron, T.D. Effort: 516.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	6
76	*Hybognathus amarus**	4

***Hybognathus amarus* (age-classes):**

age-0	
age-1	4
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-005**
Rio Grande, at US HWY 380 bridge crossing, San Antonio.
Site Number: 16 River Mile: 87.8 04 April 2022
UTM Easting: 328907 UTM Northing: 3754926 Zone: 13 USGS Quad: San Antonio
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 568.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	38
76	*Hybognathus amarus**	1
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	7
212	*Gambusia affinis*	1

***Hybognathus amarus* (age-classes):**

age-0	
age-1	1
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-004**
Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.
Site Number: 17 River Mile: 79.0 04 April 2022
UTM Easting: 327219 UTM Northing: 3740906 Zone: 13 USGS Quad: San Antonio SE
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 530.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	9
76	*Hybognathus amarus**	2
76	*Pimephales promelas*	2
93	*Ictalurus punctatus*	1

***Hybognathus amarus* (age-classes):**

age-0	
age-1	2
age-2+	

Rio Grande Silvery Minnow Population Monitoring
April 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-003**
Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.
Site Number: 18 River Mile: 68.3 04 April 2022
UTM Easting: 315091 UTM Northing: 3728487 Zone: 13 USGS Quad: San Marcial
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 557.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	9

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-002**
Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 19 River Mile: 60.1 04 April 2022
UTM Easting: 309441 UTM Northing: 3718309 Zone: 13 USGS Quad: Paraje Well
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 546.6 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	23
76	*Cyprinus carpio*	6
76	*Platygobio gracilis*	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-001**
Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 20 River Mile: 58.5 04 April 2022
UTM Easting: 307767 UTM Northing: 3716360 Zone: 13 USGS Quad: Paraje Well
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Urioste, A.D. Effort: 558.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	39
76	*Cyprinus carpio*	2

Rio Grande Silvery Minnow Population Monitoring
May 2022

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-048**
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9 06 May 2022
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13 USGS Quad: San Felipe Pueblo
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 397.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	9
76	*Platygobio gracilis*	20
76	*Rhinichthys cataractae*	23
81	*Catostomus commersonii*	55

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-049**
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9 06 May 2022
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13 USGS Quad: Bernalillo
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 446.8 sq. m

Family	Species	Total
76	*Platygobio gracilis*	16
76	*Rhinichthys cataractae*	5
81	*Catostomus commersonii*	25
93	*Ictalurus punctatus*	1

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-050**
Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.
Site Number: 3 River Mile: 199.9 06 May 2022
UTM Easting: 354728 UTM Northing: 3905587 Zone: 13 USGS Quad: Bernalillo
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 445.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	36
76	*Platygobio gracilis*	12
76	*Rhinichthys cataractae*	2
81	*Catostomus commersonii*	84
93	*Ictalurus punctatus*	2

Rio Grande Silvery Minnow Population Monitoring
May 2022

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-047**
Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.
Site Number: 4 River Mile: 183.4 06 May 2022
UTM Easting: 346719 UTM Northing: 3884331 Zone: 13 USGS Quad: Albuquerque West
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 480.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	207
76	*Platygobio gracilis*	3
93	*Ictalurus punctatus*	2

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-046**
Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.
Site Number: 5 River Mile: 178.4 06 May 2022
UTM Easting: 347468 UTM Northing: 3877400 Zone: 13 USGS Quad: Albuquerque West
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 441.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	39
76	*Platygobio gracilis*	2
93	*Ictalurus punctatus*	2
294	*Pomoxis annularis*	1

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-045**
Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 6 River Mile: 161.7 05 May 2022
UTM Easting: 343149 UTM Northing: 3853187 Zone: 13 USGS Quad: Los Lunas
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 425.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	89
76	*Platygobio gracilis*	1
93	*Ictalurus punctatus*	3
212	*Gambusia affinis*	1

Rio Grande Silvery Minnow Population Monitoring
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NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-044**
Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 7 River Mile: 150.8 05 May 2022
UTM Easting: 340105 UTM Northing: 3837722 Zone: 13 USGS Quad: Tome
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 465.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	45
76	*Hybognathus amarus**	1
76	*Pimephales promelas*	1
81	*Catostomus commersonii*	2
93	*Ictalurus punctatus*	2
212	*Gambusia affinis*	3
294	*Pomoxis annularis*	1

***Hybognathus amarus* (age-classes):**

age-0	
age-1	1
age-2+	

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-043**
Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.
Site Number: 8 River Mile: 143.2 05 May 2022
UTM Easting: 338020 UTM Northing: 3827545 Zone: 13 USGS Quad: Veguita
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 431.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	464
76	*Cyprinus carpio*	1
93	*Ictalurus punctatus*	2

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-042**
Rio Grande, at US HWY 60 bridge crossing, Bernardo.
Site Number: 9 River Mile: 130.6 05 May 2022
UTM Easting: 334578 UTM Northing: 3809921 Zone: 13 USGS Quad: Abeytas
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 443.6 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	117
93	*Ictalurus punctatus*	1

Rio Grande Silvery Minnow Population Monitoring
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NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-041**
Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.
Site Number: 10 River Mile: 126.8 05 May 2022
UTM Easting: 330946 UTM Northing: 3805307 Zone: 13 USGS Quad: Abeytas
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 473.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	2
93	*Ictalurus punctatus*	2

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-040**
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3 04 May 2022
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13 USGS Quad: La Joya
Collector(s): M.A. Farrington, A.C. Wedemeyer, J.G. Mortensen Effort: 519.1 sq. m

Family	Species	Total
76	*Platygobio gracilis*	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-039**
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6 04 May 2022
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13 USGS Quad: San Acacia
Collector(s): M.A. Farrington, A.C. Wedemeyer, J.G. Mortensen Effort: 455.9 sq. m

Family	Species	Total
69	*Dorosoma cepedianum*	2
76	*Cyprinella lutrensis*	8
76	*Hybognathus amarus**	5
76	*Platygobio gracilis*	2
212	*Gambusia affinis*	2

***Hybognathus amarus* (age-classes):**

age-0	
age-1	5
age-2+	

Rio Grande Silvery Minnow Population Monitoring
May 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-038**
Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 13 River Mile: 114.1 04 May 2022
UTM Easting: 325390 UTM Northing: 3790397 Zone: 13 USGS Quad: Lemitar
Collector(s): M.A. Farrington, A.C. Wedemeyer, J.G. Mortensen Effort: 484.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	12
76	*Hybognathus amarus**	7
76	*Platygobio gracilis*	20
81	*Ictiobus bubalus*	1
212	*Gambusia affinis*	3

***Hybognathus amarus* (age-classes):**

age-0	
age-1	7
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-037**
Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.
Site Number: 14 River Mile: 99.6 04 May 2022
UTM Easting: 327231 UTM Northing: 3771432 Zone: 13 USGS Quad: Loma de las Canas
Collector(s): M.A. Farrington, A.C. Wedemeyer, J.G. Mortensen Effort: 522.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	12
76	*Hybognathus amarus**	2
76	*Platygobio gracilis*	1
81	*Carpiodes carpio*	1

***Hybognathus amarus* (age-classes):**

age-0	
age-1	2
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-036**
Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.
Site Number: 15 River Mile: 92.0 04 May 2022
UTM Easting: 328151 UTM Northing: 3761487 Zone: 13 USGS Quad: San Antonio
Collector(s): M.A. Farrington, A.C. Wedemeyer, J.G. Mortensen Effort: 566.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	9
76	*Platygobio gracilis*	4

Rio Grande Silvery Minnow Population Monitoring
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NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-035**
Rio Grande, at US HWY 380 bridge crossing, San Antonio.
Site Number: 16 River Mile: 87.8 03 May 2022
UTM Easting: 328907 UTM Northing: 3754926 Zone: 13 USGS Quad: San Antonio
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 478.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	27
76	*Hybognathus amarus**	1
76	*Platygobio gracilis*	1
212	*Gambusia affinis*	1

***Hybognathus amarus* (age-classes):**

age-0
age-1 1
age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-034**
Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.
Site Number: 17 River Mile: 79.0 03 May 2022
UTM Easting: 327219 UTM Northing: 3740906 Zone: 13 USGS Quad: San Antonio SE
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 479.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	4
76	*Hybognathus amarus**	1

***Hybognathus amarus* (age-classes):**

age-0
age-1 1
age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-033**
Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.
Site Number: 18 River Mile: 68.3 03 May 2022
UTM Easting: 315091 UTM Northing: 3728487 Zone: 13 USGS Quad: San Marcial
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 430.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	8
76	*Hybognathus amarus**	1

***Hybognathus amarus* (age-classes):**

age-0
age-1 1
age-2+

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NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-032**
Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 19 River Mile: 60.1 03 May 2022
UTM Easting: 309441 UTM Northing: 3718309 Zone: 13 USGS Quad: Paraje Well
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 440.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	1
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	1
76	*Platygobio gracilis*	1
81	*Carpiodes carpio*	1

***Hybognathus amarus* (age-classes):**

age-0	
age-1	1
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-031**
Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 20 River Mile: 58.5 03 May 2022
UTM Easting: 307767 UTM Northing: 3716360 Zone: 13 USGS Quad: Paraje Well
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 421.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	8
76	*Cyprinus carpio*	1

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NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-068**
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9 03 June 2022
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13 USGS Quad: San Felipe Pueblo
Collector(s): Clark-Barkalow, S.L.; Wedemeyer. A.C.; Urioste, A.D. Effort: 491.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	134
76	*Pimephales promelas*	3
76	*Platygobio gracilis*	3
76	*Rhinichthys cataractae*	79
81	*Catostomus commersonii*	11
212	*Gambusia affinis*	4
294	*Lepomis cyanellus*	4
294	*Micropterus salmoides*	1

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-069**
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9 03 June 2022
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13 USGS Quad: Bernalillo
Collector(s): Clark-Barkalow, S.L.; Wedemeyer. A.C.; Urioste, A.D. Effort: 492.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	101
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	76
76	*Rhinichthys cataractae*	26
81	*Catostomus commersonii*	20

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-070**
Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.
Site Number: 3 River Mile: 199.9 03 June 2022
UTM Easting: 354728 UTM Northing: 3905587 Zone: 13 USGS Quad: Bernalillo
Collector(s): Clark-Barkalow, S.L.; Wedemeyer. A.C.; Urioste, A.D. Effort: 514.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	246
76	*Pimephales promelas*	3
76	*Platygobio gracilis*	20
76	*Rhinichthys cataractae*	4
81	*Catostomus commersonii*	25
212	*Gambusia affinis*	2

Rio Grande Silvery Minnow Population Monitoring
June 2022

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-067**
Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.
Site Number: 4 River Mile: 183.4 03 June 2022
UTM Easting: 346719 UTM Northing: 3884331 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Clark-Barkalow, S.L.; Wedemeyer. A.C.; Urioste, A.D. Effort: 491.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	41
76	*Cyprinus carpio*	4
76	*Hybognathus amarus**	4
76	*Pimephales promelas*	2
81	*Carpiodes carpio*	15
81	*Catostomus commersonii*	12
212	*Gambusia affinis*	13
294	*Pomoxis annularis*	2

***Hybognathus amarus* (age-classes):**

age-0	4
age-1	
age-2+	

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-066**
Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.
Site Number: 5 River Mile: 178.4 03 June 2022
UTM Easting: 347468 UTM Northing: 3877400 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Clark-Barkalow, S.L.; Wedemeyer. A.C.; Urioste, A.D. Effort: 556.6 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	13
76	*Cyprinus carpio*	9
76	*Hybognathus amarus**	66
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	1
81	*Catostomus commersonii*	15
212	*Gambusia affinis*	1

***Hybognathus amarus* (age-classes):**

age-0	66
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring
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NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-065**
Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 6 River Mile: 161.7 02 June 2022
UTM Easting: 343149 UTM Northing: 3853187 Zone: 13 USGS Quad: Los Lunas
Collector(s): Farrington, M.A.; Wedemeyer, A.C.; Urioste, A.D. Effort: 538.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	120
81	*Carpiodes carpio*	24

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-064**
Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 7 River Mile: 150.8 02 June 2022
UTM Easting: 340105 UTM Northing: 3837722 Zone: 13 USGS Quad: Tome
Collector(s): Farrington, M.A.; Wedemeyer, A.C.; Urioste, A.D. Effort: 497.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	229
76	*Cyprinus carpio*	2
76	*Pimephales promelas*	5
212	*Gambusia affinis*	15

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-063**
Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.
Site Number: 8 River Mile: 143.2 02 June 2022
UTM Easting: 338020 UTM Northing: 3827545 Zone: 13 USGS Quad: Veguita
Collector(s): Farrington, M.A.; Wedemeyer, A.C.; Urioste, A.D. Effort: 514.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	190
212	*Gambusia affinis*	9

Rio Grande Silvery Minnow Population Monitoring
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NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-062**
Rio Grande, at US HWY 60 bridge crossing, Bernardo.
Site Number: 9 River Mile: 130.6 02 June 2022
UTM Easting: 334578 UTM Northing: 3809921 Zone: 13 USGS Quad: Abeytas
Collector(s): Farrington, M.A.; Wedemeyer, A.C.; Urioste, A.D. Effort: 508.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	227
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	1
81	*Catostomus commersonii*	2
212	*Gambusia affinis*	6

***Hybognathus amarus* (age-classes):**

age-0	
age-1	1
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-061**
Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.
Site Number: 10 River Mile: 126.8 02 June 2022
UTM Easting: 330946 UTM Northing: 3805307 Zone: 13 USGS Quad: Abeytas
Collector(s): Farrington, M.A.; Wedemeyer, A.C.; Urioste, A.D. Effort: 501.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	243
76	*Cyprinus carpio*	1
81	*Catostomus commersonii*	5
212	*Gambusia affinis*	24

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NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-060**
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3 01 June 2022
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13 USGS Quad: La Joya
Collector(s): Dudley, R.K.; Farrington, M.A.; Urioste, A.D. Effort: 500.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	7
76	*Cyprinus carpio*	143
76	*Hybognathus amarus**	27
76	*Platygobio gracilis*	8
81	*Carpiodes carpio*	2
81	*Catostomus commersonii*	51
212	*Gambusia affinis*	16

***Hybognathus amarus* (age-classes):**

age-0	26
age-1	1
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-059**
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6 01 June 2022
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13 USGS Quad: San Acacia
Collector(s): Dudley, R.K.; Farrington, M.A.; Urioste, A.D. Effort: 482.9 sq. m

Family	Species	Total
69	*Dorosoma cepedianum*	1
76	*Cyprinella lutrensis*	51
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	10
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	112
81	*Carpiodes carpio*	11
81	*Catostomus commersonii*	3
93	*Ictalurus furcatus*	4
212	*Gambusia affinis*	5

***Hybognathus amarus* (age-classes):**

age-0	2
age-1	8
age-2+	

Rio Grande Silvery Minnow Population Monitoring
June 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-058**
Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 13 River Mile: 114.1 01 June 2022
UTM Easting: 325390 UTM Northing: 3790397 Zone: 13 USGS Quad: Lemitar
Collector(s): Dudley, R.K.; Farrington, M.A.; Urioste, A.D. Effort: 490.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	5
76	*Cyprinus carpio*	3
76	*Pimephales promelas*	3
76	*Platygobio gracilis*	1
81	*Catostomus commersonii*	3
212	*Gambusia affinis*	4

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-057**
Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.
Site Number: 14 River Mile: 99.6 01 June 2022
UTM Easting: 327231 UTM Northing: 3771432 Zone: 13 USGS Quad: Loma de las Canas
Collector(s): Dudley, R.K.; Farrington, M.A.; Urioste, A.D. Effort: 492.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	9
76	*Cyprinus carpio*	39
81	*Carpiodes carpio*	1
81	*Catostomus commersonii*	1
212	*Gambusia affinis*	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-056**
Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.
Site Number: 15 River Mile: 92.0 01 June 2022
UTM Easting: 328151 UTM Northing: 3761487 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Farrington, M.A.; Urioste, A.D. Effort: 488.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	3
76	*Cyprinus carpio*	18
76	*Hybognathus amarus**	2
81	*Catostomus commersonii*	4
93	*Ameiurus natalis*	1
212	*Gambusia affinis*	6

***Hybognathus amarus* (age-classes):**

age-0	2
age-1	
age-2+	

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NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-055**
Rio Grande, at US HWY 380 bridge crossing, San Antonio.
Site Number: 16 River Mile: 87.8 31 May 2022
UTM Easting: 328907 UTM Northing: 3754926 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Clark-Barkalow, S.L.; Urioste, A. D. Effort: 537.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	2
76	*Cyprinus carpio*	18
76	*Hybognathus amarus**	2
76	*Platygobio gracilis*	1
81	*Catostomus commersonii*	10

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	1
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-054**
Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.
Site Number: 17 River Mile: 79.0 31 May 2022
UTM Easting: 327219 UTM Northing: 3740906 Zone: 13 USGS Quad: San Antonio SE
Collector(s): Dudley, R.K.; Clark-Barkalow, S.L.; Urioste, A. D. Effort: 487.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	4
76	*Cyprinus carpio*	2
76	*Hybognathus amarus**	1

***Hybognathus amarus* (age-classes):**

age-0	
age-1	1
age-2+	

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NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-053**
Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.
Site Number: 18 River Mile: 68.3 31 May 2022
UTM Easting: 315091 UTM Northing: 3728487 Zone: 13 USGS Quad: San Marcial
Collector(s): Dudley, R.K.; Clark-Barkalow, S.L.; Urioste, A. D. Effort: 446.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	8
76	*Cyprinus carpio*	15
76	*Hybognathus amarus**	1
76	*Platygobio gracilis*	1
81	*Carpiodes carpio*	1
81	*Catostomus commersonii*	2
212	*Gambusia affinis*	1

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-052**
Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 19 River Mile: 60.1 31 May 2022
UTM Easting: 309441 UTM Northing: 3718309 Zone: 13 USGS Quad: Paraje Well
Collector(s): Dudley, R.K.; Clark-Barkalow, S.L.; Urioste, A. D. Effort: 514.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	23
76	*Cyprinus carpio*	1
76	*Platygobio gracilis*	6
81	*Catostomus commersonii*	3
212	*Gambusia affinis*	1
295	*Percina macrolepida*	4

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-051**
Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 20 River Mile: 58.5 31 May 2022
UTM Easting: 307767 UTM Northing: 3716360 Zone: 13 USGS Quad: Paraje Well
Collector(s): Dudley, R.K.; Clark-Barkalow, S.L.; Urioste, A. D. Effort: 549.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	27
76	*Cyprinus carpio*	3
81	*Catostomus commersonii*	1
212	*Gambusia affinis*	1

Rio Grande Silvery Minnow Population Monitoring
July 2022

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-088**
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9 06 July 2022
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13 USGS Quad: San Felipe Pueblo
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Winter, S. Effort: 462.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	81
76	*Pimephales promelas*	4
76	*Platygobio gracilis*	8
76	*Rhinichthys cataractae*	37
81	*Catostomus commersonii*	5
212	*Gambusia affinis*	37
294	*Lepomis cyanellus*	1

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-089**
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9 06 July 2022
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13 USGS Quad: Bernalillo
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Winter, S. Effort: 498.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	70
76	*Platygobio gracilis*	57
76	*Rhinichthys cataractae*	27
81	*Catostomus commersonii*	16
212	*Gambusia affinis*	5

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-090**
Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.
Site Number: 3 River Mile: 199.9 06 July 2022
UTM Easting: 354728 UTM Northing: 3905587 Zone: 13 USGS Quad: Bernalillo
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Winter, S. Effort: 497.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	121
76	*Platygobio gracilis*	14
76	*Rhinichthys cataractae*	1
93	*Ameiurus natalis*	3
93	*Ictalurus punctatus*	1
212	*Gambusia affinis*	7
294	*Lepomis cyanellus*	3

Rio Grande Silvery Minnow Population Monitoring
July 2022

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-087**
Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.
Site Number: 4 River Mile: 183.4 06 July 2022
UTM Easting: 346719 UTM Northing: 3884331 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Winter, S. Effort: 523.6 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	54
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	12
76	*Pimephales promelas*	9
76	*Platygobio gracilis*	5
81	*Carpiodes carpio*	3
81	*Catostomus commersonii*	7
93	*Ameiurus melas*	2
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	14
212	*Gambusia affinis*	3
294	*Micropterus salmoides*	1

***Hybognathus amarus* (age-classes):**

age-0	11
age-1	1
age-2+	

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-086**
Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.
Site Number: 5 River Mile: 178.4 06 July 2022
UTM Easting: 347468 UTM Northing: 3877400 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Winter, S. Effort: 491.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	47
76	*Cyprinus carpio*	4
76	*Hybognathus amarus**	6
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	6
81	*Carpiodes carpio*	5
81	*Catostomus commersonii*	2
93	*Ictalurus punctatus*	11
212	*Gambusia affinis*	4

***Hybognathus amarus* (age-classes):**

age-0	6
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring
July 2022

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-085**
Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 6 River Mile: 161.7 05 July 2022
UTM Easting: 343149 UTM Northing: 3853187 Zone: 13 USGS Quad: Los Lunas
Collector(s): Farrington, M.A.; Urioste, A.D.; Damron, T.D.; Willis, A.T. Effort: 498.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	144
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	33
212	*Gambusia affinis*	13

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-084**
Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 7 River Mile: 150.8 05 July 2022
UTM Easting: 340105 UTM Northing: 3837722 Zone: 13 USGS Quad: Tome
Collector(s): Farrington, M.A.; Urioste, A.D.; Damron, T.D.; Willis, A.T. Effort: 525.6 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	211
76	*Cyprinus carpio*	4
93	*Ameiurus natalis*	4
93	*Ictalurus punctatus*	54
212	*Gambusia affinis*	16

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-083**
Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.
Site Number: 8 River Mile: 143.2 05 July 2022
UTM Easting: 338020 UTM Northing: 3827545 Zone: 13 USGS Quad: Veguita
Collector(s): Farrington, M.A.; Urioste, A.D.; Damron, T.D.; Willis, A.T. Effort: 573.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	49
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	2
212	*Gambusia affinis*	10

Rio Grande Silvery Minnow Population Monitoring
July 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-082**
Rio Grande, at US HWY 60 bridge crossing, Bernardo.
Site Number: 9 River Mile: 130.6 05 July 2022
UTM Easting: 334578 UTM Northing: 3809921 Zone: 13 USGS Quad: Abeytas
Collector(s): Farrington, M.A.; Urioste, A.D.; Damron, T.D.; Willis, A.T. Effort: 508.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	384
76	*Cyprinus carpio*	1
81	*Carpiodes carpio*	1
93	*Ameiurus natalis*	5
93	*Ictalurus punctatus*	10
212	*Gambusia affinis*	34

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-081**
Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.
Site Number: 10 River Mile: 126.8 05 July 2022
UTM Easting: 330946 UTM Northing: 3805307 Zone: 13 USGS Quad: Abeytas
Collector(s): Farrington, M.A.; Urioste, A.D.; Damron, T.D.; Willis, A.T. Effort: 459.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	186
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	2
81	*Carpiodes carpio*	2
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	33
212	*Gambusia affinis*	28
294	*Micropterus salmoides*	1

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	1
age-2+	

Rio Grande Silvery Minnow Population Monitoring
July 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-080**
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3 01 July 2022
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13 USGS Quad: La Joya
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Willis, A.T. Effort: 415.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	4
76	*Hybognathus amarus**	2
76	*Platygobio gracilis*	49
81	*Carpiodes carpio*	1

***Hybognathus amarus* (age-classes):**

age-0	2
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-079**
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6 01 July 2022
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13 USGS Quad: San Acacia
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Willis, A.T. Effort: 477.0 sq. m

Family	Species	Total
69	*Dorosoma cepedianum*	2
76	*Hybognathus amarus**	2
76	*Platygobio gracilis*	31
81	*Carpiodes carpio*	2
81	*Catostomus commersonii*	1

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	1
age-2+	

Rio Grande Silvery Minnow Population Monitoring
July 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-078**
Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 13 River Mile: 114.1 01 July 2022
UTM Easting: 325390 UTM Northing: 3790397 Zone: 13 USGS Quad: Lemitar
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Willis, A.T. Effort: 529.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	23
76	*Hybognathus amarus**	12
76	*Pimephales promelas*	2
76	*Platygobio gracilis*	78
93	*Ictalurus furcatus*	1
212	*Gambusia affinis*	4

***Hybognathus amarus* (age-classes):**

age-0	12
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-077**
Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.
Site Number: 14 River Mile: 99.6 01 July 2022
UTM Easting: 327231 UTM Northing: 3771432 Zone: 13 USGS Quad: Loma de las Canas
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Willis, A.T. Effort: 494.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	5
76	*Cyprinus carpio*	2
76	*Platygobio gracilis*	5
81	*Catostomus commersonii*	2
93	*Ictalurus punctatus*	1
212	*Gambusia affinis*	2

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-076**
Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.
Site Number: 15 River Mile: 92.0 01 July 2022
UTM Easting: 328151 UTM Northing: 3761487 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Willis, A.T. Effort: 565.4 sq. m

Family	Species	Total
	No Fish Collected	

Rio Grande Silvery Minnow Population Monitoring
June 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-075**
Rio Grande, at US HWY 380 bridge crossing, San Antonio.
Site Number: 16 River Mile: 87.8 30 June 2022
UTM Easting: 328907 UTM Northing: 3754926 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Lopez-Binder, J.M. Effort: 524.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	66
76	*Cyprinus carpio*	1
76	*Platygobio gracilis*	57
93	*Ictalurus punctatus*	6
212	*Gambusia affinis*	10

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-074**
Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.
Site Number: 17 River Mile: 79.0 30 June 2022
UTM Easting: 327219 UTM Northing: 3740906 Zone: 13 USGS Quad: San Antonio SE
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Lopez-Binder, J.M. Effort: 522.9 sq. m

Family	Species	Total
76	*Cyprinus carpio*	3
76	*Hybognathus amarus**	1
81	*Carpiodes carpio*	1
93	*Ictalurus furcatus*	2
93	*Ictalurus punctatus*	2

***Hybognathus amarus* (age-classes):**

age-0	
age-1	
age-2+	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-073**
Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.
Site Number: 18 River Mile: 68.3 30 June 2022
UTM Easting: 315091 UTM Northing: 3728487 Zone: 13 USGS Quad: San Marcial
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Lopez-Binder, J.M. Effort: 539.9 sq. m

Family	Species	Total
76	*Hybognathus amarus**	1
76	*Platygobio gracilis*	1
81	*Carpiodes carpio*	1
212	*Gambusia affinis*	2

***Hybognathus amarus* (age-classes):**

age-0	
age-1	1
age-2+	

Rio Grande Silvery Minnow Population Monitoring
June 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-072**
Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 19 River Mile: 60.1 30 June 2022
UTM Easting: 309441 UTM Northing: 3718309 Zone: 13 USGS Quad: Paraje Well
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Lopez-Binder, J.M. Effort: 511.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	7
76	*Cyprinus carpio*	7
76	*Hybognathus amarus**	3
76	*Platygobio gracilis*	11
81	*Carpiodes carpio*	6
81	*Catostomus commersonii*	1

***Hybognathus amarus* (age-classes):**

age-0	2
age-1	1
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-071**
Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 20 River Mile: 58.5 30 June 2022
UTM Easting: 307767 UTM Northing: 3716360 Zone: 13 USGS Quad: Paraje Well
Collector(s): Dudley, R.K.; Urioste, A.D.; Damron, T.D.; Lopez-Binder, J.M. Effort: 503.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	32
76	*Platygobio gracilis*	2
93	*Ictalurus punctatus*	2

Rio Grande Silvery Minnow Population Monitoring
August 2022

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-108**
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9 04 August 2022
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13 USGS Quad: San Felipe Pueblo
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S. Effort: 408.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	140
76	*Hybognathus amarus**	2
76	*Platygobio gracilis*	4
76	*Rhinichthys cataractae*	113
81	*Catostomus commersonii*	6
93	*Ictalurus punctatus*	17
212	*Gambusia affinis*	4
294	*Lepomis macrochirus*	1
294	*Micropterus dolomieu*	1

***Hybognathus amarus* (age-classes):**

age-0	
age-1	2
age-2+	

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-109**
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9 04 August 2022
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13 USGS Quad: Bernalillo
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S. Effort: 496.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	22
76	*Platygobio gracilis*	10
76	*Rhinichthys cataractae*	13
93	*Ameiurus natalis*	2
93	*Ictalurus punctatus*	82
212	*Gambusia affinis*	4

Rio Grande Silvery Minnow Population Monitoring
August 2022

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-110**
Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.
Site Number: 3 River Mile: 199.9 04 August 2022
UTM Easting: 354728 UTM Northing: 3905587 Zone: 13 USGS Quad: Bernalillo
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S. Effort: 480.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	35
76	*Platygobio gracilis*	22
76	*Rhinichthys cataractae*	2
81	*Catostomus commersonii*	1
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	72
212	*Gambusia affinis*	24

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-107**
Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.
Site Number: 4 River Mile: 183.4 04 August 2022
UTM Easting: 346719 UTM Northing: 3884331 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S. Effort: 546.6 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	36
76	*Platygobio gracilis*	8
93	*Ictalurus punctatus*	85
212	*Gambusia affinis*	3

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-106**
Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.
Site Number: 5 River Mile: 178.4 04 August 2022
UTM Easting: 347468 UTM Northing: 3877400 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S. Effort: 515.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	3
76	*Hybognathus amarus**	1
93	*Ictalurus punctatus*	35
212	*Gambusia affinis*	2

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring
August 2022

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-105**
Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 6 River Mile: 161.7 03 August 2022
UTM Easting: 343149 UTM Northing: 3853187 Zone: 13 USGS Quad: Los Lunas
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S. Effort: 545.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	5
76	*Cyprinus carpio*	1
76	*Rhinichthys cataractae*	1
93	*Ictalurus punctatus*	6

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-104**
Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 7 River Mile: 150.8 03 August 2022
UTM Easting: 340105 UTM Northing: 3837722 Zone: 13 USGS Quad: Tome
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S. Effort: 462.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	104
76	*Cyprinus carpio*	1
76	*Pimephales promelas*	2
93	*Ictalurus punctatus*	69
212	*Gambusia affinis*	19

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-103**
Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.
Site Number: 8 River Mile: 143.2 03 August 2022
UTM Easting: 338020 UTM Northing: 3827545 Zone: 13 USGS Quad: Veguita
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S. Effort: 526.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	120
93	*Ameiurus natalis*	2
93	*Ictalurus punctatus*	20
212	*Gambusia affinis*	13

Rio Grande Silvery Minnow Population Monitoring
August 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-102**
Rio Grande, at US HWY 60 bridge crossing, Bernardo.
Site Number: 9 River Mile: 130.6 03 August 2022
UTM Easting: 334578 UTM Northing: 3809921 Zone: 13 USGS Quad: Abeytas
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S. Effort: 530.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	158
93	*Ictalurus punctatus*	37
212	*Gambusia affinis*	8

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-101**
Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.
Site Number: 10 River Mile: 126.8 03 August 2022
UTM Easting: 330946 UTM Northing: 3805307 Zone: 13 USGS Quad: Abeytas
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S. Effort: 471.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	183
76	*Pimephales promelas*	1
93	*Ictalurus punctatus*	33
212	*Gambusia affinis*	40

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-100**
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3 02 August 2022
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13 USGS Quad: La Joya
Collector(s): Farrington, M.A.; Wedemeyer, A.C.; Camak, D.T.; Willis, A.T. Effort: 570.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	14
76	*Hybognathus amarus**	1
76	*Platygobio gracilis*	4
212	*Gambusia affinis*	2

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring
August 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-099**
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6 02 August 2022
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13 USGS Quad: San Acacia
Collector(s): Farrington, M.A.; Wedemeyer, A.C.; Camak, D.T.; Willis, A.T. Effort: 469.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	3
76	*Platygobio gracilis*	8
93	*Ictalurus punctatus*	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-098**
Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 13 River Mile: 114.1 02 August 2022
UTM Easting: 325390 UTM Northing: 3790397 Zone: 13 USGS Quad: Lemitar
Collector(s): Farrington, M.A.; Wedemeyer, A.C.; Camak, D.T.; Willis, A.T. Effort: 514.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	16
76	*Hybognathus amarus**	5
76	*Platygobio gracilis*	48
93	*Ictalurus punctatus*	12
212	*Gambusia affinis*	3

***Hybognathus amarus* (age-classes):**

age-0	5
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-097**
Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.
Site Number: 14 River Mile: 99.6 02 August 2022
UTM Easting: 327231 UTM Northing: 3771432 Zone: 13 USGS Quad: Loma de las Canas
Collector(s): Farrington, M.A.; Wedemeyer, A.C.; Camak, D.T.; Willis, A.T. Effort: 509.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	15
76	*Hybognathus amarus**	1
76	*Platygobio gracilis*	4
93	*Ictalurus punctatus*	5
212	*Gambusia affinis*	1

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring
August 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-096**
Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.
Site Number: 15 River Mile: 92.0 02 August 2022
UTM Easting: 328151 UTM Northing: 3761487 Zone: 13 USGS Quad: San Antonio
Collector(s): Farrington, M.A.; Wedemeyer, A.C.; Camak, D.T.; Willis, A.T. Effort: 563.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	18
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	1
93	*Ictalurus punctatus*	7

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-095**
Rio Grande, at US HWY 380 bridge crossing, San Antonio.
Site Number: 16 River Mile: 87.8 01 August 2022
UTM Easting: 328907 UTM Northing: 3754926 Zone: 13 USGS Quad: San Antonio
Collector(s): Wedemeyer, A.C.; Urioste, A.D.; Camak, D.T.; Lopez-Binder, J.M. Effort: 536.7 sq. m

Family	Species	Total
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	1
76	*Platygobio gracilis*	1
93	*Ictalurus punctatus*	10
212	*Gambusia affinis*	1

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-094**
Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.
Site Number: 17 River Mile: 79.0 01 August 2022
UTM Easting: 327219 UTM Northing: 3740906 Zone: 13 USGS Quad: San Antonio SE
Collector(s): Wedemeyer, A.C.; Urioste, A.D.; Camak, D.T.; Lopez-Binder, J.M. Effort: 580.2 sq. m

Family	Species	Total
76	*Hybognathus amarus**	1
93	*Ictalurus punctatus*	4

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring
August 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-093**
Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.
Site Number: 18 River Mile: 68.3 01 August 2022
UTM Easting: 315091 UTM Northing: 3728487 Zone: 13 USGS Quad: San Marcial
Collector(s): Wedemeyer, A.C.; Urioste, A.D.; Camak, D.T.; Lopez-Binder, J.M. Effort: 544.5 sq. m

Family	Species	Total
93	*Ictalurus punctatus*	3

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-092**
Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 19 River Mile: 60.1 01 August 2022
UTM Easting: 309441 UTM Northing: 3718309 Zone: 13 USGS Quad: Paraje Well
Collector(s): Wedemeyer, A.C.; Urioste, A.D.; Camak, D.T.; Lopez-Binder, J.M. Effort: 549.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	7
76	*Cyprinus carpio*	2
76	*Platygobio gracilis*	9
93	*Ictalurus punctatus*	3
212	*Gambusia affinis*	3

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-091**
Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 20 River Mile: 58.5 01 August 2022
UTM Easting: 307767 UTM Northing: 3716360 Zone: 13 USGS Quad: Paraje Well
Collector(s): Wedemeyer, A.C.; Urioste, A.D.; Camak, D.T.; Lopez-Binder, J.M. Effort: 561.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	8
76	*Platygobio gracilis*	1
93	*Ictalurus punctatus*	4

Rio Grande Silvery Minnow Population Monitoring
September 2022

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-128**
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9 09 September 2022
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13 USGS Quad: San Felipe Pueblo
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 476.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	65
76	*Platygobio gracilis*	18
76	*Rhinichthys cataractae*	23
81	*Carpiodes carpio*	1
81	*Catostomus commersonii*	1
93	*Ictalurus punctatus*	2
212	*Gambusia affinis*	28
294	*Micropterus salmoides*	1

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-129**
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9 09 September 2022
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13 USGS Quad: Bernalillo
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 463.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	36
76	*Hybognathus amarus**	5
76	*Platygobio gracilis*	63
76	*Rhinichthys cataractae*	25
93	*Ameiurus natalis*	3
93	*Ictalurus punctatus*	2
212	*Gambusia affinis*	42

***Hybognathus amarus* (age-classes):**

age-0	5
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring
September 2022

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-130**
Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.
Site Number: 3 River Mile: 199.9 09 September 2022
UTM Easting: 354728 UTM Northing: 3905587 Zone: 13 USGS Quad: Bernalillo
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 484.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	9
76	*Platygobio gracilis*	5
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	45
212	*Gambusia affinis*	28

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-127**
Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.
Site Number: 4 River Mile: 183.4 09 September 2022
UTM Easting: 346719 UTM Northing: 3884331 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 443.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	34
76	*Cyprinus carpio*	1
76	*Pimephales promelas*	4
76	*Platygobio gracilis*	3
76	*Rhinichthys cataractae*	1
93	*Ictalurus punctatus*	11
212	*Gambusia affinis*	13

Rio Grande Silvery Minnow Population Monitoring
September 2022

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-126**
Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.
Site Number: 5 River Mile: 178.4 09 September 2022
UTM Easting: 347468 UTM Northing: 3877400 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 461.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	35
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	2
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	3
93	*Ameiurus natalis*	2
93	*Ictalurus punctatus*	17
212	*Gambusia affinis*	11

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	1
age-2+	

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-125**
Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 6 River Mile: 161.7 08 September 2022
UTM Easting: 343149 UTM Northing: 3853187 Zone: 13 USGS Quad: Los Lunas
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 540.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	21
76	*Platygobio gracilis*	1
81	*Carpiodes carpio*	1
93	*Ictalurus punctatus*	7
212	*Gambusia affinis*	4

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-124**
Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 7 River Mile: 150.8 08 September 2022
UTM Easting: 340105 UTM Northing: 3837722 Zone: 13 USGS Quad: Tome
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 485.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	143
76	*Pimephales promelas*	2
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	2
212	*Gambusia affinis*	254

Rio Grande Silvery Minnow Population Monitoring
September 2022

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-123**
Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.
Site Number: 8 River Mile: 143.2 08 September 2022
UTM Easting: 338020 UTM Northing: 3827545 Zone: 13 USGS Quad: Veguita
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 472.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	104
76	*Cyprinus carpio*	1
93	*Ictalurus punctatus*	9
212	*Gambusia affinis*	68

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-122**
Rio Grande, at US HWY 60 bridge crossing, Bernardo.
Site Number: 9 River Mile: 130.6 08 September 2022
UTM Easting: 334578 UTM Northing: 3809921 Zone: 13 USGS Quad: Abeytas
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 500.6 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	172
76	*Cyprinus carpio*	1
93	*Ictalurus punctatus*	14
212	*Gambusia affinis*	99

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-121**
Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.
Site Number: 10 River Mile: 126.8 08 September 2022
UTM Easting: 330946 UTM Northing: 3805307 Zone: 13 USGS Quad: Abeytas
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 546.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	201
76	*Cyprinus carpio*	2
76	*Pimephales promelas*	1
93	*Ictalurus punctatus*	15
212	*Gambusia affinis*	123

Rio Grande Silvery Minnow Population Monitoring
September 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-120**
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3 07 September 2022
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13 USGS Quad: La Joya
Collector(s): Dudley, R.K.; Damron, T.D.; Winter, S. Effort: 542.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	13
76	*Platygobio gracilis*	11
81	*Carpiodes carpio*	1
93	*Ictalurus punctatus*	2
212	*Gambusia affinis*	10

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-119**
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6 07 September 2022
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13 USGS Quad: San Acacia
Collector(s): Dudley, R.K.; Damron, T.D.; Winter, S. Effort: 446.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	2
76	*Cyprinus carpio*	16
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	3
93	*Ictalurus punctatus*	1
212	*Gambusia affinis*	2

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-118**
Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 13 River Mile: 114.1 07 September 2022
UTM Easting: 325390 UTM Northing: 3790397 Zone: 13 USGS Quad: Lemitar
Collector(s): Dudley, R.K.; Damron, T.D.; Winter, S. Effort: 570.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	11
76	*Platygobio gracilis*	4
93	*Ictalurus punctatus*	4
212	*Gambusia affinis*	1

Rio Grande Silvery Minnow Population Monitoring
September 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-117**
Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.
Site Number: 14 River Mile: 99.6 07 September 2022
UTM Easting: 327231 UTM Northing: 3771432 Zone: 13 USGS Quad: Loma de las Canas
Collector(s): Dudley, R.K.; Damron, T.D.; Winter, S. Effort: 546.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	3
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	1
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	5
212	*Gambusia affinis*	6

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-116**
Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.
Site Number: 15 River Mile: 92.0 07 September 2022
UTM Easting: 328151 UTM Northing: 3761487 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Damron, T.D.; Winter, S. Effort: 485.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	2
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	1

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-115**
Rio Grande, at US HWY 380 bridge crossing, San Antonio.
Site Number: 16 River Mile: 87.8 06 September 2022
UTM Easting: 328907 UTM Northing: 3754926 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 571.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	1
76	*Cyprinus carpio*	6
76	*Platygobio gracilis*	5
93	*Ameiurus natalis*	3
93	*Ictalurus punctatus*	1
212	*Gambusia affinis*	3

Rio Grande Silvery Minnow Population Monitoring
September 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-114**
Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.
Site Number: 17 River Mile: 79.0 06 September 2022
UTM Easting: 327219 UTM Northing: 3740906 Zone: 13 USGS Quad: San Antonio SE
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 512.6 sq. m

Family	Species	Total
76	*Cyprinus carpio*	4
212	*Gambusia affinis*	18

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-113**
Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.
Site Number: 18 River Mile: 68.3 06 September 2022
UTM Easting: 315091 UTM Northing: 3728487 Zone: 13 USGS Quad: San Marcial
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 502.8 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	1
76	*Cyprinus carpio*	2
76	*Platygobio gracilis*	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-112**
Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 19 River Mile: 60.1 06 September 2022
UTM Easting: 309441 UTM Northing: 3718309 Zone: 13 USGS Quad: Paraje Well
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 589.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	5
76	*Cyprinus carpio*	6
76	*Platygobio gracilis*	1
93	*Ictalurus punctatus*	2

Rio Grande Silvery Minnow Population Monitoring
September 2022

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-111**
Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 20 River Mile: 58.5 06 September 2022
UTM Easting: 307767 UTM Northing: 3716360 Zone: 13 USGS Quad: Paraje Well
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.; Winter, S. Effort: 575.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	18
76	*Cyprinus carpio*	8
93	*Ictalurus punctatus*	1
93	*Pylodictis olivaris*	1
212	*Gambusia affinis*	3

Rio Grande Silvery Minnow Population Monitoring
October 2022

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-148**
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9 05 October 2022
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13 USGS Quad: San Felipe Pueblo
Collector(s): R.K. Dudley, M.A. Farrington, S.L. Clark-Barkalow Effort: 457.7 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	19
76	*Platygobio gracilis*	9
76	*Rhinichthys cataractae*	51
212	*Gambusia affinis*	48

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-149**
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9 05 October 2022
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13 USGS Quad: Bernalillo
Collector(s): R.K. Dudley, M.A. Farrington, S.L. Clark-Barkalow Effort: 500.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	33
76	*Pimephales promelas*	2
76	*Platygobio gracilis*	41
76	*Rhinichthys cataractae*	55
93	*Ictalurus punctatus*	22
212	*Gambusia affinis*	72

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage **RKD22-150**
Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.
Site Number: 3 River Mile: 199.9 05 October 2022
UTM Easting: 354728 UTM Northing: 3905587 Zone: 13 USGS Quad: Bernalillo
Collector(s): R.K. Dudley, M.A. Farrington, S.L. Clark-Barkalow Effort: 503.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	21
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	4
81	*Catostomus commersonii*	1
93	*Ameiurus natalis*	6
93	*Ictalurus punctatus*	52
212	*Gambusia affinis*	31

Rio Grande Silvery Minnow Population Monitoring
October 2022

NEW MEXICO: Sandoval County, RIO GRANDE Drainage **RKD22-160**
Rio Grande, ca. 4.5 mi upstream of Alameda Blvd. bridge crossing (NM State HWY 528), Corrales.
Site Number: 21 River Mile: 196.5 07 October 2022
UTM Easting: 355670 UTM Northing: 3900620 Zone: 13 USGS Quad: Alameda
Collector(s): R.K. Dudley, A.C. Wedemeyer, E.S. DeArmon Effort: 493.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	77
76	*Hybognathus amarus**	2
76	*Platygobio gracilis*	81
76	*Rhinichthys cataractae*	77
81	*Carpiodes carpio*	1
93	*Ictalurus punctatus*	39
212	*Gambusia affinis*	22

***Hybognathus amarus* (age-classes):**

age-0	
age-1	2
age-2+	

NEW MEXICO: Sandoval County, RIO GRANDE Drainage **RKD22-159**
Rio Grande, ca. 1.0 mi upstream of Alameda Blvd. bridge crossing (NM State HWY 528), Corrales.
Site Number: 22 River Mile: 193.0 07 October 2022
UTM Easting: 351565 UTM Northing: 3897088 Zone: 13 USGS Quad: Los Griegos
Collector(s): R.K. Dudley, A.C. Wedemeyer, E.S. DeArmon Effort: 568.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	25
76	*Hybognathus amarus**	1
76	*Pimephales promelas*	4
76	*Platygobio gracilis*	80
76	*Rhinichthys cataractae*	1
93	*Ictalurus punctatus*	24
212	*Gambusia affinis*	3

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring
October 2022

NEW MEXICO: Bernalillo County, RIO GRANDE Drainage **RKD22-158**
Rio Grande, ca. 1.2 mi downstream of Paseo del Norte Blvd. bridge crossing (NM State HWY 423), Albuquerque.
Site Number: 23 River Mile: 189.9 07 October 2022
UTM Easting: 349121 UTM Northing: 3893113 Zone: 13 USGS Quad: Los Griegos
Collector(s): R.K. Dudley, A.C. Wedemeyer, E.S. DeArmon Effort: 543.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	26
76	*Hybognathus amarus**	2
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	80
76	*Rhinichthys cataractae*	2
93	*Ictalurus punctatus*	72
212	*Gambusia affinis*	8

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	1
age-2+	

NEW MEXICO: Bernalillo County, RIO GRANDE Drainage **RKD22-157**
Rio Grande, ca. 1.1 mi upstream of US Interstate HWY I-40 bridge crossing, Albuquerque.
Site Number: 24 River Mile: 186.1 07 October 2022
UTM Easting: 346011 UTM Northing: 3887973 Zone: 13 USGS Quad: Albuquerque West
Collector(s): R.K. Dudley, A.C. Wedemeyer, E.S. DeArmon Effort: 511.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	71
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	7
76	*Pimephales promelas*	7
76	*Platygobio gracilis*	10
93	*Ictalurus punctatus*	10
212	*Gambusia affinis*	16

***Hybognathus amarus* (age-classes):**

age-0	5
age-1	2
age-2+	

Rio Grande Silvery Minnow Population Monitoring
October 2022

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-147**
Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.
Site Number: 4 River Mile: 183.4 05 October 2022
UTM Easting: 346719 UTM Northing: 3884331 Zone: 13 USGS Quad: Albuquerque West
Collector(s): R.K. Dudley, M.A. Farrington, S.L. Clark-Barkalow Effort: 486.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	148
76	*Cyprinus carpio*	5
76	*Hybognathus amarus**	2
76	*Pimephales promelas*	7
76	*Platygobio gracilis*	2
81	*Carpiodes carpio*	1
93	*Ameiurus natalis*	2
93	*Ictalurus punctatus*	17
212	*Gambusia affinis*	27

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	
age-2+	1

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage **RKD22-146**
Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.
Site Number: 5 River Mile: 178.4 05 October 2022
UTM Easting: 347468 UTM Northing: 3877400 Zone: 13 USGS Quad: Albuquerque West
Collector(s): R.K. Dudley, M.A. Farrington, S.L. Clark-Barkalow Effort: 498.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	57
76	*Cyprinus carpio*	2
76	*Hybognathus amarus**	4
76	*Pimephales promelas*	3
76	*Platygobio gracilis*	4
76	*Rhinichthys cataractae*	1
81	*Carpiodes carpio*	1
93	*Ictalurus punctatus*	13
212	*Gambusia affinis*	2

***Hybognathus amarus* (age-classes):**

age-0	2
age-1	2
age-2+	

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NEW MEXICO: Bernalillo County, RIO GRANDE Drainage **RKD22-156**
Rio Grande, ca. 1.4 mi upstream of US Interstate HWY I-25 bridge crossing, Isleta.
Site Number: 25 River Mile: 174.0 06 October 2022
UTM Easting: 345874 UTM Northing: 3870990 Zone: 13 USGS Quad: Isleta
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 501.3 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	161
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	2
76	*Pimephales promelas*	1
93	*Ictalurus punctatus*	16
212	*Gambusia affinis*	55

***Hybognathus amarus* (age-classes):**

age-0	
age-1	2
age-2+	

NEW MEXICO: Valencia County, RIO GRANDE Drainage **RKD22-155**
Rio Grande, ca. 4.1 mi upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 26 River Mile: 165.2 06 October 2022
UTM Easting: 342799 UTM Northing: 3858637 Zone: 13 USGS Quad: Los Lunas
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 537.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	181
76	*Hybognathus amarus**	2
93	*Ictalurus punctatus*	96
212	*Gambusia affinis*	56

***Hybognathus amarus* (age-classes):**

age-0	1
age-1	1
age-2+	

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-145**
Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 6 River Mile: 161.7 11 October 2022
UTM Easting: 343149 UTM Northing: 3853187 Zone: 13 USGS Quad: Los Lunas
Collector(s): R.K. Dudley, M.A. Farrington, T.D. Damron Effort: 499.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	193
93	*Ictalurus punctatus*	30
212	*Gambusia affinis*	14

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NEW MEXICO: Valencia County, RIO GRANDE Drainage **RKD22-154**
Rio Grande, ca. 6.5 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 27 River Mile: 156.0 06 October 2022
UTM Easting: 340512 UTM Northing: 3845124 Zone: 13 USGS Quad: Tome
Collector(s): R.K. Dudley, M.A. Farrington, A.C. Wedemeyer Effort: 504.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	40
76	*Pimephales promelas*	2
81	*Carpiodes carpio*	1
93	*Ictalurus punctatus*	3
212	*Gambusia affinis*	8

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-144**
Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 7 River Mile: 150.8 11 October 2022
UTM Easting: 340105 UTM Northing: 3837722 Zone: 13 USGS Quad: Tome
Collector(s): R.K. Dudley, M.A. Farrington, T.D. Damron Effort: 497.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	115
93	*Ictalurus punctatus*	13
212	*Gambusia affinis*	15

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage **RKD22-143**
Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.
Site Number: 8 River Mile: 143.2 11 October 2022
UTM Easting: 338020 UTM Northing: 3827545 Zone: 13 USGS Quad: Veguita
Collector(s): R.K. Dudley, M.A. Farrington, T.D. Damron Effort: 517.6 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	203
76	*Cyprinus carpio*	1
93	*Ictalurus punctatus*	10
212	*Gambusia affinis*	12

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NEW MEXICO: Socorro County, RIO GRANDE Drainage **RKD22-153**
Rio Grande, ca. 3.8 mi downstream of NM State HWY 346 bridge crossing, Jarales.
Site Number: 28 River Mile: 137.0 12 October 2022
UTM Easting: 335506 UTM Northing: 3819543 Zone: 13 USGS Quad: Veguita
Collector(s): R.K. Dudley, M.A. Farrington, T.D. Damron Effort: 481.0 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	232
93	*Ictalurus punctatus*	12
212	*Gambusia affinis*	41

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-142**
Rio Grande, at US HWY 60 bridge crossing, Bernardo.
Site Number: 9 River Mile: 130.6 04 October 2022
UTM Easting: 334578 UTM Northing: 3809921 Zone: 13 USGS Quad: Abeytas
Collector(s): M.A. Farrington, S.L. Clark-Barkalow, A.C. Wedemeyer Effort: 511.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	324
76	*Cyprinus carpio*	1
93	*Ictalurus punctatus*	9
212	*Gambusia affinis*	125
294	*Micropterus salmoides*	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-141**
Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.
Site Number: 10 River Mile: 126.8 04 October 2022
UTM Easting: 330946 UTM Northing: 3805307 Zone: 13 USGS Quad: Abeytas
Collector(s): M.A. Farrington, S.L. Clark-Barkalow, A.C. Wedemeyer Effort: 529.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	153
76	*Platygobio gracilis*	1
93	*Ictalurus punctatus*	6
212	*Gambusia affinis*	80

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NEW MEXICO: Socorro County, RIO GRANDE Drainage **RKD22-152**
Rio Grande, ca. 1.4 mi upstream of the Rio Salado confluence, San Acacia.
Site Number: 29 River Mile: 120.0 12 October 2022
UTM Easting: 330550 UTM Northing: 3795050 Zone: 13 USGS Quad: La Joya
Collector(s): R.K. Dudley, M.A. Farrington, T.D. Damron Effort: 535.2 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	38
76	*Cyprinus carpio*	2
93	*Ictalurus punctatus*	16
212	*Gambusia affinis*	15

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-140**
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3 11 October 2022
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13 USGS Quad: La Joya
Collector(s): R.K. Dudley, M.A. Farrington, T.D. Damron Effort: 575.9 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	7
76	*Notemigonus crysoleucas*	1
76	*Platygobio gracilis*	14
212	*Gambusia affinis*	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-139**
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6 04 October 2022
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13 USGS Quad: San Acacia
Collector(s): M.A. Farrington, S.L. Clark-Barkalow, A.C. Wedemeyer Effort: 517.5 sq. m

Family	Species	Total
76	*Platygobio gracilis*	19
93	*Ictalurus punctatus*	4

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-138**
Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 13 River Mile: 114.1 11 October 2022
UTM Easting: 325390 UTM Northing: 3790397 Zone: 13 USGS Quad: Lemitar
Collector(s): R.K. Dudley, M.A. Farrington, T.D. Damron Effort: 569.8 sq. m

Family	Species	Total
76	*Platygobio gracilis*	20
93	*Ictalurus punctatus*	10

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NEW MEXICO: Socorro County, RIO GRANDE Drainage **RKD22-151**
Rio Grande, ca. 2.1 mi upstream of Pueblitos Rd. bridge crossing, Lemitar.
Site Number: 30 River Mile: 106.3 11 October 2022
UTM Easting: 326666 UTM Northing: 3780246 Zone: 13 USGS Quad: Lemitar
Collector(s): R.K. Dudley, M.A. Farrington, T.D. Damron Effort: 557.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	7
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	3
76	*Platygobio gracilis*	5
93	*Ictalurus punctatus*	1

***Hybognathus amarus* (age-classes):**

age-0	3
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-137**
Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.
Site Number: 14 River Mile: 99.6 04 October 2022
UTM Easting: 327231 UTM Northing: 3771432 Zone: 13 USGS Quad: Loma de las Canas
Collector(s): M.A. Farrington, S.L. Clark-Barkalow, A.C. Wedemeyer Effort: 530.4 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	23
76	*Hybognathus amarus**	2
76	*Platygobio gracilis*	8

***Hybognathus amarus* (age-classes):**

age-0	2
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-136**
Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.
Site Number: 15 River Mile: 92.0 04 October 2022
UTM Easting: 328151 UTM Northing: 3761487 Zone: 13 USGS Quad: San Antonio
Collector(s): M.A. Farrington, S.L. Clark-Barkalow, A.C. Wedemeyer Effort: 510.6 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	24
76	*Cyprinus carpio*	1
76	*Platygobio gracilis*	1

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NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-135**
Rio Grande, at US HWY 380 bridge crossing, San Antonio.
Site Number: 16 River Mile: 87.8 03 October 2022
UTM Easting: 328907 UTM Northing: 3754926 Zone: 13 USGS Quad: San Antonio
Collector(s): R.K. Dudley, S.L. Clark-Barkalow, A.C. Wedemeyer Effort: 559.1 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	2
76	*Platygobio gracilis*	4
81	*Carpiodes carpio*	1
93	*Ictalurus punctatus*	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-134**
Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.
Site Number: 17 River Mile: 79.0 03 October 2022
UTM Easting: 327219 UTM Northing: 3740906 Zone: 13 USGS Quad: San Antonio SE
Collector(s): R.K. Dudley, S.L. Clark-Barkalow, A.C. Wedemeyer Effort: 523.5 sq. m

Family	Species	Total
76	*Cyprinella lutrensis*	1
76	*Platygobio gracilis*	2
212	*Gambusia affinis*	3

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-133**
Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.
Site Number: 18 River Mile: 68.3 03 October 2022
UTM Easting: 315091 UTM Northing: 3728487 Zone: 13 USGS Quad: San Marcial
Collector(s): R.K. Dudley, S.L. Clark-Barkalow, A.C. Wedemeyer Effort: 528.6 sq. m

Family	Species	Total
	No Fish Collected	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-132**
Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 19 River Mile: 60.1 03 October 2022
UTM Easting: 309441 UTM Northing: 3718309 Zone: 13 USGS Quad: Paraje Well
Collector(s): R.K. Dudley, S.L. Clark-Barkalow, A.C. Wedemeyer Effort: 522.2 sq. m

Family	Species	Total
	No Fish Collected	

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NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD22-131**
Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 20 River Mile: 58.5 03 October 2022
UTM Easting: 307767 UTM Northing: 3716360 Zone: 13 USGS Quad: Paraje Well
Collector(s): R.K. Dudley, S.L. Clark-Barkalow, A.C. Wedemeyer Effort: 564.2 sq. m

Family	Species	Total
	No Fish Collected	