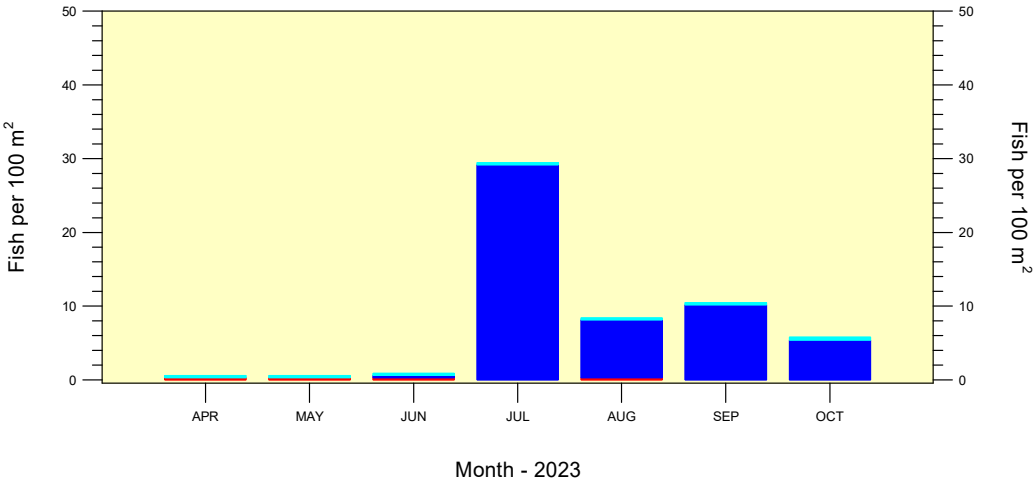
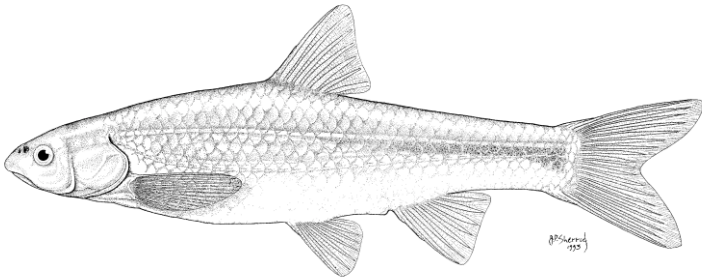


RIO GRANDE SILVERY MINNOW POPULATION MONITORING DURING 2023

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



Final Report
17 May 2024

RIO GRANDE SILVERY MINNOW POPULATION MONITORING DURING 2023

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

Contract 140R4019P0048:

Requisition 0040613161

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

Submitted to:

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

Robert K. Dudley^{1,2}, Steven P. Platania^{1,2}, and Gary C. White^{1,3}

¹ American Southwest Ichthyological Researchers (ASIR); 800 Encino Place NE; Albuquerque, NM 87102

&

² Museum of Southwestern Biology (Fishes), UNM; MSC03-2020; Albuquerque, NM 87131

&

³ Department of Fish, Wildlife, and Conservation Biology, CSU; 10 Wagar; Fort Collins, CO 80523

Final Report
17 May 2024

TABLE OF CONTENTS

TABLE OF CONTENTS	iii
LIST OF TABLES	v
<i>Appendix A</i>	vi
<i>Appendix B</i>	vi
<i>Appendix C</i>	vi
<i>Appendix E</i>	vi
LIST OF FIGURES	vii
<i>Appendix B</i>	ix
EXECUTIVE SUMMARY	x
INTRODUCTION	1
STUDY AREA	2
METHODS	7
<i>Sampling Protocols</i>	7
<i>Analytical Considerations</i>	7
<i>Statistical Analyses</i>	10
<i>Long-term analyses (1993–2023)</i>	10
<i>Mesohabitat associations (2002–2023)</i>	11
<i>Sampling variation (2005–2023)</i>	11
RESULTS	13
<i>Rio Grande Silvery Minnow</i>	13
<i>Current population status</i>	13
<i>Population trends (1993–2023)</i>	13
<i>Mesohabitat associations (2002–2023)</i>	26
<i>Sampling variation (2005–2023)</i>	40
<i>Fish Community</i>	43
<i>Population status (1993–2023)</i>	43
DISCUSSION	52
<i>Research Goals and Objectives</i>	52
<i>Population Trends vs. Population Estimates</i>	52
<i>Analytical Considerations</i>	53
<i>Additional, Dry, and Replacement Sites</i>	54
<i>Sampling Precision and Timing</i>	54
<i>Mesohabitat Associations</i>	55
<i>Spatial Distribution Patterns</i>	56
<i>Long-Term Ecological Relationships</i>	56
<i>Conclusions and Implications</i>	58
ACKNOWLEDGMENTS	59
LITERATURE CITED	60
APPENDIX A (Sampling Sites)	65
APPENDIX B (Rio Grande Silvery Minnow Site Occupancy)	71
APPENDIX C (Water Quality Summary)	83

APPENDIX D (Statistical Methods).....	84
APPENDIX E (Statistical Assumptions)	90
APPENDIX F (Site-Specific Population Monitoring Data).....	94

LIST OF TABLES

Table 1.	Scientific names, common names, and species codes of fishes collected in the Middle Rio Grande since 1993.....	8
Table 2.	Rio Grande Silvery Minnow abundance (all age-classes combined), by reach, site, and month, during 2023. Marked individuals are shown in parentheses, as a subset of the site-specific total. Blank cells indicate months when a site was not visited.	14
Table 3.	Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2023). Additional sites were excluded, and dry sites were included.....	25
Table 4.	Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2023). Additional sites and dry sites were excluded.....	28
Table 5.	Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2023). Additional sites (old only) and dry sites were included.	30
Table 6.	Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2023). Additional sites (old only) were included, and dry sites were excluded.	32
Table 7.	Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2023). Additional sites (old and new) and dry sites were included.....	34
Table 8.	Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2023). Additional sites (old and new) were included, and dry sites were excluded.	36
Table 9.	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. All combinations of additional sites (old [A_o] and new [A_n]) and dry (D) sites are presented (included [Y] or excluded [N]).	37
Table 10.	Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October mesohabitat-specific data from all sites (2002–2023).	39
Table 11.	Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using November sampling-site data from all sites (2005–2023).	42
Table 12.	Ichthyofaunal summary based on all sites (all age-classes combined), by species, during 2023. Marked and unmarked Rio Grande Silvery Minnow were included. Dashes (-) indicate species that were absent during sampling.	44
Table 13.	Ichthyofaunal summary based on all sites (all age-classes combined), by species and month, during 2023. Marked and unmarked Rio Grande Silvery Minnow were included.	45
Table 14.	Fish abundance based on all sites during October, by year and focal taxa, from 1993 to 2023. Sampling did not occur in 1998.	49
Table 15.	Fish rank-abundance based on all sites during October, by year and focal taxa, from 1993 to 2023. Sampling did not occur in 1998.	51

Appendix A

Table A1.	Sampling reaches and standard sites for population monitoring of Rio Grande Silvery Minnow in the Middle Rio Grande.	66
Table A2.	Sampling reaches and additional sites (old) for population monitoring of Rio Grande Silvery Minnow in the Middle Rio Grande.	68
Table A3.	Sampling reaches and additional sites (new) for population monitoring of Rio Grande Silvery Minnow in the Middle Rio Grande.	69
Table A4.	Sampling reaches and active replacement sites for population monitoring of Rio Grande Silvery Minnow in the Middle Rio Grande.	70

Appendix B

Table B1.	Site occupancy models for Rio Grande Silvery Minnow, using November sampling-site data (2005–2023).	75
-----------	--	----

Appendix C

Table C1.	Water quality statistics based on standard sites (April to October), by reach and site, during 2023.	83
-----------	---	----

Appendix E

Table E1.	Statistical assumptions, violation implications, violation risks, and mitigation precautions for Rio Grande Silvery Minnow population monitoring analyses.	91
Table E2.	Statistical assumptions, violation implications, violation risks, and mitigation precautions for Rio Grande Silvery Minnow site occupancy analyses.	93

LIST OF FIGURES

Figure 1.	Map of the study area, standard sites, and additional sites (old and new) for the Rio Grande Silvery Minnow population monitoring study. Site descriptions are provided in Appendix A.	3
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.	4
Figure 3.	Rio Grande mean-daily discharge, by USGS gaging station, from 1 January 2022 to 31 December 2023. Green lines are the average mean-daily discharges across years (1973–2023).	6
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 2023. The y-axis is logarithmic and larval sampling took place from April to October.	15
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 2023. When present, marked (red) and unmarked (blue) individuals were included.	16
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 2023. When present, marked (red) and unmarked [(age-0 [blue] and age-1+ [cyan]) individuals were included.	17
Figure 7.	Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. 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.	18
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 2023-12-31), 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.	19
Figure 9.	Bivariate plots of Rio Grande Silvery Minnow densities (estimated using October sampling-site data [1993–2023]), Albuquerque Gage data (A–F), and San Marcial Gage data (G–I). Additional sites were excluded, and dry sites were included.	20
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 2023-12-31), across years. Sampling did not occur in 1998. Additional sites were excluded, and dry sites were included.	21
Figure 11.	Bivariate plots of Rio Grande Silvery Minnow occurrence probabilities (estimated using October sampling-site data [1993–2023]), Albuquerque Gage data (A–F), and San Marcial Gage data (G–I). Additional sites were excluded, and dry sites were included.	22
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 2023-12-31), 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.	23

Figure 13.	Bivariate plots of Rio Grande Silvery Minnow lognormal densities (estimated using October sampling-site data [1993–2023]), Albuquerque Gage data (A–F), and San Marcial Gage data (G–I). Additional sites were excluded, and dry sites were included.	24
Figure 14.	Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. 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.	27
Figure 15.	Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. 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 (old only) and dry sites were included.	29
Figure 16.	Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. 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 (old only) were included, and dry sites were excluded.	31
Figure 17.	Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. 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 (old and new) and dry sites were included.	33
Figure 18.	Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. 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 (old and new) were included, and dry sites were excluded.	35
Figure 19.	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.	38
Figure 20.	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.	41
Figure 21.	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 2023.	46
Figure 22.	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 2023.	47
Figure 23.	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 2023.	48
Figure 24.	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.	50

Appendix B

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.	76
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 2023-12-31), across years.	77
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.	78
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 2023-12-31), across years.	79

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 an extended 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 (1993–2023).

The annual occurrence and density of Rio Grande Silvery Minnow, during October, has fluctuated widely over the past three decades (1993–2023). Estimated densities ($E(x)$; fish per 100 m²) were notably higher in 2016 and 2017, as compared with 2015, but then decreased dramatically from 2017 to 2018. Recent monitoring efforts revealed a 96.1% decrease in its density from 2019 (2.10) to 2022 (0.08), but its density again increased by 2023 (3.37). While Rio Grande Silvery Minnow represented only 0.68% of the fish community in 2022, it had increased to 8.09% by 2023.

Changes in the occurrence and density of Rio Grande Silvery Minnow were reliably predicted by seasonal differences in river flows across years (1993–2023). 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 (i.e., 92.3% of cumulative model weight) 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 [2002–2023]), or on different days during repeated sampling (November [2005–2023]), were comparable to population trends obtained from the long-term dataset (October [1993–2023]). 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, these 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 [2005–2023]), further revealed that Rio Grande Silvery Minnow occupancy probabilities decreased from 2019 (1.00) to 2022 (0.49) before improving (0.75) in 2023. While estimated extinction probabilities were elevated during an extended drought (i.e., 2012–2014), they decreased substantially from 2014 to 2017, as seasonal river flows progressively improved. Likewise, estimated colonization probabilities increased considerably from 2013 to 2017, as this species gradually repatriated multiple sites that had been previously unoccupied. However, these positive trends reversed in 2018 and 2020 following poor spring and summer flow conditions. While the long-term conservation status of Rio Grande Silvery Minnow declined from 2019 to 2022, its status again improved somewhat in 2023.

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 and productive habitats when spring flows begin to rise. These conditions, combined with a protracted spring runoff, help ensure the inundation of nursery habitats for larval fish. As growth from the egg phase through the vulnerable early larval phases (i.e., protolarvae and mesolarvae) requires about one month, 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. This long-term pattern could be explained by the cumulative displacement of propagules past instream barriers. Also, river incision, habitat degradation, abandonment of the floodplain, and reductions in suspended sediments downstream of Cochiti Dam are likely limiting the number and size 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. Fortunately, both the occurrence and density of Rio Grande Silvery Minnow increased in 2023, following high and prolonged flows during spring runoff. 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 that support the long-term recovery of Rio Grande Silvery Minnow.

INTRODUCTION

Dams, reservoirs, and their operations have profoundly impacted the distribution and abundance of native fishes within the Great Plains and desert rivers of North America for over 100 years (Stanford and Ward 1979; Cross et al. 1983, 1985; Cross and Moss 1987; Winston et al. 1991; Luttrell et al. 1999; Dudley and Platania 2007; Perkin et al. 2015; Worthington et al. 2018). Endemic pelagic-spawning leuciscids (pelagophils), with drifting propagules, have declined precipitously throughout these regions following extensive river fragmentation, flow regulation, and habitat loss (Dudley and Platania 2007; Hoagstrom 2015; Worthington et al. 2018). Many of the pelagophils 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 jemezianus*) or have become extinct (Phantom Shiner, *Alburnops orca* and Rio Grande Bluntnose Shiner, *Alburnops simus simus*) over the past century (Bestgen and Platania 1990; Platania and Altenbach 1998). Rio Grande Silvery Minnow, *Hybognathus amarus*, is the only extant pelagophil 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 myriad abiotic and biotic factors (USFWS 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. 2023a). 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 km² (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 operations have led to notably lower peak flows, greatly reduced sediment supplies, and the progressive incision, narrowing, and armoring of the river channel downstream (Lagasse 1980; Massong et al. 2006; Mortensen et al. 2023). 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, shoreline pools, and other nursery habitats likely benefit native fishes (Porter and Massong 2004a, 2004b; Pease et al. 2006), these low-velocity and often warmer mesohabitats are relatively rare (Braun et al. 2015).

The study area (Figures 1 and 2) is a portion of the Middle Rio Grande, from Angostura Diversion Dam to Elephant Butte Reservoir, which encompasses most of the current range of Rio Grande Silvery Minnow (i.e., from Cochiti Dam [although it is unknown if this species persists upstream of Angostura Diversion Dam] to the mouth 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 (Figure 1; Appendix A [Table A1]) overlap the current documented range of Rio Grande Silvery Minnow and form the basis of the long-term monitoring efforts (1993–2023). 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.

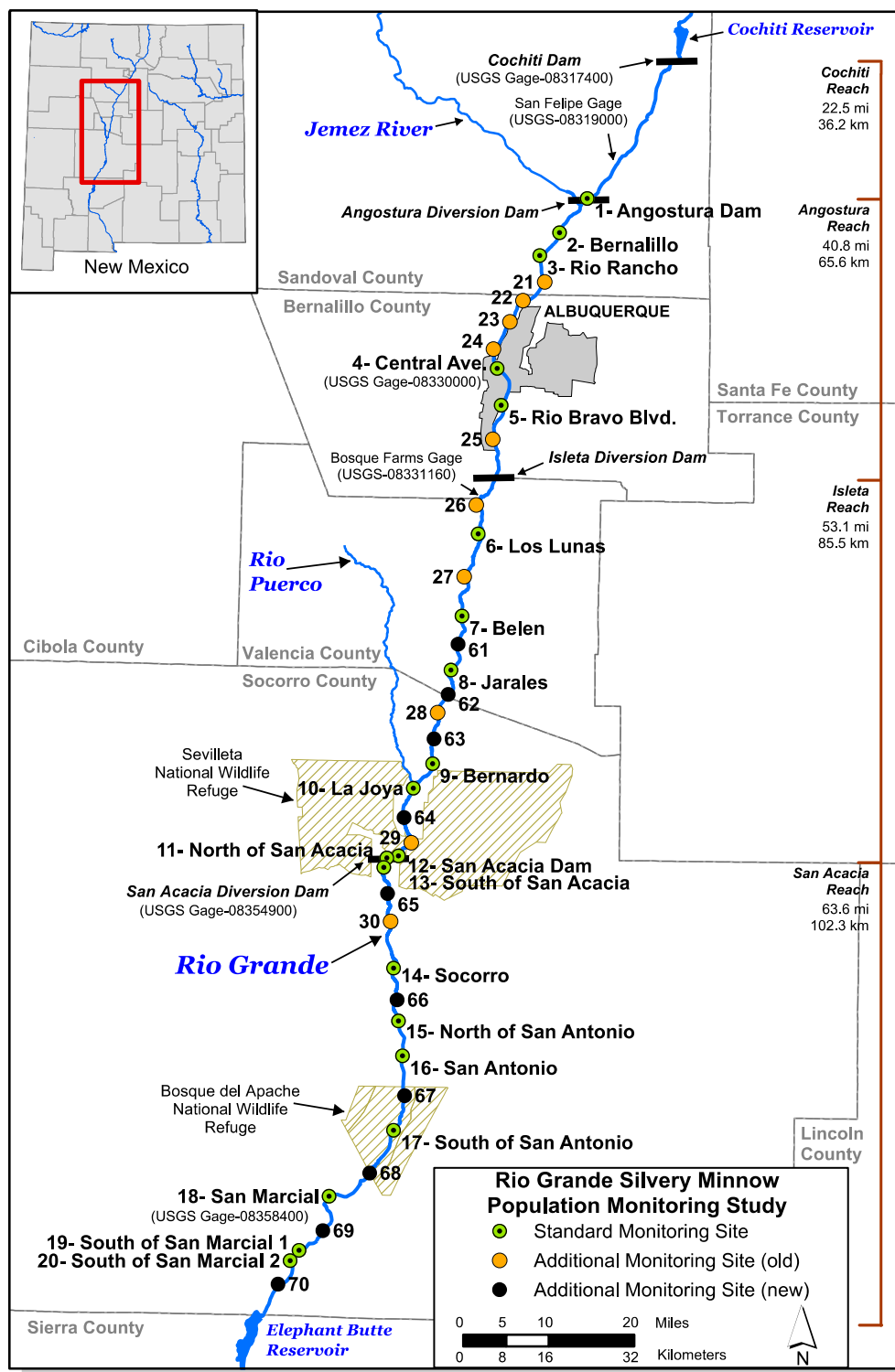


Figure 1. Map of the study area, standard sites, and additional sites (old and new) for the Rio Grande Silvery Minnow population monitoring study. Site descriptions are provided in Appendix A.

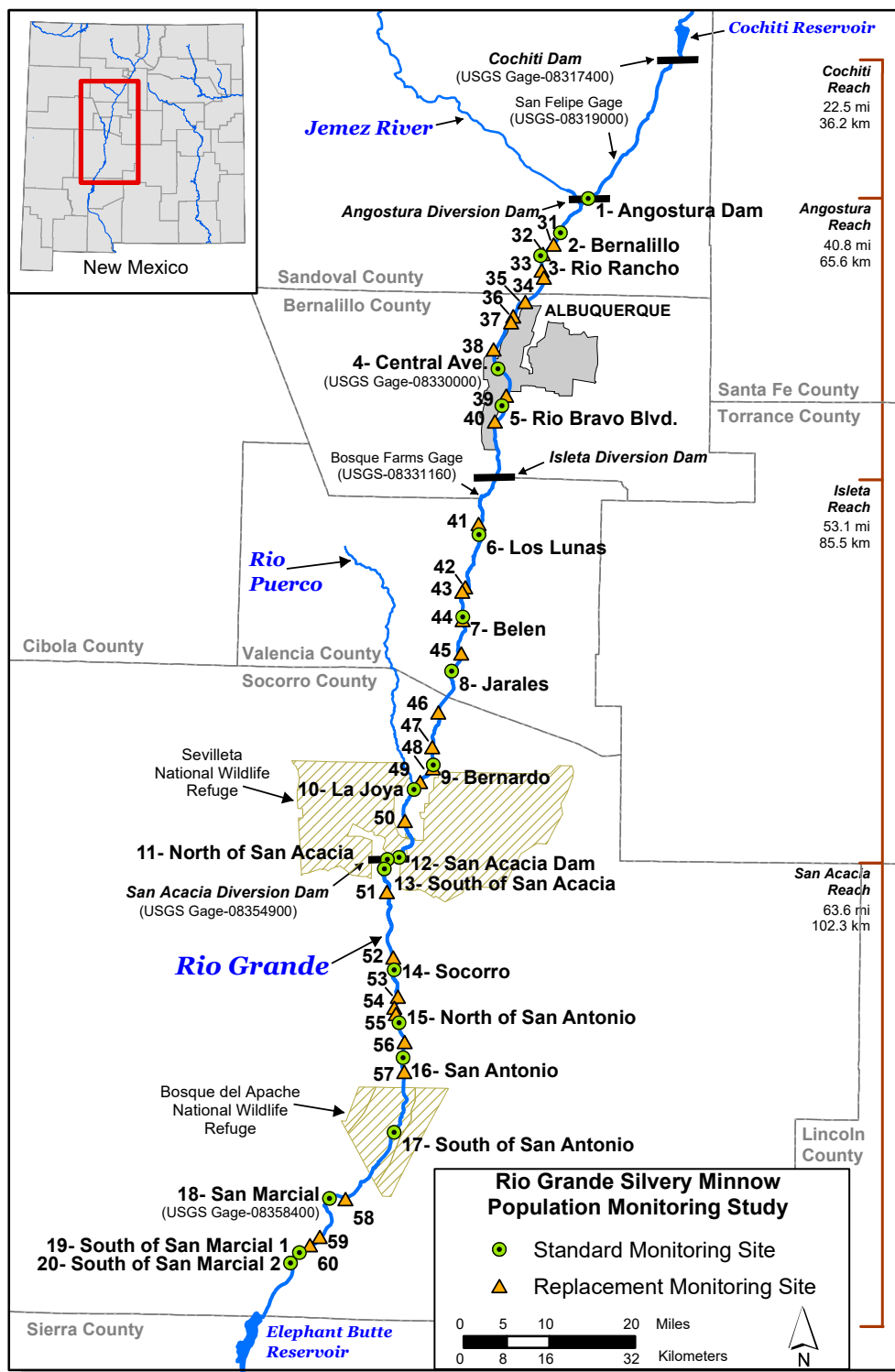


Figure 2. Map of the study area, standard sites, and replacement sites for the Rio Grande Silvery Minnow population monitoring study. Site descriptions are provided in Appendix A.

To obtain 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]). In 2023, ten new additional sampling sites were added to help fill in the largest remaining sampling gaps within the study area, while ensuring that the sampling coverage was spatially balanced both within and across reaches. To obtain this spatially-balanced coverage, four new sites were added to the Isleta Reach and six new sites were added to the San Acacia Reach (Figure 1; Appendix A [Table A3]). All additional sites (old and new) 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.

Since 2017, replacement sites (Figure 2; Appendix A [Table A4]) were also sampled whenever the river was dry at one of the standard sampling sites. As these replacement sites were meant to supplement the standard 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 2022 and 2023, 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 2023, flows were notably high throughout the study area, and there was an extended period of spring runoff. River flows peaked in May but declined rapidly to low levels by early July. Flows were persistently low from July through October, except for periodic minor increases from rainstorms. As compared to the historical spring runoff (i.e., average mean-daily discharges since 1973 [Cochiti Dam operational]), flows were low, except after periodic rainstorms, during the summer of 2022. In contrast, there was a pronounced and prolonged summer drought event in 2023. All mean daily discharge data presented in this report are provisional and subject to change.

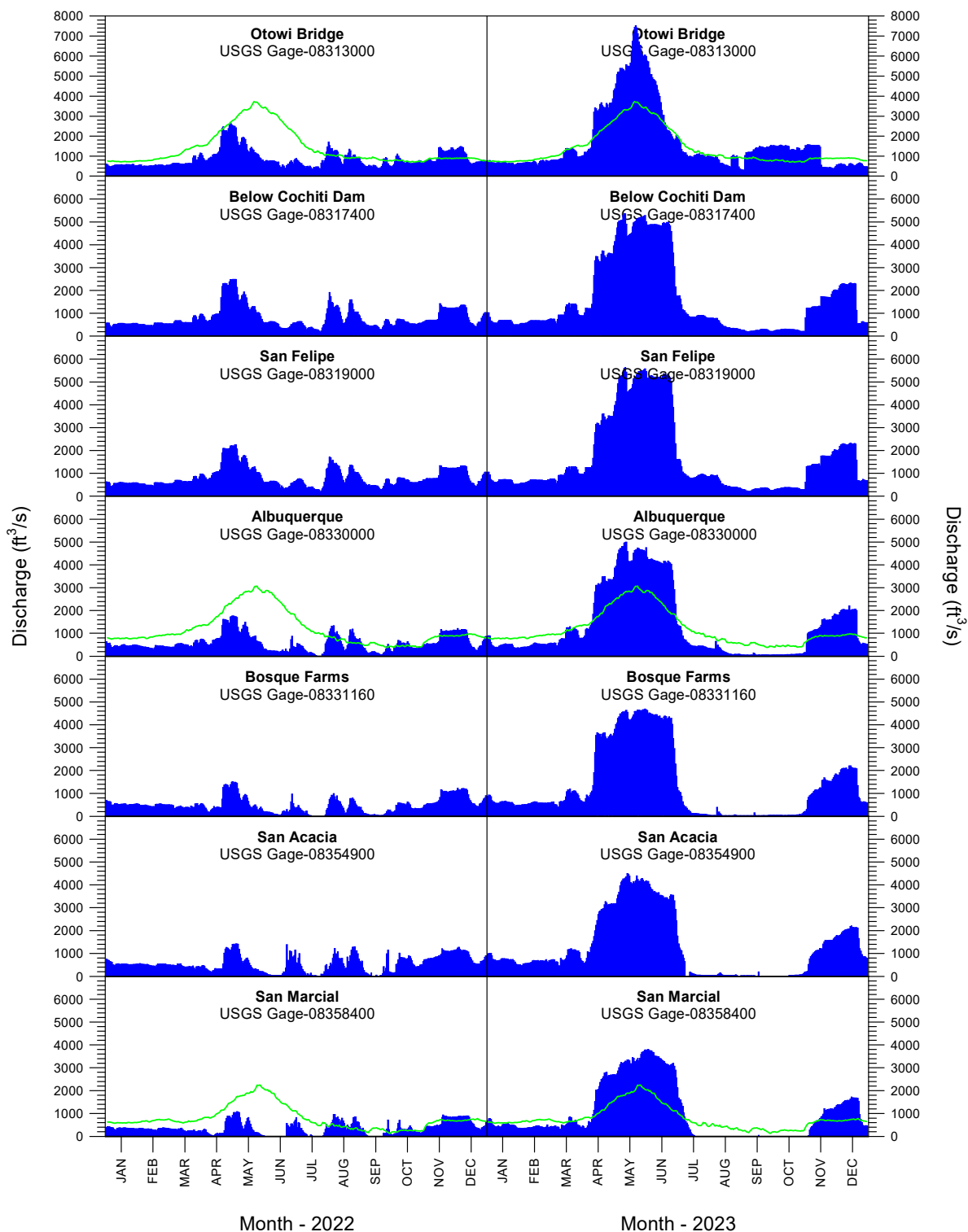


Figure 3. Rio Grande mean-daily discharge, by USGS gaging station, from 1 January 2022 to 31 December 2023. Green lines are the average mean-daily discharges across years (1973–2023).

METHODS

Sampling Protocols

This study documents long-term trends in the occurrence and density of Rio Grande Silvery Minnow, and the associated fish community, at 20 standard 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. Twenty additional sites (see Study Area) are also now sampled in April and October. 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 population 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 further disturbing the site for subsequent repeated efforts. Scientific and common names of fishes in this report follow Page et al. (2023; Table 1). Names of orders (n = 8), families (n = 13), and species (n = 39) were ordered phylogenetically throughout the report based on Page et al. (2023).

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 a handheld PIT tag reader 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.

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 Dorosomatidae		
	thread herrings	
<i>Dorosoma cepedianum</i>	Gizzard Shad	(DORCEP)
<i>Dorosoma petenense</i>	Threadfin Shad	(DORPET)
Order Cypriniformes		
Family Catostomidae		
	suckers	
<i>Carpodes carpio</i>	River Carpsucker ¹	(CARCAR)
<i>Catostomus commersonii</i>	White Sucker ¹	(CATCOM)
<i>Ictiobus bubalus</i>	Smallmouth Buffalo	(ICTBUB)
Family Cyprinidae		
	carps	
<i>Carassius auratus</i>	Goldfish	(CARAUR)
<i>Cyprinus carpio</i>	Common Carp ¹	(CYPCAR)
Family Leuciscidae		
	minnows	
<i>Campostoma anomalum</i>	Central Stoneroller	(CAMANO)
<i>Cyprinella lutrensis</i>	Red Shiner ¹	(CYPLUT)
<i>Gila pandora</i>	Rio Grande Chub	(GILPAN)
<i>Hybognathus amarus</i>	Rio Grande Silvery Minnow ¹	(HYBAMA)
<i>Notemigonus crysoleucas</i>	Golden Shiner	(NOTCRY)
<i>Pimephales promelas</i>	Fathead Minnow ¹	(PIMPRO)
<i>Pimephales vigilax</i>	Bullhead Minnow	(PIMVIG)
<i>Platygobio gracilis</i>	Flathead Chub ¹	(PLAGRA)
<i>Rhinichthys cataractae</i>	Longnose Dace ¹	(RHICAT)
Order Siluriformes		
Family Ictaluridae		
	North American catfishes	
<i>Ameiurus melas</i>	Black Bullhead	(AMEMEL)
<i>Ameiurus natalis</i>	Yellow Bullhead	(AMENAT)
<i>Ictalurus furcatus</i>	Blue Catfish	(ICTFUR)
<i>Ictalurus punctatus</i>	Channel Catfish ¹	(ICTPUN)
<i>Pygocentrus nattereri</i>	Flathead Catfish	(PYLOLI)
Family Loricariidae		
	suckermouth armored catfishes	
<i>Pterygoplichthys disjunctivus</i>	Vermiculated Sailfin Catfish	(PTEDIS)

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 Esociformes		
Family Esocidae	piques and mudminnows	
<i>Esox lucius</i>	Northern Pike	(ESOLUC)
Order Salmoniformes		
Family Salmonidae	trouts and salmons	
<i>Oncorhynchus mykiss</i>	Rainbow Trout	(ONCMYK)
<i>Salmo trutta</i>	Brown Trout	(SALTRU)
Order Cyprinodontiformes		
Family Poeciliidae	livebearers	
<i>Gambusia affinis</i>	Western Mosquitofish ¹	(GAMAFF)
Order Centrarchiformes		
Family Centrarchidae	sunfishes	
<i>Lepomis cyanellus</i>	Green Sunfish	(LEPCYA)
<i>Lepomis macrochirus</i>	Bluegill	(LEPMAC)
<i>Lepomis megalotis</i>	Longear Sunfish	(LEPMEG)
<i>Micropterus dolomieu</i>	Smallmouth Bass	(MICDOL)
<i>Micropterus salmoides</i>	Florida Bass	(MICSAL)
<i>Pomoxis annularis</i>	White Crappie	(POMANN)
<i>Pomoxis nigromaculatus</i>	Black Crappie	(POMNIG)
Order Perciformes		
Family Moronidae	temperate basses	
<i>Morone chrysops</i>	White Bass	(MORCHR)
<i>Morone saxatilis</i>	Striped Bass	(MORSAX)
Family Percidae	perches and darters	
<i>Perca flavescens</i>	Yellow Perch	(PERFLA)
<i>Percina macrolepida</i>	Bigscale Logperch	(PERMAC)
<i>Sander vitreus</i>	Walleye	(SANVIT)
Family Sciaenidae	drums and croakers	
<i>Aplodinotus grunniens</i>	Freshwater Drum	(APLGRU)

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

Site-specific density (catch-per-unit-effort [CPUE]) was estimated by dividing the total number of individuals captured by the total area sampled, multiplied by 100 (i.e., fish per 100 m²). 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 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 (1993–2023)

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 (1993–2023), based on small-mesh regular seine samples, were analyzed using PROC NLMIXED (Nonlinear Mixed Models; SAS 2023). 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 six different versions of the dataset: (1) additional sites excluded and dry sites included, (2) additional sites and dry sites excluded, (3) additional sites (old only) and dry sites included, (4) additional sites (old only) included and dry sites excluded, (5) additional sites (old and new) and dry sites included, and (6) additional sites (old and new) 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 ($\delta[\text{Year}] \mu[\text{Year}]$) represents the upper limit on the amount of explainable variation and the null model ($\delta[.] \mu[.]$) represents the lower limit of that variation. Additionally, all nested environmental covariates 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 (1993–2023) 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] ft³/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). Mean daily discharge (SANmean) and lower threshold discharge values (days < 200 [SAN<200] and 100 [SAN<100] ft³/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 functions. These fixed effects assume that variation in the dataset is explained by the covariates (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 = $-2[\log\text{-likelihood}]$ and AIC_c = Akaike's information criterion [Akaike 1973; Burnham and Anderson 2002] corrected for finite sample sizes) were generated to assess the relative fit of data to various mixture models. Lower values of AIC_c indicate a better fit of the data to the model. Models were ranked by AIC_c values, and the top ten models (based on AIC_c weight [w_i]) were presented. As nested environmental covariates were only used individually to model the population parameters (i.e., no additive effects), potential issues of multicollinearity were avoided. Further, AIC_c model selection ranks single-variable models appropriately, even if variables are highly correlated (i.e., resulting w_i values would be similar). An analysis of deviance (ANODEV) was used to determine the relative proportion of deviance in likelihood values explained by the environmental covariates, for both δ and μ models, and to assess whether that proportion was significantly different from zero ($P < 0.05$) based on an F -test (Skalski et al. 1993).

Kendall's coefficient of concordance (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 (1993–2023). This nonparametric statistical procedure was used to compute the W statistic, which ranges from zero (no concordance) to one (complete concordance). The chi-squared statistic (χ^2) was calculated to evaluate whether the concordance (W) was significantly different from zero ($P < 0.05$).

Mesohabitat associations (2002–2023)

Rio Grande Silvery Minnow mesohabitat-specific density data have been consistently collected from all sampling sites 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 (1993–2023) was site (e.g., all mesohabitat samples combined for each site). Mesohabitat-specific density data from October (2002–2023) 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 with both Mesohabitat (e.g., Year+Mesohabitat and Year**Mesohabitat*, respectively) and Reach.

Sampling variation (2005–2023)

Sampling variation was evaluated using Rio Grande Silvery Minnow sampling-site density data from repeated sampling at the 20 standard sites during November (2005–2023). For these repeated-sampling efforts, 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 (2005–2023) 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 with 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 2023, 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 2023, 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 Isleta Reach (Figure 6).

Population trends (1993–2023)

Rio Grande Silvery Minnow densities ($E(x)$; estimated using October sampling-site data [1993–2023]) were generated from the year model ($\delta[\text{Year}] \mu[\text{Year}]$). 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). Recent monitoring efforts revealed a substantial decrease (–96.1%) in the density of Rio Grande Silvery Minnow from 2019 ($E(x) = 2.10$) to 2022 ($E(x) = 0.08$), but its density increased significantly ($P < 0.05$) from 2022 to 2023 ($E(x) = 3.37$). Naïve density estimates (i.e., unmodeled), calculated using the method of moments, and model-estimated densities ($E(x)$) were similar across years. Combining a plot of $E(x)$ and mean daily discharge (1993–2023) 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 ($\delta[\text{Year}] \mu[\text{Year}]$), were also closely associated with hydrological metrics over time (1993–2023). 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 (1993–2023; Table 3). The top ecological model ($\delta[\text{Year}] \mu[\text{ABQmax} + R]$) received 52.1% of the AIC_c weight (w_i) out of the 440 models considered. The top δ covariate (SANmean) accounted for 63.0% of the deviance ($P < 0.001$) explained by the $\delta(\text{Year})$ model over the $\delta(\cdot)$ model. We also found significant effects ($P < 0.001$) for ABQmax (63.0%), ABQmean (58.2%), ABQ>2,000 (57.9%), SAN<200 (56.4%), ABQ>1,000 (53.7%), Inundation (53.5%), ABQ>3,000 (49.7%), and SAN<100 (48.0%). Further, the top μ covariate (ABQmax) accounted for 40.3% of the deviance ($P < 0.001$) explained by the $\mu(\text{Year})$ model over the $\mu(\cdot)$ model. We also found significant effects ($P < 0.001$) for ABQ>2,000 (40.0%), ABQmean (35.4%), ABQ>1,000 (34.9%), ABQ>3,000 (33.3%), Inundation (32.5%), SANmean (32.3%), SAN<200 (27.1%), and SAN<100 (24.4%). The top three ecological models, which accounted for 92.3% 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 2023. 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	0	0	6(0)	6
Angostura	2	Bernalillo	0	0	0	9(0)	62(0)	3(0)	8(0)	82
Angostura	3	Rio Rancho	0	0	0	2(0)	19(0)	14(0)	46(0)	81
Angostura	21	Site 21	0						78(0)	78
Angostura	22	Site 22	2(0)						23(0)	25
Angostura	23	Site 23	0						16(0)	16
Angostura	24	Site 24	0						47(0)	47
Angostura	4	Central Ave.	0	0	57(0)	81(0)	23(0)	22(0)	15(0)	198
Angostura	5	Rio Bravo Blvd.	4(4)	0	8(0)	358(0)	21(0)	13(0)	8(0)	412
Angostura	25	Site 25	0						3(0)	3
<i>Angostura Totals</i>			6	0	65	450	125	52	250	948
Isleta	26	Site 26	1(1)						41(0)	42
Isleta	6	Los Lunas	1(1)	0	8(0)	317(0)	13(0)	292(0)	56(0)	687
Isleta	27	Site 27	0						0	0
Isleta	7	Belen	0	0	1(0)	488(0)	104(0)	54(0)	3(0)	650
Isleta	61	Site 61							87(0)	87
Isleta	8	Jarales	0						51(0)	306
Isleta	62	Site 62							0	0
Isleta	28	Site 28	0						68(0)	68
Isleta	63	Site 63							110(0)	110
Isleta	9	Bernardo	0	0	4(0)	132(0)	10(0)	79(0)	25(0)	250
Isleta	10	La Joya	0	0	2(0)	278(0)	7(0)	16(0)	0	303
Isleta	64	Site 64							4(0)	4
Isleta	29	Site 29	0						14(0)	14
Isleta	11	North of San Acacia	0	0	0	3(0)	2(0)	3(0)	0	8
<i>Isleta Totals</i>			2	0	16	1,377	148	527	459	2,529
San Acacia	12	San Acacia Dam	4(2)	0	0	1(0)	117(3)	225(0)	2(0)	349
San Acacia	13	South of San Acacia	1(1)	1(1)	7(1)	2(0)	153(0)	56(0)	9(0)	229
San Acacia	65	Site 65							48(0)	48
San Acacia	30	Site 30	3(3)						25(0)	28
San Acacia	14	Socorro	0	0	0	4(0)	0	25(0)	65(0)	94
San Acacia	66	Site 66							16(0)	16
San Acacia	54	Site 54					5(0)			5
San Acacia	15	North of San Antonio	0	0	0	31(0)	1(1)	0	0	32
San Acacia	16	San Antonio	2(2)	3(2)	13(1)	72(0)	0	0	0	90
San Acacia	67	Site 67							0	0
San Acacia	17	South of San Antonio	0	0	0	6(0)	32(0)	0	1(0)	39
San Acacia	68	Site 68							0	0
San Acacia	18	San Marcial	1(1)	0	0	2(0)	1(0)	0	0	4
San Acacia	69	Site 69							0	0
San Acacia	59	Site 59						1(0)		1
San Acacia	60	Site 60						0		0
San Acacia	19	South of San Marcial 1	2(2)	0	29(0)	195(0)	96(0)	0	0	322
San Acacia	20	South of San Marcial 2	0	0	0	0	0	0	0	0
San Acacia	70	Site 70							0	0
<i>San Acacia Totals</i>			13	4	49	313	405	307	166	1,257
Monthly Totals			21	4	130	2,140	678	886	875	4,734

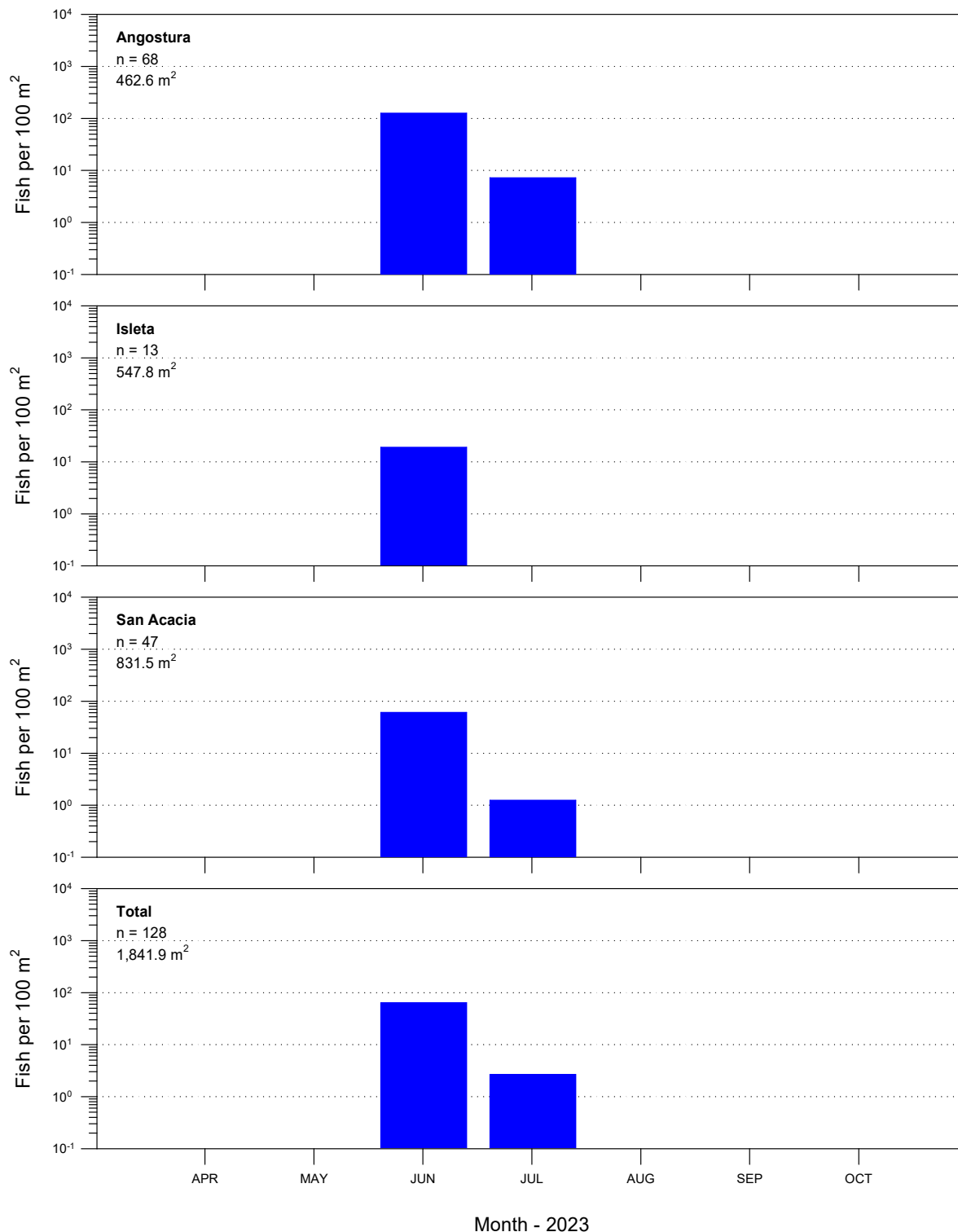


Figure 4. Rio Grande Silvery Minnow densities based on all sites (larval fish only [fine-mesh seine]; non-larval fish excluded), by reach and month, during 2023. The y-axis is logarithmic and larval sampling took place from April to October.

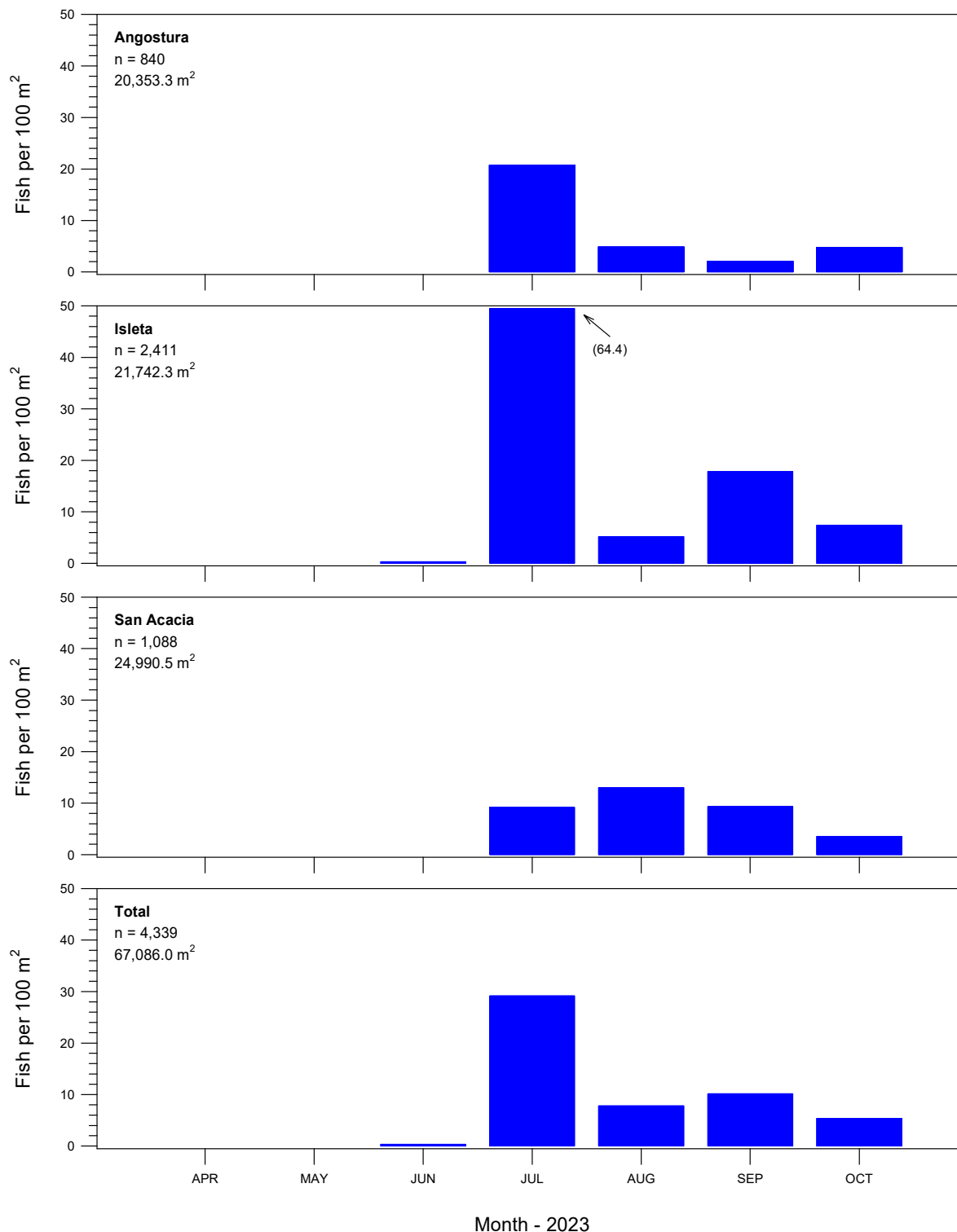


Figure 5. Rio Grande Silvery Minnow densities based on all sites (age-0 fish only [small-mesh seine]; larval fish excluded), by reach and month, during 2023. When present, marked (red) and unmarked (blue) individuals were included.

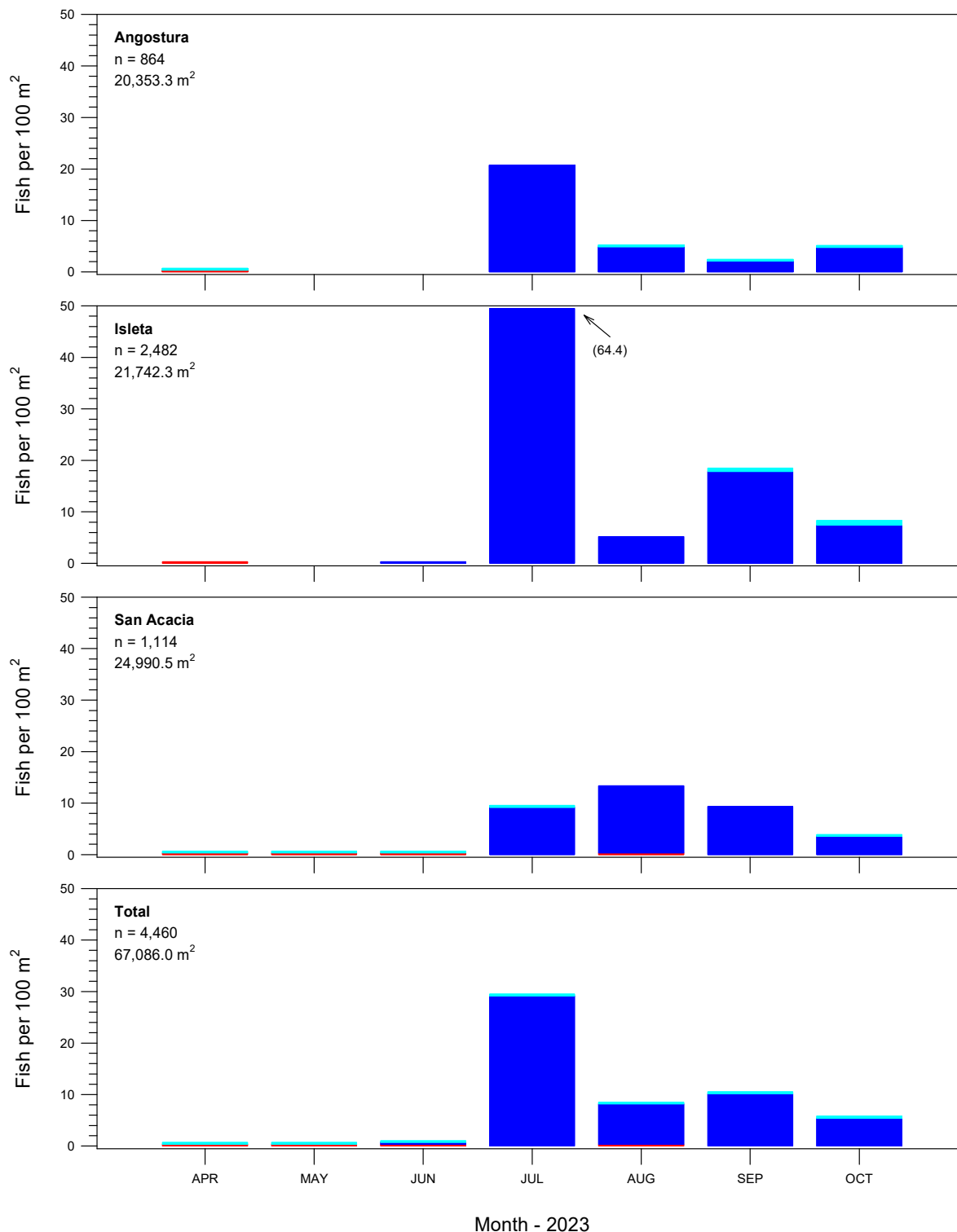


Figure 6. Rio Grande Silvery Minnow densities based on all sites (age-0 and age-1+ fish [small-mesh seine]; larval fish excluded), by reach and month, during 2023. When present, marked (red) and unmarked [(age-0 [blue] and age-1+ [cyan]) individuals were included.

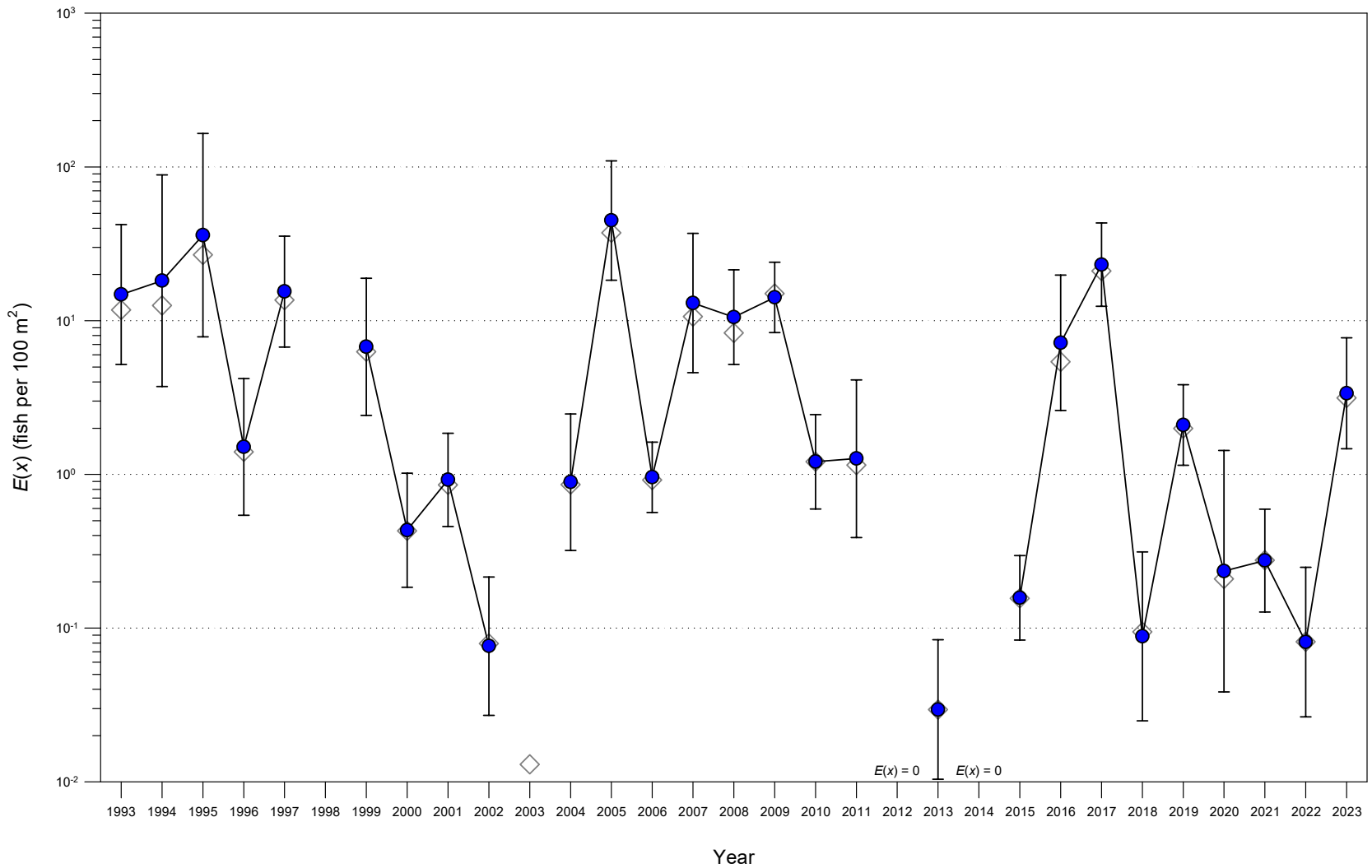


Figure 7. Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. Sampling did not occur in 1998, and density could not be estimated for 2003. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated. Additional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

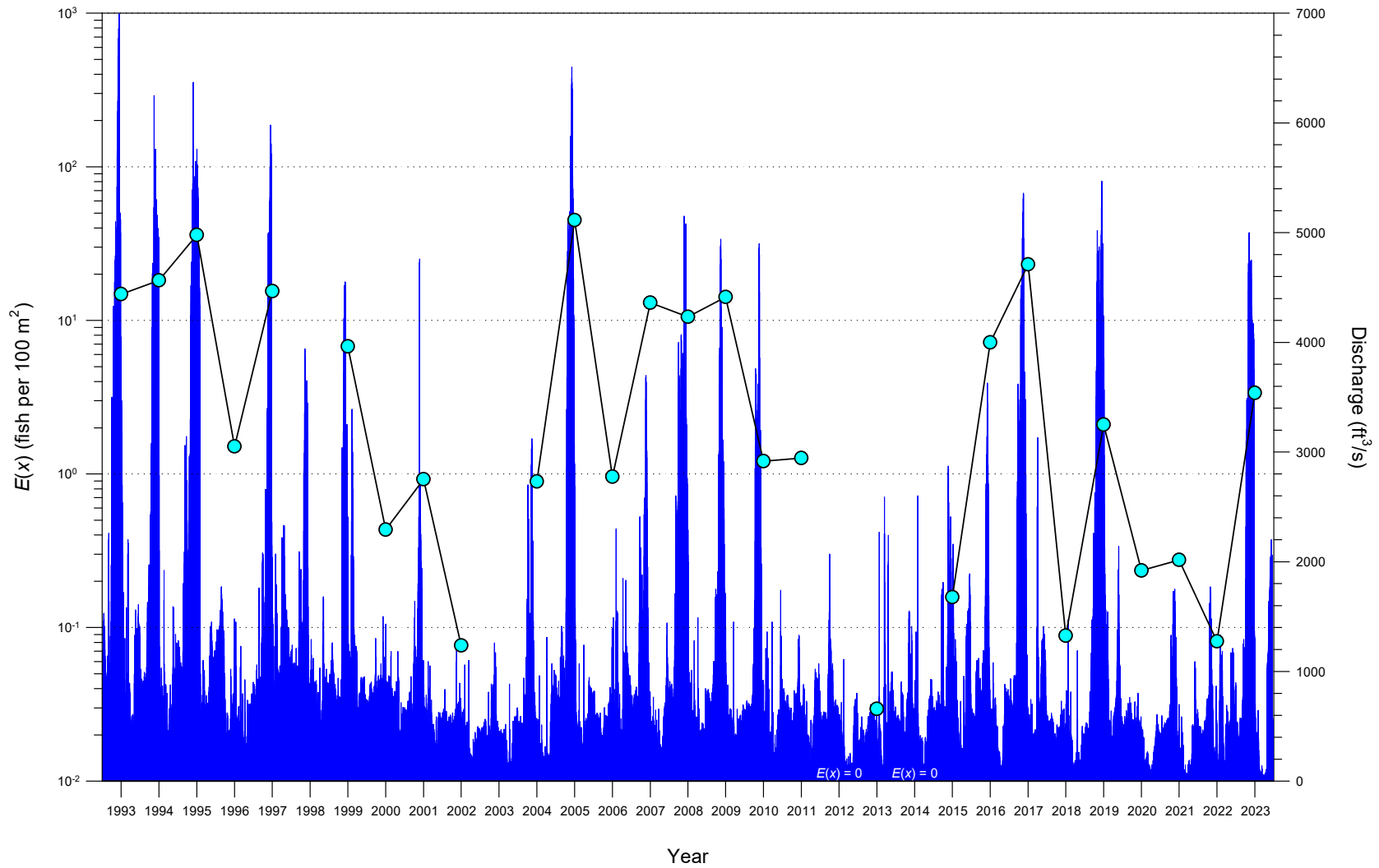


Figure 8. Rio Grande Silvery Minnow densities (estimated using October sampling-site data), and mean daily discharge data from the Albuquerque Gage (1993-01-01 to 2023-12-31), across years. Sampling did not occur in 1998, and density could not be estimated for 2003. Additional sites were excluded, and dry sites were included.

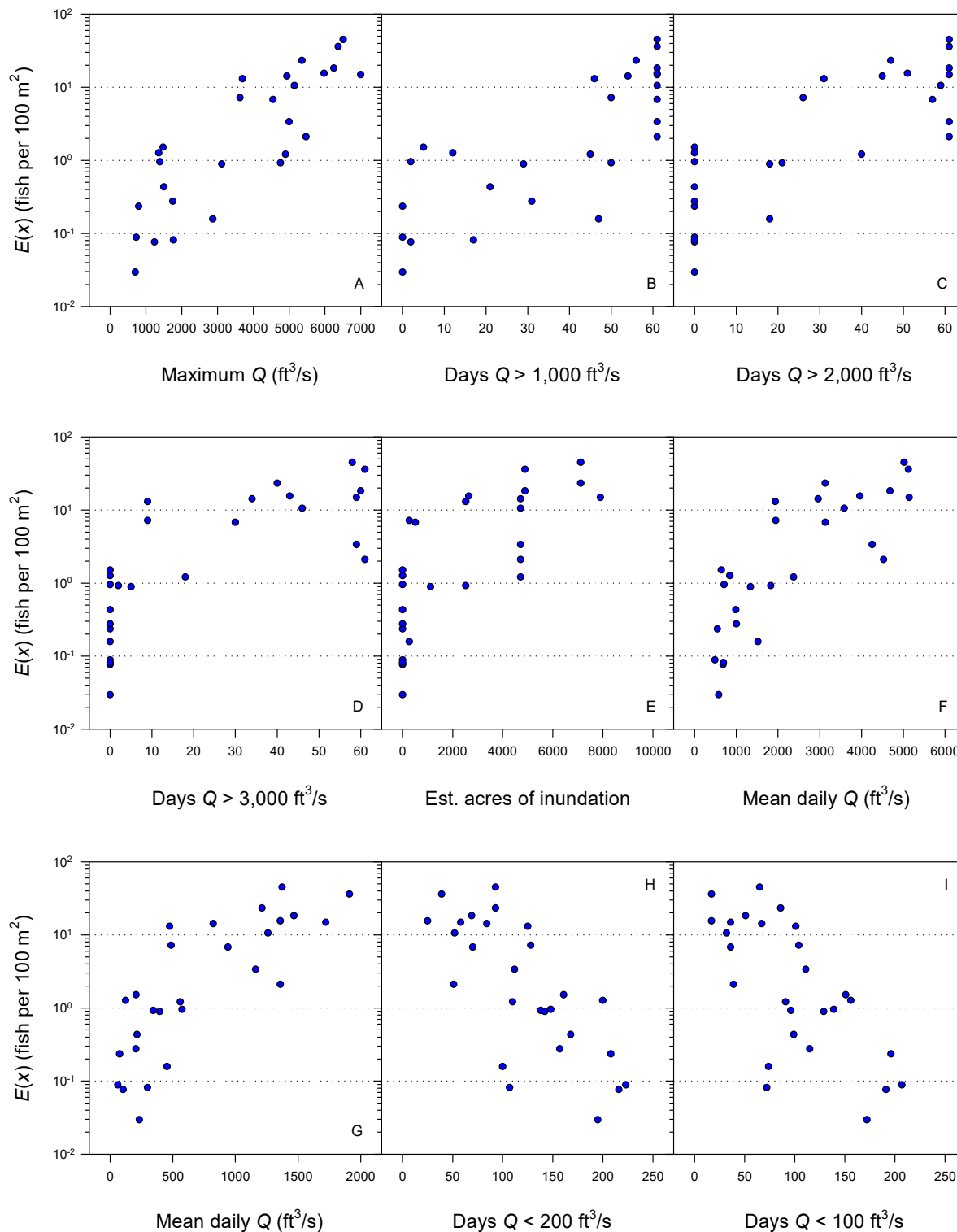


Figure 9. Bivariate plots of Rio Grande Silvery Minnow densities (estimated using October sampling-site data [1993–2023]), Albuquerque Gage data (A–F), and San Marcial Gage data (G–I). Additional sites were excluded, and dry sites were included.

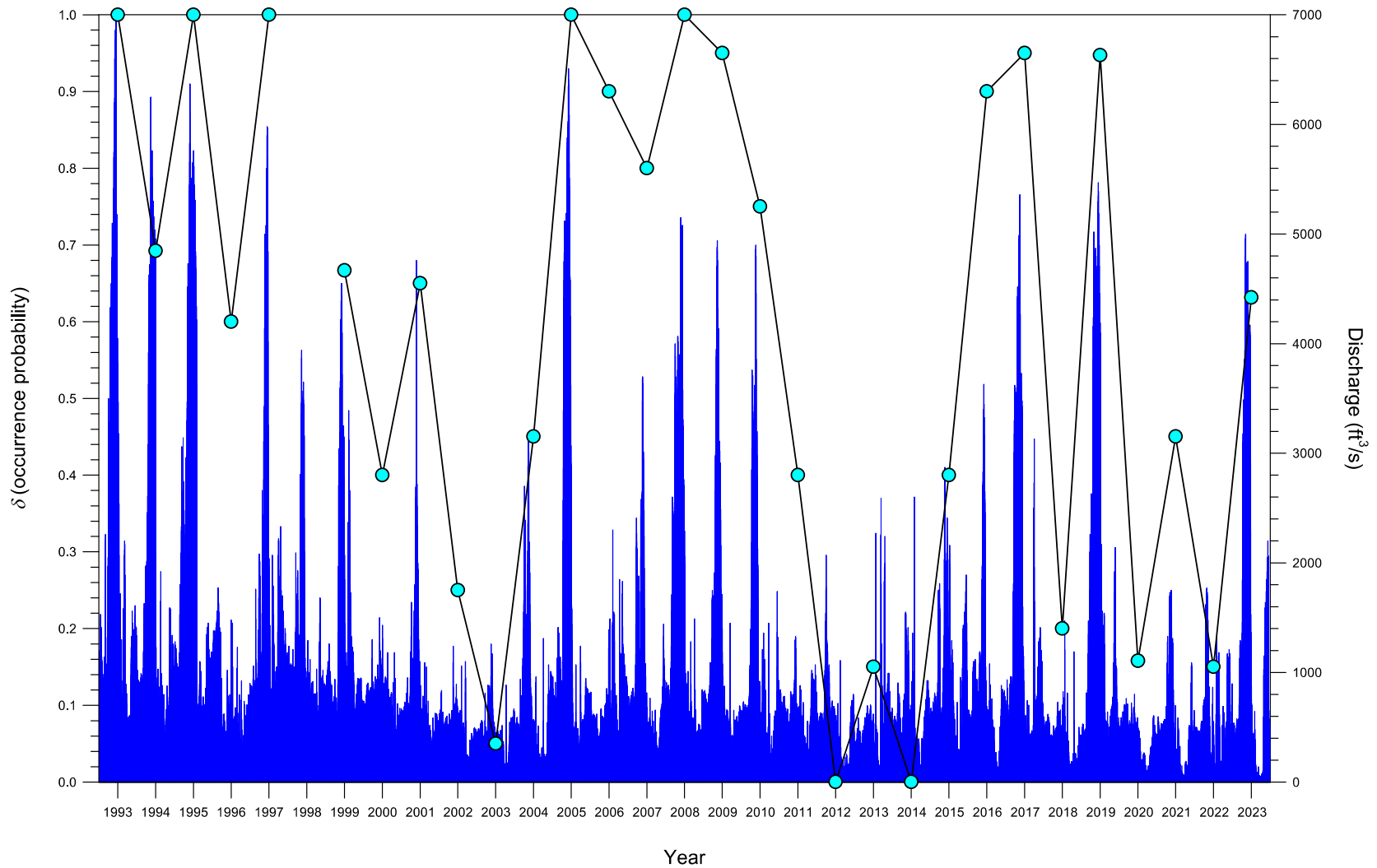


Figure 10. Rio Grande Silvery Minnow occurrence probabilities (estimated using October sampling-site data), and mean daily discharge data from the Albuquerque Gage (1993-01-01 to 2023-12-31), across years. Sampling did not occur in 1998. Additional sites were excluded, and dry sites were included.

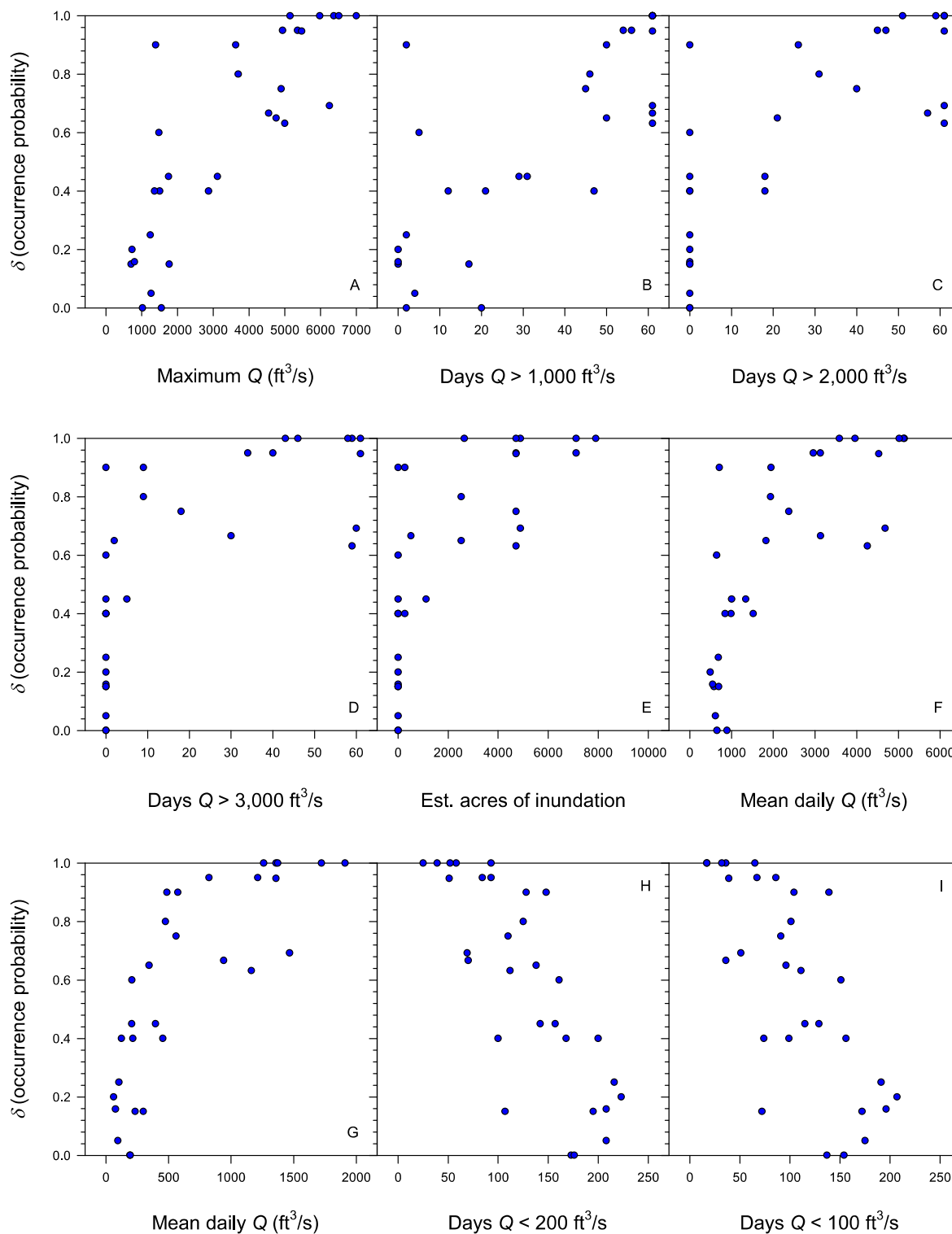


Figure 11. Bivariate plots of Rio Grande Silvery Minnow occurrence probabilities (estimated using October sampling-site data [1993–2023]), Albuquerque Gage data (A–F), and San Marcial Gage data (G–I). Additional sites were excluded, and dry sites were included.

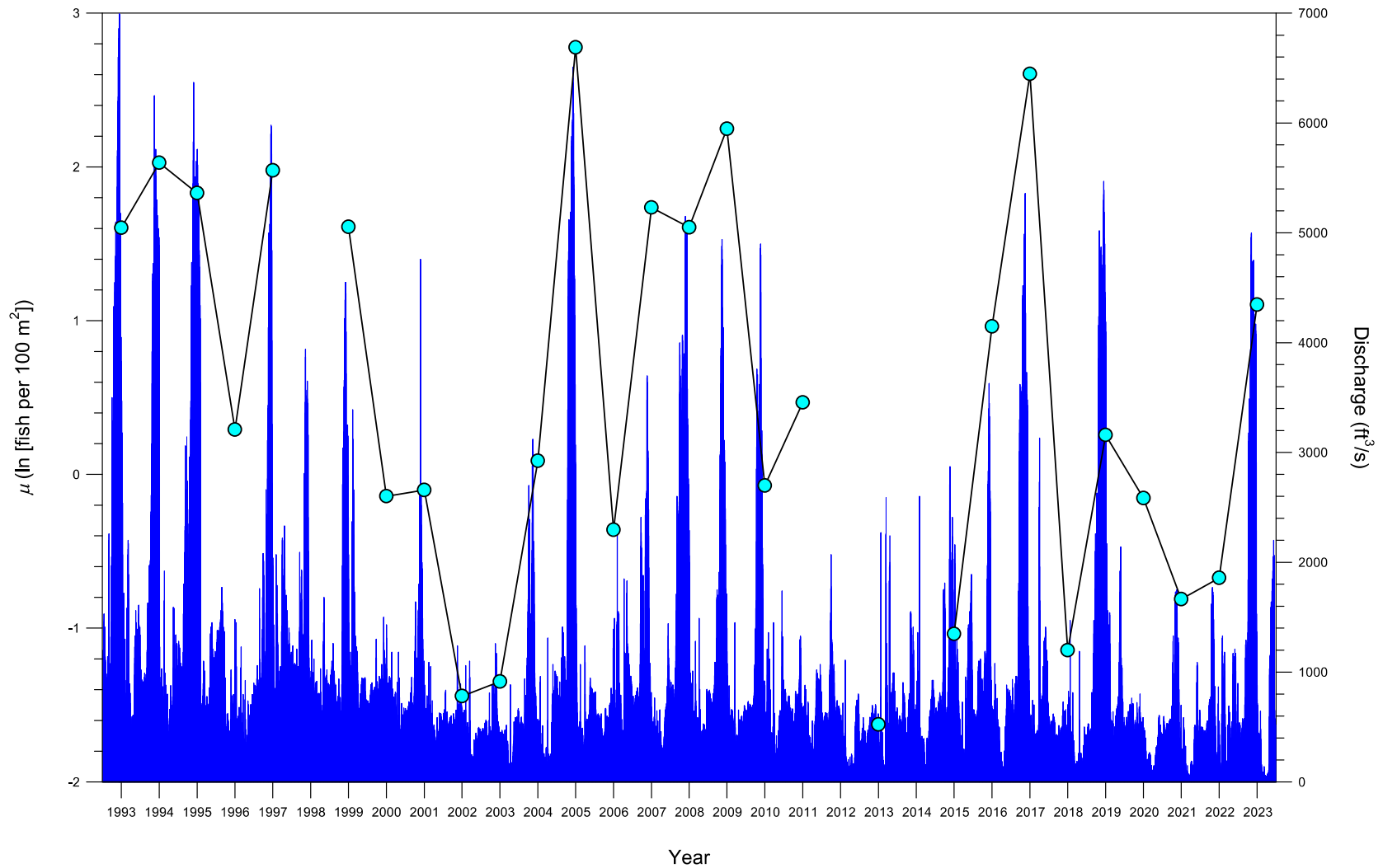


Figure 12. Rio Grande Silvery Minnow lognormal densities (estimated using October sampling-site data), and mean daily discharge data from the Albuquerque Gage (1993-01-01 to 2023-12-31), across years. Sampling did not occur in 1998, and lognormal density could not be estimated for 2012 or 2014 (i.e., all zero values). Additional sites were excluded, and dry sites were included.

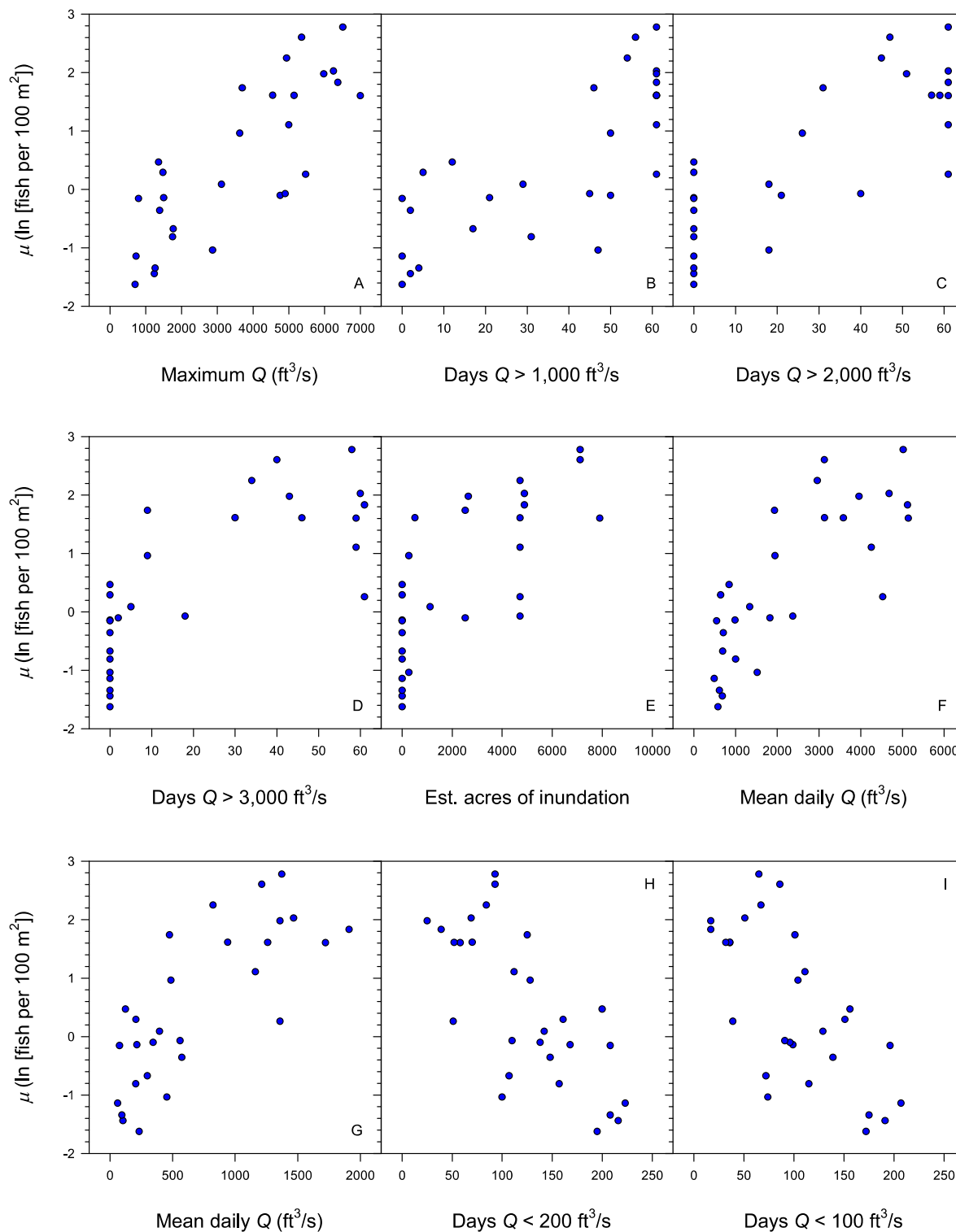


Figure 13. Bivariate plots of Rio Grande Silvery Minnow lognormal densities (estimated using October sampling-site data [1993–2023]), Albuquerque Gage data (A–F), and San Marcial Gage data (G–I). Additional sites were excluded, and dry sites were included.

Table 3. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2023). Additional sites were excluded, and dry sites were included.

Model ¹	logLike ²	K ³	AIC _c ⁴	w _i ⁴
$\delta(\text{Year}) \mu(\text{ABQmax}+R)$	921.73	35	996.52	0.5205
$\delta(\text{Year}) \mu(\text{ABQ}>2,000+R)$	923.14	35	997.93	0.2569
$\delta(\text{Year}) \mu(\text{ABQmean}+R)$	924.27	35	999.06	0.1460
$\delta(\text{Year}) \mu(\text{SANmean}+R)$	926.70	35	1,001.49	0.0433
$\delta(\text{Year}) \mu(\text{ABQ}>1,000+R)$	928.85	35	1,003.64	0.0148
$\delta(\text{Year}) \mu(\text{ABQ}>3,000+R)$	929.43	35	1,004.22	0.0111
$\delta(\text{SANmean}+R) \mu(\text{Year})$	879.38	58	1,008.98	0.0010
$\delta(\text{Year}) \mu(\text{SAN}<200+R)$	934.55	35	1,009.34	0.0009
$\delta(\text{Year}) \mu(\text{Inundation}+R)$	934.68	35	1,009.47	0.0008
$\delta(\text{ABQmax}+R) \mu(\text{Year})$	879.87	58	1,009.48	0.0008

¹ = Models included all δ and μ combinations of null effects (.), random effects (R), year (1993–2023), and hydrological metrics (with and without R) from Albuquerque (ABQ: USGS Gage-08330000) and San Marcial (SAN: USGS Gage-08358400).

² = Likelihood ($-2[\log\text{-likelihood}]$) 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).

Analyses were also conducted to evaluate the effects of including data from the additional sites (2017–2023). Estimated densities of Rio Grande Silvery Minnow were similar when the additional sites (old only) were included or excluded, and whether dry sites were included or excluded (Figures 15 and 16). Likewise, estimated densities were similar when the additional sites (old and new) were included or excluded, and whether dry sites were included or excluded (Figures 17 and 18). However, all analyses that included additional sites revealed an increased AIC_c weight for the $\mu(\text{Year})$ models (Tables 5–8). Also, the 95% confidence intervals for $E(x)$ were relatively narrower (i.e., more precise) for all analyses when the additional sites were included, as compared to when they were excluded. A summary of the estimated densities across years (Table 9) was provided to facilitate long-term comparisons among all model combinations (i.e., standard sites, old additional sites, new additional sites, and dry sites [included or excluded]).

Mesohabitat associations (2002–2023)

Rio Grande Silvery Minnow densities ($E(x)$; estimated using October sampling-site data [2002–2023]) were generated from the year-mesohabitat model ($\delta[\text{Year} \times \text{Mesohabitat}] \mu[\text{Year} \times \text{Mesohabitat}]$). Interannual density trends for the five mesohabitats (BW, PO, RU, SHPO, and SHRU) were similar over the study period (Figure 19). Densities decreased dramatically in all mesohabitats from 2017 to 2018, but then swiftly increased from 2018 to 2019. There was another notable decrease in densities across all mesohabitats from 2019 to 2022, but densities again increased in 2023. 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 estimates 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 10). The top model ($\delta[\text{Year} + \text{Mesohabitat}] \mu[\text{Year} + \text{Mesohabitat}]$) effectively received all the AIC_c weight out of the 41 models considered. A comparison of AIC_c values revealed that year ($\delta[\text{Year}] \mu[\text{Year}]$; $AIC_c = 3,114.52$) was more informative in explaining changes in model parameter values over time as compared with mesohabitat ($\delta[\text{Mesohabitat}] \mu[\text{Mesohabitat}]$; $AIC_c = 3,917.04$) or reach ($\delta[\text{Reach}] \mu[\text{Reach}]$; $AIC_c = 4,190.19$). The mesohabitat model ($\delta[\text{Mesohabitat}] \mu[\text{Mesohabitat}]$) demonstrated that estimated densities in lower velocity mesohabitats (BW [27.01], PO [6.28], and SHPO [9.67]) were higher ($P < 0.05$) than densities in higher velocity mesohabitats (RU [1.14] and SHRU [3.21]).

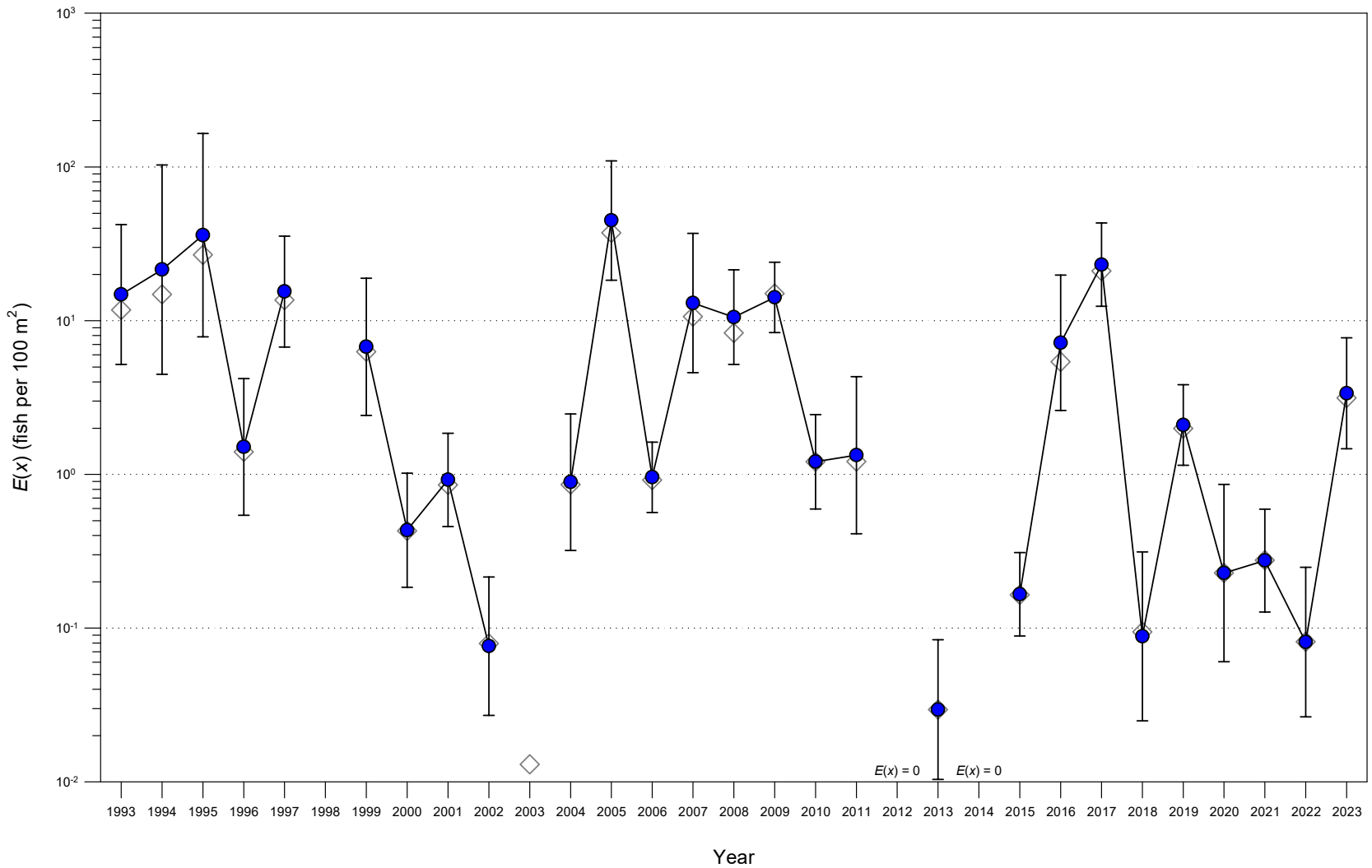


Figure 14. Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. Sampling did not occur in 1998, and density could not be estimated for 2003. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated. Additional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

Table 4. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2023). Additional sites and dry sites were excluded.

Model ¹	logLike ²	K ³	AIC _c ⁴	w _i ⁴
$\delta(\text{Year}) \mu(\text{ABQmax}+R)$	921.50	35	996.37	0.5442
$\delta(\text{Year}) \mu(\text{ABQ}>2,000+R)$	923.23	35	998.10	0.2289
$\delta(\text{Year}) \mu(\text{ABQmean}+R)$	924.43	35	999.30	0.1255
$\delta(\text{Year}) \mu(\text{SANmean}+R)$	926.89	35	1,001.75	0.0368
$\delta(\text{Year}) \mu(\text{ABQ}>1,000+R)$	928.60	35	1,003.47	0.0156
$\delta(\text{SANmean}+R) \mu(\text{ABQ}>2,000+R)$	986.05	9	1,004.38	0.0099
$\delta(\text{Year}) \mu(\text{ABQ}>3,000+R)$	929.93	35	1,004.80	0.0080
$\delta(\text{ABQmax}+R) \mu(\text{ABQmax}+R)$	987.17	9	1,005.50	0.0056
$\delta(\text{SANmean}+R) \mu(\text{Year})$	875.77	58	1,005.59	0.0054
$\delta(\text{SANmean}+R) \mu(\text{ABQmean}+R)$	987.78	9	1,006.11	0.0042

¹ = Models included all δ and μ combinations of null effects (.), random effects (R), year (1993–2023), and hydrological metrics (with and without R) from Albuquerque (ABQ: USGS Gage-08330000) and San Marcial (SAN: USGS Gage-08358400).

² = Likelihood ($-2[\log\text{-likelihood}]$) 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).

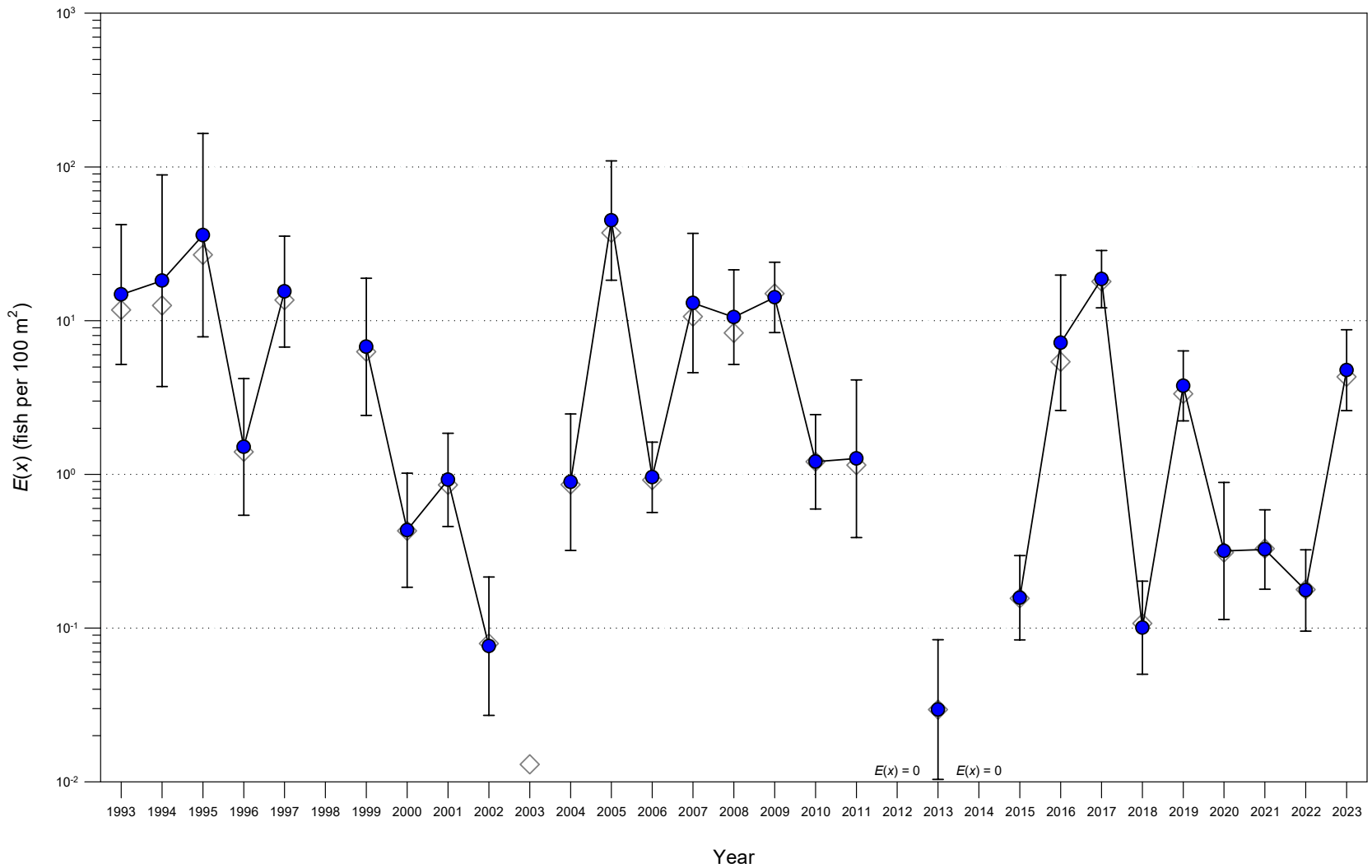


Figure 15. Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. Sampling did not occur in 1998, and density could not be estimated for 2003. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated. Additional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

Table 5. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2023). Additional sites (old only) and dry sites were included.

Model ¹	logLike ²	K ³	AIC _c ⁴	w _i ⁴
$\delta(\text{Year}) \mu(\text{ABQmax}+R)$	1,042.66	35	1,116.89	0.4476
$\delta(\text{Year}) \mu(\text{ABQ}>2,000+R)$	1,044.15	35	1,118.38	0.2123
$\delta(\text{SANmean}+R) \mu(\text{Year})$	991.56	58	1,119.50	0.1212
$\delta(\text{Year}) \mu(\text{ABQmean}+R)$	1,045.47	35	1,119.70	0.1101
$\delta(\text{ABQmax}+R) \mu(\text{Year})$	993.35	58	1,121.30	0.0494
$\delta(\text{Year}) \mu(\text{SANmean}+R)$	1,049.76	35	1,123.99	0.0128
$\delta(\text{SAN}<200+R) \mu(\text{Year})$	996.27	58	1,124.22	0.0115
$\delta(\text{ABQmean}+R) \mu(\text{Year})$	996.29	58	1,124.23	0.0114
$\delta(\text{Year}) \mu(\text{ABQ}>1,000+R)$	1,050.95	35	1,125.17	0.0071
$\delta(\text{ABQ}>2,000+R) \mu(\text{Year})$	997.63	58	1,125.58	0.0058

¹ = Models included all δ and μ combinations of null effects (.), random effects (R), year (1993–2023), and hydrological metrics (with and without R) from Albuquerque (ABQ: USGS Gage-08330000) and San Marcial (SAN: USGS Gage-08358400).

² = Likelihood ($-2[\log\text{-likelihood}]$) 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).

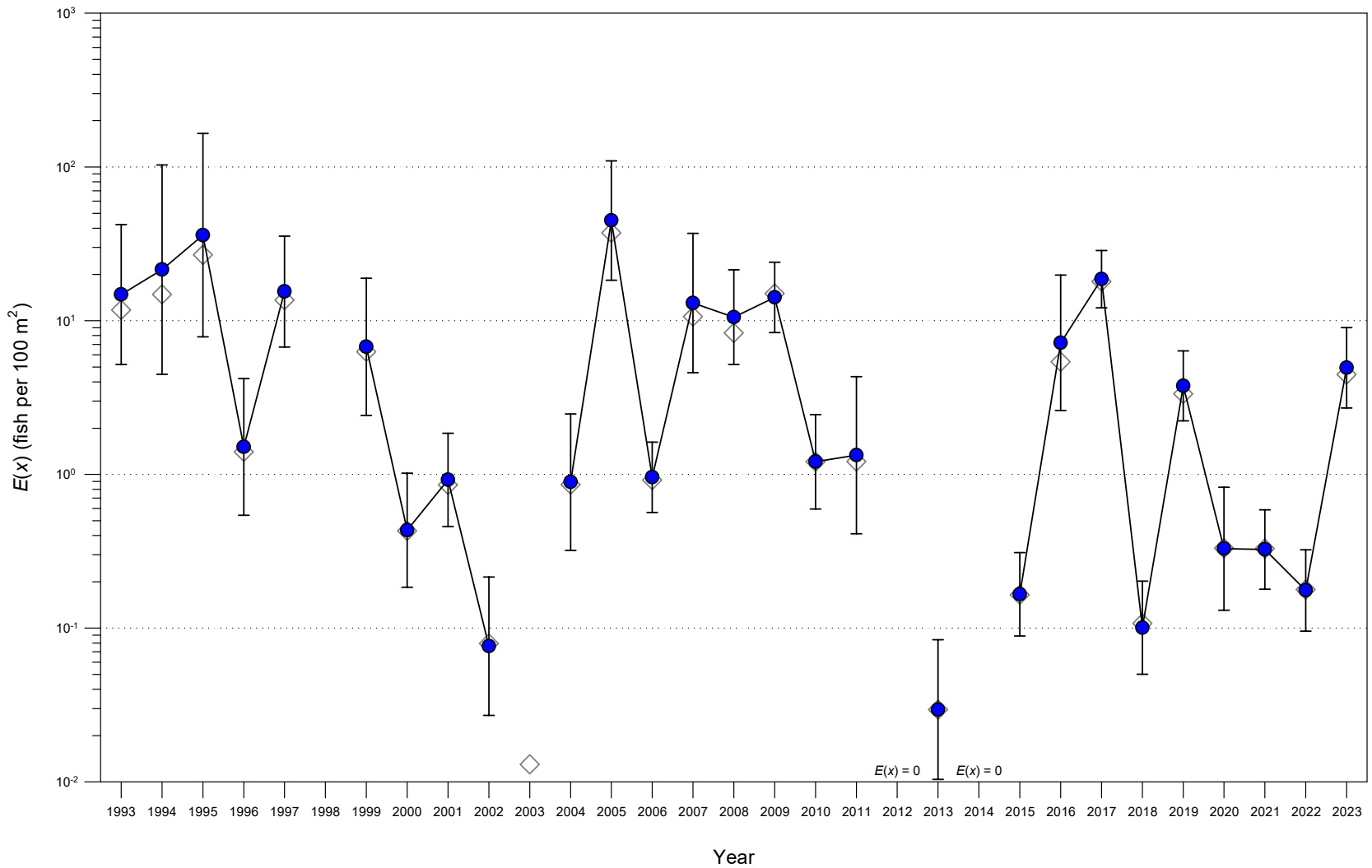


Figure 16. Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. Sampling did not occur in 1998, and density could not be estimated for 2003. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated. Additional sites (old only) 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 (1993–2023). Additional sites (old only) were included, and dry sites were excluded.

Model ¹	logLike ²	K ³	AIC _c ⁴	w _i ⁴
$\delta(\text{SANmean}+R) \mu(\text{Year})$	982.70	58	1,110.86	0.4877
$\delta(\text{Year}) \mu(\text{ABQmax}+R)$	1,038.44	35	1,112.74	0.1901
$\delta(\text{ABQmax}+R) \mu(\text{Year})$	985.80	58	1,113.96	0.1034
$\delta(\text{Year}) \mu(\text{ABQ}>2,000+R)$	1,040.03	35	1,114.33	0.0858
$\delta(\text{Year}) \mu(\text{ABQmean}+R)$	1,041.27	35	1,115.57	0.0461
$\delta(\text{ABQmean}+R) \mu(\text{Year})$	988.13	58	1,116.28	0.0323
$\delta(\text{SAN}<200+R) \mu(\text{Year})$	989.78	58	1,117.94	0.0141
$\delta(\text{ABQ}>2,000+R) \mu(\text{Year})$	990.19	58	1,118.35	0.0115
$\delta(\text{Inundation}+R) \mu(\text{Year})$	991.43	58	1,119.59	0.0062
$\delta(\text{Year}) \mu(\text{SANmean}+R)$	1,045.39	35	1,119.69	0.0059

¹ = Models included all δ and μ combinations of null effects (.), random effects (R), year (1993–2023), and hydrological metrics (with and without R) from Albuquerque (ABQ: USGS Gage-08330000) and San Marcial (SAN: USGS Gage-08358400).

² = Likelihood ($-2[\log\text{-likelihood}]$) 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).

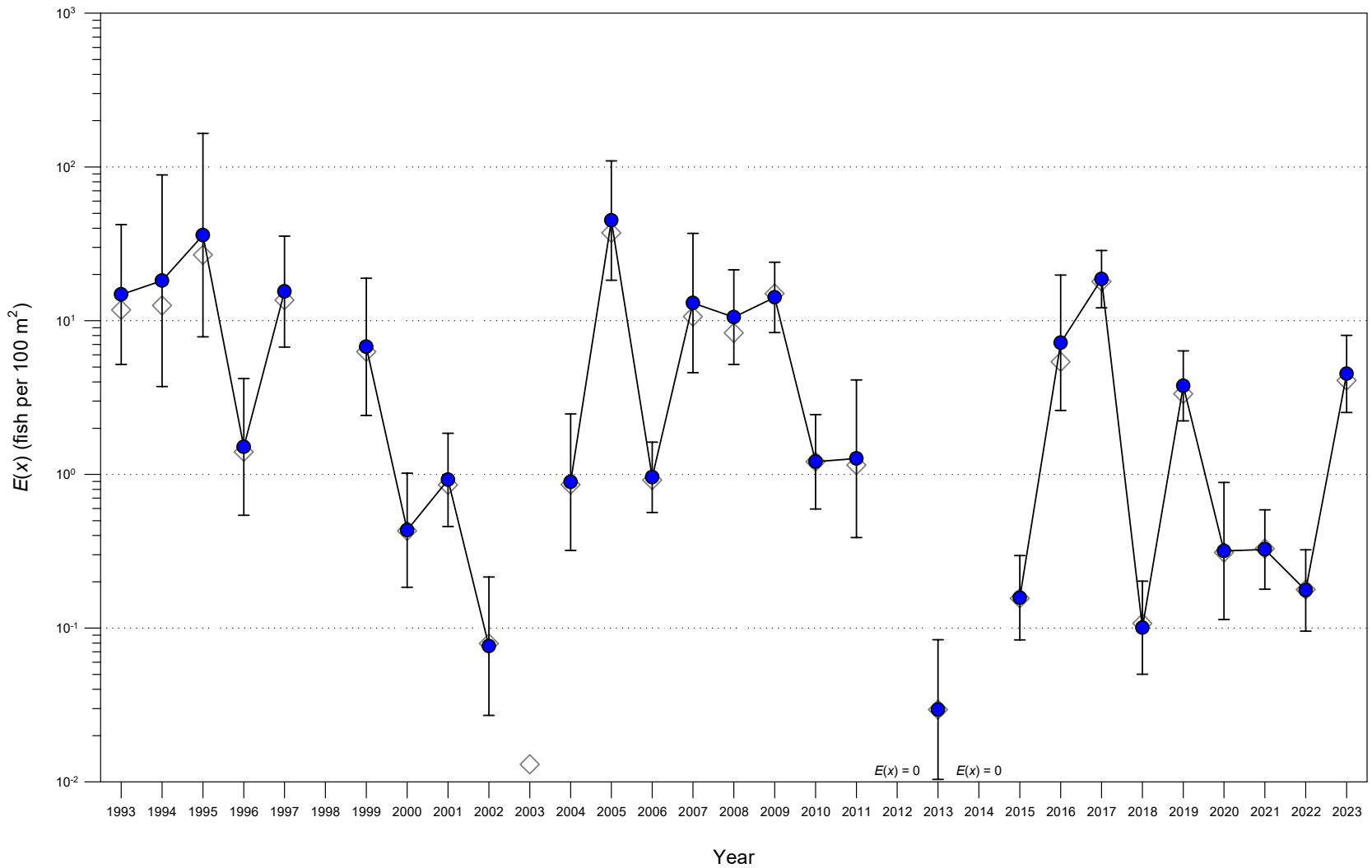


Figure 17. Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. Sampling did not occur in 1998, and density could not be estimated for 2003. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated. Additional sites (old and new) and dry sites were included.

Table 7. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2023). Additional sites (old and new) and dry sites were included.

Model ¹	logLike ²	K ³	AIC _c ⁴	w _i ⁴
$\delta(\text{Year}) \mu(\text{ABQmax}+R)$	1,062.96	35	1,137.12	0.4856
$\delta(\text{Year}) \mu(\text{ABQ}>2,000+R)$	1,064.56	35	1,138.72	0.2181
$\delta(\text{Year}) \mu(\text{ABQmean}+R)$	1,065.68	35	1,139.84	0.1246
$\delta(\text{SANmean}+R) \mu(\text{Year})$	1,012.95	58	1,140.71	0.0808
$\delta(\text{ABQmax}+R) \mu(\text{Year})$	1,014.49	58	1,142.25	0.0375
$\delta(\text{Year}) \mu(\text{SANmean}+R)$	1,069.91	35	1,144.07	0.0151
$\delta(\text{SAN}<200+R) \mu(\text{Year})$	1,016.96	58	1,144.72	0.0109
$\delta(\text{Year}) \mu(\text{ABQ}>1,000+R)$	1,071.29	35	1,145.45	0.0075
$\delta(\text{ABQmean}+R) \mu(\text{Year})$	1,017.74	58	1,145.50	0.0074
$\delta(\text{ABQ}>2,000+R) \mu(\text{Year})$	1,019.04	58	1,146.80	0.0038

¹ = Models included all δ and μ combinations of null effects (.), random effects (R), year (1993–2023), and hydrological metrics (with and without R) from Albuquerque (ABQ: USGS Gage-08330000) and San Marcial (SAN: USGS Gage-08358400).

² = Likelihood ($-2[\log\text{-likelihood}]$) 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).

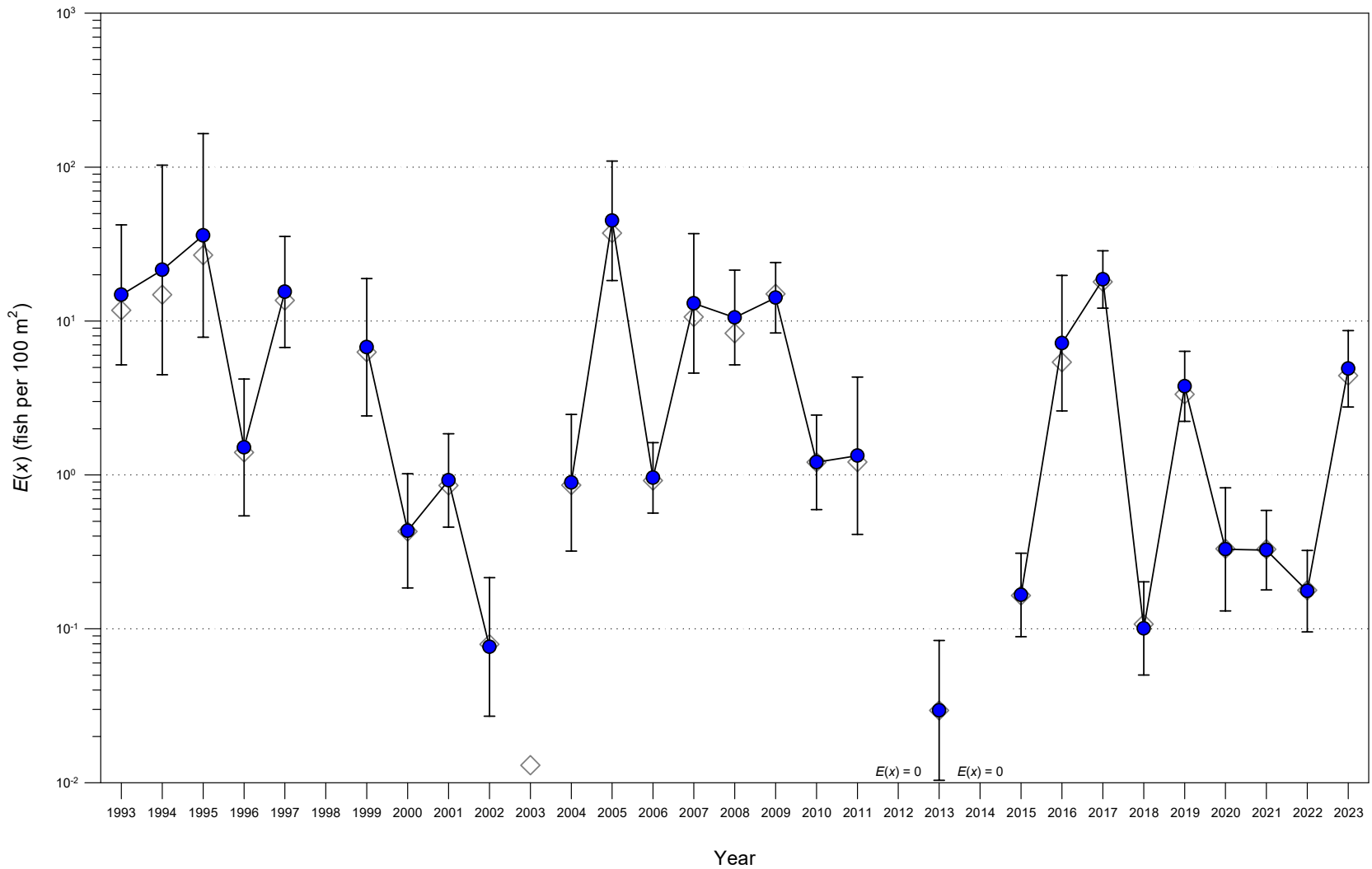


Figure 18. Rio Grande Silvery Minnow densities (estimated using October sampling-site data) across years. Sampling did not occur in 1998, and density could not be estimated for 2003. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated. Additional sites (old and new) were included, and dry sites were excluded.

Table 8. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October sampling-site data (1993–2023). Additional sites (old and new) were included, and dry sites were excluded.

Model ¹	logLike ²	K ³	AIC _c ⁴	w _i ⁴
$\delta(\text{SANmean}+R) \mu(\text{Year})$	999.53	58	1,127.54	0.4040
$\delta(\text{Year}) \mu(\text{ABQmax}+R)$	1,054.24	35	1,128.49	0.2519
$\delta(\text{Year}) \mu(\text{ABQ}>2,000+R)$	1,055.95	35	1,130.20	0.1069
$\delta(\text{ABQmax}+R) \mu(\text{Year})$	1,002.36	58	1,130.37	0.0984
$\delta(\text{Year}) \mu(\text{ABQmean}+R)$	1,057.14	35	1,131.39	0.0589
$\delta(\text{ABQmean}+R) \mu(\text{Year})$	1,004.98	58	1,132.99	0.0265
$\delta(\text{SAN}<200+R) \mu(\text{Year})$	1,006.02	58	1,134.03	0.0158
$\delta(\text{ABQ}>2,000+R) \mu(\text{Year})$	1,006.97	58	1,134.98	0.0098
$\delta(\text{Year}) \mu(\text{SANmean}+R)$	1,061.36	35	1,135.61	0.0071
$\delta(\text{Inundation}+R) \mu(\text{Year})$	1,008.02	58	1,136.03	0.0058

¹ = Models included all δ and μ combinations of null effects (.), random effects (R), year (1993–2023), and hydrological metrics (with and without R) from Albuquerque (ABQ: USGS Gage-08330000) and San Marcial (SAN: USGS Gage-08358400).

² = Likelihood ($-2[\log\text{-likelihood}]$) 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 9. 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. All combinations of additional sites (old [A_o] and new [A_n]) and dry (D) sites are presented (included [Y] or excluded [N]).

Year ¹ Sites ⁸	$A_o(N)A_n(N)D(Y)^2$ n = 20	$A_o(N)A_n(N)D(N)^3$ n = 20	$A_o(Y)A_n(N)D(Y)^4$ n = 30	$A_o(Y)A_n(N)D(N)^5$ n = 30	$A_o(Y)A_n(Y)D(Y)^6$ n = 40	$A_o(Y)A_n(Y)D(N)^7$ n = 40
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)	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)	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)	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)	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)	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)	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)	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)	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)	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)	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)	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)	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)	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)	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)	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)	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)	1.27 (0.39–4.13)	1.33 (0.41–4.33)
2012	0	0	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)	0.03 (0.01–0.08)	0.03 (0.01–0.08)
2014	0	0	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)	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)	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)	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)	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)	3.77 (2.23–6.37)	3.77 (2.23–6.37)
2020	0.23 (0.04–1.43)	0.23 (0.06–0.86)	0.32 (0.11–0.88)	0.33 (0.13–0.83)	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)	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)	0.18 (0.10–0.32)	0.18 (0.10–0.32)
2023	3.37 (1.47–7.75)	3.37 (1.47–7.75)	4.77 (2.60–8.74)	4.94 (2.71–9.02)	4.51 (2.53–8.05)	4.90 (2.77–8.67)

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 (old only) and dry sites were included.

⁵ = Additional sites (old only) were included, and dry sites were excluded.

⁶ = Additional sites (old and new) and dry sites were included.

⁷ = Additional sites (old and new) were included, and dry sites were excluded.

⁸ = Maximum number of sites sampled across all years (see Study Area for further details).

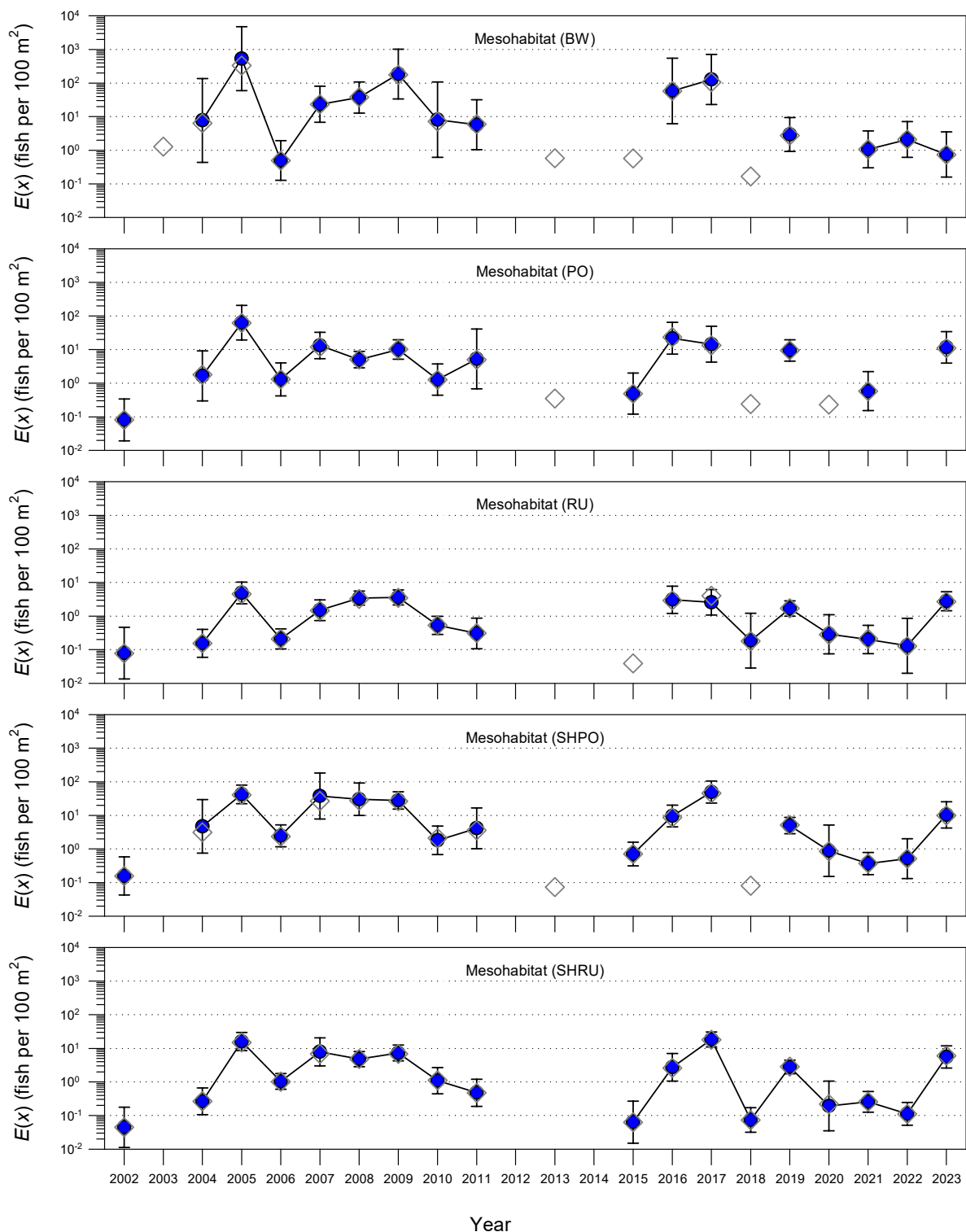


Figure 19. Rio Grande Silvery Minnow densities (estimated using October mesohabitat-specific data from all sites) across years. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated.

Table 10. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using October mesohabitat-specific data from all sites (2002–2023).

Model ¹	logLike ²	K ³	AIC _c ⁴	w _i ⁴
$\delta(\text{Year}+\text{Mesohabitat}) \mu(\text{Year}+\text{Mesohabitat})$	2,619.04	73	2,770.40	> 0.9999
$\delta(\text{Year}) \mu(\text{Year}+\text{Mesohabitat})$	2,683.73	69	2,826.51	< 0.0001
$\delta(\text{Year}*\text{Mesohabitat}) \mu(\text{Year}*\text{Mesohabitat})$	2,327.26	282	2,979.54	< 0.0001
$\delta(\text{Year}+\text{Mesohabitat}) \mu(\text{Mesohabitat})$	2,917.07	36	2,990.36	< 0.0001
$\delta(\text{Year}) \mu(\text{Mesohabitat})$	2,981.75	32	3,046.78	< 0.0001
$\delta(\text{Year}+\text{Mesohabitat}) \mu(\text{Year})$	2,924.11	65	3,058.34	< 0.0001
$\delta(R) \mu(\text{Mesohabitat})$	3,087.59	12	3,111.74	< 0.0001
$\delta(\text{Year}) \mu(\text{Year})$	2,988.79	61	3,114.52	< 0.0001
$\delta(\text{Year}) \mu(\text{Year}+\text{Reach})$	2,980.55	65	3,114.79	< 0.0001
$\delta(\text{Year}+\text{Reach}) \mu(\text{Year})$	2,987.37	63	3,117.34	< 0.0001

¹ = Models included all δ and μ combinations of null effects (.), random effects (*R*), year (2002–2023), mesohabitat (backwater, pool, run, shoreline pool, and shoreline run), and reach (Angostura, Isleta, and San Acacia).

² = Likelihood ($-2[\log\text{-likelihood}]$) 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 (2005–2023)

Rio Grande Silvery Minnow densities ($E(x)$; estimated using November sampling-site data [2005–2023]) were generated from the year-occasion model ($\delta[\text{Year} \times \text{Occasion}] \mu[\text{Year} \times \text{Occasion}]$). Interannual density trends for the sampling occasions (i.e., 1st, 2nd, 3rd, and 4th day of sampling) were similar over the study period (Figure 20). While densities had dramatically decreased ($P < 0.05$) for all sampling occasions from 2019 to 2022, there was a notable increase ($P < 0.05$) in 2023. 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 11). The top model ($\delta[\text{Year} \times \text{Reach}] \mu[\text{Year} \times \text{Reach}]$) effectively received all the AIC_c weight out of the 41 models considered. A comparison of AIC_c values revealed that year ($\delta[\text{Year}] \mu[\text{Year}]$; $AIC_c = 2,661.77$) was more informative in explaining changes in model parameter values over time as compared with reach ($\delta[\text{Reach}] \mu[\text{Reach}]$; $AIC_c = 4,032.66$) or sampling occasion ($\delta[\text{Occasion}] \mu[\text{Occasion}]$; $AIC_c = 4,071.68$). Also, there were no significant differences in estimated densities across the four sampling occasions for any year (2005–2023).

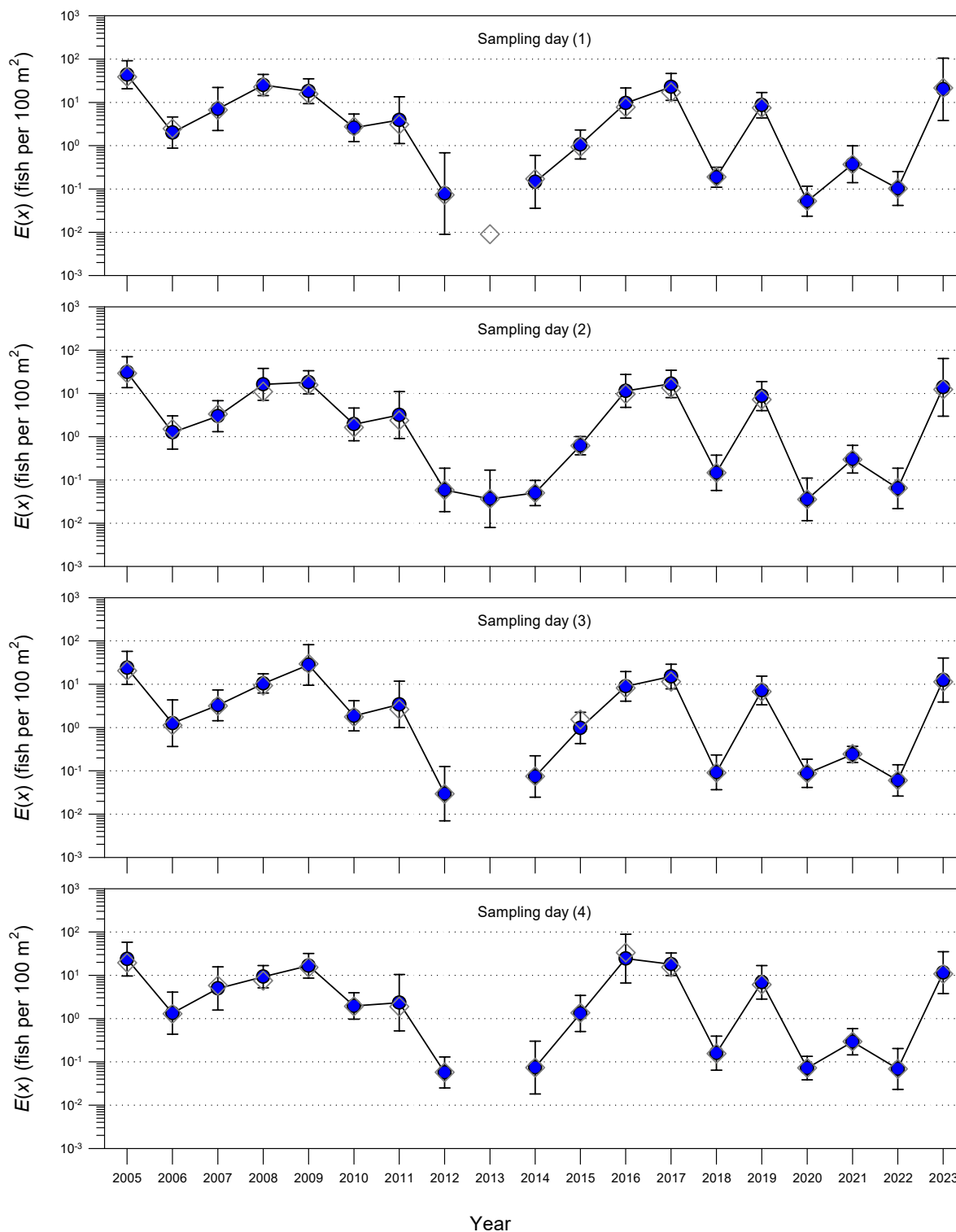


Figure 20. Rio Grande Silvery Minnow densities (estimated using November sampling-site data from all sites) across years. Modeled estimates (circles), 95% confidence intervals (bars), and naïve estimates (diamonds) are illustrated.

Table 11. Generalized linear models of Rio Grande Silvery Minnow mixture-model estimates, using November sampling-site data from all sites (2005–2023).

Model ¹	logLike ²	K ³	AIC _c ⁴	w _i ⁴
$\delta(\text{Year*Reach}) \mu(\text{Year*Reach})$	1,990.16	165	2,360.74	> 0.9999
$\delta(\text{Year+Reach}) \mu(\text{Year+Reach})$	2,462.50	63	2,594.06	< 0.0001
$\delta(\text{Year}) \mu(\text{Year+Reach})$	2,489.12	61	2,616.32	< 0.0001
$\delta(\text{Year+Reach}) \mu(\text{Year})$	2,516.63	59	2,639.49	< 0.0001
$\delta(\text{Year}) \mu(\text{Year})$	2,543.24	57	2,661.77	< 0.0001
$\delta(\text{Year}) \mu(\text{Year+Occasion})$	2,535.23	63	2,666.78	< 0.0001
$\delta(\text{Year+Occasion}) \mu(\text{Year})$	2,542.45	60	2,667.48	< 0.0001
$\delta(\text{Year+Occasion}) \mu(\text{Year+Occasion})$	2,534.43	66	2,672.54	< 0.0001
$\delta(R) \mu(\text{Year})$	2,628.87	40	2,711.09	< 0.0001
$\delta(\text{Year}) \mu(R)$	2,760.18	22	2,804.86	< 0.0001

¹ = Models included all δ and μ combinations of null effects (.), random effects (R), year (2005–2023), sampling occasion (i.e., 1st, 2nd, 3rd, and 4th day of sampling), and reach (Angostura, Isleta, and San Acacia).

² = Likelihood ($-2[\log\text{-likelihood}]$) 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 (1993–2023)

The ichthyofaunal community in the Middle Rio Grande during 2023 was numerically dominated by leuciscids (Tables 12 and 13; Appendix F). The native ichthyofauna comprised 12 species (Gizzard Shad, River Carpsucker, Smallmouth Buffalo, Red Shiner, Rio Grande Silvery Minnow, Fathead Minnow, Flathead Chub, Longnose Dace, Blue Catfish, Flathead Catfish, Bluegill, and Freshwater Drum). Red Shiner was the most abundant native species collected ($n = 7,880$), followed by Rio Grande Silvery Minnow ($n = 4,734$), and Flathead Chub ($n = 959$). The nonnative ichthyofauna comprised 15 species. The most abundant nonnative species were Western Mosquitofish ($n = 12,026$), Common Carp ($n = 4,828$), and Channel Catfish ($n = 696$).

There were notable seasonal changes in the relative abundance of the 10 focal taxa from April to October 2023 (Figures 21 and 22). Densities of all fish species generally increased during summer. Rio Grande Silvery Minnow abundance was highest in July but had declined considerably by October. Other focal species typically reached their highest densities from July to September, following their respective spawning periods.

In addition to temporal variation in the relative abundance of fish species during 2023, there were also pronounced differences in the densities of species across reaches (Figure 23). River Carpsucker, White Sucker, Flathead Chub, and Longnose Dace were most common in the Angostura Reach. Densities of Common Carp, Red Shiner, Rio Grande Silvery Minnow, and Fathead Minnow were highest in the Isleta Reach. Channel Catfish and Western Mosquitofish were most common in the San Acacia Reach.

The abundance of the ten focal species, during October, has fluctuated markedly across years (Table 14). Several species, including Rio Grande Silvery Minnow, have periodically declined to unusually 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 2023 (Figure 24). Notable changes in the relative abundance of this species mirrored similar changes in its estimated occurrence and density over the study period (1993–2023). While Rio Grande Silvery Minnow represented only 0.68% of the fish community in 2022, it had increased to 8.09% by 2023.

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 15). 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 declined precipitously from 2019 (3rd) to 2020 (8th), it again improved by 2023 (4th). The coefficient of concordance ($W = 0.66$) for the ten focal species indicated high agreement among ranks over time (1993–2023; $\chi^2 = 178.2$; $P < 0.001$) despite marked interannual changes in ranks for some species (e.g., River Carpsucker, Rio Grande Silvery Minnow, and Longnose Dace).

Table 12. Ichthyofaunal summary based on all sites (all age-classes combined), by species, during 2023. 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
Dorosomatidae	Gizzard Shad	N	116	0.35	14	8.09
Dorosomatidae	Threadfin Shad	I	-	-	-	-
Catostomidae	River Carpsucker	N	402	1.22	34	19.65
Catostomidae	White Sucker	I	416	1.26	41	23.70
Catostomidae	Smallmouth Buffalo	N	16	0.05	3	1.73
Cyprinidae	Goldfish	I	-	-	-	-
Cyprinidae	Common Carp	I	4,828	14.59	106	61.27
Leuciscidae	Central Stoneroller	I	-	-	-	-
Leuciscidae	Red Shiner	N	7,880	23.82	140	80.92
Leuciscidae	Rio Grande Chub	N	-	-	-	-
Leuciscidae	Rio Grande Silvery Minnow	N	4,734	14.31	98	56.65
Leuciscidae	Golden Shiner	I	-	-	-	-
Leuciscidae	Fathead Minnow	N	432	1.31	50	28.90
Leuciscidae	Bullhead Minnow	I	5	0.02	3	1.73
Leuciscidae	Flathead Chub	N	959	2.90	83	47.98
Leuciscidae	Longnose Dace	N	335	1.01	30	17.34
Ictaluridae	Black Bullhead	I	11	0.03	3	1.73
Ictaluridae	Yellow Bullhead	I	19	0.06	11	6.36
Ictaluridae	Blue Catfish	N	107	0.32	14	8.09
Ictaluridae	Channel Catfish	I	696	2.10	84	48.55
Ictaluridae	Flathead Catfish	N	1	< 0.01	1	0.58
Loricariidae	Vermiculated Sailfin Catfish	I	-	-	-	-
Esocidae	Northern Pike	I	1	< 0.01	1	0.58
Salmonidae	Rainbow Trout	I	-	-	-	-
Salmonidae	Brown Trout	I	1	< 0.01	1	0.58
Poeciliidae	Western Mosquitofish	I	12,026	36.35	100	57.80
Centrarchidae	Green Sunfish	I	12	0.04	7	4.05
Centrarchidae	Bluegill	N	5	0.02	3	1.73
Centrarchidae	Longear Sunfish	I	-	-	-	-
Centrarchidae	Smallmouth Bass	I	1	< 0.01	1	0.58
Centrarchidae	Florida Bass	I	38	0.11	19	10.98
Centrarchidae	White Crappie	I	16	0.05	9	5.20
Centrarchidae	Black Crappie	I	-	-	-	-
Moronidae	White Bass	I	24	0.07	12	6.94
Moronidae	Striped Bass	I	-	-	-	-
Percidae	Yellow Perch	I	-	-	-	-
Percidae	Bigscale Logperch	I	1	< 0.01	1	0.58
Percidae	Walleye	I	-	-	-	-
Sciaenidae	Freshwater Drum	N	1	< 0.01	1	0.58
Annual Total			33,083	100.00		

¹ = Native (N) or introduced (I) species (Sublette et al. 1990; Propst 1999)

² = Based on 173 samples

Table 13. Ichthyofaunal summary based on all sites (all age-classes combined), by species and month, during 2023. Marked and unmarked Rio Grande Silvery Minnow were included.

Family	Common Name	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Dorosomatidae	Gizzard Shad	0	5	0	0	35	58	18	116
Dorosomatidae	Threadfin Shad	0	0	0	0	0	0	0	0
Catostomidae	River Carpsucker	0	0	1	26	282	36	57	402
Catostomidae	White Sucker	3	2	57	121	123	57	53	416
Catostomidae	Smallmouth Buffalo	0	0	14	2	0	0	0	16
Cyprinidae	Goldfish	0	0	0	0	0	0	0	0
Cyprinidae	Common Carp	3	155	258	1,487	1,414	438	1,073	4,828
Leuciscidae	Central Stoneroller	0	0	0	0	0	0	0	0
Leuciscidae	Red Shiner	981	169	101	719	1,958	1,605	2,347	7,880
Leuciscidae	Rio Grande Chub	0	0	0	0	0	0	0	0
Leuciscidae	Rio Grande Silvery Minnow	21	4	130	2,140	678	886	875	4,734
Leuciscidae	Golden Shiner	0	0	0	0	0	0	0	0
Leuciscidae	Fathead Minnow	6	0	6	87	100	83	150	432
Leuciscidae	Bullhead Minnow	0	0	0	0	0	1	4	5
Leuciscidae	Flathead Chub	239	39	66	97	139	114	265	959
Leuciscidae	Longnose Dace	27	24	14	40	69	100	61	335
Ictaluridae	Black Bullhead	0	0	0	9	2	0	0	11
Ictaluridae	Yellow Bullhead	0	0	1	0	4	9	5	19
Ictaluridae	Blue Catfish	0	0	13	10	0	77	7	107
Ictaluridae	Channel Catfish	130	10	4	1	199	88	264	696
Ictaluridae	Flathead Catfish	0	0	0	0	0	0	1	1
Loricariidae	Vermiculated Sailfin Catfish	0	0	0	0	0	0	0	0
Esocidae	Northern Pike	0	0	0	0	1	0	0	1
Salmonidae	Rainbow Trout	0	0	0	0	0	0	0	0
Salmonidae	Brown Trout	0	0	1	0	0	0	0	1
Poeciliidae	Western Mosquitofish	16	9	7	191	2,831	3,355	5,617	12,026
Centrarchidae	Green Sunfish	1	6	0	1	1	2	1	12
Centrarchidae	Bluegill	0	0	0	2	0	0	3	5
Centrarchidae	Longear Sunfish	0	0	0	0	0	0	0	0
Centrarchidae	Smallmouth Bass	0	0	0	1	0	0	0	1
Centrarchidae	Florida Bass	0	0	0	6	13	2	17	38
Centrarchidae	White Crappie	0	0	0	4	11	1	0	16
Centrarchidae	Black Crappie	0	0	0	0	0	0	0	0
Moronidae	White Bass	0	0	0	15	1	4	4	24
Moronidae	Striped Bass	0	0	0	0	0	0	0	0
Percidae	Yellow Perch	0	0	0	0	0	0	0	0
Percidae	Bigscale Logperch	0	0	0	0	0	1	0	1
Percidae	Walleye	0	0	0	0	0	0	0	0
Sciaenidae	Freshwater Drum	0	0	0	0	1	0	0	1
Monthly Totals		1,427	423	673	4,959	7,862	6,917	10,822	33,083

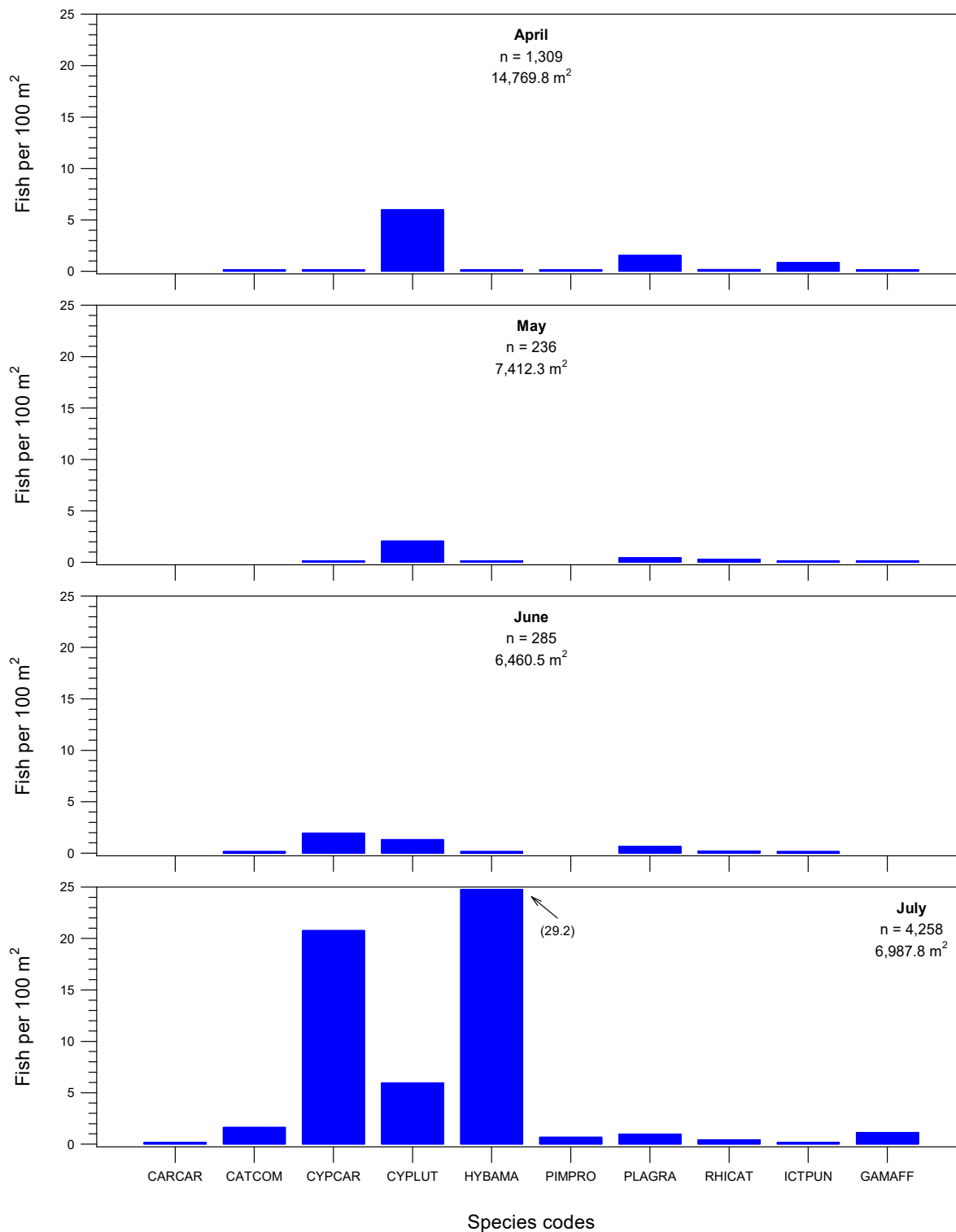


Figure 21. Fish densities based on all sites (age-0 and age-1+ fish [small-mesh seine]; larval fish excluded), by month and focal taxa, from April to July 2023.

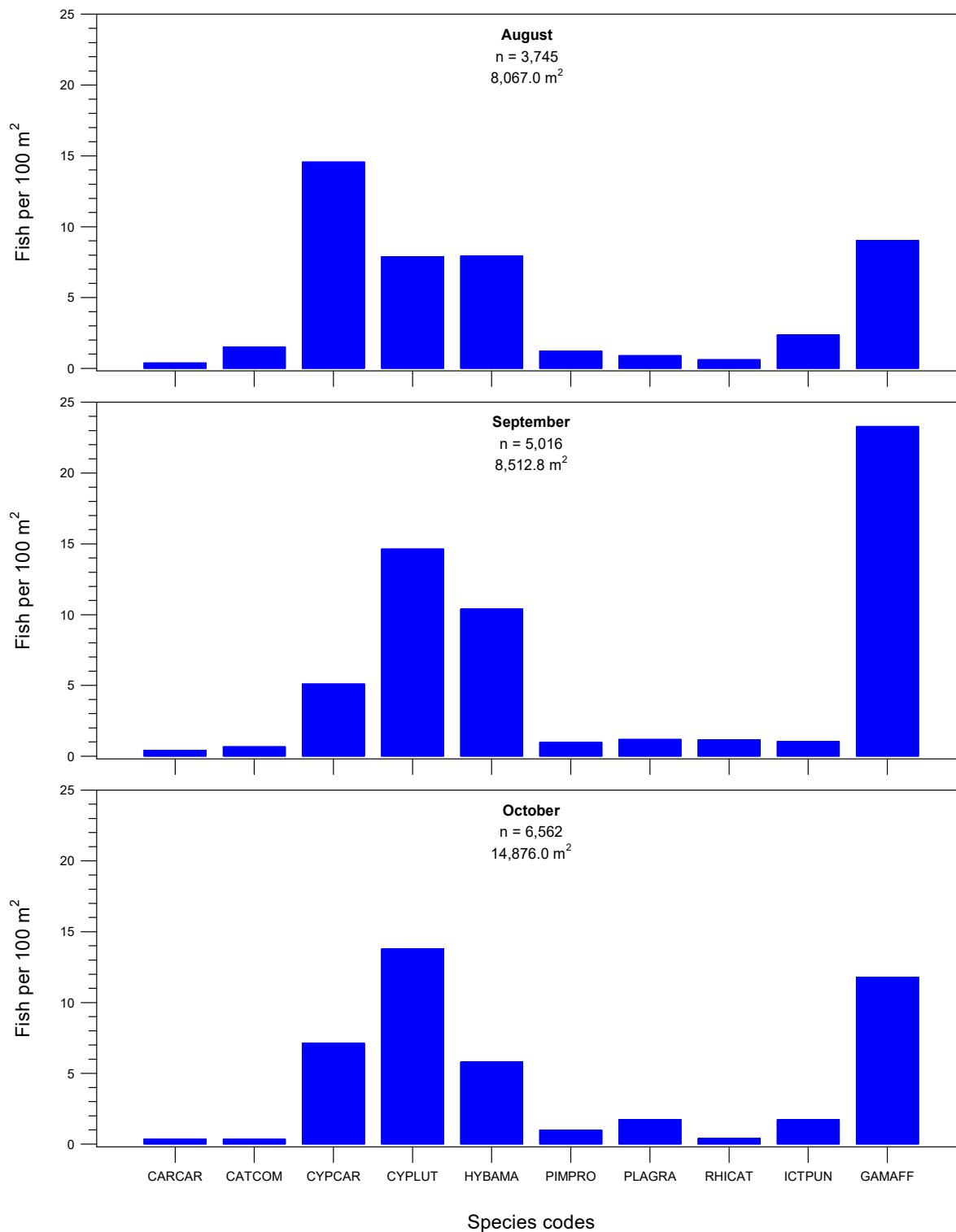


Figure 22. Fish densities based on all sites (age-0 and age-1+ fish [small-mesh seine]; larval fish excluded), by month and focal taxa, from August to October 2023.

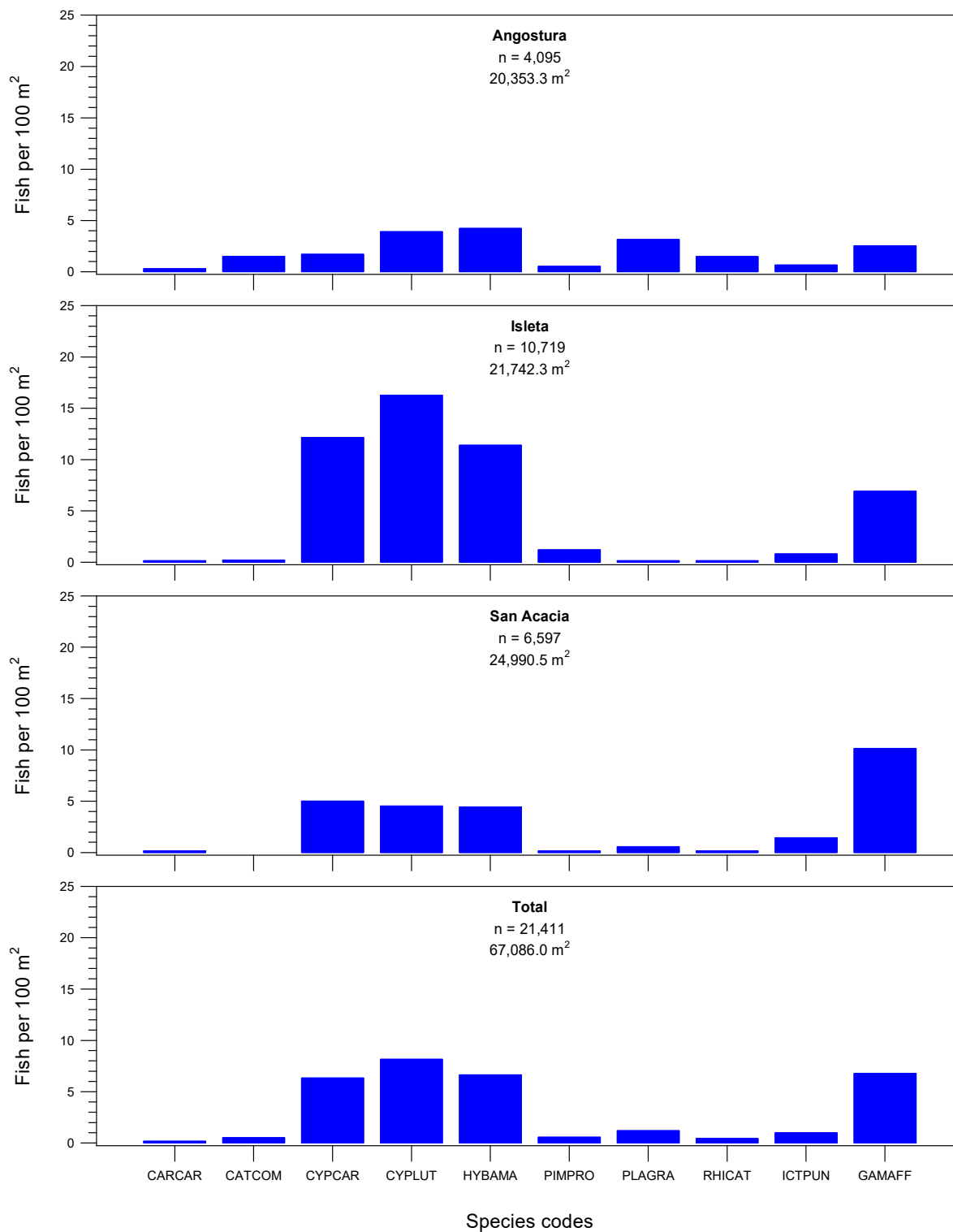


Figure 23. Fish densities based on all sites (age-0 and age-1+ fish [small-mesh seine]; larval fish excluded), by reach and focal taxa, from April to October 2023.

Table 14. Fish abundance based on all sites during October, by year and focal taxa, from 1993 to 2023. Sampling did not occur in 1998.

Year	Species Codes									
	CARCAR	CATCOM	CYPCAR	CYPLUT	HYBAMA	PIMPRO	PLAGRA	RHICAT	ICTPUN	GAMAFF
1993	322	48	24	3,585	939	315	297	11	174	185
1994	108	27	26	1,091	906	131	139	58	465	122
1995	29	71	13	510	1,292	97	308	35	170	142
1996	316	38	43	1,994	956	396	295	46	386	869
1997	100	70	18	724	606	82	196	54	257	351
1998										
1999	180	11	11	1,522	412	63	259	60	74	297
2000	251	78	13	7,511	37	399	48	53	313	2,443
2001	284	21	88	5,769	112	740	158	53	242	3,984
2002	150	43	25	8,054	11	1,564	126	198	253	1,843
2003	123	24	25	5,042	2	757	126	31	38	2,508
2004	42	5	7	3,436	78	447	194	24	60	781
2005	2	2	47	399	3,939	115	61	32	48	829
2006	3	3	1	1,669	162	76	204	23	160	192
2007	142	19	6	5,287	1,166	129	543	55	174	557
2008	18	12	41	1,635	868	114	239	29	82	745
2009	60	20	2	2,314	1,835	144	210	16	321	811
2010	15	4	6	2,518	137	54	503	41	162	489
2011	79	17	16	3,121	118	44	122	28	64	430
2012	73	19	84	5,272	0	154	781	28	184	1,237
2013	7	25	6	3,265	3	307	127	317	218	959
2014	12	2	8	1,506	0	52	215	58	167	338
2015	12	0	6	690	16	18	169	68	129	639
2016	9	2	37	1,574	584	18	183	39	135	206
2017	24	26	102	2,631	2,867	44	300	69	1,126	810
2018	298	20	55	6,552	17	188	662	179	338	1,920
2019	4	8	96	3,327	517	51	483	167	383	919
2020	405	74	37	14,003	51	363	619	47	120	3,522
2021	7	5	7	4,889	49	68	287	246	155	1,561
2022	5	1	15	2,181	27	28	385	187	476	654
2023	57	53	1,073	2,347	875	150	265	61	264	5,617

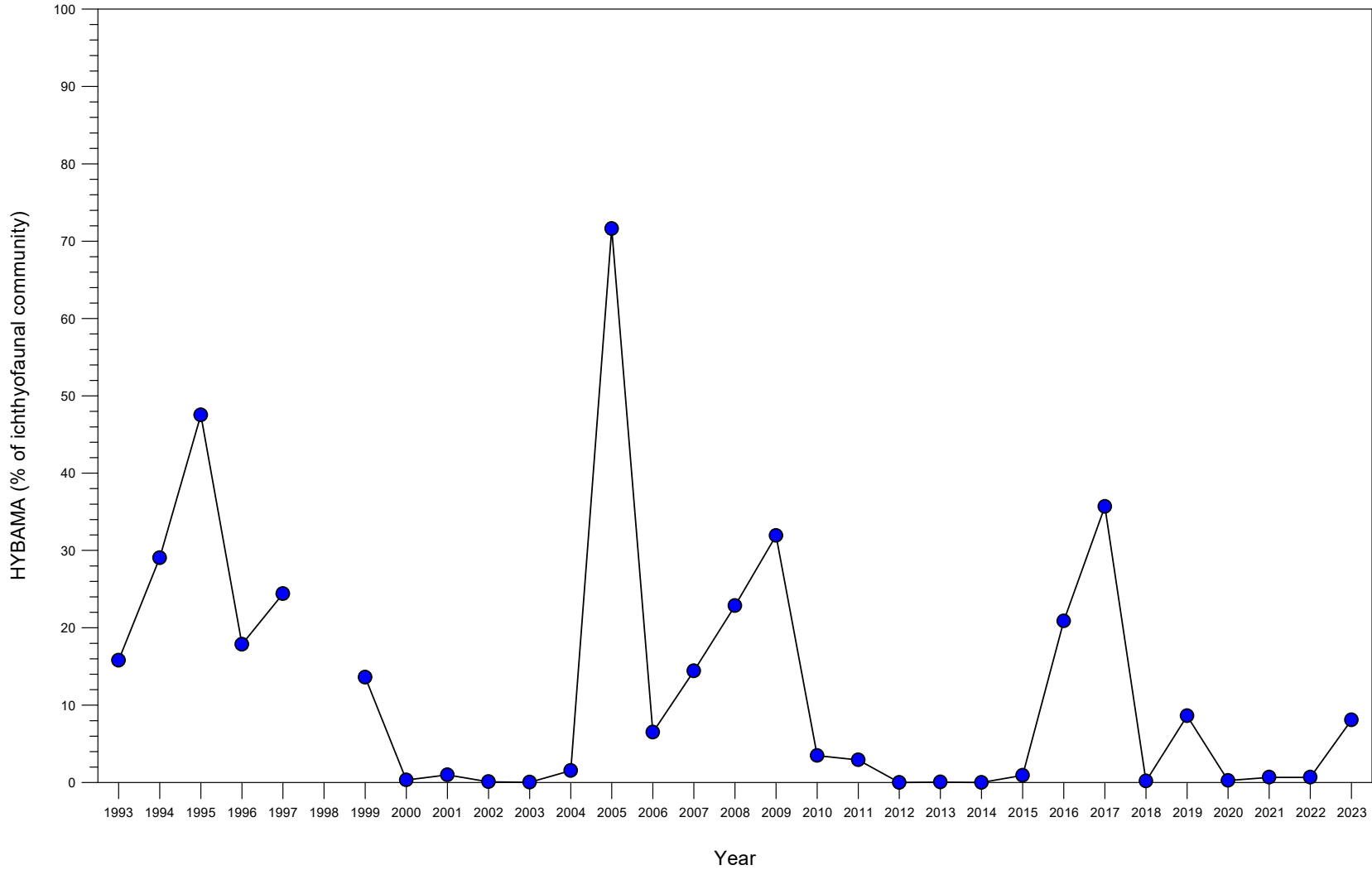


Figure 24. Relative abundance of Rio Grande Silvery Minnow as a percentage of the ichthyofaunal community, based on all sites during October, across years. Sampling did not occur in 1998.

Table 15. Fish rank-abundance based on all sites during October, by year and focal taxa, from 1993 to 2023. Sampling did not occur in 1998.

Year	Species Codes									
	CARCAR	CATCOM	CYPCAR	CYPLUT	HYBAMA	PIMPRO	PLAGRA	RHICAT	ICTPUN	GAMAFF
1993	3	8	9	1	2	4	5	10	7	6
1994	7	9	10	1	2	5	4	8	3	6
1995	9	7	10	2	1	6	3	8	4	5
1996	6	10	9	1	2	4	7	8	5	3
1997	6	8	10	1	2	7	5	9	4	3
1998										
1999	5	9.5	9.5	1	2	7	4	8	6	3
2000	5	6	10	1	9	3	8	7	4	2
2001	4	10	8	1	7	3	6	9	5	2
2002	6	8	9	1	10	3	7	5	4	2
2003	5	9	8	1	10	3	4	7	6	2
2004	7	10	9	1	5	3	4	8	6	2
2005	9.5	9.5	7	3	1	4	5	8	6	2
2006	8.5	8.5	10	1	4	6	2	7	5	3
2007	6	9	10	1	2	7	4	8	5	3
2008	9	10	7	1	2	5	4	8	6	3
2009	7	8	10	1	2	6	5	9	4	3
2010	8	10	9	1	5	6	2	7	4	3
2011	5	9	10	1	4	7	3	8	6	2
2012	7	9	6	1	10	5	3	8	4	2
2013	8	7	9	1	10	4	6	3	5	2
2014	7	9	8	1	10	6	3	5	4	2
2015	8	10	9	1	7	6	3	5	4	2
2016	9	10	7	1	2	8	4	6	5	3
2017	10	9	6	2	1	8	5	7	3	4
2018	5	9	8	1	10	6	3	7	4	2
2019	10	9	7	1	3	8	4	6	5	2
2020	4	7	10	1	8	5	3	9	6	2
2021	8.5	10	8.5	1	7	6	3	4	5	2
2022	9	10	8	1	7	6	4	5	3	2
2023	9	10	3	2	4	7	5	8	6	1

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 an extended 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), long-term population trends and management implications (Walsworth and Budy 2021 [Data: 1993–2017]; Yackulic et al. 2022 [Data: 2002–2018]), and it could also 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 (1993–2023) 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 generalized linear covariate models). Thus, we have produced estimates using a robust, yet highly flexible, approach that avoids many assumptions typically required for traditional statistical analyses (Appendix 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 20–40 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 [2002–2023]), or on different days during repeated sampling (November [2005–2023]), were remarkably like population trends obtained from the long-term dataset (October [1993–2023]).

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 generalized 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 (1993–2023).

Additional, Dry, and Replacement Sites

Based on recommendations by Hubert et al. (2016) and the Collaborative Program, we conducted statistical analyses using six different datasets: (1) additional sites excluded and dry sites included, (2) additional sites and dry sites excluded, (3) additional sites (old only) and dry sites included, (4) additional sites (old only) included and dry sites excluded, (5) additional sites (old and new) and dry sites included, and (6) additional sites (old and new) 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 six analyses were based on different versions of the long-term dataset (1993–2023), our estimated densities of Rio Grande Silvery Minnow were reasonably consistent regardless of whether additional/dry sites were included or excluded. However, we found that analyses that included additional sites had an increased AIC_c weight on the $\mu(\text{Year})$ 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 2023.

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 included substantial increases in the number of sampling sites (i.e., 20 to 40) since 2017. This recent increase in sampling renders the additional-site analyses unsuitable for long-term ecological inferences. Over time, however, the additional-site sampling design will become more suitable and robust for estimating reach-specific/range-wide density dynamics and ecological relationships.

Despite these limitations, we found that the 95% confidence intervals of estimated densities were relatively 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 six 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., additional sites excluded and dry 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 [2005–2023]) revealed that sampling reach and occasion 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 (1993–2023). 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 similar trends in the estimated densities of Rio Grande Silvery Minnow, 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 especially 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 (2005–2023; 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 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 (2002–2023), despite notable differences in the estimated densities of Rio Grande Silvery Minnow across 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 (2002–2023) and sampling-site density data (1993–2023) 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 (1993–2023), 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 (1993–2023) 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 et al. 2023; 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 incision, habitat degradation, abandonment of the floodplain, and reductions in suspended sediments (Lagasse 1980; Massong et al. 2006; Mortensen et al. 2023) are likely limiting the number and size 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 pelagic-spawning leuciscids 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. 2023b). 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 2023, 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 (1993–2023). Several species (e.g., River Carpsucker, Rio Grande Silvery Minnow, and Longnose Dace) 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 densities 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 (1993–2023) with hydrological metrics revealed several strong ecological relationships. Elevated and prolonged flows during the spawning/rearing season (i.e., primarily mid-April to mid-June [Archdeacon et al. 2024; Dudley et al. 2023b]) 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 (1993–2023). 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. 2023a).

Prolonged and elevated spring flows result in extensive overbank flooding and the formation of inundated habitats within the river channel (e.g., shoreline pools and backwaters). These shallow low-velocity habitats, which typically increase in number and extent during spring runoff, are essential for the survival and recruitment of many endemic freshwater fishes (Welcomme 1979; Junk et al. 1989; Matthews 1998). In contrast, persistently low flows during spring and summer typically result in recruitment failure for sensitive species, such as pelagic-spawning leuciscids (Perkin et al. 2019; Archdeacon et al. 2020a). Similar processes are likely reducing the survivorship of early life phases of Rio Grande Silvery Minnow during extended droughts (Pease et al. 2006; Turner et al. 2010; Hoagstrom and Turner 2013; Archdeacon et al. 2020a; Dudley et al. 2023b).

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. 2023b). 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 of eggs are likely caused by disparities in habitat complexity during higher (i.e., floodplain inundation) and lower (i.e., incised channel) flows across years, which differentially affect drifting egg transport efficiencies (Dudley and Platania 2007; Widmer et al. 2012). During years with high spring runoff, these environmental conditions synergistically result in the inundation of productive nursery habitats, which are crucial for the growth and development of early life phases (Dudley and Platania 1997a; Magaña 2012; Medley and Shirey 2013; Hutson et al. 2018; Tave et al. 2018; Valdez et al. 2019; Dudley et al. 2023b). Further, the survival and recruitment of individuals spawned during spring is likely higher than those spawned during summer because of reduced competition for food resources from later spawning species (Pease et al. 2006; Krabbenhoft et al. 2014).

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 productive 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 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, 2012–2014, and 2020–2022), it is encouraging that this species has rebounded relatively quickly following years with improved spawning and recruitment conditions (e.g., 2004–2005, 2015–2017, and 2023). Similarly, the genetic effective population size of this species was especially 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. 2024a). Based on autumn–winter sampling, there was an increase in the genetic effective population size of Rio Grande Silvery Minnow from 2015–2016 to 2020–2021, followed by a notable decrease in 2021–2022 that persisted into 2022–2023 (Osborne et al. 2024a). Although extinction risk has been tempered during substantial population declines by stocking hatchery-reared fish (Archdeacon et al. 2023), recurring periods with abundant hatchery-origin spawners have caused erosion of genetic diversity over time (Osborne et al. 2024b). These rising and falling trends in genetic diversity generally reflect the underlying population trends that we have documented in our study of this species since 1993. 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. Fortunately, both the occurrence and density of Rio Grande Silvery Minnow increased in 2023, following high and prolonged flows during spring runoff. 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 that support the long-term recovery of Rio Grande Silvery Minnow.

ACKNOWLEDGMENTS

We thank David T. Camak, Martinique J. Chavez, Stephani L. Clark-Barkalow, Tyler D. Damron, Emily S. DeArmon, Michael A. Farrington, Richard C. Keller, Andrea D. Urioste, and Soren Winter (ASIR) for their assistance with the field, laboratory, and data-entry aspects of this project. Martinique J. Chavez and Donald A. Helfrich (ASIR) skillfully prepared all study area maps. Emily S. DeArmon and Thomas F. Turner, along with other staff at the Museum of Southwestern Biology (Fishes), graciously provided ongoing assistance with all aspects of curating preserved specimens. Numerous people from a variety of local, state, and federal agencies also collaborated to help make this study possible. The City of Rio Rancho (Department of Parks, Recreation, and Community Services), through the assistance of Dyane N. Sonier, allowed us access to their park lands. The City of Albuquerque (Open Space Division), with the assistance of Dionne L. Epps, granted us access to multiple sampling sites throughout the Angostura Reach. The Middle Rio Grande Conservancy District (MRGCD), through the assistance of Matthew Martinez, provided us access to multiple sampling locations in the Angostura and Isleta reaches. The Sevilleta National Wildlife Refuge, with the assistance of Jeff Sanchez, granted us access to their refuge lands. The Bosque del Apache National Wildlife Refuge, with the help of Claire L. Revekant, allowed us access to their refuge lands. Eric J. Gonzales and Mary B. Maestas (U.S. Bureau of Reclamation; USBR) assisted with all technical and contract administration aspects of this study. Eric J. Gonzales also provided an insightful and helpful review of the draft report. The U.S. Fish and Wildlife Service authorized our handling and collection of Rio Grande Silvery Minnow (Permit TE001623-5). The N.M. Department of Game and Fish authorized our handling and collection of all other native and nonnative fishes (Permit 1896). The Collaborative Program has provided valuable scientific input on our research since 2000. This study was funded by USBR, and its Albuquerque Area Office and Salt Lake City Regional Office administered all funds (Contract 140R4019P0048: Requisition 0040613161).

LITERATURE CITED

- Adair, J.B.M. 2016. Reconstructing the historical Albuquerque reach of the Middle Rio Grande to evaluate the influence of river engineering on floodplain inundation. M.S. thesis, Civil Engineering, University of New Mexico, Albuquerque, New Mexico, USA.
- Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Pages 267–281 in B.N. Petrov and F. Csáki, editors. Proceedings of the Second International Symposium on Information Theory. Akadémiai Kiadó, Budapest, Hungary.
- Al-Chokhachy, R., P. Budy, and M. Conner. 2009. Detecting declines in the abundance of a bull trout (*Salvelinus confluentus*) population: understanding the accuracy, precision, and costs of our efforts. Canadian Journal of Fisheries and Aquatic Sciences 66:649–658.
- Alò, D., and T.F. Turner. 2005. Effects of habitat fragmentation on effective population size in the endangered Rio Grande Silvery Minnow. Conservation Biology 19:1138–1148.
- Archdeacon, T.P. 2016. Reduction in spring flow threatens Rio Grande Silvery Minnow: trends in abundance during river intermittency. Transactions of the American Fisheries Society 145:754–765.
- Archdeacon, T.P. 2023. Rio Grande Silvery Minnow augmentation in the Middle Rio Grande, New Mexico: annual report 2022. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.2.35050.18888>
- Archdeacon, T.P., T.A. Diver-Franssen, N.G. Bertrand, and J.D. Grant. 2020a. Drought results in recruitment failure of Rio Grande Silvery Minnow (*Hybognathus amarus*), an imperiled, pelagic broadcast-spawning minnow. Environmental Biology of Fishes 103:1033–1044.
- Archdeacon, T.P., T.A. Diver, and R.E. Grey. 2024. Reproductive phenology of wild and hatchery-reared Rio Grande Silvery Minnow. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.2.29854.92485>
- Archdeacon, T.P., R.K. Dudley, W.J. Remshardt, W. Knight, M. Ulibarri, and E.J. Gonzales. 2023. Hatchery supplementation increases potential spawning stock of Rio Grande Silvery Minnow after population bottlenecks. Transactions of the American Fisheries Society 152:187–200.
- Archdeacon, T.P., K.R. Henderson, T.J. Austring, and R.L. Cook. 2015. Comparison of fish communities at random and nonrandom locations in a sand-bed river. North American Journal of Fisheries Management 35:578–585.
- Archdeacon, T.P., and J.K. Reale. 2020. No quarter: Lack of refuge during flow intermittency results in catastrophic mortality of an imperiled minnow. Freshwater Biology 65:2108–2123.
- Archdeacon, T.P., J.K. Reale, E.J. Gonzales, and J.D. Grant. 2020b. Effects of seining effort and site length on variability of small-bodied fish catch-rates in a sand-bed river. River Research and Applications 36:1588–1597.
- Armantrout, N.B. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, Maryland, USA.
- Bestgen, K.R., and S.P. Platania. 1990. Extirpation of *Notropis simus simus* (Cope) and *Notropis orca* Woolman (Pisces: Cyprinidae) from the Rio Grande in New Mexico, with notes on their life history. Occasional Papers of the Museum of Southwestern Biology 6:1–8.
- Bestgen, K.R., and S.P. Platania. 1991. Status and conservation of the Rio Grande Silvery Minnow, *Hybognathus amarus*. Southwestern Naturalist 36:225–232.
- Braun, C.L., D.K. Pearson, M.D. Porter, and J.B. Moring. 2015. Physical characteristics and fish assemblage composition at site and mesohabitat scales over a range of streamflows in the Middle Rio Grande, New Mexico, winter 2011–12, summer 2012. Scientific Investigations Report 2015–5025. U.S. Geological Survey, Reston, Virginia, USA. <https://doi.org/10.3133/sir20155025>
- Burnham, K.P., and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York, New York, USA.
- Cao, Y., L. Hinz, B. Metzke, J. Stein, and A. Holtrop. 2016. Modeling and mapping fish abundance across wadeable streams of Illinois, USA, based on landscape-level environmental variables. Canadian Journal of Fisheries and Aquatic Sciences 73:1031–1046.

- Crane, D.P., and K.L. Kapuscinski. 2018. Capture efficiency of a fine mesh seine in a large river: implications for abundance, richness, and diversity analyses. *Fisheries Research* 205:149–157.
- Cross, F.B., O.T. Gorman, and S.G. Haslouer. 1983. The Red River Shiner, *Notropis bairdi*, in Kansas with notes on depletion of its Arkansas River cognate, *Notropis girardi*. *Transactions of the Kansas Academy of Science* 86:93–98.
- Cross, F.B., and R.E. Moss. 1987. Historic changes in fish communities and aquatic habitats in plains streams of Kansas. Pages 155–165 in W.J. Matthews and D.C. Heins, editors. *Community and evolutionary ecology of North American stream fishes*. University of Oklahoma Press, Norman, Oklahoma, USA.
- Cross, F.B., R.E. Moss, and J.T. Collins. 1985. Assessment of dewatering impacts on stream fisheries in the Arkansas and Cimarron rivers. Museum of Natural History, University of Kansas, Lawrence, Kansas, USA.
- Dudley, R.K., D.A. Helfrich, and S.P. Platania. 2009. Effects of river intermittency on populations of Rio Grande Silvery Minnow. Submitted to the Middle Rio Grande Endangered Species Collaborative Program and the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.1.2661.2640>
- Dudley, R.K., and S.P. Platania. 1996. 1995 population monitoring of Rio Grande Silvery Minnow. Submitted to the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.1.3484.5607>
- Dudley, R.K., and S.P. Platania. 1997a. Habitat use of Rio Grande Silvery Minnow. Submitted to the New Mexico Department of Game and Fish, Santa Fe, New Mexico, and to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.1.1874.8324>
- Dudley, R.K., and S.P. Platania. 1997b. 1996 population monitoring of Rio Grande Silvery Minnow. Submitted to the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.1.4533.1362>
- Dudley, R.K., and S.P. Platania. 1999. 1997 population monitoring of Rio Grande Silvery Minnow. Submitted to the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.1.3758.9924>
- Dudley, R.K., and S.P. Platania. 2002. 2001 population monitoring of Rio Grande Silvery Minnow. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.1.5069.7127>
- Dudley, R.K., and S.P. Platania. 2007. Flow regulation and fragmentation imperil pelagic-spawning riverine fishes. *Ecological Applications* 17:2074–2086.
- Dudley, R.K., S.P. Platania, and G.C. White. 2023a. Rio Grande Silvery Minnow population monitoring during 2022. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.2.24201.83042>
- Dudley, R.K., S.P. Platania, and G.C. White. 2023b. Rio Grande Silvery Minnow reproductive monitoring during 2023. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.2.28001.48481>
- Dudley, R.K., G.C. White, S.P. Platania, and D.A. Helfrich. 2012. Rio Grande Silvery Minnow population estimation program results from October 2011. Submitted to the Middle Rio Grande Endangered Species Collaborative Program and the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.1.4201.3601>
- Fletcher, D., D. Mackenzie, and E. Villouta. 2005. Modelling skewed data with many zeros: a simple approach combining ordinary and logistic regression. *Environmental and Ecological Statistics* 12:45–54.
- Gonzales, E.J., D. Tave, and G.M. Haggerty. 2014. Endangered Rio Grande Silvery Minnow use constructed floodplain habitat. *Ecohydrology* 7:1087–1093.
- Hatch, M.D., F. Abadi, W.J. Boeing, S. Lois, M.D. Porter, and D.E. Cowley. 2020. Sustainability management of short-lived freshwater fish in human-altered ecosystems should focus on adult survival. *PLOS ONE* 15: e0232872.
- Hoagstrom, C.W. 2015. Habitat loss and subdivision are additive mechanisms of fish extinction in fragmented rivers. *Global Change Biology* 21:4–5.

- Hoagstrom, C.W., W.J. Remshardt, J.R. Smith, and J.E. Brooks. 2010. Changing fish faunas in two reaches of the Rio Grande in the Albuquerque Basin. *Southwestern Naturalist* 55:78–88.
- Hoagstrom, C.W., and T.F. Turner. 2013. Recruitment ecology of pelagic-broadcast spawning minnows: Paradigms from the ocean advance science and conservation of an imperilled freshwater fauna. *Fish and Fisheries* 16:282–299.
- Horwitz, R.J., D.H. Keller, P.F. Overbeck, S.P. Platania, R.K. Dudley, and E.W. Carson. 2018. Age and growth of the Rio Grande Silvery Minnow, an endangered, short-lived cyprinid of the North American Southwest. *Transactions of the American Fisheries Society* 147:265–277.
- Hubert, W.A., M.C. Fabrizio, and R.M. Hughes. 2016. Summary of findings by the external expert panelists: Rio Grande Silvery Minnow population monitoring workshop. Submitted to the Middle Rio Grande Endangered Species Collaborative Program and the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.
- Hutson, A.M., L.A. Toya, and D. Tave. 2018. Determining preferred spawning habitat of the endangered Rio Grande Silvery Minnow by hydrological manipulation of a conservation aquaculture facility and the implications for management. *Ecohydrology* 11: e1964.
- Jennings, C.A., B.L. Sloss, B.A. Lasee, G.J. Burtle, and G.R. Moyer. 2012. Care, handling, and examination of sampled organisms. Pages 163–221 in A.V. Zale, D.L. Parrish, and T.M. Sutton, editors. *Fisheries techniques*. Second edition. American Fisheries Society, Bethesda, Maryland, USA.
- Johnson, D.H. 2008. In defense of the indices: the case of bird surveys. *The Journal of Wildlife Management* 72:857–868.
- Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Pages 110–127 in D.P. Dodge, editor. *Proceedings of the International Large River Symposium*. Canadian Special Publication of Fisheries and Aquatic Sciences 106, Department of Fisheries and Oceans, Ottawa, Canada.
- Krabbenhoft, T.J., S.P. Platania, and T.F. Turner. 2014. Interannual variation in reproductive phenology in a riverine fish assemblage: implications for predicting the effects of climate change and altered flow regimes. *Freshwater Biology* 59:1744–1754.
- Lagasse, P.F. 1980. An assessment of the response of the Rio Grande to dam construction — Cochiti to Isleta reach. Submitted to the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA.
- Luttrell, G.R., A.A. Echelle, W.L. Fisher, and D.J. Eisenhour. 1999. Declining status of two species of the *Macrhybopsis aestivalis* complex (Teleostei: Cyprinidae) in the Arkansas River Basin and related effects of reservoirs as barriers to dispersal. *Copeia* 1999:981–989.
- Magaña, H.A. 2012. Habitat use of the Rio Grande Silvery Minnow (*Hybognathus amarus*) during a long-term flood pulse in the Middle Rio Grande, New Mexico. *Environmental Biology of Fishes* 95:201–212.
- Martin, T.G., B.A. Wintle, J.R. Rhodes, P.M. Kuhnert, S.A. Field, S.J. Low-Choy, A.J. Tyre, and H.P. Possingham. 2005. Zero tolerance ecology: improving ecological inference by modelling the source of zero observations. *Ecology Letters* 8:1235–1246.
- Massong, T.M., P.J. Tashjian, and P.W. Makar. 2006. Recent channel incision and floodplain evolution within the Middle Rio Grande, NM. Joint Eighth Federal Interagency Sedimentation Conference and Third Federal Interagency Hydrologic Modeling Conference, Reno, Nevada, USA.
- Matthews, W.J. 1998. *Patterns in freshwater fish ecology*. Chapman and Hall, London, UK.
- Medley, C.N., and P.D. Shirey. 2013. Review and reinterpretation of Rio Grande Silvery Minnow reproductive ecology using egg biology, life history, hydrology, and geomorphology information. *Ecohydrology* 6:491–505.
- Mortensen, J.G., R.K. Dudley, S.P. Platania, G.C. White, T.F. Turner, P.Y. Julien, C. Radobenko, T. Anderson, and B. Corsi. 2023. Linking morpho-dynamics and bio-habitat conditions on the Middle Rio Grande: process-linkage report III – Angostura Reach analyses. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.
- Osborne, M.J., T.P. Archdeacon, C.B. Yackulic, R.K. Dudley, G. Caeiro-Dias, T.F. Turner. 2024b. Genetic erosion in an endangered desert fish during a megadrought despite long-term supportive breeding. *Conservation Biology* 38: e14154.

- Osborne, M.J., E.W. Carson, and T.F. Turner. 2012. Genetic monitoring and complex population dynamics: insights from a 12-year study of the Rio Grande Silvery Minnow. *Evolutionary Applications* 5:553–574.
- Osborne, M.J., G. Caeiro-Dias, and T.F. Turner. 2024a. Genetic monitoring of the Rio Grande Silvery Minnow: genetic status of wild and captive stocks in 2023. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.
- Otis, D.L., K.P. Burnham, G.C. White, and D.R. Anderson. 1978. Statistical inference from capture data on closed animal populations. *Wildlife Monographs* 62:3–135.
- Page, L.M., K.E. Bemis, T.E. Dowling, H.S. Espinosa-Pérez, L.T. Findley, C.R. Gilbert, K.E. Hartel, R.N. Lea, N.E. Mandrak, M.A. Neighbors, J.J. Schmitter-Soto, and H.J. Walker, Jr. 2023. Common and scientific names of fishes from the United States, Canada, and Mexico. Eighth edition. American Fisheries Society, Special Publication 37, Bethesda, Maryland, USA.
- Pease, A.A., J.J. Davis, M.S. Edwards, and T.F. Turner. 2006. Habitat and resource use by larval and juvenile fishes in an arid-land river (Rio Grande, New Mexico). *Freshwater Biology* 51:475–486.
- Perkin, J.S., K.B. Gido, A.R. Cooper, T.F. Turner, M.J. Osborne, E.R. Johnson, and K.B. Mayes. 2015. Fragmentation and dewatering transform Great Plains stream fish communities. *Ecological Monographs* 85:73–92.
- Perkin, J.S., T.A. Starks, C.A. Pennock, K.B. Gido, G.W. Hopper, S.C. Hedden. 2019. Extreme drought causes fish recruitment failure in a fragmented Great Plains riverscape. *Ecohydrology* 12: e2120.
- Pinheiro, J.C., and D.M. Bates. 1995. Approximations to the log-likelihood function in the nonlinear mixed-effects model. *Journal of Computational and Graphical Statistics* 4:12–35.
- Platania, S.P. 1991. Fishes of the Rio Chama and Upper Rio Grande, New Mexico, with preliminary comments on their longitudinal distribution. *Southwestern Naturalist* 36:186–193.
- Platania, S.P. 1993a. The fishes of the Rio Grande between Velarde and Elephant Butte Reservoir and their habitat associations. Submitted to the New Mexico Department of Game and Fish, Santa Fe, New Mexico, USA and to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.
- Platania, S.P. 1993b. Ichthyofaunal survey of the Rio Grande and Santa Fe River, Cochiti Pueblo, New Mexico, July 1993. Submitted to the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA.
- Platania, S.P. 1995a. Ichthyofaunal survey of the Rio Grande, Santo Domingo and San Felipe Pueblos, New Mexico, July 1994. Submitted to the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA.
- Platania, S.P. 1995b. Reproductive biology and early life-history of Rio Grande Silvery Minnow, *Hybognathus amarus*. Submitted to the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA.
- Platania, S.P., and C.S. Altenbach. 1998. Reproductive strategies and egg types of seven Rio Grande Basin cyprinids. *Copeia* 1998:559–569.
- Platania, S.P., J.G. Mortensen, M.A. Farrington, W.H. Brandenburg, and R.K. Dudley. 2020. Dispersal of stocked Rio Grande Silvery Minnow (*Hybognathus amarus*) in the Middle Rio Grande, New Mexico. *Southwestern Naturalist* 64:31–42.
- Porter, M.D., and T.M. Massong. 2004a. Analyzing changes in river channel morphology using GIS for Rio Grande Silvery Minnow habitat assessment. Pages 433–446 in T. Nishida, P.J. Kailola, and C.E. Hollingworth, editors. *Proceedings of the Second International Symposium on GIS/Spatial Analyses in Fishery and Aquatic Sciences*. Fishery-Aquatic GIS Research Group, Saitama, Japan.
- Porter, M.D., and T.M. Massong. 2004b. Contributions to delisting Rio Grande Silvery Minnow: egg habitat identification. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA.
- Propst, D.L. 1999. Threatened and endangered fishes of New Mexico. Technical Report No. 1. New Mexico Department of Game and Fish, Santa Fe, New Mexico, USA.
- Rabeni, C.F., J. Lyons, N. Mercado-Silva, and J.T. Peterson. 2009. Warmwater fish in Wadeable streams. Pages 43–58 in S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. *Standard methods for sampling North American freshwater fishes*. American Fisheries Society, Bethesda, Maryland, USA.
- SAS. 2023. Version 9.4 for Windows. SAS Institute Inc., Cary, North Carolina, USA.

- Skalski, J.R., A. Hoffmann, and S.G. Smith. 1993. Testing the significance of individual- and cohort-level covariates in animal survival studies. Pages 9–28 in J. D. Lebreton and P. M. North, editors. *Marked individuals in the study of bird population*. Birkhäuser Verlag, Basel, Switzerland.
- Stanford, J.A., and J.V. Ward. 1979. Stream regulation in North America. Pages 215–236 in J.V. Ward and J.A. Stanford, editors. *The ecology of regulated streams*. Plenum Press, New York, New York, USA.
- Stevens, D.L., and A.R. Olsen. 1999. Spatially restricted surveys over time for aquatic resources. *Journal of Agricultural, Biological, and Environmental Statistics* 4:415–428.
- Stevens, D.L., and A.R. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. *Environmetrics* 14:593–610.
- Stevens, D.L., and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99:262–278.
- Sublette, J.E., M.D. Hatch, and M. Sublette. 1990. *The fishes of New Mexico*. University of New Mexico Press, Albuquerque, New Mexico, USA.
- Tave, D., L.A. Toya, and A.M. Hutson. 2018. Behavioral observations of the endangered Rio Grande Silvery Minnow in a conservation aquaculture facility. *Croatian Journal of Fisheries* 76:7–26.
- Turner, T.F., T.J. Krabbenhoft, and A.S. Burdett. 2010. Reproductive phenology and fish community structure in an arid-land river system. Pages 427–446 in K.B. Gido and D.A. Jackson, editors. *Community ecology of stream fishes: concepts, approaches, and techniques*. American Fisheries Society, Symposium Series 73, Bethesda, Maryland, USA.
- USACE (U.S. Army Corps of Engineers). 2010. Historic inundation analysis along the Middle Rio Grande for the period 1990 to 2009. Submitted to the Middle Rio Grande Endangered Species Collaborative Program, Population Viability Analysis Work Group, Albuquerque, New Mexico, USA.
- USFWS (U.S. Fish and Wildlife Service). 1994. Endangered and threatened wildlife and plants; final rule to list the Rio Grande Silvery Minnow as an endangered species. *Federal Register* 59:138(20 July 1994):36988–36995.
- USFWS (U.S. Fish and Wildlife Service). 2016. Final biological and conference opinion for Bureau of Reclamation, Bureau of Indian Affairs, and non-federal water management and maintenance activities on the Middle Rio Grande, New Mexico. U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office, Albuquerque, New Mexico, USA.
- Valdez, R.A., G.M. Haggerty, K. Richard, and D. Klobucar. 2019. Managed spring runoff to improve nursery floodplain habitat for endangered Rio Grande Silvery Minnow. *Ecohydrology* 12: e2134.
- Walsworth, T.E., and P. Budy. 2021. An empirically based simulation model to inform flow management for endangered species conservation. *Canadian Journal of Fisheries and Aquatic Sciences* 78:1770–1781.
- Welcomme, R.L. 1979. *The fisheries ecology of floodplain rivers*. Longman, London, UK.
- Welsh, A.H., R.B. Cunningham, C.F. Donnelly, and D.B. Lindenmayer. 1996. Modelling the abundance of rare species: statistical models for counts with extra zeros. *Ecological Modelling* 88:297–308.
- White, G.C. 1978. Estimation of plant biomass from quadrat data using the lognormal distribution. *Journal of Range Management* 31:118–120.
- Widmer, A.M., J.J. Fluder, J.W. Kehmeier, C.N. Medley, and R.A. Valdez. 2012. Drift and retention of pelagic spawning minnow eggs in a regulated river. *River Research and Applications* 28:192–203.
- Winston, M.R., C.M. Taylor, and J. Pigg. 1991. Upstream extirpation of four minnow species due to damming of a prairie stream. *Transactions of the American Fisheries Society* 120:98–105.
- Worthington, T.A., A.A. Echelle, J.S. Perkin, R. Mollenhauer, N. Farless, J.J. Dyer, D. Logue, S.K. Brewer. 2018. The emblematic minnows of the North American Great Plains: a synthesis of threats and conservation opportunities. *Fish and Fisheries* 19:271–307.
- Yackulic, C.B., T.P. Archdeacon, R.A. Valdez, M. Hobbs, M.D. Porter, J. Lusk, A. Tanner, E.J. Gonzales, D.Y. Lee, and G.M. Haggerty. 2022. Quantifying flow and nonflow management impacts on an endangered fish by integrating data, research, and expert opinion. *Ecosphere* 13: e4240.
- Zar, J.H. 2010. *Biostatistical Analysis*. Fifth edition. Prentice Hall Inc., Upper Saddle River, New Jersey, USA.

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 (old) 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 additional sites (new) for population monitoring of Rio Grande Silvery Minnow in the Middle Rio Grande.

Reach and Site	Locality
Isleta Reach	
61	New Mexico, Valencia County, Rio Grande, ca. 6.2 mi upstream of NM State HWY 346 bridge crossing, Jarales. River Mile: 147.0; UTM Easting: 339379; UTM Northing: 3832429; Zone: 13; Datum: NAD83
62	New Mexico, Valencia County, Rio Grande, ca. 0.7 mi downstream of NM State HWY 346 bridge crossing, Jarales. River Mile: 140.0; UTM Easting: 337520; UTM Northing: 3822964; Zone: 13; Datum: NAD83
63	New Mexico, Socorro County, Rio Grande, ca. 3.1 mi upstream of US HWY 60 bridge crossing, Bernardo. River Mile: 133.7; UTM Easting: 334853; UTM Northing: 3814593; Zone: 13; Datum: NAD83
64	New Mexico, Socorro County, Rio Grande, ca. 4.7 mi upstream of the Rio Salado confluence, San Acacia. River Mile: 123.2; UTM Easting: 329215; UTM Northing: 3799784; Zone: 13; Datum: NAD83
San Acacia Reach	
65	New Mexico, Socorro County, Rio Grande, ca. 5.4 mi downstream of San Acacia Diversion Dam, San Acacia. River Mile: 110.3; UTM Easting: 326105; UTM Northing: 3785502; Zone: 13; Datum: NAD83
66	New Mexico, Socorro County, Rio Grande, ca. 3.8 mi downstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro. River Mile: 95.1; UTM Easting: 327905; UTM Northing: 3765463; Zone: 13; Datum: NAD83
67	New Mexico, Socorro County, Rio Grande, ca. 4.3 mi downstream of San Antonio bridge crossing, San Antonio. River Mile: 83.3; UTM Easting: 329319; UTM Northing: 3747431; Zone: 13; Datum: NAD83
68	New Mexico, Socorro County, Rio Grande, ca. 5.3 mi upstream of San Marcial Railroad bridge crossing, San Marcial. River Mile: 73.7; UTM Easting: 322751; UTM Northing: 3732864; Zone: 13; Datum: NAD83
69	New Mexico, Socorro County, Rio Grande, ca. 4.4 mi downstream of San Marcial Railroad bridge crossing, San Marcial. River Mile: 63.9; UTM Easting: 313940; UTM Northing: 3722027; Zone: 13; Datum: NAD83
70	New Mexico, Socorro County, Rio Grande, ca. 12.9 mi downstream of San Marcial Railroad bridge crossing, San Marcial. River Mile: 55.5; UTM Easting: 305502; UTM Northing: 3711951; Zone: 13; Datum: NAD83

Table A4. Sampling reaches and active replacement sites for population monitoring of Rio Grande Silvery Minnow in the Middle Rio Grande.

Reach and Site	Locality
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 (2005–2023). 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 (2005–2023).

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 (2005–2023). Our site occupancy analyses also complement and enhance the ecological insights provided by the long-term population monitoring study (1993–2023). 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 [2005–2023]) 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., mesohabitat 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 (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., $\psi[.] \epsilon[Year] \gamma[Year] p[Year]$). 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 (2005–2023) sampling-site data (Table B1). The top AIC_c model (AIC_c weight = 65.9%) had constant occupancy (ψ) and colonization (γ) probabilities, but extinction (ε) and detection probabilities (p) that varied across years. The second ranked model (AIC_c weight = 34.1%) had only detection probabilities that varied across years. Models that included sampling occasion (e.g., $\psi(\cdot)$ $\varepsilon(\cdot)$ $\gamma(\cdot)$ $p(\text{Year*Occasion})$) 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 before again improving (0.75) in 2023. 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., 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 (2005–2023; 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 increased from 0.07 in 2021 to 0.53 in 2022, it decreased to 0.11 by 2023.

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 0.57 in 2022 and was similar (0.62) in 2023.

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 declined from 2021 to 2022, its status again improved somewhat in 2023.

Table B1. Site occupancy models for Rio Grande Silvery Minnow, using November sampling-site data (2005–2023).

Site Occupancy Models ¹	logLike ²	K ³	AIC _c ⁴	w _i ⁴
$\psi(.) \varepsilon(\text{Year}) \gamma(.) p(\text{Year})$	997.85	39	1,085.02	0.6590
$\psi(.) \varepsilon(.) \gamma(.) p(\text{Year})$	1,039.51	22	1,086.34	0.3410
$\psi(.) \varepsilon(\text{Year}) \gamma(\text{Year}) p(\text{Year})$	975.58	56	1,107.35	< 0.0001
$\psi(.) \varepsilon(.) \gamma(\text{Year}) p(\text{Year})$	1,020.60	39	1,107.78	< 0.0001
$\psi(.) \varepsilon(.) \gamma(.) p(\text{Year} * \text{Occasion})$	987.54	79	1,187.68	< 0.0001
$\psi(.) \varepsilon(\text{Year}) \gamma(.) p(\text{Year} * \text{Occasion})$	943.17	96	1,200.98	< 0.0001
$\psi(.) \varepsilon(.) \gamma(\text{Year}) p(\text{Year} * \text{Occasion})$	968.14	96	1,225.95	< 0.0001
$\psi(.) \varepsilon(\text{Year}) \gamma(\text{Year}) p(\text{Year} * \text{Occasion})$	917.44	113	1,240.29	< 0.0001
$\psi(.) \varepsilon(\text{Year}) \gamma(.) p(.)$	1,313.61	21	1,358.19	< 0.0001
$\psi(.) \varepsilon(\text{Year}) \gamma(\text{Year}) p(.)$	1,279.21	38	1,363.91	< 0.0001

¹ = Models included all ε , γ , and p combinations of null effects (.) and year (2005–2023), along with a multiplicative effect (year and sampling occasion [i.e., 1st, 2nd, 3rd, or 4th day of sampling]) for detection probability.

² = Likelihood ($-2[\log\text{-likelihood}]$) 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).

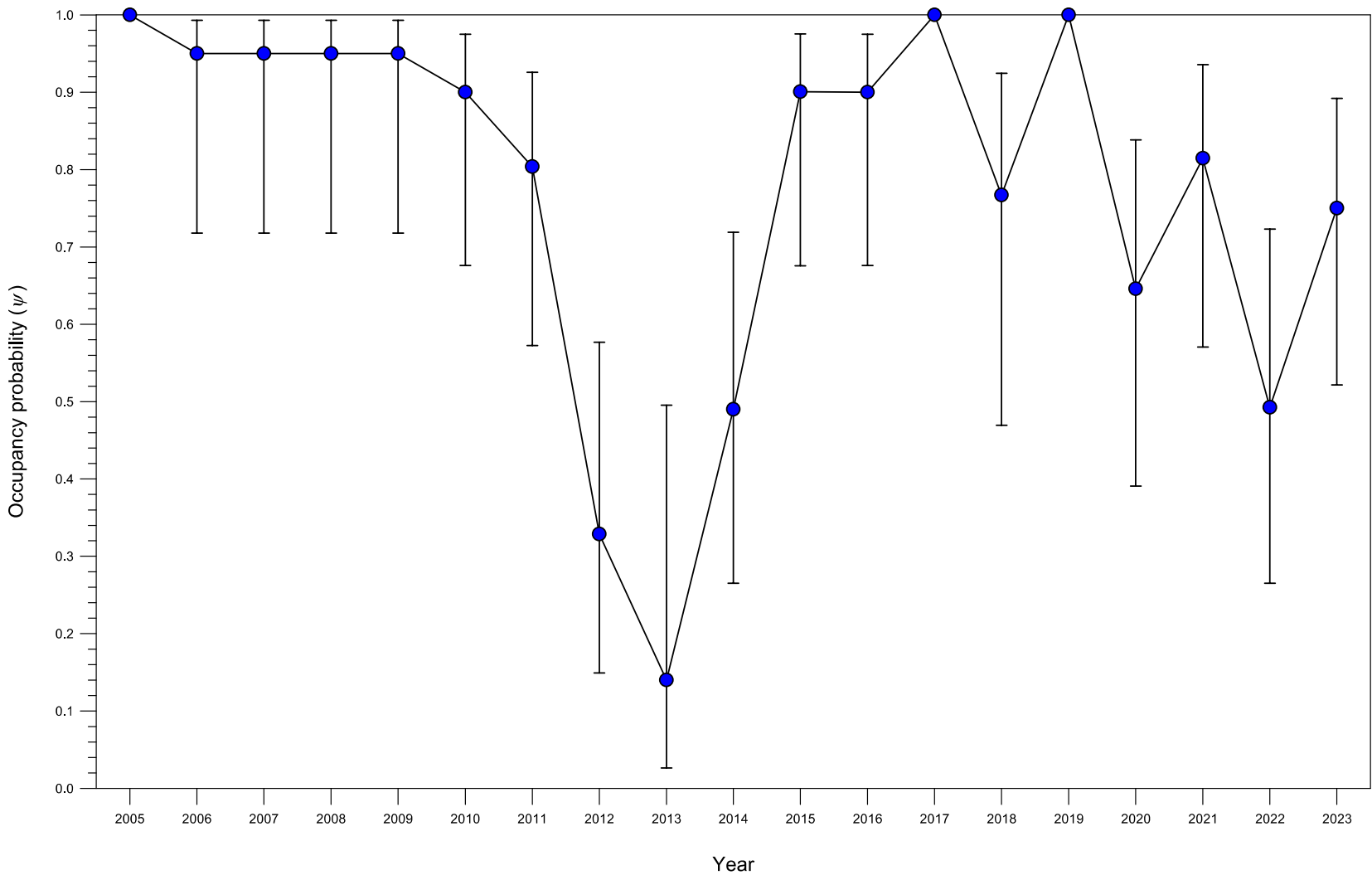


Figure B1. Rio Grande Silvery Minnow occupancy probabilities (estimated using November sampling-site data) across years. Modeled estimates (circles) and 95% confidence intervals (bars) are illustrated.

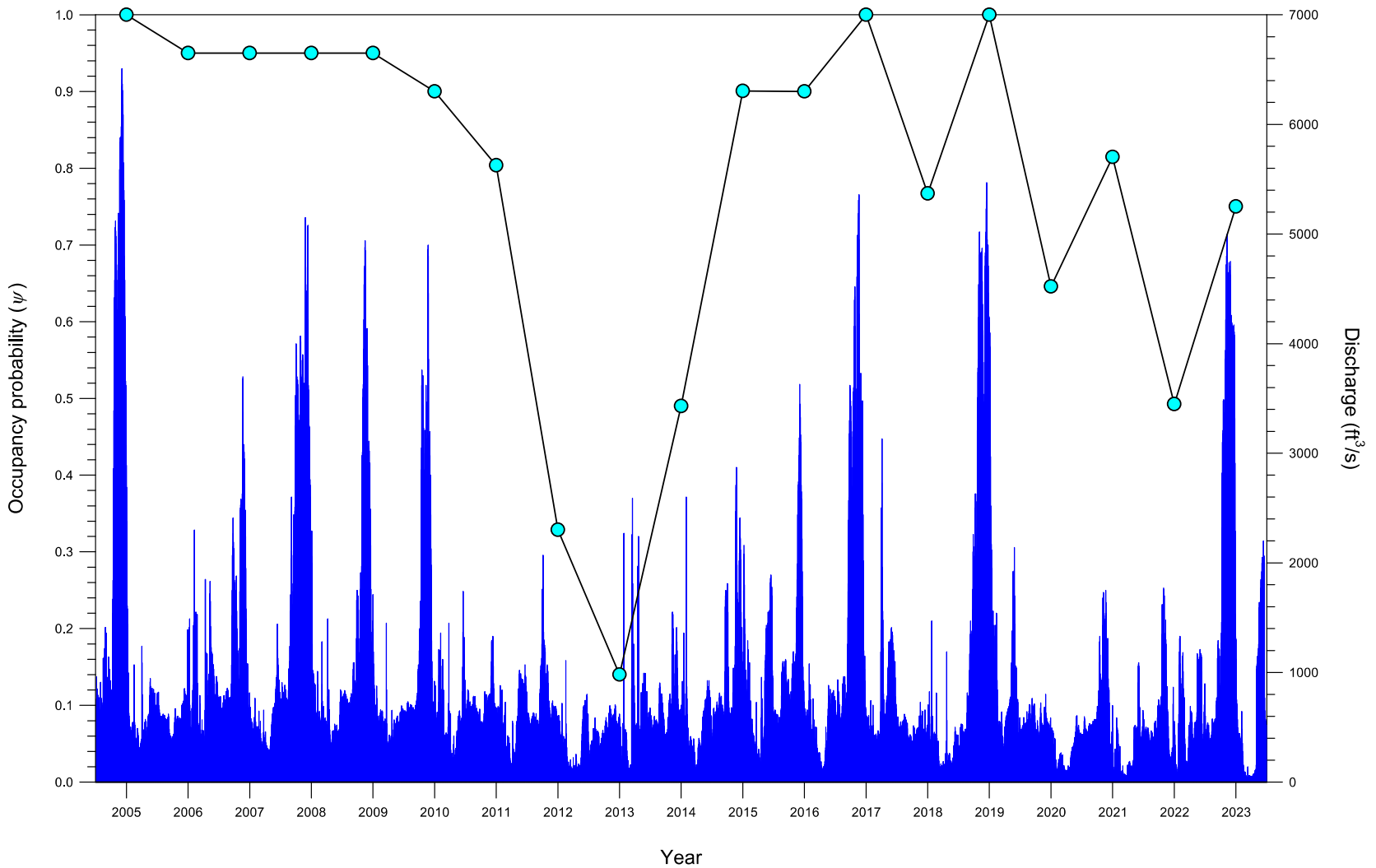


Figure B2. Rio Grande Silvery Minnow occupancy probabilities (estimated using November sampling-site data), and mean daily discharge data from the Albuquerque Gage (2005-01-01 to 2023-12-31), across years.

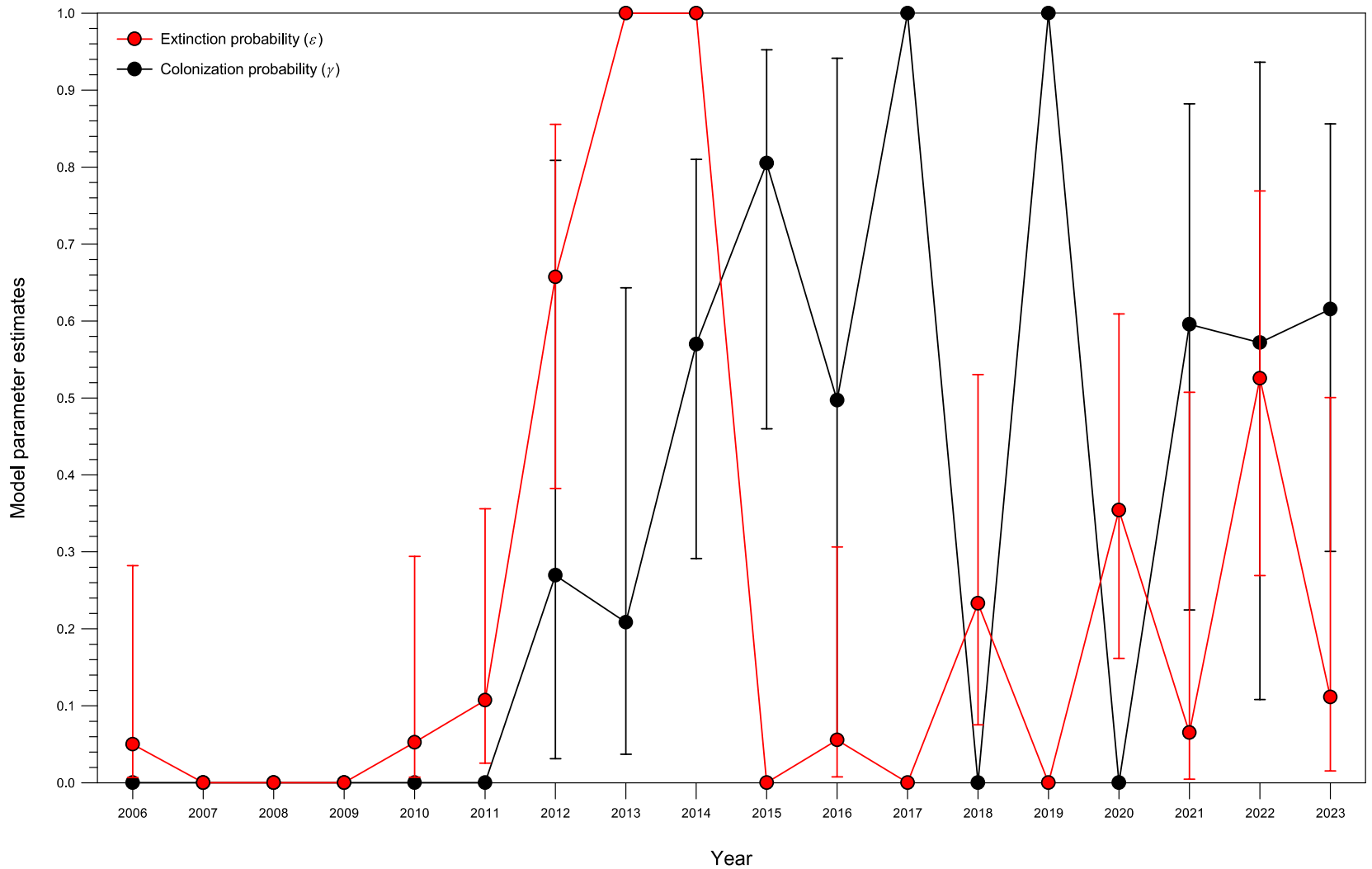


Figure B3. Rio Grande Silvery Minnow extinction/colonization probabilities (estimated using November sampling-site data) across years. Modeled estimates (symbols) and 95% confidence intervals (bars) are illustrated.

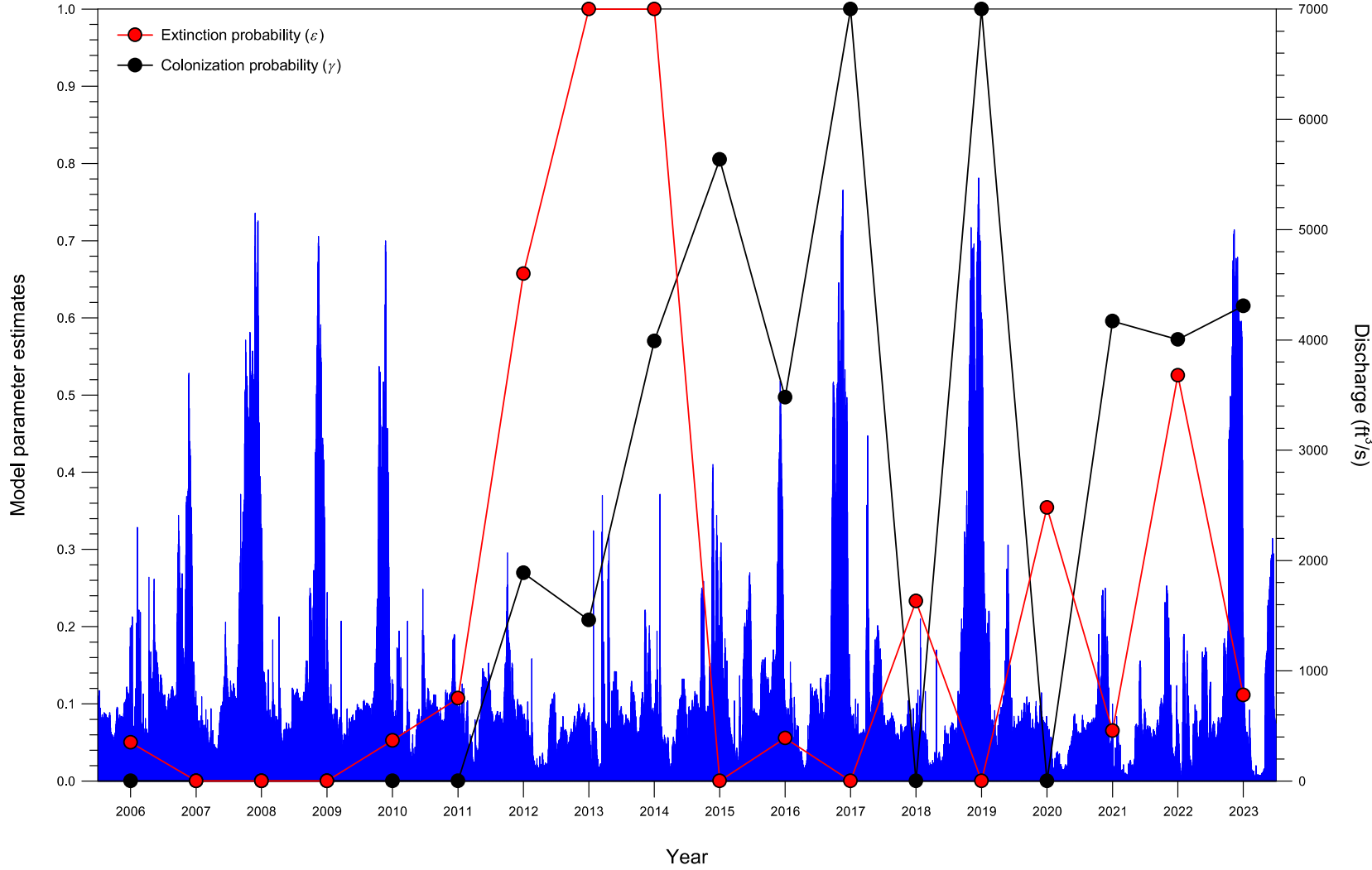


Figure B4. Rio Grande Silvery Minnow extinction/colonization probabilities (estimated using November sampling-site data), and mean daily discharge data from the Albuquerque Gage (2006-01-01 to 2023-12-31), across years.

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 2023, 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 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 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 sequentially sampled four times for the site occupancy study vs. once 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 unusually 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 increased from 2020 to 2021, there was a marked decline in 2022, followed by a rebound in 2023. 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 for Rio Grande Silvery Minnow 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 during that period. While the improved spring and summer flows of 2017 and 2019 coincided with increased colonization probabilities and decreased extinction probabilities, these trends again reversed in 2020 following poor spring and summer flow conditions. In contrast, the high and prolonged flows during spring runoff in 2023, as compared with 2022, coincided with a marked decrease in the extinction probability and a slight increase in the colonization probability.

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 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 for 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 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. 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, density, and conservation status 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 underscore the importance of ensuring 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. 2023). For example, poor spring runoff may inhibit spawning and limit recruitment to such a degree that its densities decline several orders of magnitude within one year (Dudley et al. 2023). 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 and 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. 2023). 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 ecological and management implications of these site-occupancy results will be evaluated annually, these ongoing insights 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.

LITERATURE CITED

- Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Pages 267–281 in B.N. Petrov and F. Csáki, editors. *Proceedings of the Second International Symposium on Information Theory*. Akadémiai Kiadó, Budapest, Hungary.
- Archdeacon, T.P. 2016. Reduction in spring flow threatens Rio Grande Silvery Minnow: trends in abundance during river intermittency. *Transactions of the American Fisheries Society* 145:754–765.
- Archdeacon, T.P., K.R. Henderson, T.J. Austring, and R.L. Cook. 2015. Comparison of fish communities at random and nonrandom locations in a sand-bed river. *North American Journal of Fisheries Management* 35:578–585.
- Archdeacon, T.P., and J.K. Reale. 2020. No quarter: Lack of refuge during flow intermittency results in catastrophic mortality of an imperiled minnow. *Freshwater Biology* 65:2108–2123.
- Burnham, K.P., and D.R. Anderson. 2002. *Model selection and multimodel inference: a practical information-theoretic approach*. Second edition. Springer-Verlag, New York, New York, USA.
- Dudley, R.K., and S.P. Platania. 1996. 1995 population monitoring of Rio Grande Silvery Minnow. Submitted to the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.1.3484.5607>
- Dudley, R.K., and S.P. Platania. 1997. 1996 population monitoring of Rio Grande Silvery Minnow. Submitted to the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.1.4533.1362>
- Dudley, R.K., S.P. Platania, and G.C. White. 2023. Rio Grande Silvery Minnow population monitoring during 2022. Submitted to the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.2.24201.83042>
- Dudley, R.K., G.C. White, S.P. Platania, and D.A. Helfrich. 2012. Rio Grande Silvery Minnow population estimation program results from October 2011. Submitted to the Middle Rio Grande Endangered Species Collaborative Program and the U.S. Bureau of Reclamation, Albuquerque, New Mexico, USA. <https://doi.org/10.13140/RG.2.1.4201.3601>
- Finley, D.J., G.C. White, and J.P. Fitzgerald. 2005. Estimation of swift fox population size and occupancy rates in eastern Colorado. *Journal of Wildlife Management* 69:861–873.
- Groom, M.J., G.K. Meffe, and C.R. Carroll. 2006. *Principles of Conservation Biology*. Third edition. Sinauer Associates, Inc., Sunderland, Massachusetts, USA.
- Hatch, M.D., F. Abadi, W.J. Boeing, S. Lois, M.D. Porter, and D.E. Cowley. 2020. Sustainability management of short-lived freshwater fish in human-altered ecosystems should focus on adult survival. *PLOS ONE* 15: e0232872.
- Horwitz, R.J., D.H. Keller, P.F. Overbeck, S.P. Platania, R.K. Dudley, and E.W. Carson. 2018. Age and growth of the Rio Grande Silvery Minnow, an endangered, short-lived cyprinid of the North American Southwest. *Transactions of the American Fisheries Society* 147:265–277.
- MacKenzie, D.I., J.D. Nichols, J.E. Hines, M.G. Knutson, and A.B. Franklin. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology* 84:2200–2207.
- MacKenzie, D.I., J.D. Nichols, G.B. Lachman, S. Droege, J.A. Royle, and C.A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology* 83:2248–2255.
- MacKenzie, D.I., J.D. Nichols, J.A. Royle, K.H. Pollock, L.L. Bailey, and J.E. Hines. 2006. *Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence*. Elsevier, Amsterdam, Netherlands.
- Royle, J.A., and J.D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. *Ecology* 84:777–790.
- White, G.C. 2005. Correcting wildlife counts using detection probabilities. *Wildlife Research* 32:211–216.
- White, G.C., and K.P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46: S120–S139.

APPENDIX C (Water Quality Summary)

Table C1. Water quality statistics based on standard sites (April to October), by reach and site, during 2023.

Reach (Site & Locality)	Water Quality Measurements ¹ : Mean (Standard Error)						pH
	Sec.	Temp.	Sal.	D.O.	Con. T.	Con. S.	
Angostura Reach							
1 Angostura Dam	35.7 (7.4)	17.7 (2)	0.2 (< 0.1)	6.8 (0.3)	385.9 (32.4)	450.1 (36.1)	8.3 (0.1)
2 Bernalillo	24 (3.7)	18.3 (2.2)	0.2 (< 0.1)	6.9 (0.3)	398 (34.2)	453 (33)	8.2 (0.1)
3 Rio Rancho	21 (2.8)	19.5 (2.3)	0.2 (< 0.1)	7.1 (0.3)	409.4 (35.8)	461.4 (35)	8.3 (0.1)
4 Central Ave.	17.6 (4.3)	19 (2.9)	0.2 (< 0.1)	6.8 (0.3)	441.6 (44.6)	497.9 (39.2)	8.3 (0.1)
5 Rio Bravo Blvd.	14.7 (2.7)	17.8 (2.8)	0.2 (< 0.1)	7.1 (0.3)	431.9 (40)	500 (37.3)	8.5 (0.2)
Isleta Reach							
6 Los Lunas	20.1 (3.8)	22.1 (2.8)	0.3 (< 0.1)	8.7 (1.5)	669.4 (86.1)	701.6 (66.5)	8.4 (0.2)
7 Belen	20.7 (4)	25 (2.9)	0.3 (< 0.1)	6.7 (0.4)	652 (60.1)	664 (44)	8.4 (0.1)
8 Jarales	18.7 (3)	21.4 (3)	0.4 (< 0.1)	7.6 (1.2)	748.6 (100)	800 (89.8)	8.4 (0.2)
9 Bernardo	24.1 (5)	21.5 (2.7)	0.4 (< 0.1)	6.6 (0.4)	690.6 (81.5)	734.3 (62.9)	8.3 (0.1)
10 La Joya	22.7 (5.8)	19.3 (2.4)	0.6 (0.1)	6.4 (0.5)	966.6 (222.8)	1,100.9 (269.7)	8.2 (0.1)
11 North of San Acacia	14.7 (2.3)	21.9 (1.7)	0.4 (0.1)	6.9 (0.6)	862.6 (156)	902.3 (137.9)	8.4 (0.1)
San Acacia Reach							
12 San Acacia Dam	20.9 (3.8)	21.2 (1.8)	0.4 (0.1)	6.7 (0.3)	822.3 (121.1)	876.7 (106.9)	8.4 (0.1)
13 South of San Acacia	15 (3.2)	21.3 (2.1)	0.5 (0.1)	7.3 (0.6)	954 (201.5)	1,010.6 (181.1)	8.4 (0.1)
14 Socorro	14.4 (5.7)	20.4 (2.5)	0.5 (0.1)	6.7 (0.3)	931.9 (194.3)	1,003.4 (178.7)	8.4 (0.1)
15 North of San Antonio	10.1 (1.2)	19.4 (2.3)	0.6 (0.2)	5.6 (0.6)	1,070.3 (310)	1,175.4 (316.9)	8.2 (0.1)
16 San Antonio	8.8 (2)	21.5 (1.8)	0.4 (0.1)	6.1 (0.5)	766 (131)	825.8 (136.7)	8.2 (0.1)
17 South of San Antonio	11.8 (4.2)	20.3 (2.4)	0.5 (0.1)	4.1 (1)	918 (207.3)	996.7 (187.8)	7.8 (0.2)
18 San Marcial	16.6 (6)	21.3 (2.1)	0.4 (< 0.1)	7.6 (1.8)	815.4 (110.7)	877.6 (96.9)	8.3 (0.2)
19 South of San Marcial 1	16.9 (5.9)	22.2 (2.4)	0.5 (0.1)	7.5 (0.6)	972 (201.2)	1,012.1 (169)	8.1 (0.1)
20 South of San Marcial 2	15.7 (7.5)	21 (2.2)	0.7 (0.2)	7 (0.5)	1,278.4 (359.2)	1,329 (325.8)	8 (0.1)

¹ = Water quality descriptions were based on USGS definitions (i.e., National field manual for the collection of water-quality data [https://pubs.water.usgs.gov/twri9A/]);

Sec. = Secchi depth (cm); Disk with black and white quadrants for measuring water clarity

Temp. = Water temperature (°C); Accurate measurements were 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 sampling 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:

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

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:

$$\begin{aligned} \text{if } x_i = 0, \quad \log L(x_i) &= \log(1 - \delta) \\ \text{else for } x_i > 0, \quad \log L(x_i) &= \log(\delta) - \frac{(\log(x_i) - \mu)^2}{2\sigma^2} - \log(\sigma) \end{aligned}$$

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:

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

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 $\log(\delta) - (\log(x_i) - \mu)^2$ for a single positive value of x .

Numerical maximization of this log-likelihood is computed using PROC NLMIXED (Nonlinear Mixed Models; SAS 2023) 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:

$$\begin{aligned}\delta &= \text{expit}[\beta_{\delta 0} + \beta_{\delta 1} \cdot \text{Covariate}] \\ \mu &= \beta_{\mu 0} + \beta_{\mu 1} \cdot \text{Covariate} \\ \sigma &= \exp[\beta_{\sigma 0} + \beta_{\sigma 1} \cdot \text{Covariate}]\end{aligned}$$

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 $-\infty$ and $+\infty$, 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 (μ and σ) might be quite different than covariates best related to the occurrence probability (δ).

In addition, random effects are considered by year:

$$\begin{aligned}\delta &= \text{expit}[\beta_{\delta 0} + \text{Normal}(0, \sigma_{\delta}^2)] \\ \mu &= \beta_{\mu 0} + \text{Normal}(0, \sigma_{\mu}^2)\end{aligned}$$

where we assume a normal distribution with a mean of zero and a nonzero standard deviation. The associated variances (σ_{δ}^2 and σ_{μ}^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 ($\text{logLike} = -2[\text{log-likelihood}]$ and $\text{AIC}_c = \text{Akaike's information criterion}$ [Akaike 1973; Burnham and Anderson 2002] corrected for finite sample sizes).

The estimated fish density $E(x)$, and its standard deviation $\text{SD}(E(x))$, are generated from PROC NLMIXED using these equations:

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

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

$$LCI = \exp[\log(E(x)) - 1.96 \cdot SE(E(x)) / E(x)]$$
$$UCI = \exp[\log(E(x)) + 1.96 \cdot SE(E(x)) / E(x)]$$

where LCI is the lower 95% confidence interval, UCI is the upper 95% confidence interval, and the standard error $SE(E(x))$ 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, meaningful environmental covariates are used to model the key population 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 $t = 1, 2, \dots, K$ years (primary occasions) and l_t site visits (secondary occasions), following the methods of MacKenzie et al. (2003, 2006):

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

where the estimated parameters are ψ_t (probability a site is occupied in year t) and p_{jt} (probability of detection during visit j , $j = 1, 2, \dots, l_t$, 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):

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

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 key model parameters (ψ , ε , and γ), based on the Robust Design Occupancy Estimation (RDOccupEG) statistical procedure. With this site occupancy model, estimates of ψ_t for the primary occasions ($t = 2, 3, \dots, K$) 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 $\text{LCI} \geq 0$ and $\text{UCI} \leq 1$, 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 $\text{LCI} \geq 0$ and $\text{UCI} \leq 1$. Annual parameter values (ψ_t , ε_t , or γ_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 comprise values of either 1 (species detected) or 0 (species not detected), which eliminates the uncertainty associated with 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 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 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 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 in this study, did not make this assumption.	We considered site heterogeneity in species detection probabilities for 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 inadequately fit the data (i.e., overly simplistic or complicated models).

APPENDIX F (Site-Specific Population Monitoring Data)

Site-specific data, collected in 2023, 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 2023

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-018

06 April 2023
USGS Quad: San Felipe Pueblo
Effort: 469.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	1
4	<i>Cyprinella lutrensis</i>	2
4	<i>Platygobio gracilis</i>	2
4	<i>Rhinichthys cataractae</i>	2

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-019

06 April 2023
USGS Quad: Bernalillo
Effort: 479.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	1
3	<i>Cyprinus carpio</i>	1
4	<i>Cyprinella lutrensis</i>	6
4	<i>Pimephales promelas</i>	4
4	<i>Platygobio gracilis</i>	20
4	<i>Rhinichthys cataractae</i>	6
5	<i>Ictalurus punctatus</i>	1

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.
Site Number: 3 River Mile: 199.9
UTM Easting: 354728 UTM Northing: 3905587 Zone: 13
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-020

06 April 2023
USGS Quad: Bernalillo
Effort: 447.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	2
4	<i>Platygobio gracilis</i>	22
4	<i>Rhinichthys cataractae</i>	1
5	<i>Ictalurus punctatus</i>	8

Rio Grande Silvery Minnow Population Monitoring April 2023

NEW MEXICO: Sandoval County, RIO GRANDE Drainage **RKD23-030**
Rio Grande, ca. 4.5 mi upstream of Alameda Blvd. bridge crossing (NM State HWY 528), Corrales.
Site Number: 21 River Mile: 196.5 12 April 2023
UTM Easting: 355670 UTM Northing: 3900620 Zone: 13 USGS Quad: Alameda
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T. Effort: 515.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	2
4	<i>Platygobio gracilis</i>	64
4	<i>Rhinichthys cataractae</i>	17
5	<i>Ictalurus punctatus</i>	2

NEW MEXICO: Sandoval County, RIO GRANDE Drainage **RKD23-029**
Rio Grande, ca. 1.0 mi upstream of Alameda Blvd. bridge crossing (NM State HWY 528), Corrales.
Site Number: 22 River Mile: 193.0 12 April 2023
UTM Easting: 351565 UTM Northing: 3897088 Zone: 13 USGS Quad: Los Griegos
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T. Effort: 547.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	13
4	<i>Hybognathus amarus*</i>	2
4	<i>Platygobio gracilis</i>	19
5	<i>Ictalurus punctatus</i>	1

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

age-0	
age-1	
age-2+	2

NEW MEXICO: Bernalillo County, RIO GRANDE Drainage **RKD23-028**
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 12 April 2023
UTM Easting: 349121 UTM Northing: 3893113 Zone: 13 USGS Quad: Los Griegos
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T. Effort: 524.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	2
4	<i>Platygobio gracilis</i>	37
4	<i>Rhinichthys cataractae</i>	1
5	<i>Ictalurus punctatus</i>	1

Rio Grande Silvery Minnow Population Monitoring April 2023

NEW MEXICO: Bernalillo County, RIO GRANDE Drainage

Rio Grande, ca. 1.1 mi upstream of US Interstate HWY I-40 bridge crossing, Albuquerque.

Site Number: 24

River Mile: 186.1

UTM Easting: 346011

UTM Northing: 3887973

Zone: 13

USGS Quad: Albuquerque West

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-027

12 April 2023

Effort: 478.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	18
4	<i>Platygobio gracilis</i>	6
5	<i>Ictalurus punctatus</i>	2

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage

Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.

Site Number: 4

River Mile: 183.4

UTM Easting: 346719

UTM Northing: 3884331

Zone: 13

USGS Quad: Albuquerque West

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-017

06 April 2023

Effort: 579.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	1
4	<i>Cyprinella lutrensis</i>	53
4	<i>Platygobio gracilis</i>	30
5	<i>Ictalurus punctatus</i>	27

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage

Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.

Site Number: 5

River Mile: 178.4

UTM Easting: 347468

UTM Northing: 3877400

Zone: 13

USGS Quad: Albuquerque West

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-016

06 April 2023

Effort: 520.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	27
4	<i>Hybognathus amarus</i> *	4
4	<i>Platygobio gracilis</i>	14
5	<i>Ictalurus punctatus</i>	22

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

age-0	
age-1	4
age-2+	

Rio Grande Silvery Minnow Population Monitoring April 2023

NEW MEXICO: Bernalillo County, RIO GRANDE Drainage

RKD23-026

Rio Grande, ca. 1.4 mi upstream of US Interstate HWY I-25 bridge crossing, Isleta.

Site Number: 25 River Mile: 174.0

11 April 2023

UTM Easting: 345874 UTM Northing: 3870990 Zone: 13

USGS Quad: Isleta

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

Effort: 441.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	23
4	<i>Platygobio gracilis</i>	1
5	<i>Ictalurus punctatus</i>	11
9	<i>Gambusia affinis</i>	1

NEW MEXICO: Valencia County, RIO GRANDE Drainage

RKD23-025

Rio Grande, ca. 4.1 mi upstream of NM State HWY 6 bridge crossing, Los Lunas.

Site Number: 26 River Mile: 165.2

11 April 2023

UTM Easting: 342799 UTM Northing: 3858637 Zone: 13

USGS Quad: Los Lunas

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

Effort: 498.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	33
4	<i>Hybognathus amarus</i> *	1
5	<i>Ictalurus punctatus</i>	14

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

age-0	
age-1	1
age-2+	

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

RKD23-015

Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.

Site Number: 6 River Mile: 161.7

05 April 2023

UTM Easting: 343149 UTM Northing: 3853187 Zone: 13

USGS Quad: Los Lunas

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

Effort: 404.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	50
4	<i>Hybognathus amarus</i> *	1
4	<i>Platygobio gracilis</i>	1

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

age-0	
age-1	1
age-2+	

Rio Grande Silvery Minnow Population Monitoring April 2023

NEW MEXICO: Valencia County, RIO GRANDE Drainage

Rio Grande, ca. 6.5 mi upstream of NM State HWY 309 bridge crossing, Belen.

Site Number: 27 River Mile: 156.0

UTM Easting: 340512 UTM Northing: 3845124

Zone: 13

USGS Quad: Tome

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-024

11 April 2023

Effort: 517.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	1
5	<i>Ictalurus punctatus</i>	3

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.

Site Number: 7 River Mile: 150.8

UTM Easting: 340105 UTM Northing: 3837722

Zone: 13

USGS Quad: Tome

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-014

05 April 2023

Effort: 488.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	221
4	<i>Pimephales promelas</i>	2
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	13

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.

Site Number: 8 River Mile: 143.2

UTM Easting: 338020 UTM Northing: 3827545

Zone: 13

USGS Quad: Veguita

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-013

05 April 2023

Effort: 435.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	1
4	<i>Cyprinella lutrensis</i>	206

NEW MEXICO: Socorro County, RIO GRANDE Drainage

Rio Grande, ca. 3.8 mi downstream of NM State HWY 346 bridge crossing, Jarales.

Site Number: 28 River Mile: 137.0

UTM Easting: 335506 UTM Northing: 3819543

Zone: 13

USGS Quad: Veguita

Collector(s): Farrington, M.A.; Urioste, A.D.; Camak, D.T.

RKD23-023

10 April 2023

Effort: 497.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	90
5	<i>Ictalurus punctatus</i>	14

Rio Grande Silvery Minnow Population Monitoring April 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at US HWY 60 bridge crossing, Bernardo.

Site Number: 9

River Mile: 130.6

UTM Easting: 334578

UTM Northing: 3809921

Zone: 13

USGS Quad: Abeytas

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-012

05 April 2023

Effort: 467.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	136
5	<i>Ictalurus punctatus</i>	2

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.

Site Number: 10

River Mile: 126.8

UTM Easting: 330946

UTM Northing: 3805307

Zone: 13

USGS Quad: Abeytas

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-011

05 April 2023

Effort: 467.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	47
4	<i>Platygobio gracilis</i>	1
5	<i>Ictalurus punctatus</i>	1
10	<i>Lepomis cyanellus</i>	1

NEW MEXICO: Socorro County, RIO GRANDE Drainage

Rio Grande, ca. 1.4 mi upstream of the Rio Salado confluence, San Acacia.

Site Number: 29

River Mile: 120.0

UTM Easting: 330550

UTM Northing: 3795050

Zone: 13

USGS Quad: La Joya

Collector(s): Farrington, M.A.; Urioste, A.D.; Camak D.T.

RKD23-022

10 April 2023

Effort: 463.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	1
4	<i>Cyprinella lutrensis</i>	3
5	<i>Ictalurus punctatus</i>	12

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.

Site Number: 11

River Mile: 117.3

UTM Easting: 328152

UTM Northing: 3792564

Zone: 13

USGS Quad: La Joya

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-010

04 April 2023

Effort: 581.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	No Fish Collected	

Rio Grande Silvery Minnow Population Monitoring April 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-009

04 April 2023
USGS Quad: San Acacia
Effort: 463.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	11
4	<i>Hybognathus amarus</i> *	4
4	<i>Platygobio gracilis</i>	3
5	<i>Ictalurus punctatus</i>	1

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

age-0	
age-1	4
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 13 River Mile: 114.1
UTM Easting: 325390 UTM Northing: 3790397 Zone: 13
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-008

04 April 2023
USGS Quad: Lemitar
Effort: 514.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	3
4	<i>Hybognathus amarus</i> *	1
4	<i>Platygobio gracilis</i>	2
5	<i>Ictalurus punctatus</i>	1

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

age-0	
age-1	1
age-2+	

Rio Grande Silvery Minnow Population Monitoring April 2023

NEW MEXICO: Socorro County, RIO GRANDE Drainage
Rio Grande, ca. 2.1 mi upstream of Pueblitos Rd. bridge crossing, Lemitar.
Site Number: 30 River Mile: 106.3
UTM Easting: 326666 UTM Northing: 3780246 Zone: 13
Collector(s): Farrington, M.A.; Urioste, A.D.; Camak D.T.

RKD23-021

10 April 2023
USGS Quad: Lemitar
Effort: 510.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	4
4	<i>Hybognathus amarus</i> *	3
4	<i>Platygobio gracilis</i>	2
5	<i>Ictalurus punctatus</i>	3
9	<i>Gambusia affinis</i>	2

**Hybognathus amarus* (age-classes):

age-0	
age-1	3
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-007

Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.
Site Number: 14 River Mile: 99.6
UTM Easting: 327231 UTM Northing: 3771432 Zone: 13
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

04 April 2023
USGS Quad: Loma de las Canas
Effort: 545.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	1
4	<i>Platygobio gracilis</i>	5
5	<i>Ictalurus punctatus</i>	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-006

Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.
Site Number: 15 River Mile: 92.0
UTM Easting: 328151 UTM Northing: 3761487 Zone: 13
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

04 April 2023
USGS Quad: San Antonio
Effort: 527.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	No Fish Collected	

Rio Grande Silvery Minnow Population Monitoring April 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at US HWY 380 bridge crossing, San Antonio.

Site Number: 16 River Mile: 87.8

UTM Easting: 328907 UTM Northing: 3754926 Zone: 13

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-005

03 April 2023

USGS Quad: San Antonio

Effort: 553.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	9
4	<i>Hybognathus amarus</i> *	2
4	<i>Platygobio gracilis</i>	5

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

age-0	
age-1	2
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.

Site Number: 17 River Mile: 79.0

UTM Easting: 327219 UTM Northing: 3740906 Zone: 13

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-004

03 April 2023

USGS Quad: San Antonio SE

Effort: 506.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	18
4	<i>Platygobio gracilis</i>	4
5	<i>Ictalurus punctatus</i>	2

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.

Site Number: 18 River Mile: 68.3

UTM Easting: 315091 UTM Northing: 3728487 Zone: 13

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-003

03 April 2023

USGS Quad: San Marcial

Effort: 533.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Hybognathus amarus</i> *	1

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

age-0	
age-1	1
age-2+	

Rio Grande Silvery Minnow Population Monitoring April 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 19 River Mile: 60.1

UTM Easting: 309441 UTM Northing: 3718309 Zone: 13

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-002

03 April 2023

Paraje Well

Effort: 529.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Hybognathus amarus</i> *	2
4	<i>Platygobio gracilis</i>	1

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

age-0	
age-1	2
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 20 River Mile: 58.5

UTM Easting: 307767 UTM Northing: 3716360 Zone: 13

Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-001

03 April 2023

Paraje Well

Effort: 554.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	No Fish Collected	

Rio Grande Silvery Minnow Population Monitoring May 2023

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13
Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-048

05 May 2023
USGS Quad: San Felipe Pueblo
Effort: 353.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	15
4	<i>Platygobio gracilis</i>	16
4	<i>Rhinichthys cataractae</i>	13
10	<i>Lepomis cyanellus</i>	6

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13
Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-049

05 May 2023
USGS Quad: Bernalillo
Effort: 391.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Platygobio gracilis</i>	5
4	<i>Rhinichthys cataractae</i>	6

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.
Site Number: 3 River Mile: 199.9
UTM Easting: 354728 UTM Northing: 3905587 Zone: 13
Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-050

05 May 2023
USGS Quad: Bernalillo
Effort: 310.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	6
4	<i>Platygobio gracilis</i>	7
4	<i>Rhinichthys cataractae</i>	5
5	<i>Ictalurus punctatus</i>	1

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage
Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.
Site Number: 4 River Mile: 183.4
UTM Easting: 346719 UTM Northing: 3884331 Zone: 13
Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-047

05 May 2023
USGS Quad: Albuquerque West
Effort: 441.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Platygobio gracilis</i>	1

Rio Grande Silvery Minnow Population Monitoring May 2023

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage
Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.
Site Number: 5 River Mile: 178.4
UTM Easting: 347468 UTM Northing: 3877400 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-046

02 May 2023
Effort: 432.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Platygobio gracilis</i>	6
5	<i>Ictalurus punctatus</i>	2

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage
Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 6 River Mile: 161.7
UTM Easting: 343149 UTM Northing: 3853187 Zone: 13 USGS Quad: Los Lunas
Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-045

03 May 2023
Effort: 406.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	2
3	<i>Cyprinus carpio</i>	152
4	<i>Cyprinella lutrensis</i>	22
5	<i>Ictalurus punctatus</i>	2

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage
Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 7 River Mile: 150.8
UTM Easting: 340105 UTM Northing: 3837722 Zone: 13 USGS Quad: Tome
Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-044

03 May 2023
Effort: 281.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	10

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage
Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.
Site Number: 8 River Mile: 143.2
UTM Easting: 338020 UTM Northing: 3827545 Zone: 13 USGS Quad: Veguita
Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-043

03 May 2023
Effort: 273.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	1
4	<i>Cyprinella lutrensis</i>	93
9	<i>Gambusia affinis</i>	6

Rio Grande Silvery Minnow Population Monitoring May 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at US HWY 60 bridge crossing, Bernardo.

Site Number: 9 River Mile: 130.6

UTM Easting: 334578 UTM Northing: 3809921 Zone: 13

Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-042

03 May 2023

USGS Quad: Abeytas

Effort: 316.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	1
9	<i>Gambusia affinis</i>	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.

Site Number: 10 River Mile: 126.8

UTM Easting: 330946 UTM Northing: 3805307 Zone: 13

Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-041

03 May 2023

USGS Quad: Abeytas

Effort: 294.3 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	No Fish Collected	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.

Site Number: 11 River Mile: 117.3

UTM Easting: 328152 UTM Northing: 3792564 Zone: 13

Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-040

02 May 2023

USGS Quad: La Joya

Effort: 445.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	2

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.

Site Number: 12 River Mile: 115.6

UTM Easting: 325960 UTM Northing: 3792183 Zone: 13

Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-039

02 May 2023

USGS Quad: San Acacia

Effort: 414.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	2
4	<i>Cyprinella lutrensis</i>	9
4	<i>Platygobio gracilis</i>	1
5	<i>Ictalurus punctatus</i>	2
9	<i>Gambusia affinis</i>	2

Rio Grande Silvery Minnow Population Monitoring May 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.

Site Number: 13 River Mile: 114.1

UTM Easting: 325390 UTM Northing: 3790397 Zone: 13

Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-038

02 May 2023

USGS Quad: Lemitar

Effort: 343.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Hybognathus amarus</i> *	1
5	<i>Ictalurus punctatus</i>	1

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

age-0	
age-1	1
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.

Site Number: 14 River Mile: 99.6

UTM Easting: 327231 UTM Northing: 3771432 Zone: 13

Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-037

02 May 2023

USGS Quad: Loma de las Canas

Effort: 429.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	1
5	<i>Ictalurus punctatus</i>	2

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.

Site Number: 15 River Mile: 92.0

UTM Easting: 328151 UTM Northing: 3761487 Zone: 13

Collector(s): Dudley, R.K.; Farrington, M.A.; Camak, D.T.

RKD23-036

02 May 2023

USGS Quad: San Antonio

Effort: 511.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	2

Rio Grande Silvery Minnow Population Monitoring May 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at US HWY 380 bridge crossing, San Antonio.

Site Number: 16 River Mile: 87.8

UTM Easting: 328907 UTM Northing: 3754926 Zone: 13

Collector(s): Dudley, R.K.; Farrington, M.A.; DeArmon, E.S.

RKD23-035

01 May 2023

USGS Quad: San Antonio

Effort: 350.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	1
4	<i>Hybognathus amarus</i> *	3
4	<i>Platygobio gracilis</i>	3

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

age-0	
age-1	3
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.

Site Number: 17 River Mile: 79.0

UTM Easting: 327219 UTM Northing: 3740906 Zone: 13

Collector(s): Dudley, R.K.; Farrington, M.A.; DeArmon, E.S.

RKD23-034

01 May 2023

USGS Quad: San Antonio SE

Effort: 285.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	4

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.

Site Number: 18 River Mile: 68.3

UTM Easting: 315091 UTM Northing: 3728487 Zone: 13

Collector(s): Dudley, R.K.; Farrington, M.A.; DeArmon, E.S.

RKD23-033

01 May 2023

USGS Quad: San Marcial

Effort: 450.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	3

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 19 River Mile: 60.1

UTM Easting: 309441 UTM Northing: 3718309 Zone: 13

Collector(s): Dudley, R.K.; Farrington, M.A.; DeArmon, E.S.

RKD23-032

01 May 2023

USGS Quad: Paraje Well

Effort: 469.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	4

**Rio Grande Silvery Minnow Population Monitoring
May 2023**

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-031

Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 20

River Mile: 58.5

01 May 2023

UTM Easting: 307767

UTM Northing: 3716360

Zone: 13

USGS Quad: Paraje Well

Collector(s): Dudley, R.K.; Farrington, M.A.; DeArmon, E.S.

Effort: 396.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	1

Rio Grande Silvery Minnow Population Monitoring June 2023

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-068

06 June 2023
USGS Quad: San Felipe Pueblo
Effort: 353.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	44
4	<i>Cyprinella lutrensis</i>	16
4	<i>Platygobio gracilis</i>	9
4	<i>Rhinichthys cataractae</i>	12
8	<i>Salmo trutta</i>	1

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-069

06 June 2023
USGS Quad: Bernalillo
Effort: 189.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	1
4	<i>Cyprinella lutrensis</i>	2
4	<i>Platygobio gracilis</i>	1
4	<i>Rhinichthys cataractae</i>	1

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.
Site Number: 3 River Mile: 199.9
UTM Easting: 354728 UTM Northing: 3905587 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-070

06 June 2023
USGS Quad: Bernalillo
Effort: 325.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	7
3	<i>Cyprinus carpio</i>	1
4	<i>Cyprinella lutrensis</i>	7
4	<i>Platygobio gracilis</i>	12

Rio Grande Silvery Minnow Population Monitoring June 2023

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage
Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.
Site Number: 4 River Mile: 183.4
UTM Easting: 346719 UTM Northing: 3884331 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-067

07 June 2023
USGS Quad: Albuquerque West
Effort: 471.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	1
3	<i>Cyprinus carpio</i>	30
4	<i>Cyprinella lutrensis</i>	8
4	<i>Hybognathus amarus</i> *	57
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	5
4	<i>Rhinichthys cataractae</i>	1
9	<i>Gambusia affinis</i>	1

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

age-0 57
age-1
age-2+

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage
Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.
Site Number: 5 River Mile: 178.4
UTM Easting: 347468 UTM Northing: 3877400 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-066

07 June 2023
USGS Quad: Albuquerque West
Effort: 483.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	1
4	<i>Cyprinella lutrensis</i>	5
4	<i>Hybognathus amarus</i> *	8
4	<i>Platygobio gracilis</i>	22
5	<i>Ictalurus punctatus</i>	3

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

age-0 8
age-1
age-2+

Rio Grande Silvery Minnow Population Monitoring June 2023

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage
Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 6 River Mile: 161.7
UTM Easting: 343149 UTM Northing: 3853187 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-065

06 June 2023
USGS Quad: Los Lunas
Effort: 484.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	1
2	<i>Catostomus commersonii</i>	1
3	<i>Cyprinus carpio</i>	44
4	<i>Hybognathus amarus*</i>	8
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	11
9	<i>Gambusia affinis</i>	1

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

age-0 8
age-1
age-2+

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage
Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 7 River Mile: 150.8
UTM Easting: 340105 UTM Northing: 3837722 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-064

05 June 2023
USGS Quad: Tome
Effort: 320.3 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	2
4	<i>Cyprinella lutrensis</i>	11
4	<i>Hybognathus amarus*</i>	1
4	<i>Platygobio gracilis</i>	1

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

age-0 1
age-1
age-2+

Rio Grande Silvery Minnow Population Monitoring June 2023

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

RKD23-063

05 June 2023
Effort: 275.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	83
4	<i>Cyprinella lutrensis</i>	31
4	<i>Hybognathus amarus</i> *	1

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

age-0	1
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, at US HWY 60 bridge crossing, Bernardo.
Site Number: 9 River Mile: 130.6
UTM Easting: 334578 UTM Northing: 3809921 Zone: 13 USGS Quad: Abeytas
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-062

05 June 2023
Effort: 183.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	1
3	<i>Cyprinus carpio</i>	39
4	<i>Cyprinella lutrensis</i>	1
4	<i>Hybognathus amarus</i> *	4
4	<i>Platygobio gracilis</i>	1
5	<i>Ameiurus natalis</i>	1

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

age-0	4
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.
Site Number: 10 River Mile: 126.8
UTM Easting: 330946 UTM Northing: 3805307 Zone: 13 USGS Quad: Abeytas
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-061

05 June 2023
Effort: 309.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	7
4	<i>Hybognathus amarus</i> *	2

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

age-0	2
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring June 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-060

02 June 2023
USGS Quad: La Joya
Effort: 272.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-059

02 June 2023
USGS Quad: San Acacia
Effort: 255.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	12
5	<i>Ictalurus furcatus</i>	4
9	<i>Gambusia affinis</i>	5

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 13 River Mile: 114.1
UTM Easting: 325390 UTM Northing: 3790397 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-058

02 June 2023
USGS Quad: Lemitar
Effort: 273.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	2
3	<i>Cyprinus carpio</i>	23
4	<i>Cyprinella lutrensis</i>	5
4	<i>Hybognathus amarus*</i>	7
4	<i>Platygobio gracilis</i>	1
5	<i>Ictalurus furcatus</i>	1
5	<i>Ictalurus punctatus</i>	1

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

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

Rio Grande Silvery Minnow Population Monitoring June 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD23-057**
Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.
Site Number: 14 River Mile: 99.6 02 June 2023
UTM Easting: 327231 UTM Northing: 3771432 Zone: 13 USGS Quad: Loma de las Canas
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T. Effort: 383.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Platygobio gracilis</i>	1
5	<i>Ictalurus furcatus</i>	4

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD23-056**
Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.
Site Number: 15 River Mile: 92.0 02 June 2023
UTM Easting: 328151 UTM Northing: 3761487 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T. Effort: 354.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	1
5	<i>Ictalurus furcatus</i>	1

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD23-055**
Rio Grande, at US HWY 380 bridge crossing, San Antonio.
Site Number: 16 River Mile: 87.8 01 June 2023
UTM Easting: 328907 UTM Northing: 3754926 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T. Effort: 426.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	16
4	<i>Hybognathus amarus*</i>	13

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

age-0	12
age-1	1
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage **RKD23-054**
Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.
Site Number: 17 River Mile: 79.0 01 June 2023
UTM Easting: 327219 UTM Northing: 3740906 Zone: 13 USGS Quad: San Antonio SE
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T. Effort: 365.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	4

Rio Grande Silvery Minnow Population Monitoring June 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.
Site Number: 18 River Mile: 68.3
UTM Easting: 315091 UTM Northing: 3728487 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-053

01 June 2023
USGS Quad: San Marcial
Effort: 242.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
5	<i>Ictalurus furcatus</i>	2

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 19 River Mile: 60.1
UTM Easting: 309441 UTM Northing: 3718309 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-052

01 June 2023
USGS Quad: Paraje Well
Effort: 460.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Ictiobus bubalus</i>	14
3	<i>Cyprinus carpio</i>	8
4	<i>Hybognathus amarus</i> *	29
4	<i>Pimephales promelas</i>	4
4	<i>Platygobio gracilis</i>	2
5	<i>Ictalurus furcatus</i>	1

**Hybognathus amarus* (age-classes):

age-0	29
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 20 River Mile: 58.5
UTM Easting: 307767 UTM Northing: 3716360 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-051

01 June 2023
USGS Quad: Paraje Well
Effort: 222.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
4	<i>Cyprinella lutrensis</i>	1

Rio Grande Silvery Minnow Population Monitoring July 2023

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S.

RKD23-088

05 July 2023
USGS Quad: San Felipe Pueblo
Effort: 344.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	11
3	<i>Cyprinus carpio</i>	4
4	<i>Cyprinella lutrensis</i>	145
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	11
4	<i>Rhinichthys cataractae</i>	13
9	<i>Gambusia affinis</i>	4
10	<i>Lepomis cyanellus</i>	1
10	<i>Micropterus dolomieu</i>	1
10	<i>Pomoxis annularis</i>	3
11	<i>Morone chrysops</i>	1

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13
Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S.

RKD23-089

05 July 2023
USGS Quad: Bernalillo
Effort: 409.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	51
3	<i>Cyprinus carpio</i>	110
4	<i>Cyprinella lutrensis</i>	12
4	<i>Hybognathus amarus*</i>	9
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	39
4	<i>Rhinichthys cataractae</i>	19
9	<i>Gambusia affinis</i>	32

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

age-0 9
age-1
age-2+

Rio Grande Silvery Minnow Population Monitoring July 2023

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

RKD23-090

05 July 2023
Effort: 372.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	28
3	<i>Cyprinus carpio</i>	12
4	<i>Cyprinella lutrensis</i>	1
4	<i>Hybognathus amarus*</i>	2
4	<i>Pimephales promelas</i>	10
4	<i>Platygobio gracilis</i>	12
4	<i>Rhinichthys cataractae</i>	7
9	<i>Gambusia affinis</i>	4
10	<i>Lepomis macrochirus</i>	1
11	<i>Morone chrysops</i>	1

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

age-0 2
age-1
age-2+

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

RKD23-087

06 July 2023
Effort: 494.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	11
2	<i>Catostomus commersonii</i>	9
3	<i>Cyprinus carpio</i>	14
4	<i>Cyprinella lutrensis</i>	3
4	<i>Hybognathus amarus*</i>	81
4	<i>Pimephales promelas</i>	41
4	<i>Platygobio gracilis</i>	14
9	<i>Gambusia affinis</i>	7
10	<i>Micropterus salmoides</i>	3
11	<i>Morone chrysops</i>	4

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

age-0 81
age-1
age-2+

Rio Grande Silvery Minnow Population Monitoring July 2023

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

RKD23-086

06 July 2023
Effort: 542.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	5
2	<i>Catostomus commersonii</i>	10
3	<i>Cyprinus carpio</i>	77
4	<i>Cyprinella lutrensis</i>	14
4	<i>Hybognathus amarus</i> *	358
4	<i>Pimephales promelas</i>	13
4	<i>Platygobio gracilis</i>	8
11	<i>Morone chrysops</i>	2

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

age-0 358
age-1
age-2+

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

RKD23-085

05 July 2023
Effort: 413.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	2
3	<i>Cyprinus carpio</i>	88
4	<i>Cyprinella lutrensis</i>	76
4	<i>Hybognathus amarus</i> *	317
4	<i>Pimephales promelas</i>	2
4	<i>Platygobio gracilis</i>	2
9	<i>Gambusia affinis</i>	19

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

age-0 317
age-1
age-2+

Rio Grande Silvery Minnow Population Monitoring July 2023

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.

Site Number: 7

River Mile: 150.8

UTM Easting: 340105

UTM Northing: 3837722

Zone: 13

USGS Quad: Tome

Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S.

RKD23-084

03 July 2023

Effort: 426.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	8
2	<i>Catostomus commersonii</i>	5
2	<i>Ictiobus bubalus</i>	1
3	<i>Cyprinus carpio</i>	196
4	<i>Cyprinella lutrensis</i>	285
4	<i>Hybognathus amarus</i> *	488
4	<i>Pimephales promelas</i>	7
9	<i>Gambusia affinis</i>	43
10	<i>Pomoxis annularis</i>	1

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

age-0 488

age-1

age-2+

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.

Site Number: 8

River Mile: 143.2

UTM Easting: 338020

UTM Northing: 3827545

Zone: 13

USGS Quad: Veguita

Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S.

RKD23-083

03 July 2023

Effort: 297.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	75
4	<i>Cyprinella lutrensis</i>	69
4	<i>Hybognathus amarus</i> *	159
4	<i>Pimephales promelas</i>	12
9	<i>Gambusia affinis</i>	15
10	<i>Lepomis macrochirus</i>	1
10	<i>Micropterus salmoides</i>	2

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

age-0 159

age-1

age-2+

Rio Grande Silvery Minnow Population Monitoring July 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at US HWY 60 bridge crossing, Bernardo.

Site Number: 9

River Mile: 130.6

UTM Easting: 334578

UTM Northing: 3809921

Zone: 13

Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S.

RKD23-082

03 July 2023

USGS Quad: Abeytas

Effort: 342.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	1
2	<i>Catostomus commersonii</i>	3
3	<i>Cyprinus carpio</i>	68
4	<i>Cyprinella lutrensis</i>	27
4	<i>Hybognathus amarus</i> *	132
9	<i>Gambusia affinis</i>	7
11	<i>Morone chrysops</i>	7

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

age-0 132

age-1

age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.

Site Number: 10

River Mile: 126.8

UTM Easting: 330946

UTM Northing: 3805307

Zone: 13

Collector(s): Dudley, R.K.; Camak, D.T.; Winter, S.

RKD23-081

03 July 2023

USGS Quad: Abeytas

Effort: 394.3 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	2
3	<i>Cyprinus carpio</i>	308
4	<i>Cyprinella lutrensis</i>	27
4	<i>Hybognathus amarus</i> *	278
4	<i>Rhinichthys cataractae</i>	1
5	<i>Ameiurus melas</i>	9
9	<i>Gambusia affinis</i>	28
10	<i>Micropterus salmoides</i>	1

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

age-0 278

age-1

age-2+

Rio Grande Silvery Minnow Population Monitoring June 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-080

30 June 2023
USGS Quad: La Joya
Effort: 263.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	87
4	<i>Hybognathus amarus</i> *	3
9	<i>Gambusia affinis</i>	2

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

age-0	3
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-079

30 June 2023
USGS Quad: San Acacia
Effort: 255.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	69
4	<i>Cyprinella lutrensis</i>	1
4	<i>Hybognathus amarus</i> *	1
5	<i>Ictalurus furcatus</i>	2
9	<i>Gambusia affinis</i>	1

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

age-0	
age-1	
age-2+	1

Rio Grande Silvery Minnow Population Monitoring June 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.

Site Number: 13

River Mile: 114.1

UTM Easting: 325390

UTM Northing: 3790397

Zone: 13

USGS Quad: Lemitar

Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-078

30 June 2023

Effort: 217.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	21
4	<i>Cyprinella lutrensis</i>	1
4	<i>Hybognathus amarus</i> *	2
4	<i>Platygobio gracilis</i>	1
9	<i>Gambusia affinis</i>	24

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

age-0	2
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.

Site Number: 14

River Mile: 99.6

UTM Easting: 327231

UTM Northing: 3771432

Zone: 13

USGS Quad: Loma de las Canas

Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-077

30 June 2023

Effort: 265.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	1
4	<i>Hybognathus amarus</i> *	4
4	<i>Platygobio gracilis</i>	2
5	<i>Ictalurus furcatus</i>	5

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

age-0	4
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring June 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.
Site Number: 15 River Mile: 92.0
UTM Easting: 328151 UTM Northing: 3761487 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-076

30 June 2023
Effort: 395.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	14
4	<i>Cyprinella lutrensis</i>	16
4	<i>Hybognathus amarus</i> *	31
4	<i>Platygobio gracilis</i>	7
9	<i>Gambusia affinis</i>	1

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

age-0 31
age-1
age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, at US HWY 380 bridge crossing, San Antonio.
Site Number: 16 River Mile: 87.8
UTM Easting: 328907 UTM Northing: 3754926 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-075

29 June 2023
Effort: 311.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	7
4	<i>Hybognathus amarus</i> *	72
9	<i>Gambusia affinis</i>	1

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

age-0 72
age-1
age-2+

Rio Grande Silvery Minnow Population Monitoring June 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.
Site Number: 17 River Mile: 79.0
UTM Easting: 327219 UTM Northing: 3740906 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-074

29 June 2023
USGS Quad: San Antonio SE
Effort: 278.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	1
3	<i>Cyprinus carpio</i>	296
4	<i>Cyprinella lutrensis</i>	16
4	<i>Hybognathus amarus</i> *	6
9	<i>Gambusia affinis</i>	2

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

age-0	6
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.
Site Number: 18 River Mile: 68.3
UTM Easting: 315091 UTM Northing: 3728487 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-073

29 June 2023
USGS Quad: San Marcial
Effort: 421.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	4
4	<i>Cyprinella lutrensis</i>	2
4	<i>Hybognathus amarus</i> *	2
4	<i>Platygobio gracilis</i>	1
5	<i>Ictalurus furcatus</i>	1
5	<i>Ictalurus punctatus</i>	1

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

age-0	2
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring June 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 19

River Mile: 60.1

UTM Easting: 309441

UTM Northing: 3718309

Zone: 13

USGS Quad:

Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-072

29 June 2023

Paraje Well

Effort: 494.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Ictiobus bubalus</i>	1
3	<i>Cyprinus carpio</i>	36
4	<i>Cyprinella lutrensis</i>	24
4	<i>Hybognathus amarus</i> *	195
5	<i>Ictalurus furcatus</i>	2
9	<i>Gambusia affinis</i>	1

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

age-0 194

age-1 1

age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 20

River Mile: 58.5

UTM Easting: 307767

UTM Northing: 3716360

Zone: 13

USGS Quad:

Collector(s): Dudley, R.K.; Damron, T.D.; Camak, D.T.

RKD23-071

29 June 2023

Paraje Well

Effort: 234.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	<i>No Fish Collected</i>	

Rio Grande Silvery Minnow Population Monitoring August 2023

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-108

04 August 2023
USGS Quad: San Felipe Pueblo
Effort: 446.3 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	36
3	<i>Cyprinus carpio</i>	1
4	<i>Cyprinella lutrensis</i>	26
4	<i>Platygobio gracilis</i>	20
4	<i>Rhinichthys cataractae</i>	57
7	<i>Esox lucius</i>	1
9	<i>Gambusia affinis</i>	35
10	<i>Lepomis cyanellus</i>	1
10	<i>Micropterus salmoides</i>	3
10	<i>Pomoxis annularis</i>	4

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-109

04 August 2023
USGS Quad: Bernalillo
Effort: 464.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpoides carpio</i>	7
2	<i>Catostomus commersonii</i>	24
3	<i>Cyprinus carpio</i>	15
4	<i>Cyprinella lutrensis</i>	110
4	<i>Hybognathus amarus*</i>	62
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	25
4	<i>Rhinichthys cataractae</i>	8
5	<i>Ameiurus melas</i>	1
5	<i>Ameiurus natalis</i>	1
9	<i>Gambusia affinis</i>	73
10	<i>Micropterus salmoides</i>	1
10	<i>Pomoxis annularis</i>	1

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

age-0	56
age-1	6
age-2+	

Rio Grande Silvery Minnow Population Monitoring August 2023

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.
Site Number: 3 River Mile: 199.9
UTM Easting: 354728 UTM Northing: 3905587 Zone: 13 USGS Quad: Bernalillo
Collector(s): Dudley, R.K.; Urioste, A.D.; Camak, D.T.

RKD23-110

04 August 2023
Effort: 535.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	16
3	<i>Cyprinus carpio</i>	16
4	<i>Cyprinella lutrensis</i>	6
4	<i>Hybognathus amarus*</i>	19
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	6
4	<i>Rhinichthys cataractae</i>	3
5	<i>Ictalurus punctatus</i>	3
9	<i>Gambusia affinis</i>	10
10	<i>Pomoxis annularis</i>	2

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

age-0 19
age-1
age-2+

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage
Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.
Site Number: 4 River Mile: 183.4
UTM Easting: 346719 UTM Northing: 3884331 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Dudley, R.K.; Keller, R.C.; Winter, S.

RKD23-107

03 August 2023
Effort: 530.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpoides carpio</i>	200
2	<i>Catostomus commersonii</i>	9
3	<i>Cyprinus carpio</i>	20
4	<i>Cyprinella lutrensis</i>	207
4	<i>Hybognathus amarus*</i>	23
4	<i>Pimephales promelas</i>	6
4	<i>Platygobio gracilis</i>	65
4	<i>Rhinichthys cataractae</i>	1
5	<i>Ictalurus punctatus</i>	3
9	<i>Gambusia affinis</i>	10

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

age-0 23
age-1
age-2+

Rio Grande Silvery Minnow Population Monitoring August 2023

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage
Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.
Site Number: 5 River Mile: 178.4
UTM Easting: 347468 UTM Northing: 3877400 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Dudley, R.K.; Keller, R.C.; Winter, S.

RKD23-106

03 August 2023
Effort: 489.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	26
2	<i>Catostomus commersonii</i>	1
3	<i>Cyprinus carpio</i>	17
4	<i>Cyprinella lutrensis</i>	119
4	<i>Hybognathus amarus*</i>	21
4	<i>Pimephales promelas</i>	4
4	<i>Platygobio gracilis</i>	4
9	<i>Gambusia affinis</i>	202
10	<i>Pomoxis annularis</i>	1

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

age-0 21
age-1
age-2+

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage
Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 6 River Mile: 161.7
UTM Easting: 343149 UTM Northing: 3853187 Zone: 13 USGS Quad: Los Lunas
Collector(s): Dudley, R.K.; Keller, R.C.; Winter, S.

RKD23-105

03 August 2023
Effort: 526.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	215
4	<i>Cyprinella lutrensis</i>	207
4	<i>Hybognathus amarus*</i>	13
4	<i>Pimephales promelas</i>	19
4	<i>Platygobio gracilis</i>	1
5	<i>Ictalurus punctatus</i>	4
9	<i>Gambusia affinis</i>	134

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

age-0 13
age-1
age-2+

Rio Grande Silvery Minnow Population Monitoring August 2023

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.

Site Number: 7

River Mile: 150.8

UTM Easting: 340105

UTM Northing: 3837722

Zone: 13

USGS Quad: Tome

Collector(s): Dudley, R.K.; Keller, R.C.; Winter, S.

RKD23-104

03 August 2023

Effort: 471.3 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	13
3	<i>Cyprinus carpio</i>	221
4	<i>Cyprinella lutrensis</i>	108
4	<i>Hybognathus amarus*</i>	104
4	<i>Pimephales promelas</i>	42
5	<i>Ameiurus natalis</i>	3
9	<i>Gambusia affinis</i>	401

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

age-0 104

age-1

age-2+

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.

Site Number: 8

River Mile: 143.2

UTM Easting: 338020

UTM Northing: 3827545

Zone: 13

USGS Quad: Veguita

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

RKD23-103

02 August 2023

Effort: 493.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	2
3	<i>Cyprinus carpio</i>	52
4	<i>Cyprinella lutrensis</i>	29
4	<i>Hybognathus amarus*</i>	12
4	<i>Pimephales promelas</i>	21
5	<i>Ictalurus punctatus</i>	8
9	<i>Gambusia affinis</i>	20
10	<i>Micropterus salmoides</i>	3

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

age-0 12

age-1

age-2+

Rio Grande Silvery Minnow Population Monitoring August 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at US HWY 60 bridge crossing, Bernardo.

Site Number: 9

River Mile: 130.6

UTM Easting: 334578

UTM Northing: 3809921

Zone: 13

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

RKD23-102

02 August 2023

USGS Quad: Abeytas

Effort: 504.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	36
3	<i>Cyprinus carpio</i>	80
4	<i>Cyprinella lutrensis</i>	34
4	<i>Hybognathus amarus*</i>	10
4	<i>Pimephales promelas</i>	2
5	<i>Ictalurus punctatus</i>	25
9	<i>Gambusia affinis</i>	36
10	<i>Micropterus salmoides</i>	1
11	<i>Morone chrysops</i>	1

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

age-0 10

age-1

age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.

Site Number: 10

River Mile: 126.8

UTM Easting: 330946

UTM Northing: 3805307

Zone: 13

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

RKD23-101

02 August 2023

USGS Quad: Abeytas

Effort: 512.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	7
2	<i>Carpiodes carpio</i>	2
2	<i>Catostomus commersonii</i>	1
3	<i>Cyprinus carpio</i>	145
4	<i>Cyprinella lutrensis</i>	26
4	<i>Hybognathus amarus*</i>	7
9	<i>Gambusia affinis</i>	38
10	<i>Micropterus salmoides</i>	2

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

age-0 7

age-1

age-2+

Rio Grande Silvery Minnow Population Monitoring August 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13
Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

RKD23-100

02 August 2023
USGS Quad: La Joya
Effort: 412.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	19
4	<i>Cyprinella lutrensis</i>	412
4	<i>Hybognathus amarus</i> *	2
4	<i>Platygobio gracilis</i>	1
5	<i>Ictalurus punctatus</i>	6
9	<i>Gambusia affinis</i>	43
10	<i>Pomoxis annularis</i>	2

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

age-0	2
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13
Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

RKD23-099

02 August 2023
USGS Quad: San Acacia
Effort: 418.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	2
3	<i>Cyprinus carpio</i>	49
4	<i>Cyprinella lutrensis</i>	9
4	<i>Hybognathus amarus</i> *	117
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	8
5	<i>Ictalurus punctatus</i>	6
9	<i>Gambusia affinis</i>	25
13	<i>Aplodinotus grunniens</i>	1

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

age-0	114
age-1	3
age-2+	

Rio Grande Silvery Minnow Population Monitoring August 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.

Site Number: 13

River Mile: 114.1

UTM Easting: 325390

UTM Northing: 3790397

Zone: 13

USGS Quad: Lemitar

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

RKD23-098

01 August 2023

Effort: 466.3 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	47
4	<i>Cyprinella lutrensis</i>	3
4	<i>Hybognathus amarus</i> *	153
5	<i>Ameiurus melas</i>	1
5	<i>Ictalurus punctatus</i>	14
9	<i>Gambusia affinis</i>	26
10	<i>Micropterus salmoides</i>	1
10	<i>Pomoxis annularis</i>	1

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

age-0 153

age-1

age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.

Site Number: 14

River Mile: 99.6

UTM Easting: 327231

UTM Northing: 3771432

Zone: 13

USGS Quad: Loma de las Canas

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

RKD23-097

01 August 2023

Effort: 500.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpoides carpio</i>	1
3	<i>Cyprinus carpio</i>	56
4	<i>Cyprinella lutrensis</i>	66
4	<i>Platygobio gracilis</i>	3
5	<i>Ictalurus punctatus</i>	35
9	<i>Gambusia affinis</i>	44

Rio Grande Silvery Minnow Population Monitoring August 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-111

Rio Grande, ca. 4.7 mi downstream of the Socorro Low Flow Conveyance Channel bridge crossing, Socorro.

Site Number: 54

River Mile: 94.2

01 August 2023

UTM Easting: 327241

UTM Northing: 3764475

Zone: 13

USGS Quad: Loma de las Canas

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

Effort: 491.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	4
2	<i>Carpodes carpio</i>	4
3	<i>Cyprinus carpio</i>	54
4	<i>Cyprinella lutrensis</i>	259
4	<i>Hybognathus amarus*</i>	5
4	<i>Platygobio gracilis</i>	5
5	<i>Ictalurus punctatus</i>	49
9	<i>Gambusia affinis</i>	158
10	<i>Micropterus salmoides</i>	1

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

age-0 5

age-1

age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-096

Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.

Site Number: 15

River Mile: 92.0

01 August 2023

UTM Easting: 328151

UTM Northing: 3761487

Zone: 13

USGS Quad: San Antonio

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

Effort: 34.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	13
2	<i>Carpodes carpio</i>	26
3	<i>Cyprinus carpio</i>	186
4	<i>Cyprinella lutrensis</i>	283
4	<i>Hybognathus amarus*</i>	1
5	<i>Ictalurus punctatus</i>	2
9	<i>Gambusia affinis</i>	530
10	<i>Micropterus salmoides</i>	1

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

age-0

age-1 1

age-2+

Rio Grande Silvery Minnow Population Monitoring July 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at US HWY 380 bridge crossing, San Antonio.

Site Number: 16 River Mile: 87.8

UTM Easting: 328907 UTM Northing: 3754926 Zone: 13

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

RKD23-095

31 July 2023

USGS Quad: San Antonio

Effort: sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	<i>Site Dry</i>	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.

Site Number: 17 River Mile: 79.0

UTM Easting: 327219 UTM Northing: 3740906 Zone: 13

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

RKD23-094

31 July 2023

USGS Quad: San Antonio SE

Effort: 5.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	35
4	<i>Cyprinella lutrensis</i>	1
4	<i>Hybognathus amarus*</i>	32
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	55

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

age-0	32
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.

Site Number: 18 River Mile: 68.3

UTM Easting: 315091 UTM Northing: 3728487 Zone: 13

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

RKD23-093

31 July 2023

USGS Quad: San Marcial

Effort: 22.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	16
4	<i>Cyprinella lutrensis</i>	2
4	<i>Hybognathus amarus*</i>	1
9	<i>Gambusia affinis</i>	377

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

age-0	1
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring July 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-092

Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 19

River Mile: 60.1

31 July 2023

UTM Easting: 309441

UTM Northing: 3718309

Zone: 13

USGS Quad: Paraje Well

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

Effort: 476.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	9
3	<i>Cyprinus carpio</i>	121
4	<i>Cyprinella lutrensis</i>	11
4	<i>Hybognathus amarus</i> *	96
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	303

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

age-0 96

age-1

age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-091

Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 20

River Mile: 58.5

31 July 2023

UTM Easting: 307767

UTM Northing: 3716360

Zone: 13

USGS Quad: Paraje Well

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

Effort: 514.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpodes carpio</i>	1
3	<i>Cyprinus carpio</i>	49
4	<i>Cyprinella lutrensis</i>	40
4	<i>Pimephales promelas</i>	3
4	<i>Platygobio gracilis</i>	1
5	<i>Ictalurus punctatus</i>	42
9	<i>Gambusia affinis</i>	311

Rio Grande Silvery Minnow Population Monitoring September 2023

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-129

08 September 2023
USGS Quad: San Felipe Pueblo
Effort: 455.3 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	12
4	<i>Cyprinella lutrensis</i>	17
4	<i>Platygobio gracilis</i>	4
4	<i>Rhinichthys cataractae</i>	36
5	<i>Ameiurus natalis</i>	2
9	<i>Gambusia affinis</i>	96
10	<i>Lepomis cyanellus</i>	1
11	<i>Morone chrysops</i>	2

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-130

08 September 2023
USGS Quad: Bernalillo
Effort: 478.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpionodes carpio</i>	1
2	<i>Catostomus commersonii</i>	12
3	<i>Cyprinus carpio</i>	4
4	<i>Cyprinella lutrensis</i>	7
4	<i>Hybognathus amarus*</i>	3
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	12
4	<i>Rhinichthys cataractae</i>	60
5	<i>Ameiurus natalis</i>	2
5	<i>Ictalurus punctatus</i>	3
9	<i>Gambusia affinis</i>	37

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

age-0 3
age-1
age-2+

Rio Grande Silvery Minnow Population Monitoring September 2023

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage

Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.

Site Number: 3

River Mile: 199.9

UTM Easting: 354728

UTM Northing: 3905587

Zone: 13

USGS Quad: Bernalillo

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-131

08 September 2023

Effort: 507.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	19
3	<i>Cyprinus carpio</i>	4
4	<i>Cyprinella lutrensis</i>	90
4	<i>Hybognathus amarus*</i>	14
4	<i>Rhinichthys cataractae</i>	2
5	<i>Ameiurus natalis</i>	3
5	<i>Ictalurus punctatus</i>	13
9	<i>Gambusia affinis</i>	38

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

age-0 14

age-1

age-2+

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage

Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.

Site Number: 4

River Mile: 183.4

UTM Easting: 346719

UTM Northing: 3884331

Zone: 13

USGS Quad: Albuquerque West

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-128

08 September 2023

Effort: 529.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	6
2	<i>Catostomus commersonii</i>	8
3	<i>Cyprinus carpio</i>	20
4	<i>Cyprinella lutrensis</i>	82
4	<i>Hybognathus amarus*</i>	22
4	<i>Pimephales promelas</i>	4
4	<i>Platygobio gracilis</i>	36
4	<i>Rhinichthys cataractae</i>	2
5	<i>Ictalurus punctatus</i>	3
9	<i>Gambusia affinis</i>	48
10	<i>Lepomis cyanellus</i>	1
11	<i>Morone chrysops</i>	1

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

age-0 21

age-1 1

age-2+

Rio Grande Silvery Minnow Population Monitoring September 2023

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage

Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.

Site Number: 5

River Mile: 178.4

UTM Easting: 347468

UTM Northing: 3877400

Zone: 13

USGS Quad: Albuquerque West

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-127

08 September 2023

Effort: 463.3 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	23
2	<i>Catostomus commersonii</i>	6
3	<i>Cyprinus carpio</i>	9
4	<i>Cyprinella lutrensis</i>	30
4	<i>Hybognathus amarus*</i>	13
4	<i>Pimephales promelas</i>	6
4	<i>Platygobio gracilis</i>	5
5	<i>Ictalurus punctatus</i>	4
9	<i>Gambusia affinis</i>	47
10	<i>Pomoxis annularis</i>	1
11	<i>Morone chrysops</i>	1

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

age-0	12
age-1	1
age-2+	

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.

Site Number: 6

River Mile: 161.7

UTM Easting: 343149

UTM Northing: 3853187

Zone: 13

USGS Quad: Los Lunas

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-126

07 September 2023

Effort: 611.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	33
4	<i>Cyprinella lutrensis</i>	454
4	<i>Hybognathus amarus*</i>	292
4	<i>Pimephales promelas</i>	4
4	<i>Platygobio gracilis</i>	15
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	31

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

age-0	289
age-1	3
age-2+	

Rio Grande Silvery Minnow Population Monitoring September 2023

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.

Site Number: 7

River Mile: 150.8

UTM Easting: 340105

UTM Northing: 3837722

Zone: 13

USGS Quad: Tome

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-125

07 September 2023

Effort: 403.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	4
3	<i>Cyprinus carpio</i>	109
4	<i>Cyprinella lutrensis</i>	210
4	<i>Hybognathus amarus*</i>	54
4	<i>Pimephales promelas</i>	48
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	248

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

age-0 54

age-1

age-2+

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.

Site Number: 8

River Mile: 143.2

UTM Easting: 338020

UTM Northing: 3827545

Zone: 13

USGS Quad: Veguita

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-124

07 September 2023

Effort: 544.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	44
4	<i>Cyprinella lutrensis</i>	113
4	<i>Hybognathus amarus*</i>	83
4	<i>Pimephales promelas</i>	5
5	<i>Ictalurus punctatus</i>	10
9	<i>Gambusia affinis</i>	114
10	<i>Micropterus salmoides</i>	1

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

age-0 70

age-1 13

age-2+

Rio Grande Silvery Minnow Population Monitoring September 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at US HWY 60 bridge crossing, Bernardo.

Site Number: 9

River Mile: 130.6

UTM Easting: 334578

UTM Northing: 3809921

Zone: 13

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-123

07 September 2023

USGS Quad: Abeytas

Effort: 484.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	18
4	<i>Cyprinella lutrensis</i>	128
4	<i>Hybognathus amarus</i> *	79
4	<i>Pimephales promelas</i>	6
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	141
10	<i>Micropterus salmoides</i>	1

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

age-0 77

age-1 2

age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.

Site Number: 10

River Mile: 126.8

UTM Easting: 330946

UTM Northing: 3805307

Zone: 13

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-122

07 September 2023

USGS Quad: Abeytas

Effort: 473.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	9
4	<i>Cyprinella lutrensis</i>	52
4	<i>Hybognathus amarus</i> *	16
4	<i>Pimephales promelas</i>	8
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	400

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

age-0 16

age-1

age-2+

Rio Grande Silvery Minnow Population Monitoring September 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13
Collector(s): Dudley, R.K.; Keller, R.C.; Winter, S.

RKD23-121

06 September 2023
USGS Quad: La Joya
Effort: 398.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	16
4	<i>Cyprinella lutrensis</i>	2
4	<i>Hybognathus amarus</i> *	3
9	<i>Gambusia affinis</i>	25

**Hybognathus amarus* (age-classes):

age-0	3
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13
Collector(s): Dudley, R.K.; Keller, R.C.; Winter, S.

RKD23-120

06 September 2023
USGS Quad: San Acacia
Effort: 447.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	62
4	<i>Cyprinella lutrensis</i>	51
4	<i>Hybognathus amarus</i> *	225
4	<i>Platygobio gracilis</i>	33
5	<i>Ictalurus punctatus</i>	5
9	<i>Gambusia affinis</i>	240

**Hybognathus amarus* (age-classes):

age-0	225
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring September 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 13 River Mile: 114.1
UTM Easting: 325390 UTM Northing: 3790397 Zone: 13 USGS Quad: Lemitar
Collector(s): Dudley, R.K.; Keller, R.C.; Winter, S.

RKD23-119

06 September 2023
Effort: 524.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	1
2	<i>Carpodes carpio</i>	1
3	<i>Cyprinus carpio</i>	27
4	<i>Cyprinella lutrensis</i>	173
4	<i>Hybognathus amarus</i> *	56
4	<i>Platygobio gracilis</i>	1
5	<i>Ameiurus natalis</i>	2
5	<i>Ictalurus punctatus</i>	30
9	<i>Gambusia affinis</i>	202

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

age-0 56
age-1
age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.

RKD23-118

Site Number: 14 River Mile: 99.6
UTM Easting: 327231 UTM Northing: 3771432 Zone: 13 USGS Quad: Loma de las Canas
Collector(s): Dudley, R.K.; Keller, R.C.; Winter, S.

06 September 2023
Effort: 519.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpodes carpio</i>	1
3	<i>Cyprinus carpio</i>	8
4	<i>Cyprinella lutrensis</i>	30
4	<i>Hybognathus amarus</i> *	25
4	<i>Pimephales vigilax</i>	1
4	<i>Platygobio gracilis</i>	8
5	<i>Ictalurus punctatus</i>	15
9	<i>Gambusia affinis</i>	171

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

age-0 25
age-1
age-2+

Rio Grande Silvery Minnow Population Monitoring September 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.
Site Number: 15 River Mile: 92.0
UTM Easting: 328151 UTM Northing: 3761487 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Keller, R.C.; Winter, S.

RKD23-117

06 September 2023
Effort: 2.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	<i>No Fish Collected</i>	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, at US HWY 380 bridge crossing, San Antonio.
Site Number: 16 River Mile: 87.8
UTM Easting: 328907 UTM Northing: 3754926 Zone: 13 USGS Quad: San Antonio
Collector(s): Dudley, R.K.; Keller, R.C.; Winter, S.

RKD23-116

06 September 2023
Effort: sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	<i>Site Dry</i>	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.
Site Number: 17 River Mile: 79.0
UTM Easting: 327219 UTM Northing: 3740906 Zone: 13 USGS Quad: San Antonio SE
Collector(s): Urioste, A.D.; Keller, R.C.; Winter, S.

RKD23-115

05 September 2023
Effort: sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	<i>Site Dry</i>	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.
Site Number: 18 River Mile: 68.3
UTM Easting: 315091 UTM Northing: 3728487 Zone: 13 USGS Quad: San Marcial
Collector(s): Urioste, A.D.; Keller, R.C.; Winter, S.

RKD23-114

05 September 2023
Effort: 54.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	8
4	<i>Cyprinella lutrensis</i>	6
9	<i>Gambusia affinis</i>	23

Rio Grande Silvery Minnow Population Monitoring September 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-133

Rio Grande, ca. 5.1 mi downstream of San Marcial Railroad bridge crossing, San Marcial

Site Number: 59

River Mile: 63.3

05 September 2023

UTM Easting: 313269

UTM Northing: 3721434

Zone: 13

USGS Quad:

Paraje Well

Collector(s): Urioste, A.D.; Keller, R.C.; Winter, S.

Effort: 383.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	23
3	<i>Cyprinus carpio</i>	41
4	<i>Cyprinella lutrensis</i>	42
4	<i>Hybognathus amarus</i> *	1
5	<i>Ictalurus furcatus</i>	76
9	<i>Gambusia affinis</i>	325
12	<i>Percina macrolepida</i>	1

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

age-0	1
age-1	
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-132

Rio Grande, ca. 6.4 mi downstream of San Marcial Railroad bridge crossing, San Marcial

Site Number: 60

River Mile: 61.8

05 September 2023

UTM Easting: 311422

UTM Northing: 3719864

Zone: 13

USGS Quad:

Paraje Well

Collector(s): Urioste, A.D.; Keller, R.C.; Winter, S.

Effort: 445.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	8
3	<i>Cyprinus carpio</i>	4
4	<i>Cyprinella lutrensis</i>	27
9	<i>Gambusia affinis</i>	452

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-113

Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 19

River Mile: 60.1

05 September 2023

UTM Easting: 309441

UTM Northing: 3718309

Zone: 13

USGS Quad:

Paraje Well

Collector(s): Urioste, A.D.; Keller, R.C.; Winter, S.

Effort: 497.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	4
4	<i>Cyprinella lutrensis</i>	30
4	<i>Pimephales promelas</i>	1
5	<i>Ictalurus furcatus</i>	1
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	345

Rio Grande Silvery Minnow Population Monitoring September 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-112

Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 20

River Mile: 58.5

05 September 2023

UTM Easting: 307767

UTM Northing: 3716360

Zone: 13

USGS Quad: Paraje Well

Collector(s): Urioste, A.D.; Keller, R.C.; Winter, S.

Effort: 498.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	26
3	<i>Cyprinus carpio</i>	18
4	<i>Cyprinella lutrensis</i>	61
9	<i>Gambusia affinis</i>	372

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, just downstream of Angostura Diversion Dam, Algodones.
Site Number: 1 River Mile: 209.9
UTM Easting: 363665 UTM Northing: 3916331 Zone: 13
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-151

04 October 2023
USGS Quad: San Felipe Pueblo
Effort: 477.3 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	17
3	<i>Cyprinus carpio</i>	1
4	<i>Cyprinella lutrensis</i>	26
4	<i>Hybognathus amarus*</i>	6
4	<i>Platygobio gracilis</i>	7
4	<i>Rhinichthys cataractae</i>	24
5	<i>Ameiurus natalis</i>	2
9	<i>Gambusia affinis</i>	197
10	<i>Lepomis macrochirus</i>	3
10	<i>Micropterus salmoides</i>	3

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

age-0 6
age-1
age-2+

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage
Rio Grande, at US HWY 550 bridge crossing, Bernalillo.
Site Number: 2 River Mile: 203.9
UTM Easting: 358457 UTM Northing: 3909887 Zone: 13
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-152

04 October 2023
USGS Quad: Bernalillo
Effort: 492.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	12
4	<i>Cyprinella lutrensis</i>	22
4	<i>Hybognathus amarus*</i>	8
4	<i>Platygobio gracilis</i>	10
4	<i>Rhinichthys cataractae</i>	13
5	<i>Ictalurus punctatus</i>	5
9	<i>Gambusia affinis</i>	165

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

age-0 6
age-1 2
age-2+

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: SANDOVAL County, RIO GRANDE Drainage

RKD23-153

Rio Grande, ca. 4.0 mi downstream of US HWY 550 bridge crossing, Rio Rancho.

Site Number: 3

River Mile: 199.9

04 October 2023

UTM Easting: 354728

UTM Northing: 3905587

Zone: 13

USGS Quad: Bernalillo

Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

Effort: 494.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	9
4	<i>Cyprinella lutrensis</i>	17
4	<i>Hybognathus amarus*</i>	46
4	<i>Pimephales promelas</i>	2
4	<i>Platygobio gracilis</i>	2
9	<i>Gambusia affinis</i>	16

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

age-0 46

age-1

age-2+

NEW MEXICO: Sandoval County, RIO GRANDE Drainage

RKD23-163

Rio Grande, ca. 4.5 mi upstream of Alameda Blvd. bridge crossing (NM State HWY 528), Corrales.

Site Number: 21

River Mile: 196.5

09 October 2023

UTM Easting: 355670

UTM Northing: 3900620

Zone: 13

USGS Quad: Alameda

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

Effort: 465.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpionodes carpio</i>	1
2	<i>Catostomus commersonii</i>	3
3	<i>Cyprinus carpio</i>	3
4	<i>Cyprinella lutrensis</i>	23
4	<i>Hybognathus amarus*</i>	78
4	<i>Pimephales promelas</i>	9
4	<i>Platygobio gracilis</i>	16
4	<i>Rhinichthys cataractae</i>	20
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	32
11	<i>Morone chrysops</i>	1

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

age-0 78

age-1

age-2+

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: Sandoval County, RIO GRANDE Drainage

RKD23-162

Rio Grande, ca. 1.0 mi upstream of Alameda Blvd. bridge crossing (NM State HWY 528), Corrales.

Site Number: 22

River Mile: 193.0

09 October 2023

UTM Easting: 351565

UTM Northing: 3897088

Zone: 13

USGS Quad: Los Griegos

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

Effort: 497.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	2
2	<i>Catostomus commersonii</i>	2
3	<i>Cyprinus carpio</i>	4
4	<i>Cyprinella lutrensis</i>	13
4	<i>Hybognathus amarus*</i>	23
4	<i>Platygobio gracilis</i>	73
4	<i>Rhinichthys cataractae</i>	1
9	<i>Gambusia affinis</i>	37

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

age-0 22

age-1 1

age-2+

NEW MEXICO: Bernalillo County, RIO GRANDE Drainage

RKD23-161

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

09 October 2023

UTM Easting: 349121

UTM Northing: 3893113

Zone: 13

USGS Quad: Los Griegos

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

Effort: 516.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	3
3	<i>Cyprinus carpio</i>	6
4	<i>Cyprinella lutrensis</i>	17
4	<i>Hybognathus amarus*</i>	16
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	9
4	<i>Rhinichthys cataractae</i>	1
5	<i>Ictalurus punctatus</i>	5
9	<i>Gambusia affinis</i>	55
10	<i>Lepomis cyanellus</i>	1
10	<i>Micropterus salmoides</i>	1

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

age-0 15

age-1 1

age-2+

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: Bernalillo County, RIO GRANDE Drainage

Rio Grande, ca. 1.1 mi upstream of US Interstate HWY I-40 bridge crossing, Albuquerque.

Site Number: 24

River Mile: 186.1

UTM Easting: 346011

UTM Northing: 3887973

Zone: 13

USGS Quad: Albuquerque West

Collector(s): Dudley, R.K.; Urioste, A.D.; Keller, R.C.

RKD23-160

09 October 2023

Effort: 524.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	3
2	<i>Catostomus commersonii</i>	3
3	<i>Cyprinus carpio</i>	2
4	<i>Cyprinella lutrensis</i>	22
4	<i>Hybognathus amarus*</i>	47
4	<i>Pimephales promelas</i>	2
4	<i>Platygobio gracilis</i>	12
5	<i>Ictalurus punctatus</i>	2
9	<i>Gambusia affinis</i>	108
11	<i>Morone chrysops</i>	1

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

age-0	44
age-1	3
age-2+	

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage

Rio Grande, at Central Ave. bridge crossing (US HWY 66), Albuquerque.

Site Number: 4

River Mile: 183.4

UTM Easting: 346719

UTM Northing: 3884331

Zone: 13

USGS Quad: Albuquerque West

Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-150

04 October 2023

Effort: 518.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Catostomus commersonii</i>	3
3	<i>Cyprinus carpio</i>	2
4	<i>Cyprinella lutrensis</i>	55
4	<i>Hybognathus amarus*</i>	15
4	<i>Platygobio gracilis</i>	51
4	<i>Rhinichthys cataractae</i>	1
5	<i>Ictalurus punctatus</i>	5
9	<i>Gambusia affinis</i>	105

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

age-0	14
age-1	1
age-2+	

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: BERNALILLO County, RIO GRANDE Drainage
Rio Grande, at Rio Bravo Blvd. bridge crossing (NM State HWY 500), Albuquerque.
Site Number: 5 River Mile: 178.4
UTM Easting: 347468 UTM Northing: 3877400 Zone: 13 USGS Quad: Albuquerque West
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-149

04 October 2023
Effort: 503.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	17
2	<i>Catostomus commersonii</i>	1
3	<i>Cyprinus carpio</i>	8
4	<i>Cyprinella lutrensis</i>	23
4	<i>Hybognathus amarus</i> *	8
4	<i>Pimephales promelas</i>	24
4	<i>Platygobio gracilis</i>	16
5	<i>Ictalurus punctatus</i>	2
9	<i>Gambusia affinis</i>	63

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

age-0	6
age-1	2
age-2+	

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

RKD23-159

06 October 2023
Effort: 507.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	3
4	<i>Cyprinella lutrensis</i>	270
4	<i>Hybognathus amarus</i> *	3
4	<i>Pimephales promelas</i>	3
4	<i>Platygobio gracilis</i>	6
5	<i>Ictalurus punctatus</i>	9
9	<i>Gambusia affinis</i>	20

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

age-0	3
age-1	
age-2+	

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: Valencia County, RIO GRANDE Drainage
Rio Grande, ca. 4.1 mi upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 26 River Mile: 165.2
UTM Easting: 342799 UTM Northing: 3858637 Zone: 13 USGS Quad: Los Lunas
Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-158

06 October 2023
Effort: 542.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	11
4	<i>Cyprinella lutrensis</i>	176
4	<i>Hybognathus amarus</i> *	41
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	1
5	<i>Ictalurus punctatus</i>	2
9	<i>Gambusia affinis</i>	122

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

age-0 41
age-1
age-2+

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage
Rio Grande, just upstream of NM State HWY 6 bridge crossing, Los Lunas.
Site Number: 6 River Mile: 161.7
UTM Easting: 343149 UTM Northing: 3853187 Zone: 13 USGS Quad: Los Lunas
Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-148

06 October 2023
Effort: 517.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	16
4	<i>Cyprinella lutrensis</i>	220
4	<i>Hybognathus amarus</i> *	56
4	<i>Pimephales promelas</i>	1
5	<i>Ictalurus punctatus</i>	2
9	<i>Gambusia affinis</i>	6

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

age-0 56
age-1
age-2+

NEW MEXICO: Valencia County, RIO GRANDE Drainage
Rio Grande, ca. 6.5 mi upstream of NM State HWY 309 bridge crossing, Belen.
Site Number: 27 River Mile: 156.0
UTM Easting: 340512 UTM Northing: 3845124 Zone: 13 USGS Quad: Tome
Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-157

06 October 2023
Effort: sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	<i>Site Dry</i>	

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

Rio Grande, ca. 1.0 mi upstream of NM State HWY 309 bridge crossing, Belen.

Site Number: 7

River Mile: 150.8

UTM Easting: 340105

UTM Northing: 3837722

Zone: 13

USGS Quad: Tome

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-147

05 October 2023

Effort: 376.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	44
4	<i>Cyprinella lutrensis</i>	231
4	<i>Hybognathus amarus</i> *	3
4	<i>Pimephales promelas</i>	71
9	<i>Gambusia affinis</i>	299

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

age-0	3
age-1	
age-2+	

NEW MEXICO: Valencia County, RIO GRANDE Drainage

Rio Grande, ca. 6.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.

Site Number: 61

River Mile: 147.0

UTM Easting: 339379

UTM Northing: 3832429

Zone: 13

USGS Quad: Veguita

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-173

05 October 2023

Effort: 497.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpionodes carpio</i>	2
3	<i>Cyprinus carpio</i>	66
4	<i>Cyprinella lutrensis</i>	48
4	<i>Hybognathus amarus</i> *	87
4	<i>Pimephales promelas</i>	4
9	<i>Gambusia affinis</i>	127
10	<i>Micropterus salmoides</i>	1

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

age-0	85
age-1	2
age-2+	

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: VALENCIA County, RIO GRANDE Drainage

Rio Grande, ca. 2.2 mi upstream of NM State HWY 346 bridge crossing, Jarales.

Site Number: 8

River Mile: 143.2

UTM Easting: 338020

UTM Northing: 3827545

Zone: 13

USGS Quad: Veguita

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-146

05 October 2023

Effort: 561.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	19
4	<i>Cyprinella lutrensis</i>	129
4	<i>Hybognathus amarus</i> *	51
4	<i>Pimephales promelas</i>	8
5	<i>Ictalurus punctatus</i>	11
9	<i>Gambusia affinis</i>	206

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

age-0	31
age-1	20
age-2+	

NEW MEXICO: Valencia County, RIO GRANDE Drainage

Rio Grande, ca. 0.7 mi downstream of NM State HWY 346 bridge crossing, Jarales.

Site Number: 62

River Mile: 140.0

UTM Easting: 337520

UTM Northing: 3822964

Zone: 13

USGS Quad: Veguita

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-172

05 October 2023

Effort: 510.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpoides carpio</i>	1
3	<i>Cyprinus carpio</i>	4
4	<i>Cyprinella lutrensis</i>	17
9	<i>Gambusia affinis</i>	167

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: Socorro County, RIO GRANDE Drainage

Rio Grande, ca. 3.8 mi downstream of NM State HWY 346 bridge crossing, Jarales.

Site Number: 28

River Mile: 137.0

UTM Easting: 335506

UTM Northing: 3819543

Zone: 13

USGS Quad: Veguita

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-156

04 October 2023

Effort: 440.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	1
3	<i>Cyprinus carpio</i>	34
4	<i>Cyprinella lutrensis</i>	43
4	<i>Hybognathus amarus</i> *	68
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	11
10	<i>Micropterus salmoides</i>	2

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

age-0	44
age-1	24
age-2+	

NEW MEXICO: Socorro County, RIO GRANDE Drainage

Rio Grande, ca. 3.1 mi upstream of US HWY 60 bridge crossing, Bernardo.

Site Number: 63

River Mile: 133.7

UTM Easting: 334853

UTM Northing: 3814593

Zone: 13

USGS Quad: Abeytas

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-171

04 October 2023

Effort: 141.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	11
2	<i>Carpoides carpio</i>	1
3	<i>Cyprinus carpio</i>	513
4	<i>Cyprinella lutrensis</i>	77
4	<i>Hybognathus amarus</i> *	110
4	<i>Pimephales promelas</i>	5
5	<i>Ameiurus natalis</i>	1
5	<i>Ictalurus punctatus</i>	14
9	<i>Gambusia affinis</i>	36
10	<i>Micropterus salmoides</i>	7
11	<i>Morone chrysops</i>	2

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

age-0	106
age-1	4
age-2+	

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at US HWY 60 bridge crossing, Bernardo.

Site Number: 9

River Mile: 130.6

UTM Easting: 334578

UTM Northing: 3809921

Zone: 13

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-145

04 October 2023

USGS Quad: Abeytas

Effort: 474.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	1
3	<i>Cyprinus carpio</i>	26
4	<i>Cyprinella lutrensis</i>	287
4	<i>Hybognathus amarus*</i>	25
4	<i>Pimephales promelas</i>	8
5	<i>Ictalurus punctatus</i>	2
9	<i>Gambusia affinis</i>	134

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

age-0 25

age-1

age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 3.7 mi downstream of US HWY 60 bridge crossing, Bernardo.

Site Number: 10

River Mile: 126.8

UTM Easting: 330946

UTM Northing: 3805307

Zone: 13

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-144

04 October 2023

USGS Quad: Abeytas

Effort: 531.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	3
4	<i>Cyprinella lutrensis</i>	4
9	<i>Gambusia affinis</i>	30

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: Socorro County, RIO GRANDE Drainage
Rio Grande, ca. 4.7 mi upstream of the Rio Salado confluence, San Acacia.
Site Number: 64 River Mile: 123.2
UTM Easting: 329215 UTM Northing: 3799784 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-170

03 October 2023
USGS Quad: La Joya
Effort: 492.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	27
4	<i>Cyprinella lutrensis</i>	15
4	<i>Hybognathus amarus</i> *	4
4	<i>Pimephales promelas</i>	2
5	<i>Ameiurus natalis</i>	1
5	<i>Ictalurus punctatus</i>	25
9	<i>Gambusia affinis</i>	57

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

age-0	4
age-1	
age-2+	

NEW MEXICO: Socorro County, RIO GRANDE Drainage
Rio Grande, ca. 1.4 mi upstream of the Rio Salado confluence, San Acacia.
Site Number: 29 River Mile: 120.0
UTM Easting: 330550 UTM Northing: 3795050 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-155

03 October 2023
USGS Quad: La Joya
Effort: 472.9 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	29
4	<i>Cyprinella lutrensis</i>	23
4	<i>Hybognathus amarus</i> *	14
4	<i>Pimephales promelas</i>	5
5	<i>Ictalurus punctatus</i>	16
9	<i>Gambusia affinis</i>	90
10	<i>Micropterus salmoides</i>	3

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

age-0	13
age-1	1
age-2+	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 1.2 mi upstream of San Acacia Diversion Dam, San Acacia.
Site Number: 11 River Mile: 117.3
UTM Easting: 328152 UTM Northing: 3792564 Zone: 13
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-143

05 October 2023
USGS Quad: La Joya
Effort: 73.3 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
5	<i>Ictalurus punctatus</i>	1

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, just downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 12 River Mile: 115.6
UTM Easting: 325960 UTM Northing: 3792183 Zone: 13
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-142

05 October 2023
USGS Quad: San Acacia
Effort: 437.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	1
3	<i>Cyprinus carpio</i>	64
4	<i>Cyprinella lutrensis</i>	113
4	<i>Hybognathus amarus</i> *	2
4	<i>Platygobio gracilis</i>	24
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	5

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

age-0 2
age-1
age-2+

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, ca. 1.5 mi downstream of San Acacia Diversion Dam, San Acacia.
Site Number: 13 River Mile: 114.1
UTM Easting: 325390 UTM Northing: 3790397 Zone: 13
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-141

05 October 2023
USGS Quad: Lemitar
Effort: 462.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	11
4	<i>Cyprinella lutrensis</i>	19
4	<i>Hybognathus amarus</i> *	9
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	6
4	<i>Rhinichthys cataractae</i>	1
5	<i>Ictalurus punctatus</i>	9
9	<i>Gambusia affinis</i>	15

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

age-0 9
age-1
age-2+

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: Socorro County, RIO GRANDE Drainage

Rio Grande, ca. 5.4 mi downstream of San Acacia Diversion Dam, San Acacia.

Site Number: 65

River Mile: 110.3

UTM Easting: 326105

UTM Northing: 3785502

Zone: 13

USGS Quad: Lemitar

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-169

03 October 2023

Effort: 537.4 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	9
4	<i>Cyprinella lutrensis</i>	26
4	<i>Hybognathus amarus</i> *	48
4	<i>Platygobio gracilis</i>	1
5	<i>Ictalurus punctatus</i>	29
9	<i>Gambusia affinis</i>	43

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

age-0 48

age-1

age-2+

NEW MEXICO: Socorro County, RIO GRANDE Drainage

Rio Grande, ca. 2.1 mi upstream of Pueblitos Rd. bridge crossing, Lemitar.

Site Number: 30

River Mile: 106.3

UTM Easting: 326666

UTM Northing: 3780246

Zone: 13

USGS Quad: Lemitar

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-154

03 October 2023

Effort: 496.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	11
4	<i>Cyprinella lutrensis</i>	31
4	<i>Hybognathus amarus</i> *	25
4	<i>Platygobio gracilis</i>	3
5	<i>Ictalurus punctatus</i>	24
9	<i>Gambusia affinis</i>	51

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

age-0 25

age-1

age-2+

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

RKD23-140

Rio Grande, ca. 0.5 mi upstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.

Site Number: 14

River Mile: 99.6

05 October 2023

UTM Easting: 327231

UTM Northing: 3771432

Zone: 13

USGS Quad: Loma de las Canas

Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

Effort: 480.5 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	1
3	<i>Cyprinus carpio</i>	11
4	<i>Cyprinella lutrensis</i>	48
4	<i>Hybognathus amarus*</i>	65
4	<i>Pimephales promelas</i>	2
4	<i>Platygobio gracilis</i>	24
5	<i>Ictalurus punctatus</i>	21
5	<i>Pylodictis olivaris</i>	1
9	<i>Gambusia affinis</i>	13

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

age-0 64

age-1 1

age-2+

NEW MEXICO: Socorro County, RIO GRANDE Drainage

RKD23-168

Rio Grande, ca. 3.8 mi downstream of Socorro Low Flow Conveyance Channel bridge crossing, Socorro.

Site Number: 66

River Mile: 95.1

02 October 2023

UTM Easting: 327905

UTM Northing: 3765463

Zone: 13

USGS Quad: Loma de las Canas

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

Effort: 562.0 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	26
3	<i>Cyprinus carpio</i>	37
4	<i>Cyprinella lutrensis</i>	145
4	<i>Hybognathus amarus*</i>	16
4	<i>Pimephales promelas</i>	1
4	<i>Platygobio gracilis</i>	4
5	<i>Ictalurus punctatus</i>	60
9	<i>Gambusia affinis</i>	67

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

age-0 16

age-1

age-2+

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 4.5 mi upstream of US HWY 380 bridge crossing, San Antonio.

Site Number: 15

River Mile: 92.0

UTM Easting: 328151

UTM Northing: 3761487

Zone: 13

USGS Quad: San Antonio

Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-139

05 October 2023

Effort: 516.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	1
4	<i>Cyprinella lutrensis</i>	1
5	<i>Ictalurus punctatus</i>	4
9	<i>Gambusia affinis</i>	32

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, at US HWY 380 bridge crossing, San Antonio.

Site Number: 16

River Mile: 87.8

UTM Easting: 328907

UTM Northing: 3754926

Zone: 13

USGS Quad: San Antonio

Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-138

03 October 2023

Effort: 62.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
9	<i>Gambusia affinis</i>	5

NEW MEXICO: Socorro County, RIO GRANDE Drainage

Rio Grande, ca. 4.3 mi downstream of San Antonio bridge crossing, San Antonio.

Site Number: 67

River Mile: 83.3

UTM Easting: 329319

UTM Northing: 3747431

Zone: 13

USGS Quad: San Antonio SE

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-167

02 October 2023

Effort: sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	Site Dry	

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, east of Bosque del Apache NWR headquarters, San Antonio.
Site Number: 17 River Mile: 79.0
UTM Easting: 327219 UTM Northing: 3740906 Zone: 13
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-137

03 October 2023
USGS Quad: San Antonio SE
Effort: 17.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
2	<i>Carpiodes carpio</i>	1
4	<i>Cyprinella lutrensis</i>	4
4	<i>Hybognathus amarus*</i>	1
5	<i>Ameiurus natalis</i>	1
5	<i>Ictalurus punctatus</i>	1
9	<i>Gambusia affinis</i>	113

**Hybognathus amarus* (age-classes):

age-0	1
age-1	
age-2+	

NEW MEXICO: Socorro County, RIO GRANDE Drainage
Rio Grande, ca. 5.3 mi upstream of San Marcial Railroad bridge crossing, San Marcial.
Site Number: 68 River Mile: 73.7
UTM Easting: 322751 UTM Northing: 3732864 Zone: 13
Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-166

02 October 2023
USGS Quad: San Marcial
Effort: sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
	<i>Site Dry</i>	

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage
Rio Grande, at San Marcial Railroad bridge crossing, San Marcial.
Site Number: 18 River Mile: 68.3
UTM Easting: 315091 UTM Northing: 3728487 Zone: 13
Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-136

03 October 2023
USGS Quad: San Marcial
Effort: 43.7 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
5	<i>Ictalurus furcatus</i>	3
5	<i>Ictalurus punctatus</i>	4
9	<i>Gambusia affinis</i>	5

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: Socorro County, RIO GRANDE Drainage

Rio Grande, ca. 4.4 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 69

River Mile: 63.9

UTM Easting: 313940

UTM Northing: 3722027

Zone: 13

USGS Quad:

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

RKD23-165

02 October 2023

Paraje Well

Effort: 41.8 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	2
4	<i>Cyprinella lutrensis</i>	12
9	<i>Gambusia affinis</i>	2228

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 8.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 19

River Mile: 60.1

UTM Easting: 309441

UTM Northing: 3718309

Zone: 13

USGS Quad:

Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-135

03 October 2023

Paraje Well

Effort: 327.1 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	37
4	<i>Cyprinella lutrensis</i>	30
5	<i>Ictalurus punctatus</i>	6
9	<i>Gambusia affinis</i>	259

NEW MEXICO: SOCORRO County, RIO GRANDE Drainage

Rio Grande, ca. 10.0 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 20

River Mile: 58.5

UTM Easting: 307767

UTM Northing: 3716360

Zone: 13

USGS Quad:

Collector(s): Farrington, M.A.; Clark-Barkalow, S.L.; Chavez, M.J.

RKD23-134

03 October 2023

Paraje Well

Effort: 267.6 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
3	<i>Cyprinus carpio</i>	39
4	<i>Cyprinella lutrensis</i>	47
4	<i>Pimephales vigilax</i>	3
9	<i>Gambusia affinis</i>	208

Rio Grande Silvery Minnow Population Monitoring October 2023

NEW MEXICO: Socorro County, RIO GRANDE Drainage

RKD23-164

Rio Grande, ca. 12.9 mi downstream of San Marcial Railroad bridge crossing, San Marcial.

Site Number: 70

River Mile: 55.5

02 October 2023

UTM Easting: 305502

UTM Northing: 3711951

Zone: 13

USGS Quad: Paraje Well

Collector(s): Dudley, R.K.; Damron, T.D.; Keller, R.C.

Effort: 517.2 sq. m

<u>Family</u>	<u>Species</u>	<u>Total</u>
1	<i>Dorosoma cepedianum</i>	6
3	<i>Cyprinus carpio</i>	30
4	<i>Cyprinella lutrensis</i>	113
4	<i>Pimephales vigilax</i>	1
5	<i>Ictalurus furcatus</i>	4
5	<i>Ictalurus punctatus</i>	2
9	<i>Gambusia affinis</i>	490