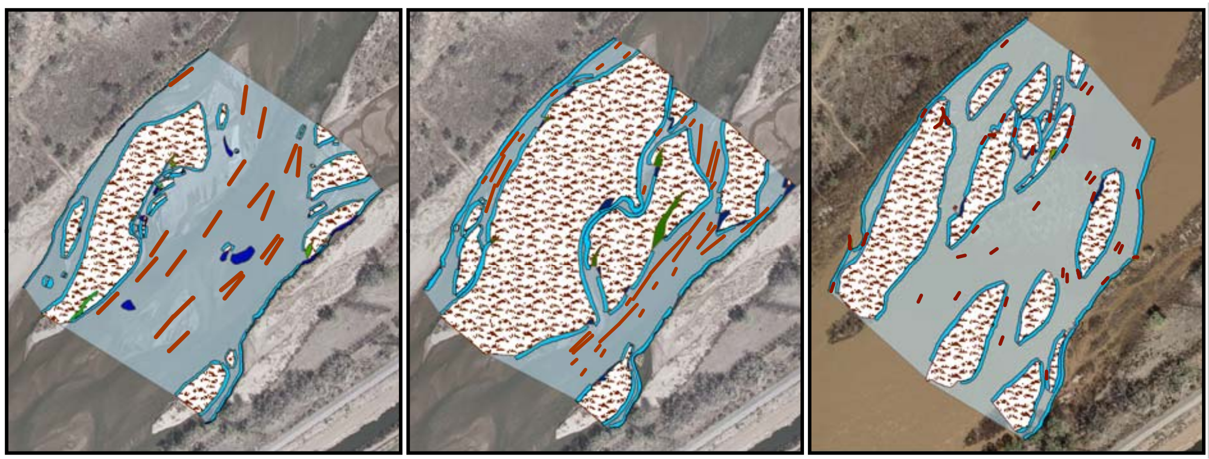
RIO GRANDE SILVERY MINNOW POPULATION ESTIMATION PROGRAM RESULTS FROM OCTOBER (2006 TO 2008)

FINAL

A Middle Rio Grande Endangered Species Act Collaborative Program Funded Research Project



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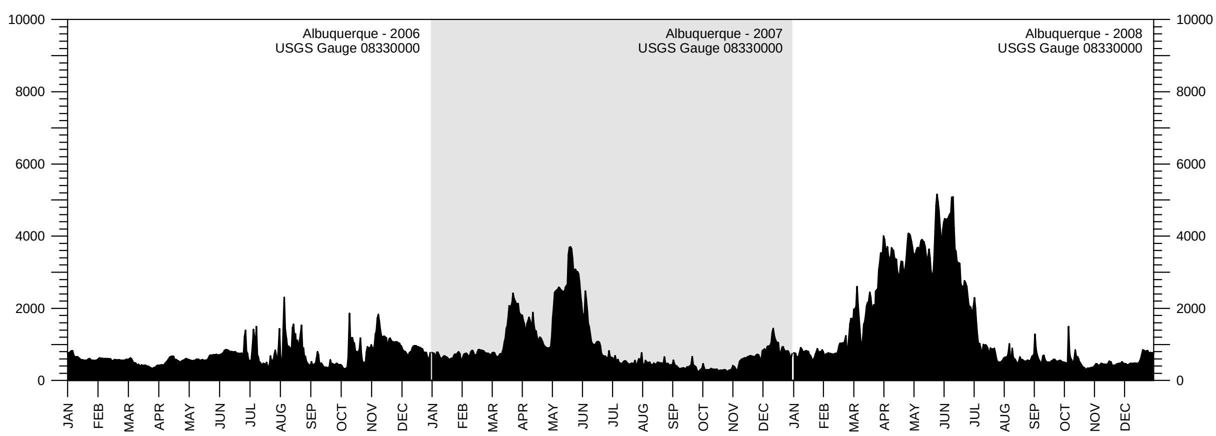

Month - 2006 Month - 2007 Month - 2008

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10 February 2011

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Funded through the Middle Rio Grande Endangered Species Act Collaborative Program.

Prepared by:

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IMPORTANT CAUTIONARY NOTE REGARDING ANNUAL REPORT DATA

The three year pilot portion of the Rio Grande silvery minnow Population Estimation Program (2006 to 2008) was designed to develop, refine, test, and implement methods that could be used to generate statistically robust population estimates for that species in the Middle Rio Grande, New Mexico. Numerous modifications to the original field sampling methods were made annually during this pilot study, which resulted in the development of the sampling protocols implemented and used consistently since 2008. For this reason, the 2008 Rio Grande silvery minnow Population Estimation Program study is the baseline (as opposed to the 2006 or 2007 studies) from which to compare results of future studies, including interpretation of Rio Grande silvery minnow population size trends over time.

The data generated from the Rio Grande silvery minnow Population Estimation Program are iterative and revised annually with the completion of each autumn's sampling effort. Development of the model employed to generate estimates of Rio Grande silvery minnow population size is an ongoing process that requires robust capture probability estimates among different mesohabitat types (based on multiple depletion sampling efforts). As each year's new data are acquired and incorporated, the model is further refined and the population estimates for all previous comparable years (i.e., since 2008) are revised accordingly. The statistical rigor of the model will increase concurrently with the annual inclusion of additional mesohabitat-specific depletion data and, likewise, the magnitude of change in recalculated population estimates from past years will likely decrease. One ramification of the annual iterations and associated changes is that new annual computations will yield population estimates that will supersede all those made in the past (i.e., since 2008).

The 2006-2008 Rio Grande silvery minnow Population Estimation Program summary final report (Date: 10 February 2011), the 2009 Rio Grande silvery minnow Population Estimation Program final report (Date: 10 February 2011), and the 2010 Rio Grande silvery minnow Population Estimation Program draft report (Date: 28 February 2011) were prepared simultaneously to provide the most comprehensive information on recent Rio Grande silvery minnow population trends. Each document provides population estimates that were based on global capture probability estimates derived from the most recent mesohabitat-specific depletion data (i.e., 2008 to 2010). Similarly, the 2011 mesohabitat-specific depletion data will be used to further refine the global capture probability estimates and will provide an even more robust estimate of Rio Grande silvery minnow population size trends since 2008. This means that, starting in 2011, all historical population estimates contained within past Rio Grande silvery minnow Population Estimation Program annual reports (since 2008) will be superseded by those presented in the most current annual report.

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PREFACE

The three year pilot portion of the Rio Grande silvery minnow Population Estimation Program (2006 to 2008) was designed to develop, refine, test, and implement methods that could be used to generate statistically rigorous population estimates for that species in the Middle Rio Grande, New Mexico. The final year of three years of fieldwork for this Middle Rio Grande Endangered Species Act Collaborative Program (MRGESACP) project was initiated in autumn 2008. The sampling methods employed in 2008 were the culmination of a two year test of field sampling methods (2006-2007) during this pilot study and incorporated over 20 years of sampling experience on the Middle Rio Grande.

Given that the sampling and analytical aspects of this project evolved over time, the results presented in this report must be interpreted cautiously given the substantial changes in methodology from 2006 to 2008. While the statistical methods employed to generate the 2006-2008 Rio Grande silvery minnow population numbers contained herein are statistically sound, determination of the relationship between the number of fish taken through sampling efforts versus the number of fish present at any given sampling unit is dependent on the complex computational synthesis of multiple layers of data (e.g., fish densities, mesohabitat-specific depletion efforts, and mesohabitat availability). The 2008 study represents the culmination of three years of field sampling and statistical refinements and is the protocol followed in subsequent years. Thus, the 2008 Rio Grande silvery minnow Population Estimation Program study is the baseline (as opposed to the 2006 or 2007 studies) from which to compare results of future studies, including interpretation of Rio Grande silvery minnow population size trends over time.

EXECUTIVE SUMMARY

Systematic monitoring of Rio Grande silvery minnow, *Hybognathus amarus*, and the associated Middle Rio Grande fish community has been conducted since 1993 and has provided relevant, quantifiable, and timely information regarding the status of this species both spatially and temporally. In contrast to the Population Monitoring Program, which continues to provide necessary year-round documentation of trends for the entire ichthyofaunal community, the Population Estimation Program provides an annual estimate of the Rio Grande silvery minnow population during a single time-period (October). Estimating population size required employing statistical techniques that were subject to a series of assumptions. Estimates of the number of Rio Grande silvery minnow are presented within the context of those assumptions, especially given the inherent variation in the density and distribution of organisms within their environment. The objectives of this study were to 1) Develop and implement methods that provide statistically robust population estimates of Rio Grande silvery minnow, 2) Provide a population estimate of Rio Grande silvery minnow based on fish densities stratified by mesohabitat for 20 sampling units, 3) Develop site occupancy rates for Rio Grande silvery minnow populations based on repeated sampling in November, 4) Calculate a population estimate of Rio Grande silvery minnow using Population Monitoring Program data, controlling for mesohabitat, and compare this value to that generated in Objective #2, and 5) Synthesize the results of the first three years of this study (2006 to 2008) into a single comprehensive document.

The ichthyofaunal community in the Middle Rio Grande during October (2006 to 2008) was numerically dominated by cyprinids. The native ichthyofauna consisted of seven species (red shiner, Rio Grande silvery minnow, fathead minnow, flathead chub, longnose dace, river carpsucker, and bluegill) in 2006 and 2008 but included smallmouth buffalo in 2007. Red shiner was the most abundant native species collected in 2006 (N = 7,885) and 2007 (N = 18,826) but was the second most abundant species in 2008 (N = 909). Rio Grande silvery minnow varied widely in abundance among years (range = 339 to 3,122) and was the most abundant native species in 2008 (N = 1,576). Other commonly collected native species included fathead minnow and flathead chub. Longnose dace, rivercarpsucker (with the exception of 2007), smallmouth buffalo, and bluegill were often the least abundant native fishes. The most abundant introduced species collected in all years were common carp, white sucker, channel catfish, and western mosquitofish.

The availability of data from 2005 to 2008 allowed for a preliminary calculation of the probability of occupancy for all sampling units combined based on collections within each sampling unit over time. The minimum AIC_c model had constant occupancy (psi, ψ), extinction (epsilon, ε), and colonization (gamma, γ) parameters across the two intervals, but detection probabilities (p) varying by year (y) and discharge (d). The site occupancy estimate was 1.0 for all age-classes combined and for age-0 individuals but was lower for age-1 (0.5726) and age-2 (0.5125) individuals. Estimates of the probability of extinction were relatively low for all age-classes (0.0172) and age-0 (0.0697) individuals. The probability of extinction was higher for both age-1 and age-2 individuals (0.2236 and 0.1242, respectively). Estimates of the probability of colonization were relatively high for age-0 (0.5877) and age-1 (0.7414) individuals. However, because a site for all age-classes never went from unoccupied to occupied, the colonization estimate for this group was zero. Estimates of the probability of occupancy varied among years and age-classes but were most variable for groups with fewer data (i.e., age-1 and age-2 individuals).

The overall population estimate in 2006 (N = 56,690; S.E. = 19,253.09) was the lowest recorded during this pilot study. The population size estimate for 2007 had increased to 613,638 (S.E. = 259,983.21). In 2008, the total population estimate was the highest recorded during this pilot study (N = 1,108,430; S.E. = 332,470.15). The total population estimate was highest in the Angostura Reach during 2006 (N = 21,668) and highest in the Isleta Reach during 2007 (N = 417,099) and 2008 (N = 453,267).

Population estimates were also generated using data from the Population Monitoring Program October sampling efforts (2006 to 2008). The 2006 population estimate was 91,336 and had a standard error [S.E.] of 33,917.53. In 2007, the population estimate was 276,181 (S.E. = 71,114.79). The overall population estimate using the 2008 data (N = 544,170) was the highest of the study and had a standard error [SE] of 90,271.14.

The 2006-2008 estimates of Rio Grande silvery minnow population size should be viewed cautiously as they are only a few data points and are preceded by the rigorous long-term Population Monitoring Program that was initiated in 1993. There have been numerous periods of rapidly expanding and contracting population size that have occurred over the past 15 years. While estimates from a few years provide a useful starting point for long-term monitoring, its importance (both statistically and from a resource management standpoint) will only be realized after multiple years of population estimation data are collected and analyzed. The 2008 results represent the culmination of three years of refinements to the Population Estimation Program pilot study and should be used as the baseline from which to compare the results of future studies, including the interpretation of Rio Grande silvery minnow population size trends over time.

The site occupancy data should be used in combination with population estimate data to provide a more complete understanding of the conservation status of Rio Grande silvery minnow. It is well known that simply having large numbers of a particular species in an area doesn't ensure its long-term survival. This is particularly true for short-lived species such as Rio Grande silvery minnow. The vast changes in populations of this species within short time periods underscore the need to ensure the presence of individuals over a broad geographical range. Changing environmental conditions within a particular region (either natural or manmade) can have rapid and severe impacts to local populations of Rio Grande silvery minnow. Large populations within these affected regions can be decimated within days because of river dewatering. Alternatively, the lack of spring runoff can inhibit spawning and limit recruitment to such a degree that populations decline several orders of magnitude within a year. The short life span of this species means that, following periods of low recruitment, total population size is not well buffered by surviving age-classes. For these reasons, it is imperative that populations of Rio Grande silvery minnow are established at multiple locations within its current and historical range to ensure its long-term persistence in the wild.

The success of this project will be evaluated annually but insight into the efficacy of estimating the population size of Rio Grande silvery minnow will require a multi-year commitment. Data from future year's efforts will provide additional information that will supplement recent population estimation activities and furnish valuable information necessary to gauge recovery of Rio Grande silvery minnow in the three principal reaches of the Middle Rio Grande. Ultimately, these data will be used to evaluate progress towards meeting Rio Grande silvery minnow recovery goals, following both management actions and stochastic environmental events.

INTRODUCTION

Population information on Rio Grande silvery minnow and the associated Middle Rio Grande fish community has been gathered regularly since 1987. The first population monitoring studies were conducted from 1987-1992 (Platania, 1993a) with the goal of determining spatial and temporal changes in the ichthyofaunal community and providing resolution of species-specific mesohabitat use patterns. An additional purpose of those preliminary studies was to supply information on the conservation status of Rio Grande silvery minnow. The quarterly sampling efforts revealed that Rio Grande silvery minnow had declined markedly during the study period and was extremely rare in portions of its remaining range. The 90-95% reduction in the range of Rio Grande silvery minnow and threats to its continued existence in the Middle Rio Grande were central to this species being listed as endangered by the U. S. Fish and Wildlife Service (U. S. Department of Interior, 1994).

Systematic monitoring of populations of Rio Grande silvery minnow, *Hybognathus amarus*, and the associated Middle Rio Grande fish community has been conducted since 1993. The U. S. Bureau of Reclamation, U. S. Fish and Wildlife Service, New Mexico Department of Game and Fish, and U. S. Army Corps of Engineers have cooperated to fund numerous ichthyofaunal studies in the Middle Rio Grande. Among those studies was long-term monitoring of the Middle Rio Grande fish community at numerous sites between Angostura Diversion Dam and Elephant Butte Reservoir. While Rio Grande silvery minnow was the primary focus of most efforts, research activities also provided information on the associated fish community.

The information generated during this decade-long effort has provided the foundation necessary to assess spatial and temporal changes in the Middle Rio Grande ichthyofaunal community. Catch-per-unit-effort (CPUE = $\#/m^2$) is the primary metric used to monitor spatiotemporal trends in population levels of Rio Grande silvery minnow for each sampling effort at Middle Rio Grande sites. This metric provides a gauge by which to measure the relative increase or decrease in the population temporally (among months or years) or spatially (among sites or reaches). The current population monitoring protocol is not designed to provide an estimate of the total number of Rio Grande silvery minnow but rather an estimate of trends in abundance over time and space.

However, estimating the population size of Rio Grande silvery minnow on an annual basis may provide a useful gauge by which to assess the total increase or decrease in abundance of this federally endangered species over time. Analyzing population fluctuations of fishes and assessing the influence of environmental variability may lend insight to important mechanisms that regulate community structure (Starrett, 1951; Schlosser, 1985). Changes in the abundance of an organism, especially over long periods, can be strongly influenced by environmentally stochastic factors (Grossman et al., 1982). Short-lived fishes, such as Rio Grande silvery minnow and other Middle Rio Grande cyprinids, are well suited for the study of short-term ichthyofaunal dynamics (<5 years) as populations often fluctuate drastically within a few years. Quantitative and qualitative analyses of these changes using current and past Middle Rio Grande fish population monitoring data have provided insight to causal mechanisms that may control species abundance and community structure.

Techniques to estimate the presence and abundance of organisms, which do not require full site depletion or marking and recapture of individuals, have been shown to be reliable for a variety of species (e.g., Royle and Nichols, 2003). Statistical methods have been developed that account for the inherent heterogeneity of population abundance among different sites. Data on the presence-absence of organisms provides useful information about the probabilities that underlie spatial patterns of abundance in the environment, and for detecting trends in population status (MacKenzie et al. 2003). Occupancy surveys provide a way to assess the likelihood of detecting the presence or absence of an organism by calculating the probability based on the detection history (i.e., previous information on presence/absence can be used to predict likelihood of non-detection versus unoccupied). Failure to detect a species during sampling does not mean that the species is truly absent from the area (MacKenzie et al., 2002, Finley et al., 2005, White 2005).

An estimate of population size and historical patterns of site occupancy can be used to complement data collected during the long-term Population Monitoring Program for the Middle Rio Grande ichthyofaunal community (Angostura, NM to Elephant Butte Reservoir). In contrast to population monitoring that documents spatial and temporal trends in abundance for the entire ichthyofaunal community, population estimation supplements the current Population Monitoring Program by providing a rigorous yearly estimate of the Rio Grande silvery minnow population during a single time-period (October). The objectives of this study were to 1) Develop and implement methods that provide statistically robust population estimates of Rio Grande silvery minnow, 2) Provide a population estimate of Rio Grande silvery minnow based on fish densities stratified by mesohabitat for 20 sampling units, 3) Develop site occupancy rates for Rio Grande silvery minnow populations based on repeated sampling in November, 4) Calculate a population estimate of Rio Grande silvery minnow using Population Monitoring Program data, controlling for mesohabitat, and compare this value to that generated in Objective #2, and 5) Synthesize the results of the first three years of this study (2006 to 2008) into a single comprehensive document.

STUDY AREA

The headwaters of the Rio Grande are located in the San Juan Mountains of southern Colorado. The mainstem Rio Grande flows 750 km through New Mexico, draining an area of about 68,104 km^2 (excluding closed basins). The Rio Chama is the only major perennial tributary of the Rio Grande in New Mexico and confluences with it near the city of Española. Snowmelt from southern Colorado and northern New Mexico yields the majority of water for the Rio Grande, but trans-mountain diversions from the San Juan River (Colorado River Basin) supplement flow by providing water in route to agricultural users and municipalities. The highest flow in the Rio Grande generally occurs shortly after spring snowmelt, while the lowest flow usually occurs in late summer and early autumn prior to the cessation of irrigation season (October 31). Summer thunderstorms periodically augment low flow in discrete reaches, but do not ensure that the river channel will remain wetted. Precipitation in the region is low and averages <25 cm/year (Gold and Denis, 1985).

Several large reservoirs on the Rios Chama and Grande and numerous smaller irrigation diversion dams regulate flow in the Middle Rio Grande. The complex system of ditches, drains, and conveyance channels provide water for extensive irrigated agriculture in the Rio Grande Valley. Cochiti Reservoir is the primary flood control reservoir and regulates discharge in the mainstem Middle Rio Grande. The Middle Rio Grande has been greatly modified over the last 50 years; this has led to degradation, armoring, and narrowing of the river channel in addition to floodplain abandonment across various portions of the overall reach (Lagasse, 1980; Massong et al., 2006; Makar et al., 2006).

The Middle Rio Grande is defined as the reach between Velarde, New Mexico and Elephant Butte Reservoir. The study area (Figure 1) is a portion of the Middle Rio Grande, from Angostura Diversion Dam to the inflow of Elephant Butte Reservoir, that encompasses most of the current range of Rio Grande silvery minnow (i.e., below Cochiti Dam to the inflow of Elephant Butte Reservoir). The Cochiti Reach of the Rio Grande (between Cochiti Dam and Angostura Diversion Dam) passes first through Cochiti Pueblo, then Santo Domingo Pueblo, and finally San Felipe Pueblo. Access is currently restricted or unreliable in the Cochiti Reach, precluding long-term fish monitoring in this area. The last comprehensive ichthyofaunal surveys of the Rio Grande in the Cochiti Reach documented the presence, at low abundance, of Rio Grande silvery minnow on Santo Domingo and San Felipe pueblos (Platania, 1995). Rio Grande silvery minnow was not found within the boundaries of Cochiti Pueblo (Platania, 1993b).

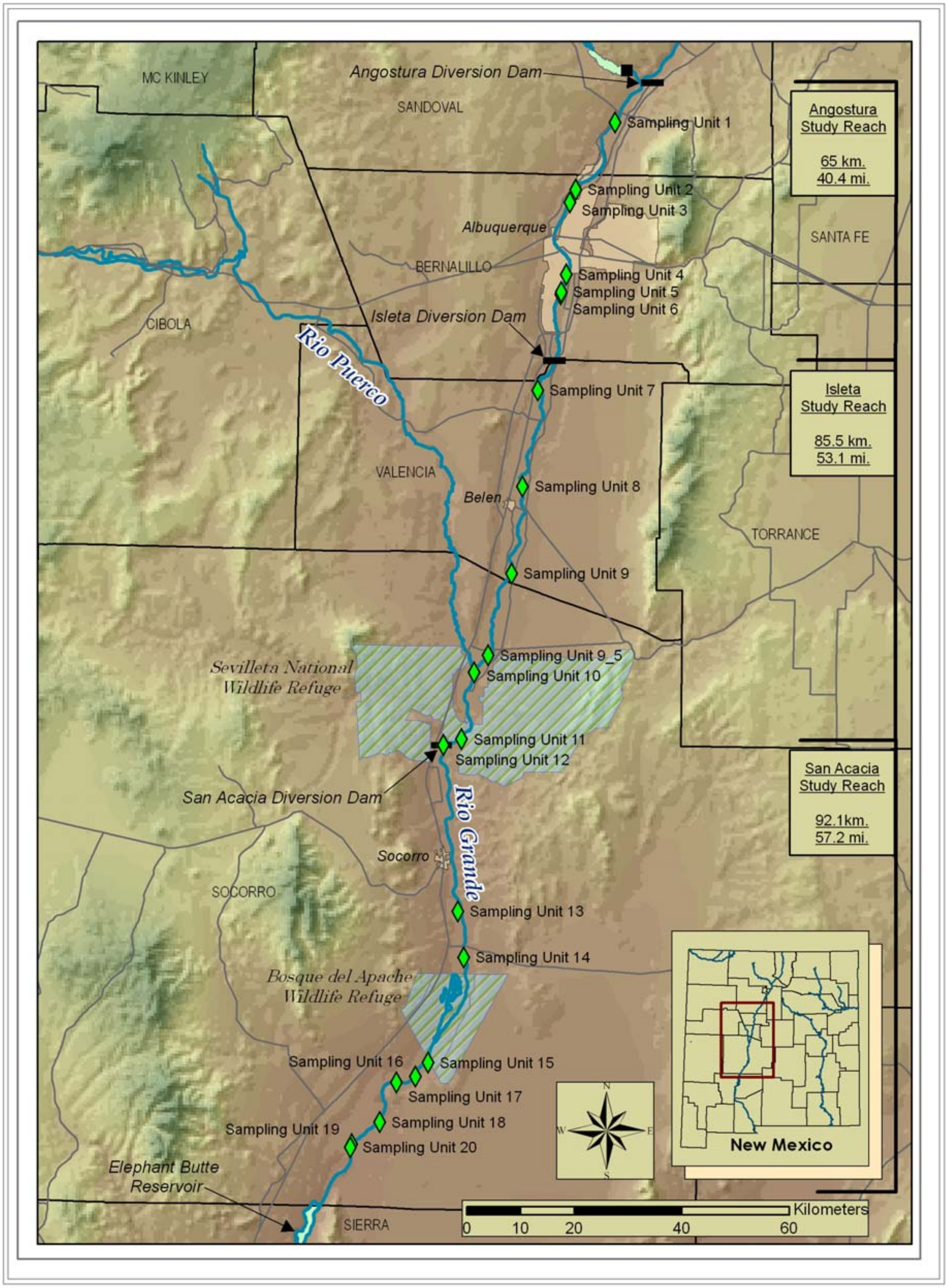


Figure 1. Map of the study area, reaches, and sampling units (numbered) for the Rio Grande silvery minnow Population Estimation Program. Sampling unit information is provided in Appendix A (Table A-1).

Reach names were derived from the diversion structure at the top of the reach. The Angostura Reach (Angostura Diversion Dam to Isleta Diversion Dam) had six sampling units in 2006 and five sampling units in 2007-2008 while the Isleta Reach (Isleta Diversion Dam to San Acacia Diversion Dam) had five sampling units in 2006 and six sampling units in 2007-2008. There were nine sampling units in the San Acacia Reach (San Acacia Diversion Dam to inflow of Elephant Butte Reservoir). The 20 sampling units in the Middle Rio Grande overlap the current range of Rio Grande silvery minnow.

Diel and seasonal discharge varied greatly from 2005 to 2008, especially in southern reaches of the Middle Rio Grande (Figures 2 and 3). There was a general trend of lower flow at downstream locations (e.g., U. S. Geological Survey (USGS) San Marcial Gauge [#08358400]) compared to upstream locations (e.g., USGS Albuquerque Gauge [#08330000]). Flows were generally elevated from April to June with the notable exception of 2006. While flow conditions in 2006 and 2007 included periods of low flow, these were not nearly as low or as persistent as they were during the last pronounced drought period (i.e., 2002 and 2003).

METHODS

Sampling and Mapping Methodology

Sampling unit location, selection, and timing

This study was structured to provide an estimation of the population of Rio Grande silvery minnow based on data collected from 20 sampling units in the study area. To maintain an unbiased probability of sampling at localities that support differing densities of Rio Grande silvery minnow, sampling units in this study were selected randomly using a spatially balanced statistical design. The use of generalized randomized tessellation stratified (GRTS) sampling, for long-term ecological studies, was discussed extensively by Stevens and Olsen (1999, 2003, 2004). The advantage this technique has over simple random sampling is that it ensures spatially balanced samples. This is important because the spatial distribution of an organism is necessary to understand abundance trends over both space and time. Additionally, the GRTS method is flexible in its ability to gain or lose units later while retaining spatial balance of the sampling design.

The computer program "S-Draw" (Western EcoSystems Technology, Inc. - Trent L. McDonald) was used to randomly select study units within the Middle Rio Grande. This program allows for efficient one-dimensional or two-dimensional drawing of GRTS samples. Additional features of S-Draw include allowing inputs such as population and sample size, or complex enumeration sampling frames containing UTM coordinates, ID's, and weights.

An initial step in generating the list of potential fish sampling units was to determine an appropriate length for each unit. The sampling unit had to be long enough to encompass the suite of mesohabitats present and to adequately represent the fish community in that area. Previous Middle Rio Grande fish-mesohabitat association studies demonstrated that multiple 200-m sampling units were of sufficient length to include a representative selection of the mesohabitats that occur in the Rio Grande from Angostura Diversion Dam to Elephant Butte reservoir (Platania 1993a, Dudley and Platania, 1997). The 234 river km (ca. 145.4 river miles) study area (Middle Rio Grande between Angostura Diversion Dam and Elephant Butte Reservoir) was partitioned (using aerial photographs, GIS data, and ArcView software) into 200-m sampling units (N = 1,170) starting immediately upstream of Bernalillo (just downstream of the southern boundary of Santa Ana Pueblo) and ending at Elephant Butte Reservoir. The Cochiti Reach (ca. 35 km) of the Middle Rio Grande was not included in this proposed study as all except a very small portion (< 5 km) drain sovereign Native American nations and are generally inaccessible.

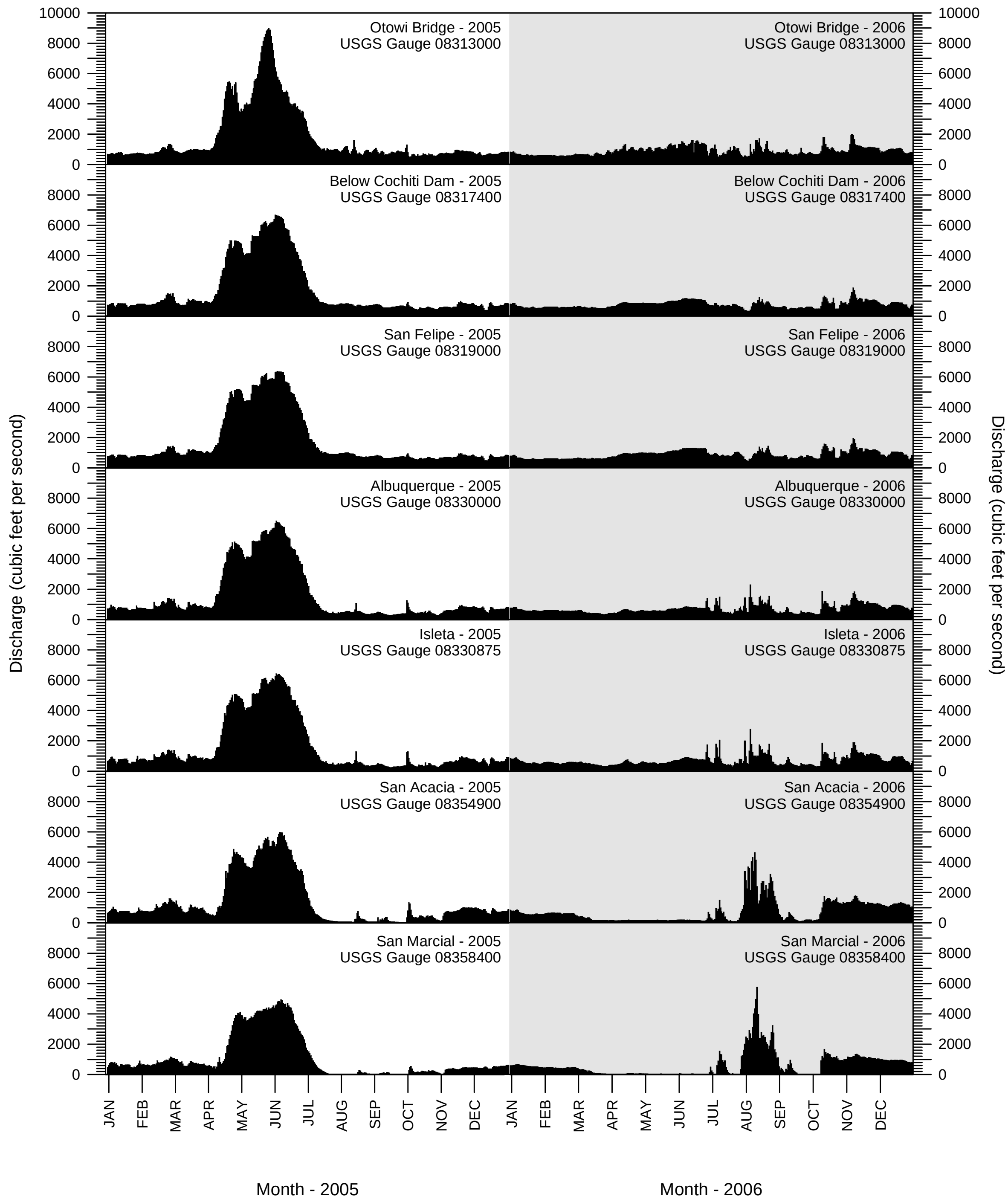


Figure 2. Discharge in the Rio Grande from January 2005 through December 2006 as recorded at seven U. S. Geological Survey (USGS) gauging stations. The Otowi Bridge gauge site is outside of the study area (ca. 25.5 river miles upstream of Cochiti Dam) but is provided for reference. USGS discharge data are provisional and subject to change.

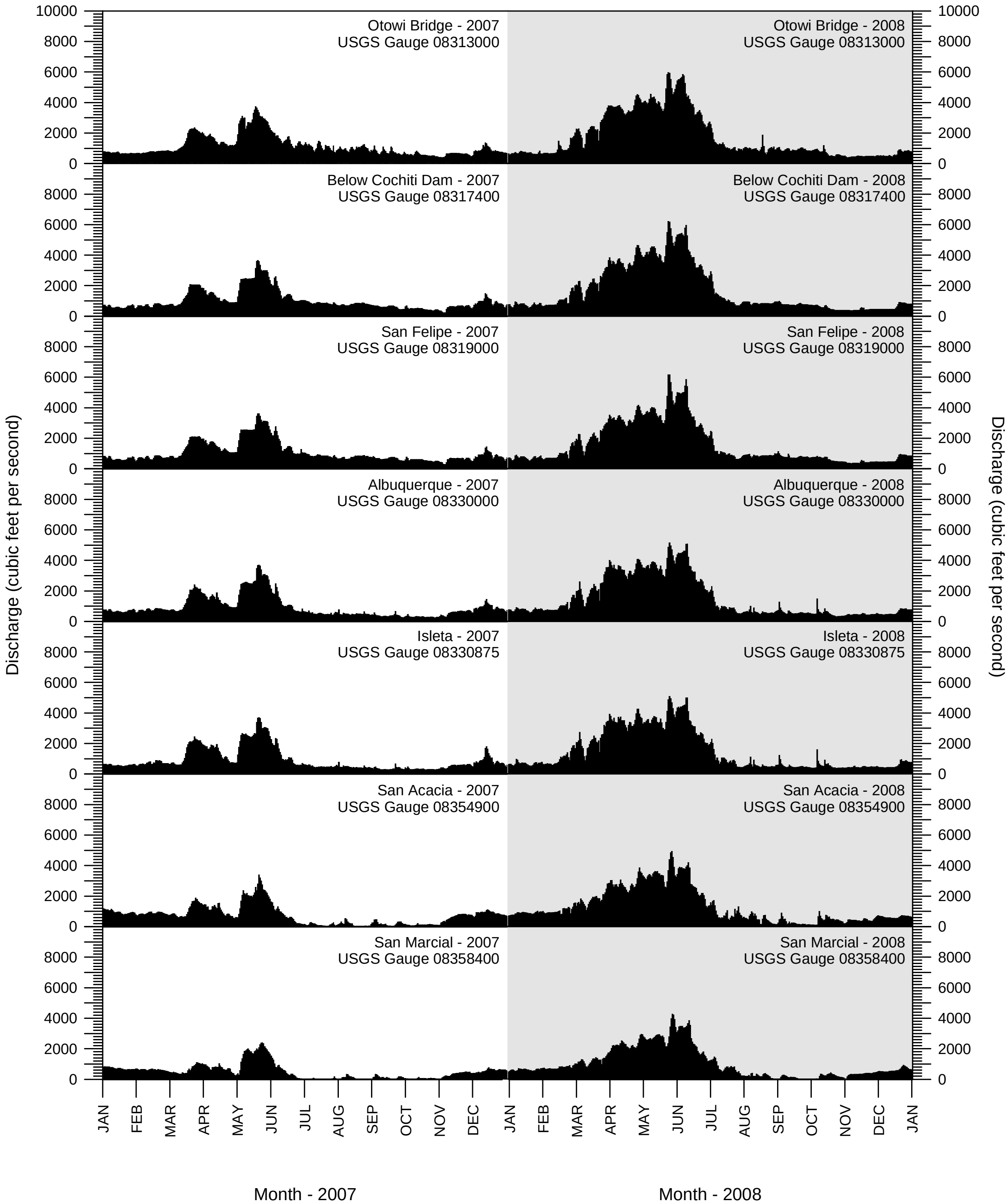


Figure 3. Discharge in the Rio Grande from January 2007 through December 2008 as recorded at seven U. S. Geological Survey (USGS) gauging stations. The Otowi Bridge gauge site is outside of the study area (ca. 25.5 river miles upstream of Cochiti Dam) but is provided for reference. USGS discharge data are provisional and subject to change.

The primary data that were used in S-Draw included UTM coordinates corresponding to the upper and lower boundaries of each 200-m sampling unit (N = 1,170) within the Middle Rio Grande study area. The first 20 sampling units (Appendix A, Table A-1) were used for this study in 2006 with the intention that the loss of a unit would simply require selecting the next sampling unit on the list (i.e., #21). This scenario (loss of a unit) happened in 2007 when the river at sampling unit #1 was diverted across the natural channel and turned into a channeled manmade ditch while heavy construction (levee reinforcement) proceeded along the original eastern shoreline. This site was dropped from sampling and the 21st locality (sampling unit #9_5) was selected from the list. This procedure could be repeated as necessary in the future and has the added benefit of maintaining the randomized spatial balance of the sampling units.

The rationale for sampling at 20 units for the Population Estimation Program was also based on the statistical analyses and modeling techniques employed in this study. Power analysis of Rio Grande Population Monitoring Program data also supports using a sample size of about 20 to adequately detect population trends over time (MRGESACP, 2006). Rio Grande silvery minnow population estimates were generated from October 2008 samples obtained at each of the 20 units. Samples of Rio Grande silvery minnow from October provide a general assessment of results of the spring/summer spawn and subsequent recruitment. October collections also provide a reasonable estimate of the cohort available for spawning during the following year. Another factor in selecting October for population estimation sampling was because this was the time identified as the gauge by which recovery of Rio Grande silvery minnow would be measured (U. S. Fish and Wildlife Service, 2007).

Mesohabitat mapping and analysis

The October 2008 sampling effort was structured to acquire data about the relative proportion of mesohabitats at each sampling locality. Aquatic mesohabitats were segregated into seven broad categories: backwater, debris, pool, run, riffle, shoreline pool, and shoreline run (Table 1). The seven mesohabitats have been designated, based on past autumnal Middle Rio Grande fish population monitoring and habitat use/availability studies (e.g., Dudley and Platania, 1997, 2008), as high (backwater, shoreline pool, debris), medium (pool, shoreline run), or low density (run, riffle) Rio Grande silvery minnow mesohabitats.

Ground measurements of mesohabitat spatial scale and location were acquired with Trimble GPS units and mapped in ArcInfo GIS to provide a detailed mesohabitat mosaic of the river for each sampling unit (Appendix B). Pathfinder Office was used for all post-processing of raw data. High quality natural color orthophotography images (15 cm resolution) were used for all sampling units in the Angostura and Isleta reaches. Near infrared color orthophotography images (0.5 m resolution) were used for sampling units in the San Acacia Reach only when high quality natural color orthophotography images were not available. There were noticeable shifts in the location of channel banks for some sampling units (e.g., #11) in 2006 because of notable floods (early August 2006) that occurred after the original photography dates (April 2006).

All coordinates of the wetted perimeter and individual perimeters within each non-run mesohabitat were recorded with a backpack-mounted Pathfinder GPS Receiver and a Ranger Handheld Data Collector for reliable submeter (RMS) 2-D data collection with a published accuracy of about 20 cm RMS. The precision of GPS mapping allowed for accurate calculation of the area, even for small mesohabitats. Two crews worked simultaneously with GPS units to collect the perimeter information (i.e., one for wetted perimeter and one for mesohabitat perimeters). Run mesohabitat was, by default, all the remaining area after the non-run mesohabitat area was subtracted (based on GPS mapping). Surveyor flags and bamboo posts were used to delineate the perimeter of each mesohabitat, taking care not to enter or disturb the area that would later be

Table 1. Codes used for mesohabitat type classification in the Middle Rio Grande during this study.

MESOHABITAT TYPES	
BW	**Backwater-** a body of water, connected to the main channel, with no appreciable flow; often created by a drop in flow which partially isolates a former channel.
DE	**Debris-** any habitat that has associated organic cover (e.g., grasses, woody vegetation etc.).
PO	**Pool-** the portion of the river that is deep and with very low velocity compared to the rest of the channel.
RU	**Run-** a reach of relatively fast velocity water with laminar flow and a non-turbulent surface.
RI	**Riffle-** a shallow and high velocity habitat where the water surface is irregular and broken by waves; generally indicates gravel-cobble substrate.
SHPO	**Shoreline pool-** usually a shallower, very low velocity, area that is adjacent to shore of either the river channel margins or instream islands.
SHRU	**Shoreline run-** usually a shallower, relatively fast velocity, area that is adjacent to shore of either the river channel margins or instream islands.

sampled (It was determined that collecting fish prior to habitat mapping yielded less precise delineation of mesohabitats because the crew had to make immediate decisions as to the location of mesohabitat boundaries while actively sampling). Codes for spatial location (e.g., main channel left [ml], main channel right [mr], island #1 left [il-1] etc.) were used in addition to mesohabitat codes to facilitate later fish sampling of mapped locations. There were some minor changes in flow for some of the sampling units even during the same day. In these instances, a small fraction of the total fish sampling locations were shifted <1 m to ensure collection of fish in the same habitat conditions as were mapped. It was determined that even modest changes in flow between days could cause notable shifts in the location and physical parameters (e.g., depth and velocity) of individual mapped mesohabitat localities. Thus, habitat mapping and sampling for fish occurred sequentially on the same day.

Fish sampling and analysis

Surveyor flags were used to mark the start and stop points for each fish sample location. Likewise, GPS coordinates were acquired for each fish sample location. Each selected mesohabitat represented a discrete sample and the results (species composition, Rio Grande silvery minnow age structure, and number of individuals per species) of those samples were maintained accordingly. Scientific and common names of fishes in this report follow Nelson et al. (2004; Table 2). Common names are arranged in phylogenetic order and appear throughout this report in tables, figures, and text.

Fish collected from individual mesohabitats during all years were handled briefly for identification and enumeration, placed in one of several fine mesh (nylon) holding cages (= live-well) present at the sampling unit (in the river), and released near their site of capture after sampling had concluded. Prior to release, all Rio Grande silvery minnow collected were examined for Visible Implant Elastomer (VIE) tags (= stocked fish), measured (standard length range), and identified to age-class (based on standard length and past length-frequency histograms during the same time of year [unpubl. data]). Selected water quality parameters (temperature, conductivity, specific conductance, pH, salinity, and dissolved oxygen) were obtained for each sampling unit as well as digital photographs of physical river conditions.

Sampling was conducted within each 200-m unit, using a random stratified subset of the available non-run mesohabitats in 2008. This was in contrast to 2006 and 2007 when sampling efforts were extended to all available non-run mesohabitats. This change in protocol was necessary because of the greatly increased time required to complete closed mesohabitat samples at all selected locations in 2008. The length of each non-run mesohabitat type was measured during sampling (using GPS units) and a running tally of the total number of possible samples was recorded. Depletion samples were five meters in length with a five meter buffer on either side to minimize disturbance prior to sampling. At sampling units where there were five or fewer possible sample locations in a particular mesohabitat, all of the locations were sampled. At sampling units where there were >5 possible sample locations in a particular mesohabitat, a random selection (N = 5) of the total number of locations was sampled. The only exception to this sampling protocol was for shoreline run mesohabitats where 10 sample locations were selected at random and sampled. The increased sampling in shoreline run mesohabitats was implemented because this was the most common non-run mesohabitat present at all sampling units and was sometimes the only non-run mesohabitat available.

The low density of fish in runs, combined with its abundant availability (often >75%), also made it prudent to take random samples in this mesohabitat type in all years of the study. In contrast to the disjointed distribution of non-run mesohabitats, possible sampling locations for runs were distributed both longitudinally and laterally over a continuous area. Thus, the same GRTS method

Table 2. Scientific and common names and species codes of fish collected in the Middle Rio Grande from 1993 to 2008.

Scientific Name	Common Name	Code
Order Clupeiformes		
Family Clupeidae	herrings	
Dorosoma cepedianum	gizzard shad	(GZS)
Dorosoma petenense	threadfin shad	(TFS)
Order Cypriniformes		
Family Cyprinidae	carps and minnows	
Cyprinella lutrensis	red shiner [1]	(RDS)
Cyprinus carpio	common carp [1]	(CCA)
Gila pandora	Rio Grande chub	(RGC)
Hybognathus amarus	Rio Grande silvery minnow [1]	(RGM)
Pimephales promelas	fathead minnow [1]	(FHM)
Pimephales vigilax	bullhead minnow	(BHM)
Platygobio gracilis	flathead chub [1]	(FHC)
Rhinichthys cataractae	longnose dace [1]	(LND)
Family Catostomidae	suckers	
Carpiodes carpio	river carpsucker [1]	(RCS)
Catostomus commersonii	white sucker [1]	(WHS)
Ictiobus bubalus	smallmouth buffalo	(SMB)
Order Siluriformes		
Family Ictaluridae	North American catfishes	
Ameiurus melas	black bullhead	(BBH)
Ameiurus natalis	yellow bullhead	(YBH)
Ictalurus furcatus	blue catfish	(BCT)
Ictalurus punctatus	channel catfish [1]	(CCT)
Pylodictis olivaris	flathead catfish	(FCT)
Order Salmoniformes		
Family Salmonidae	trouts and salmons	
Oncorhynchus mykiss	rainbow trout	(RBT)
Salmo trutta	brown trout	(BNT)
Order Cyprinodontiformes		
Family Poeciliidae	livebearers	
Gambusia affinis	western mosquitofish [1]	(MOS)

Table 2. Scientific and common names and species codes of fish collected in the Middle Rio Grande from 1993 to 2008 (continued).

Scientific Name	Common Name	Code
Order Perciformes		
Family Percichthyidae	temperate basses	
Morone chrysops	white bass	(WHB)
Order Perciformes		
Family Centrarchidae	sunfishes	
Lepomis cyanellus	green sunfish	(GNS)
Lepomis macrochirus	bluegill	(BGL)
Micropterus salmoides	largemouth bass	(LMB)
Pomoxis annularis	white crappie	(WCR)
Pomoxis nigromaculatus	black crappie	(BCR)
Family Percidae	perches	
Perca flavescens	yellow perch	(YWP)
Perca macrolepida	bigscale logperch	(BLP)
Sander vitreus	walleye	(WLE)

[1] Focal taxa represent the 10 most abundant species present in recent Middle Rio Grande collections and are illustrated in monthly plots of data.

that was used to generate the list of spatially-balanced sampling units in the Middle Rio Grande was also employed to determine fish sampling locations for run mesohabitats in 2006, 2007, and 2008. For the purposes of this analysis, a series of ten transects (perpendicular to flow and spaced 20 m apart) were generated within ArcView. A unique identifying value was assigned to every available point along each transect, excluding non-run mesohabitats, at 2.5 m intervals. A total of 20 sampling start points in runs were generated based on the X, Y coordinates (e.g., X = 5.0 m from left shore, Y = 40 m from top of unit) of all possibilities. Sampling locations were kept consistent over time by using the same points selected using the GRTS method in the first year of sampling during subsequent years of sampling. In areas where samples could not be completed (e.g., shift in channel location, formation of islands, etc.), the nearest available GRTS points on the same transect were used.

Sampling in 2006, 2007, and 2008 was designed to investigate three possible sampling techniques for collecting fish and deriving an estimate of population size. The first year of the study (2006) was designed to use seining sampling techniques in open habitats employed as part of the long-term Population Monitoring Program (e.g., Dudley and Platania, 2008) along with select electrofishing/seining depletions of closed habitats. During the second year of the study (2007), the sampling techniques were expanded to include a formal comparison of depletion estimates in open and closed habitats in both run and non-run habitats using electrofishing/seining. The sampling techniques in 2008 were further refined, based on the results of the first two years of study, and included only electrofishing/seining sampling in closed habitats (both runs and non-runs).

Capture probability estimates derived during 2006 indicated that closed sampling in some mesohabitats would be beneficial for future sampling efforts. Shoreline run capture probability estimates were used for run mesohabitats in 2006 because of the low number of Rio Grande silvery minnow collected in runs. A similar situation occurred in pools (also not associated with the shoreline) where only a small number of individuals were collected and capture probability estimates in 2006 were based on only a few data points.

It was determined that more intense closed sampling in run and pool mesohabitats (not associated with the shoreline) would provide additional rigor to the population estimates generated in 2007. For closed sampling of run and pool mesohabiats, a box (2 m wide, 10 m long, and 1.5 m high) was constructed out of PVC (open-ended to allow rapid sinking and draining) and screened using small mesh (4.8 mm) seine material. All sides of the box (except the top and bottom) were screened with mesh to prevent the entrance or exit of fish. Lead weights attached to the mesh prevented the movement of fish underneath the sampling box. A seine bag (ca. 0.5 m long with 4.8 mm mesh) was added to the downstream panel of the box; this panel was modified so that it could be removed immediately after sampling was complete (i.e., trapping all fish inside the bag) while blocking the entrance or exit of fish during sampling. The sampling box was carried out over the water and then dropped quickly into place at the sampling location. Five personnel were required to operate the box under normal flow conditions (two to secure the box in place, two to operate the removable panel and collect the fish, and one to electrofish the inside of the box). The person with the electrofishing unit operated two wands (one on either side of the box) and moved slowly through the box until reaching the downstream end. During electrofishing, one person used a large dipnet to create additional flow within the box, if necessary, and to capture any stunned fish not carried into the downstream seine bag by the current. The downstream panel of the box was removed immediately after electrofishing was complete. Fish from individual collecting efforts using the sampling box were handled briefly for identification and enumeration, placed in one of several fine nylon mesh holding cages (= live-well) present at the sampling unit (in the river), and released near their site of capture after sampling had concluded. At sampling units where there were five or fewer pool mesohabitats, all of the locations were sampled. At sampling units where there were >5 pool mesohabitats, a random selection (N=5) of the total number of locations was sampled. A total of 20 closed samples in run mesohabitat were generally made for each sampling unit. For sampling units with a channel width that couldn't accommodate 20 run mesohabitat samples, the maximum number of available samples was taken.

A series of analyses and experiments were conducted in 2007 to assist in the continued refinement of sampling techniques. One concern from the first year of the study was that fish collected in run mesohabitats (as compared to non-run mesohabitats) might be particularly difficult to capture effectively and consistently using open seining sampling techniques. A further concern was that sampling in run mesohabitats did not yield adequate numbers of fish from which to derive a robust capture probability estimate. To address these concerns, a total of 20 box (closed samples) and 20 seining (open samples) in runs were made for each sampling unit in 2007. For sampling units with a channel width that couldn't accommodate 40 run mesohabitat samples, half of the samples were conducted with the box and half were seined. The densities of Rio Grande silvery minnow were then compared for the two classes (sampling unit and sampling technique {open vs. closed}) and analyzed by age-class (all ages, age-0, and age-1), using ANOVA to determine the significance of source variation for sampling unit, sampling technique, and the interaction between those two class variables.

Another experiment conducted in 2007 was designed to determine differences in capture probabilities between open and closed shoreline (i.e., non-run) mesohabitat sampling to possibly modify existing first-pass capture efficiencies in open samples. It was noted that some percentage of fish were missed on each sampling pass during closed sampling of non-run mesohabitats in 2006. This is common during any sampling for mobile organisms and forms the basis for calculating the mesohabitat-specific capture probability estimates. Unlike closed sampling, it is also possible that some unknown percentage of fish left the mesohabitat patch during or just prior to the first pass of open first-pass sampling. While it is expected that some fish will leave the mesohabitat during open sampling, densities were corrected by accounting for the difference in capture probabilities between open and closed samples. To test for these differences, mesohabitats were sampled at three locations in the Middle Rio Grande (Population Monitoring sampling units [#2 and #7] and Population Estimation sampling unit [#7]) over the course of six days. On day one (at each sampling unit), depletion sampling was conducted at 20-26 mesohabitat locations (half open samples and half closed samples). We employed the same depletion-sampling scheme where replicate samples were made in a single mesohabitat until less than 5% of the original number of fish captured on the first haul were captured on a subsequent haul. On day two, the same 20-26 mesohabitat locations were sampled but closed samples were taken where open samples were taken on day one and vice versa. Capture probability estimates were made for both open and closed samples using the same statistical techniques employed for the other depletion efforts.

For closed sampling of shoreline mesohabitats in 2007, sampling areas were blocked off (to prevent immigration or emigration) during depletion efforts by a panel (5 m long and 1.5 m high) that was constructed out of PVC (open-ended to allow rapid sinking and draining) and screened using small mesh (4.8 mm) seine material. The panel was screened with mesh to prevent the entrance or exit of fish. Lead weights attached to the mesh prevented the movement of fish underneath the sampling panel. A small mesh seine (4.8 mm), which was staked to bamboo posts and weighted, was used to close off the upstream portion of the panel. Two 3.1 m x 1.8 m small mesh (4.8 mm) seines (two-person) were used to close off the downstream portion of the panel. The panel and attached upstream seine were carried out over the water and then quickly dropped and staked into place at the sampling location (about 2 meters from the shoreline). At the same time, the two downstream seines were set into place and tucked inside a seine flap at the downstream portion of the panel (to ensure complete and simultaneous closure of the sample area). Five personnel were required to operate the shoreline sampler under normal flow conditions (two to secure the panel in place, two to operate the downstream seines, and one to electrofish the inside of the enclosure). The person with the electrofishing unit operated two wands (one on either side of the enclosure) and moved slowly through the box until reaching the downstream end. During electrofishing, one person used a large dipnet to create additional flow within the box, if necessary, and to capture any stunned fish not carried into the downstream seine bag by the current. The two downstream seines were rotated after each pass to allow for additional depletion sampling if necessary.

The final experiment conducted in 2007 involved the use of hatchery-raised Rio Grande silvery minnow (in closed depletion sampling efforts) to determine if there were differences between the capture probabilities of wild and stocked fish. The sampling protocol was based, in part, on the fact that power analyses indicated that large numbers of wild and hatchery individuals (N = 100 for each group) would be needed to detect differences (power>0.7) between groups (unpublished data). Sampling efforts with hatchery fish were used to determine the relative precision of capture probability estimates since the total number of individuals was know prior to sampling. A total of 200 hatchery individuals (marked with VIE tags) was released into 10 closed mesohabitats at Population Monitoring sampling unit #2. Stocked fish were given about six hours to acclimate to local river conditions before sampling commenced. Capture probability estimates for wild and hatchery fish were made for closed samples using the same statistical techniques employed for the other depletion efforts.

As part of the three-year Population Estimation Program pilot study, we used the final year (2008) to collect all data using the closed mesohabitat depletion sampling protocol that was developed and tested in 2007. Experiments to determine differences in capture probabilities estimates between open and closed mesohabitat sampling in 2007 yielded inconclusive results in non-run mesohabitats. However, similar experiments in run mesohabitats suggested that densities of fish were higher than expected when employing a closed depletion sampling protocol compared with an open first-pass sampling protocol (corrected with run-mesohabitat capture probability estimate). While closed mesohabitat depletion sampling in 2008 reduced the number and area of mesohabitats sampled (compared to either 2006 or 2007), it provided a useful point of reference to compare the costs and benefits of the different sampling regimes and statistical correction factors over the duration of the study.

Capture probability estimates were generated, based on depletion efforts, for all mesohabitat types sampled during the pilot study. Multiple depletion efforts within the same mesohabitat were taken when the abundance of Rio Grande silvery minnow collected on the first pass was adequate (i.e., ≥10 individuals) to obtain a reliable estimate of capture probability. In 2006 and 2007, depletions were made using both seines and electrofishing within enclosures for all non-run habitats but no depletions were made in run habitats because of inadequate numbers of Rio Grande silvery minnow. Capture probability estimates in 2008 were generated for the various mesohabitat types by using all closed habitat electrofishing depletion data that were available at the time this report was finalized (i.e., 2008 to 2010). For all years of the pilot study, we employed a depletion-sampling scheme where replicate depletion passes were made in a single mesohabitat until ≤5% of the original number of fish captured on the first pass or ≤4 individuals (whichever was higher) were captured on a subsequent pass. In most instances, this only required a second or third pass but sometimes required four passes. The collection of high numbers of Rio Grande silvery minnow in the first pass allowed for development of a more robust model. The Akaike Information Criterion (AIC; Akaike, 1973; Burnham and Anderson, 2002) using the Huggins removal estimator (Huggins, 1989, 1991) was used to generate the most parsimonious model based on the observed depletion data. The Huggins model, which is similar in approach to the Horvitz-Thompson sampling design, computes a population estimate for this type of removal study based on constant mesohabitat specific initial capture probabilities. Program MARK (White and Burnham, 1999) was used to compute all removal estimates.

Determining Occupancy Rates from Past Population Monitoring Data

Intensive sampling data from population monitoring efforts (repeated sampling efforts in November [2005-2008]) were used to generate estimates of site occupancy rates based on methods developed by MacKenzie et al. (2002, 2003, 2006). Objective 3 (Develop site occupancy rates of Rio Grande silvery minnow) enabled assessment of the likelihood of detecting the presence or absence of Rio Grande silvery minnow by calculating the detection history probability. The encounter history was computed using data that were collected during intensive repeated monitoring of the same seine haul locations during November (2005-2008). For the intensive sampling effort, units were sampled once per day for four days. A variety of mesohabitats were sampled on the first day and samples were taken at the same locations on subsequent days; in rare cases the location of the sample had to be shifted to a different area with similar mesohabitat conditions if there was a change in flow. This study was conducted using the same sampling protocols established for regular population monitoring efforts. These repeated samples were taken at our 20 Population Monitoring Program sampling units (Appendix C, Table C-1). The data were organized into categories based on the presence/absence of Rio Grande silvery minnow over the four day sampling effort. The encounter history was based on the presence of Rio Grande silvery minnow at individual mesohabitat locations. For example, an encounter history of 1101 meant that individuals were collected on days one, two, and four but not on day three. A higher proportion of presence encounters was interpreted as indicating that individuals were more consistently detected within the mesohabitat patch over time. The sampling unit was large enough (200 m) so that it was unlikely that the area would change in status from occupied to unoccupied among days. Additional assumptions included that there could be no false detections, that there could be mesohabitats where the species was present but undetected, and that species detection within a specific mesohabitat was independent of species detection at other mesohabitats. Cumulative frequency and percent columns were included in output to allow simple comparison between encounter histories. The probability of detection was calculated for Rio Grande silvery minnow at individual seine haul locations along with the standard error and confidence intervals, following methods of MacKenzie et al. (2006). Estimates of the probability of detection were computed for all individuals and then separately for the different age-classes using Program MARK (White and Burnham 1999).

Site occupancy estimates for each of the sampling units were calculated using probability of detection estimates. Site occupancy was the proportion of mesohabitat locations occupied relative to those surveyed. The November 2005-2008 Population Monitoring Program data sets were used for the purposes of calculating estimates of site occupancy. The site occupancy estimate for each sampling unit was based on the probability of detection estimate (and its associated variance) and the actual site occupancy data calculated from raw data. In this way, the site occupancy was corrected using the detection estimate (MacKenzie et al., 2006). A higher degree of consistency between days (either 0000 or 1111) will result in a site occupancy model that yields results that more closely match those obtained from the original estimate of site occupancy based on a single survey. The specific pattern of presence/absence (i.e., 0010 vs. 0101) was incorporated into the model to determine the likelihood of detection over time for a particular mesohabitat patch. A measure of the variance associated with the resulting site occupancy estimate based on mesohabitat locations occupied was calculated, following methods of MacKenzie et al. (2006) for single sample locality surveys.

In addition to calculating the site occupancy estimates within sampling units, we also constructed a multi-year statistical model based on the patterns of occupancy observed within and among sampling units from 2005 to 2008. Encounter histories were constructed on the presence or absence of Rio Grande silvery minnow at the Population Monitoring Program sampling units based on repeated sampling efforts (N = 4). The encounter history data from the 20 sampling units over time allowed for a robust-design model of occupancy (MacKenzie et al. 2003) to estimate the probability of occupancy each year (ψ_i, *i* = 1,2,3...), the probability of extinction given a sampling unit is occupied (ε_i, *i* = 2,3...), and the probability of colonization given a sampling unit is not occupied (γ_i, *i* = 2,3...). Site occupancy models were constructed for age-classes (all fish, age-0, age-1, age-2; each age class was a separate attribute group), with covariates of year (*y* = 2005 to 2008), and a discharge (*d*) covariate for measured flow (from the nearest USGS gauging station) during sampling. The Akaike Information Criterion corrected for small sample sizes (AIC_C; Akaike, 1973; Burnham and Anderson, 2002) was used to select the most parsimonious site occupancy model based on the encounter history data. In addition to the basic parameter estimates ordered by the age-class variable, detailed estimates of the probability of occupancy were also generated by group and year. All parameter estimates are presented with their associated measure of sampling variance (SE = standard error) and confidence intervals (LCI = 95% lower confidence interval, UCI = 95% upper confidence interval).

Population Estimation of Rio Grande Silvery Minnow

Generating population estimates from October data (2006 to 2008)

Population estimates of Rio Grande silvery minnow from individual sampling units were based on densities within occupied mesohabitats and the total available area of mesohabitats. Fish densities were calculated as the number of individuals collected divided by the area sampled ($\#/m^2$). Densities were grouped by mesohabitat for the purposes of estimating population size for a particular sampling unit. The final density calculation of individuals by mesohabitat was corrected using data generated from the depletion sampling model results (i.e., mesohabitat-specific capture probability estimate and the associated standard error). The number of sampled quadrats was determined for each mesohabitat category within a unit. The number of unsampled quadrats was calculated using the total unsampled area divided by the average area of the sampled quadrats. The total number of quadrats was the sum of the sampled and unsampled quadrats. Mesohabitat-specific calculations of density were made by multiplying the total number of quadrats by the average number of individuals collected per sampled quadrat and then dividing this product by the capture probability estimate. The associated standard errors for mesohabitat-specific calculations of density were made using detailed formulae outlined in Thompson (1992) and Skalski (1994). The total population estimate for each sampling unit was calculated as the sum of the population estimates for each mesohabitat. The standard error of the population estimate for each sampling unit was calculated by taking the sum of squares for all of the mesohabitat-specific standard errors (i.e., sampling variances) and then taking the square root of the resulting value. The upper and lower 95% confidence intervals were calculated around log-normal(N) and then converted back to linear scale; variance estimates were equivalent between scales (i.e., Var(log-normal($\hat{N}$)) = Var($\hat{N}$)/ $\hat{N}^2$)). The coefficient of variation (CV = ratio of the standard deviation to the mean) was calculated for the reach-specific average population estimates for all categories (i.e., all individuals vs. unmarked individuals and different age-classes).

The GRTS locality selection methodology allowed Rio Grande silvery minnow population estimates to be calculated for each of the three study reaches as well as the entire Middle Rio Grande study area. However, the resulting values do not necessarily sum to the same value (e.g., estimates of the three reaches won’t sum to the total study area) because the number of units per reach is not strictly proportional to the length of the reach. Estimates of Rio Grande silvery minnow (for different reaches, the total study area, different age-classes, and all individuals vs. unmarked individuals) were generated, assuming random sampling across all units.

Rio Grande silvery minnow population estimates generated in 2008 were based on global capture probability estimates that utilized all comparable closed habitat electrofishing data available at the time this report was finalized (i.e., 2008 to 2010). This approach resulted in more robust depletion models, as compared to using data from only a single year (i.e., 2006 or 2007), because the higher sample size among mesohabitats, especially rare mesohabitats, increased the statistical power of these analyses. The use of global capture probability estimates will also result in the continual refinement and presumed accuracy of population estimates made in the past. For this reason, the 2008 population estimates were recomputed with the new global capture probability estimates, and so the 2008 population estimates that appear in this report supersede those that appear in the previous annual report (i.e., Dudley et al., 2009). In contrast, the population estimates made in 2006 and 2007 will not be further refined because those data were primarily based on open habitat seining as opposed to closed habitat electrofishing (2008 to 2010) and, thus, the capture probability estimates would not be comparable to among years.

Comparing RGSM estimates from Population Monitoring and Population Estimation data

In addition to population estimates of Rio Grande silvery minnow generated from data collected during this study, population size was also estimated using Population Monitoring Program density data (#/m^2). Estimates were generated for each of the three study reaches (Angostura, Isleta, and San Acacia). Densities were grouped by mesohabitat for the purposes of estimating population size in a particular sampling reach. Unlike the robust capture probability estimates derived from the closed habitat electrofishing depletion data collected during the Population Estimation Program, the open habitat seining sampling methodology of the Population Monitoring Program did not yield data for calculating capture probability estimates. Thus, a conservative approach was taken in generating population estimates based on the Population Monitoring Program data by setting all capture probability estimates equal to one. This factor along with other factors described below likely contributed to a substantial underestimate of the population based on the Population Monitoring Program data.

An estimate of mesohabitat availability was necessary to complete the calculation of density using Population Monitoring Program data. However, as the perimeter of each sampling unit was not mapped during population monitoring efforts, the area of the wetted channel was estimated by multiplying the approximate width of the river channel by the length of the sampling unit. Nearly all non-run mesohabitats were measured and sampled in their entirety, with the exception of shoreline runs. The remaining available shoreline run mesohabitat was calculated as the approximate area of all shoreline mesohabitat minus the area of shoreline mesohabitat that was sampled. This was a conservative approach to estimating non-run mesohabitat area as no available areas were calculated for non-shoreline mesohabitats (e.g., backwaters, pools, shoreline pools) and because shoreline mesohabitat availability was not calculated around islands. Run mesohabitat area was calculated as the approximate area of all wetted mesohabitat minus the sum of the non-run mesohabitat and sampled run mesohabitat areas. Population estimates of Rio Grande silvery minnow (for different reaches, the total study area, different age-classes, and all individuals vs. unmarked individuals) were made using the same methods that were used for determining population size in the Population Estimation Program. However, the lack of detailed mesohabitat maps combined with the simplistic approach to calculating mesohabitat area likely resulted in a substantial underestimate of total mesohabitat availability, which likely contributed to an substantial underestimate of the population based on the Population Monitoring Program data.

The undertaking of this computational exercise was recommended by MRGESACP peer-review statisticians and biologists. Those individuals, as well as the authors of this study, clearly recognize that Population Monitoring Program generated population estimates are based on conservative estimates of mesohabitat area, rely on non-randomly selected sampling units, do not incorporate valid capture probability estimates, will violate numerous statistical assumptions, and thus must be viewed very cautiously. The estimates generated from the Population Monitoring Program data were not designed to provide the same high level of rigor inherent in the statistical methodology used to calculate estimates based Population Estimation Program data. The primary reason for performing this computational exercise was to determine if additional investigation should be pursued regarding a potential relationship between data collected as part of the Population Monitoring Program and the Population Estimation Program. Rather than a statistical comparison of the actual estimates of population obtained from the Population Monitoring Program and Population Estimation Program data, the purpose of this analysis was to compare the general population trends of Rio Grande silvery minnow over time as inferred from these two studies.

However, population estimates generated from the 2006 and 2007 Population Estimation Program data (part of an initial research study that employed different sampling methodologies) could not be included in any long-term trend comparison because those early data were not comparable with data collected in 2008. The data collected in 2006 and 2007 were part of an evolving research study to identify the most statistically valid sampling methodologies to estimate populations of Rio Grande silvery minnow. The change in methodology from primarily open habitat seine samples (2006 and 2007) to exclusively closed habitat electrofishing samples in 2008 precluded comparisons among population trends during this study. Population trend comparisons, derived from Population Estimation Program and Population Monitoring Program data collected in 2008 and 2009, do appear in the 2009 Rio Grande silvery minnow Population Estimation Program report (Dudley et al., 2011) and the 2010 report will present those trends over a three year period.

RESULTS

Fish Community

Population status

The ichthyofaunal community in the Middle Rio Grande between Angostura Diversion Dam and Elephant Butte Reservoir during October (2006 to 2008) was numerically dominated by cyprinids (Tables 3 to 5; Appendix D). The native ichthyofauna consisted of seven species (red shiner, Rio Grande silvery minnow, fathead minnow, flathead chub, longnose dace, river carpsucker, and bluegill) in 2006 and 2008 but included smallmouth buffalo in 2007. Red shiner was the most abundant native species collected in 2006 (N = 7,885) and 2007 (N = 18,826) but was the second most abundant species in 2008 (N = 909). Rio Grande silvery minnow varied widely in abundance among years (range = 339 to 3,122) and was the most abundant native species in 2008 (N = 1,576). Other commonly collected native species included fathead minnow and flathead chub. Longnose dace, rivercarpsucker (with the exception of 2007), smallmouth buffalo, and bluegill were often the least abundant native fishes. The most abundant introduced species collected in all years were common carp, white sucker, channel catfish, and western mosquitofish.

Abundance and distribution

The largest numbers of fish were collected in the Isleta Reach during all years of the study (N = 6,623 in 2006, N = 18,681 in 2007, and N = 1,771 in 2008; Tables 6 to 8). Fish were distributed unevenly within this reach, particularly in 2008. The Angostura Reach produced the second highest overall catch rates of fish in 2006 (N=2,718 in 19,994.3 m^2 sampled) and 2007 (N = 5,778 in 18,159.9 m^2 sampled). The San Acacia Reach produced the second highest overall catch rate of fish in 2008

Table 3. Summary of the Rio Grande silvery minnow Population Estimation Program fish collections from October 2006.

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT (%) OF TOTAL	FREQUENCY OF OCCURRENCE[2]	% FREQUENCY OCCURRENCE[2]
HERRINGS					
gizzard shad	I	—	0.00	—	—
CARPS AND MINNOWS					
red shiner	N	7,885	66.46	19	95
common carp	I	11	0.09	6	30
Rio Grande chub	N	—	0.00	—	—
Rio Grande silvery minnow	N	339	2.86	17	85
fathead minnow	N	593	5.00	15	75
bullhead minnow	I	—	0.00	—	—
flathead chub	N	587	4.95	15	75
longnose dace	N	44	0.37	6	30
SUCKERS					
river carpsucker	N	29	0.24	13	65
white sucker	I	10	0.08	5	25
smallmouth buffalo	N	—	0.00	—	—
BULLHEAD CATFISHES					
black bullhead	I	—	0.00	—	—
yellow bullhead	I	18	0.15	17	85
channel catfish	I	797	6.72	19	95
flathead catfish	I	1	0.01	1	5
TROUTS					
rainbow trout	I	—	0.00	—	—
brown trout	I	—	0.00	—	—
LIVEBEARERS					
western mosquitofish	I	1,545	13.02	14	70
TEMPERATE BASSES					
white bass	I	—	0.00	—	—
SUNFISHES					
green sunfish	I	—	0.00	—	—
bluegill	N	2	0.02	2	10
largemouth bass	I	1	0.01	1	5
white crappie	I	2	0.02	2	10
black crappie	I	—	0.00	—	—
PERCHES					
yellow perch	I	—	0.00	—	—
bigscale logperch	I	—	0.00	—	—
walleye	I	—	0.00	—	—
TOTAL		11,864			

[1] N = native; I = introduced
[2] Frequency and % frequency of occurrence are based on n=20 sample sites

Table 4. Summary of the Rio Grande silvery minnow Population Estimation Program fish collections from October 2007.

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT (%) OF TOTAL	FREQUENCY OF OCCURRENCE[2]	% FREQUENCY OCCURRENCE[2]
HERRINGS					
gizzard shad	I	--	0.00	--	--
CARPS AND MINNOWS					
red shiner	N	18,826	66.39	20	100
common carp	I	37	0.13	12	60
Rio Grande chub	N	--	0.00	--	--
Rio Grande silvery minnow	N	3,122	11.01	19	95
fathead minnow	N	273	0.96	14	70
bullhead minnow	I	--	0.00	--	--
flathead chub	N	852	3.00	16	80
longnose dace	N	39	0.14	6	30
SUCKERS					
river carpsucker	N	429	1.51	14	70
white sucker	I	24	0.08	6	30
smallmouth buffalo	N	1	0.00	1	5
BULLHEAD CATFISHES					
black bullhead	I	--	0.00	--	--
yellow bullhead	I	2	0.01	1	5
channel catfish	I	1,351	4.76	20	100
flathead catfish	I	--	0.00	--	--
TROUTS					
rainbow trout	I	--	0.00	--	--
brown trout	I	--	0.00	--	--
LIVEBEARERS					
western mosquitofish	I	3,397	11.98	18	90
TEMPERATE BASSES					
white bass	I	--	0.00	--	--
SUNFISHES					
green sunfish	I	--	0.00	--	--
bluegill	N	1	0.00	1	5
largemouth bass	I	2	0.01	1	5
white crappie	I	1	0.00	1	5
black crappie	I	—	0.00	—	—
PERCHES					
yellow perch	I	--	0.00	--	--
bigscale logperch	I	--	0.00	--	--
walleye	I	--	0.00	--	--
TOTAL		28,357			

[1] N = native; I = introduced
[2] Frequency and % frequency of occurrence are based on n=20 sampling units

Table 5. Summary of the Rio Grande silvery minnow Population Estimation Program fish collections from October 2008.

SPECIES	RESIDENCE STATUS[1]	TOTAL NUMBER OF SPECIMENS	PERCENT (%) OF TOTAL	FREQUENCY OF OCCURRENCE[2]	% FREQUENCY OCCURRENCE[2]
HERRINGS					
gizzard shad	I	--	0.00	--	--
CARPS AND MINNOWS					
red shiner	N	909	21.73	20	100
common carp	I	26	0.62	10	50
Rio Grande chub	N	--	0.00	--	--
Rio Grande silvery minnow	N	1,576	37.68	20	100
fathead minnow	N	329	7.87	12	60
bullhead minnow	I	--	0.00	--	--
flathead chub	N	251	6.00	18	90
longnose dace	N	9	0.22	3	15
SUCKERS					
river carpsucker	N	9	0.22	7	35
white sucker	I	13	0.31	5	25
smallmouth buffalo	N	--	0.00	--	--
BULLHEAD CATFISHES					
black bullhead	I	4	0.09	3	15
yellow bullhead	I	9	0.22	6	30
channel catfish	I	666	15.92	20	100
flathead catfish	I	13	0.31	3	15
TROUTS					
rainbow trout	I	--	0.00	--	--
brown trout	I	--	0.00	--	--
LIVEBEARERS					
western mosquitofish	I	363	8.68	17	85
TEMPERATE BASSES					
white bass	I	1	0.02	1	5
SUNFISHES					
green sunfish	I	--	0.00	--	--
bluegill	N	2	0.05	2	10
largemouth bass	I	--	0.00	--	--
white crappie	I	2	0.05	2	10
black crappie	I	--	0.00	--	--
PERCHES					
yellow perch	I	--	0.00	--	--
bigscale logperch	I	--	0.00	--	--
walleye	I	1	0.02	1	5
TOTAL		4,183			

[1] N = native; I = introduced
[2] Frequency and % frequency of occurrence are based on n=20 sampling units

Table 6. Summary of Rio Grande silvery minnow (including marked individuals) and total fish abundance and sampling effort, by sampling unit and reach, during the 2006 Rio Grande silvery minnow Population Estimation Program.

REACH Sampling Unit and Name	TOTAL NUMBER OF RGSM	TOTAL NUMBER OF MARKED RGSM	TOTAL NUMBER OF ALL FISH	SAMPLING EFFORT (m^2)
ANGOSTURA REACH				
1 Bernalillo	76	63	831	3,104,8
2 Paseo del Norte upper	26	—	437	3,856.8
3 Paseo del Norte lower	56	1	541	4,339.7
4 Rio Bravo upper	—	—	4	2,556.9
5 Rio Bravo middle	7	—	202	3,220.8
6 Rio Bravo lower	1	—	703	2,915.5
Angostura Reach Total	166	64	2,718	19,994.3
ISLETA REACH				
7 Los Lunas	13	—	1,914	4,993.3
8 Belen	19	—	1,298	3,769.1
9 Jarales	9	—	2,163	2,602.3
10 Bernardo	1	—	1,073	1,391.4
11 South of Bernardo	2	1	175	3,988.0
Isleta Reach Total	44	—	6,623	16,744.1
SAN ACACIA REACH				
12 S of San Acacia	4	4	106	2,810.5
13 Socorro	22	—	948	2,822.8
14 San Antonio	—	—	33	3,224.3
15 Bosque del Apache	5	—	85	1,933.0
16 S of Bosque del Apache	90	—	617	1,969.9
17 San Marcial	—	—	359	2,010.9
18 S of San Marcial	1	—	215	3,826.8
19 S of LFCC Return	6	—	107	5,581.6
20 S of Site 19	1	—	53	2,667.2
San Acacia Reach Total	129	4	2,523	26,846.9
MONTHLY TOTALS	339	69	11,864	63,585.4

Table 7. Summary of Rio Grande silvery minnow (including marked individuals) and total fish abundance and sampling effort, by sampling unit and reach, during the 2007 Rio Grande silvery minnow Population Estimation Program.

REACH Sampling Unit and Name		TOTAL NUMBER OF RGSM	TOTAL NUMBER OF MARKED RGSM	TOTAL NUMBER OF ALL FISH	SAMPLING EFFORT (m^2)
ANGOSTURA REACH					
2	Paseo del Norte upper	150	-	822	2,584.964
3	Paseo del Norte lower	254	-	1,309	6,319.197
4	Rio Bravo upper	23	-	919	3,078.569
5	Rio Bravo middle	51	-	1,194	3,545.019
6	Rio Bravo lower	77	-	1,534	2,632.178
	Angostura Reach Total	555	0	5,778	18,159.927
ISLETA REACH					
7	Los Lunas	1,925	-	3,652	3,633.836
8	Belen	112	-	2,961	1,205.926
9	Jarales	158	-	5,137	3,910.236
9_5	Bernardo	101	11	4,272	2,274.752
10	S of Bernardo	231	1	2,418	2,813.585
11	Sevilleta	4	-	241	3,084.615
	Isleta Reach Total	2,531	12	18,681	16,922.950
SAN ACACIA REACH					
12	S of San Acacia	7	-	418	2,506.894
13	Socorro	12	2	155	3,187.863
14	San Antonio	4	-	157	1,685.933
15	Bosque del Apache	1	-	476	1,900.724
16	S of Bosque del Apache	3	-	551	2,917.638
17	San Marcial	3	-	498	2,485.861
18	S of San Marcial	1	-	1,161	3,668.971
19	S of LFCC Return	5	-	304	2,620.499
20	S of Site 19	0	-	178	2,354.438
	San Acacia Reach Total	36	2	3,898	23,328.821
MONTHLY TOTALS		3,122	14	28,357	58,411.7

Table 8. Summary of Rio Grande silvery minnow (including marked individuals) and total fish abundance and sampling effort, by sampling unit and reach, during the 2008 Rio Grande silvery minnow Population Estimation Program.

REACH Sampling Unit and Name		TOTAL NUMBER OF RGSM	TOTAL NUMBER OF MARKED RGSM	TOTAL NUMBER OF ALL FISH	SAMPLING EFFORT (m^2)
ANGOSTURA REACH					
2	Paseo del Norte upper	47	-	141	328.38
3	Paseo del Norte lower	175	-	427	317.08
4	Rio Bravo upper	3	-	93	288.95
5	Rio Bravo middle	20	-	147	448.43
6	Rio Bravo lower	34	-	297	323.94
	Angostura Reach Total	279	0	1,105	1,706.78
ISLETA REACH					
7	Los Lunas	440	-	685	589.61
8	Belen	76	-	224	540.47
9	Jarales	27	-	162	441.40
9_5	Bernardo	41	-	302	407.33
10	S of Bernardo	2	-	154	316.52
11	Sevilleta	100	-	244	452.97
	Isleta Reach Total	685	0	1,771	2,748.30
SAN ACACIA REACH					
12	S of San Acacia	18	-	132	325.43
13	Socorro	167	-	269	456.61
14	San Antonio	22	-	164	316.40
15	Bosque del Apache	10	-	132	291.50
16	S of Bosque del Apache	106	-	138	422.69
17	San Marcial	161	-	228	327.43
18	S of San Marcial	55	-	96	317.36
19	S of LFCC Return	36	-	76	156.17
20	S of Site 19	36	-	72	275.39
	San Acacia Reach Total	611	0	1,307	2,888.99
MONTHLY TOTALS		1,576	0	4,183	7,344.08

(N = 1,307 in 2,888.99 m^2 sampled). The distribution of fish within the Angostura and San Acacia reaches was uneven with the highest densities of fish generally in the upper portion of each reach.

The fish composition and species-specific relative abundance of the three sampling reaches varied considerably (Figures 4 to 6). The relative abundance of species in the Angostura Reach varied among years and was relatively uneven. The most commonly collected species included red shiner, Rio Grande silvery minnow, fathead minnow, flathead chub, channel catfish, and western mosquitofish. The most abundant species changed for each year (western mosquitofish in 2006, red shiner in 2007, and Rio Grande silvery minnow in 2008). In the Isleta Reach, red shiner dominated the catch in 2006 and 2007 but Rio Grande silvery minnow was the most abundant species in 2008. The ichthyofaunal composition over the course of the study was similar to the Angostura Reach. The San Acacia Reach was dominated by red shiner in 2006 and 2007 but was more varied in 2008. Rio Grande silvery minnow was the most abundant taxon in this reach during 2008. Other commonly collected fishes in the San Acacia Reach included flathead chub, channel catfish, and western mosquitofish.

Rio Grande silvery minnow was found in moderate densities throughout the study area (Figures 7 to 9). In 2006, Rio Grande silvery minnow was found in the highest densities in the Angostura and San Acacia reaches. This pattern was reversed in 2007 and 2008 when the highest densities of Rio Grande silvery minnow were recorded in the Isleta Reach. The upper portions of each of the sampling reaches often yielded the highest densities of Rio Grande silvery minnow.

Depletion Sampling

Multiple seine haul samples within discrete mesohabitats were used to generate depletion model estimates. In 2006 and 2007, the best model for the seine haul data was by mesohabitat only (based on the lowest AIC_C value) and was supported by a high model weight (Tables 9 and 10). The second best model was by mesohabitat and location combined, but the model weight was substantially lower (0.018) than that for the mesohabitat-only model. The capture probability estimates (i.e., proportion of fish removed per seine haul) for the different mesohabitats varied from 0.241 (backwaters) to 0.823 (shoreline pools). Low numbers of Rio Grande silvery minnow in offshore pools (PO) precluded the calculation of a rigorous capture probability estimate for this mesohabitat during 2006. However, additional data were collected during 2007 in pool mesohabitat, which greatly reduced the variability and provided a more precise capture probability. The associated standard errors for estimates were consistent between mesohabitats and ranged between 0.044 and 0.076. Riffles (RI) did not yield Rio Grande silvery minnow and so capture probability was not estimated in this mesohabitat. Debris piles (DE) almost invariably formed pools along the shoreline of the main bank or islands and so the capture probability estimate for SHPO was used for this mesohabitat; low densities of fish in DE mesohabitat precluded a separate calculation. In 2006, main channel runs did not yield adequate numbers of Rio Grande silvery minnow to calculate a capture probability estimate; values for SHRU were used for this mesohabitat.

A series of experiments were conducted in 2006 and 2007 to access the influence of different sampling techniques (i.e., seining vs. electrofishing and open vs. closed sampling) on capture probability estimates and associated standard errors. In 2006, analysis of electrofishing data yielded two models (equal capture probability among mesohabitats and by mesohabitat only) with relatively high model weights. The model using location had a low weight (0.019). The capture probability estimate for the first model was 0.423 with a standard error of 0.067. Capture probability estimates for the mesohabitat model ranged between 0.247 (shoreline pools) and 0.729 (shoreline runs). Standard errors were higher in all cases than those recorded from the seining depletion data.

In 2007, there were differences in mean densities of Rio Grande silvery minnow between open and closed samples made in run habitats for individual sampling units and for all sampling

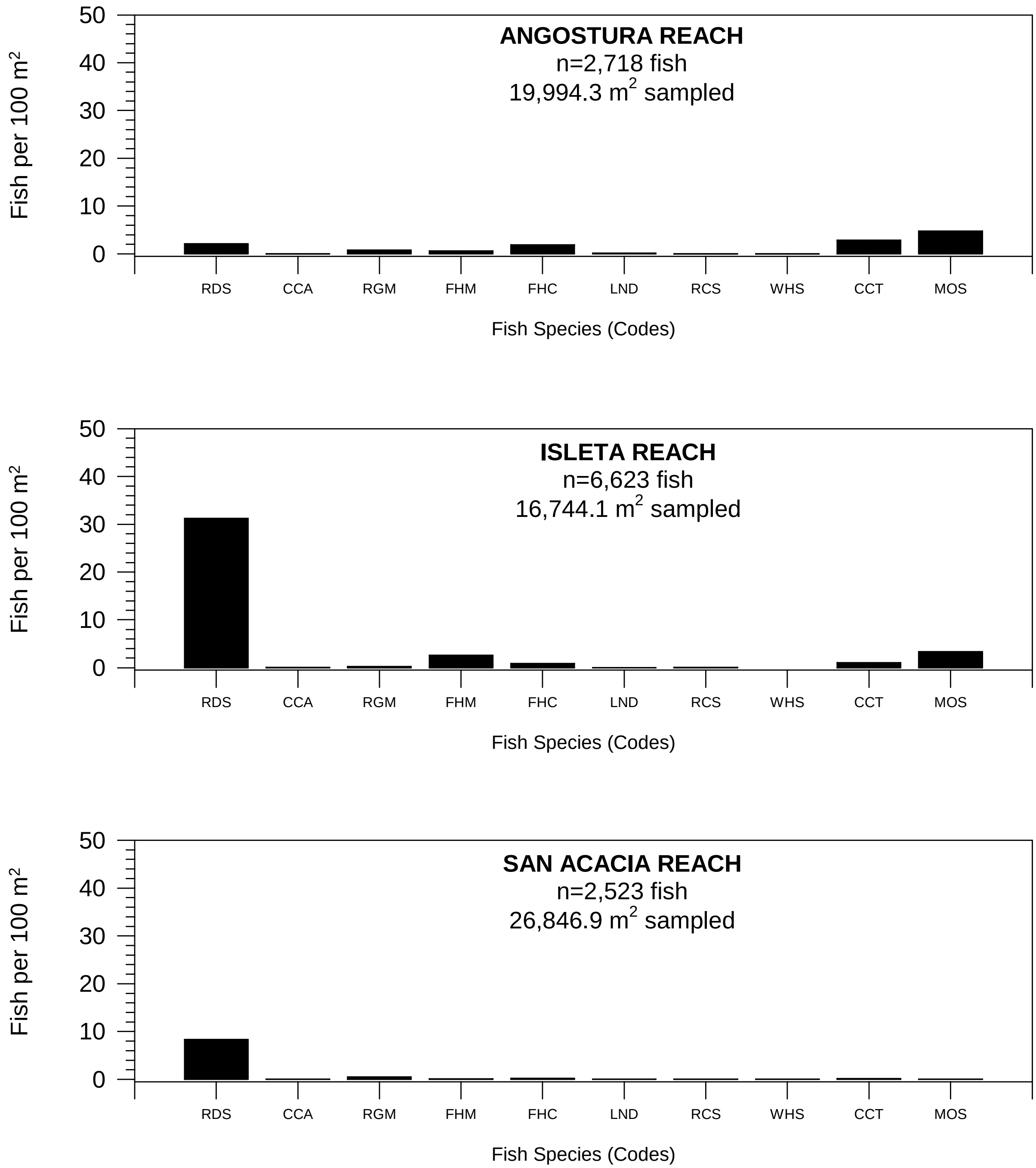


Figure 4. Catch rates, for the 10 focal species, by river reach during October 2006 at Rio Grande silvery minnow Population Estimation Program sampling units (see Table 2 for fish species codes).

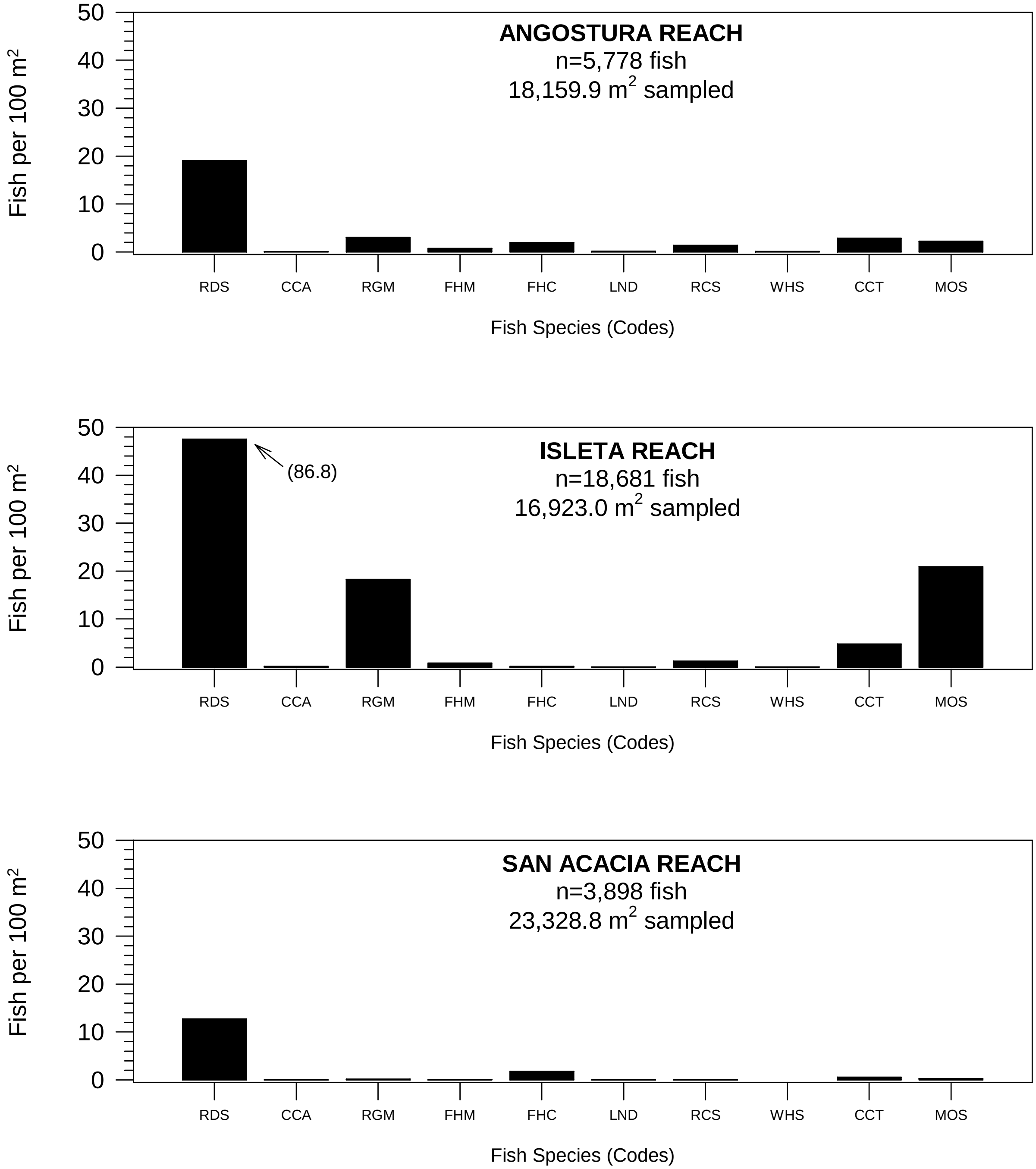


Figure 5. Catch rates, for the 10 focal species, by river reach during October 2007 at Rio Grande silvery minnow Population Estimation Program sampling units (see Table 2 for fish species codes).

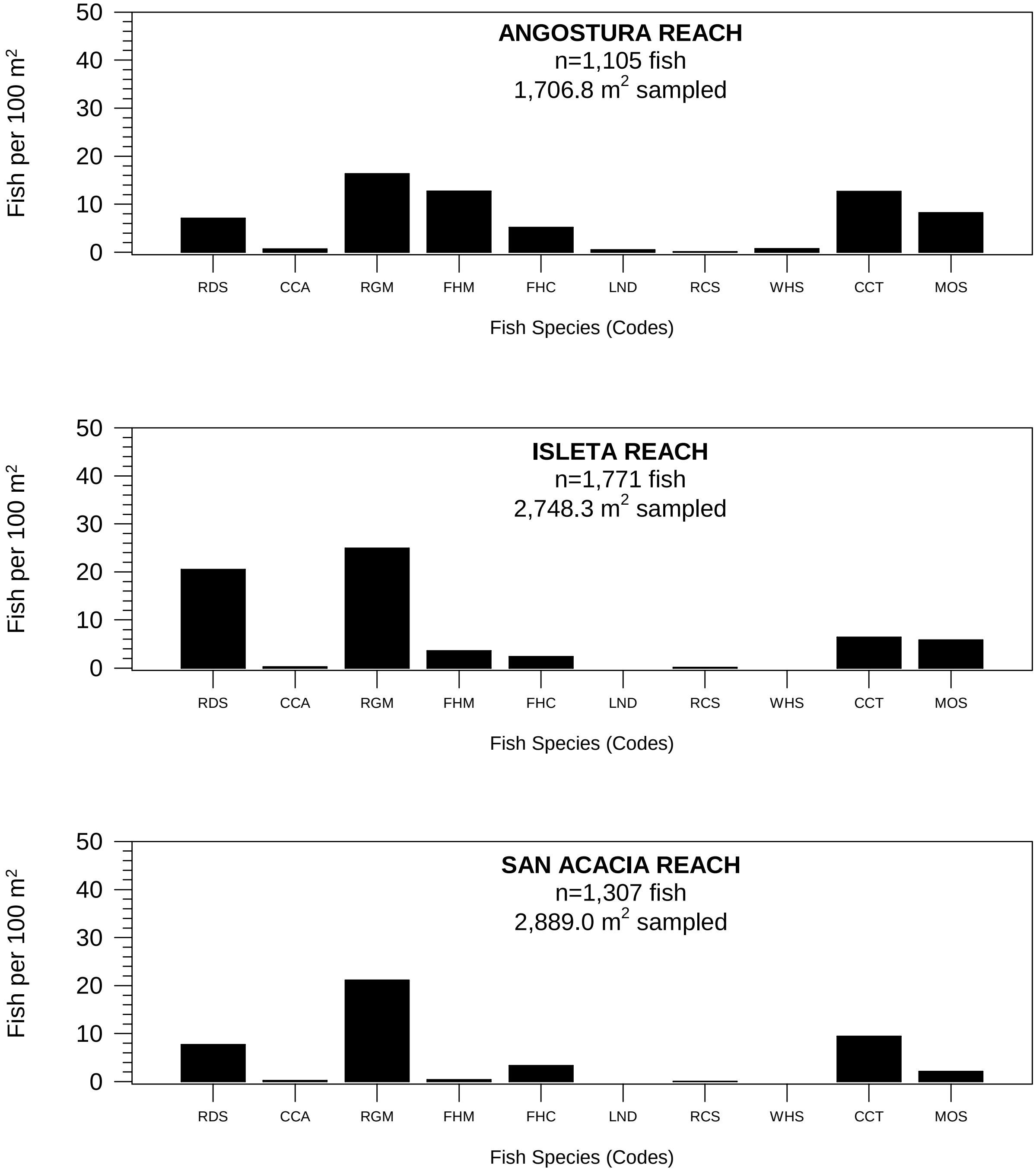


Figure 6. Catch rates, for the 10 focal species, by river reach during October 2008 at Rio Grande silvery minnow Population Estimation Program sampling units (see Table 2 for fish species codes).

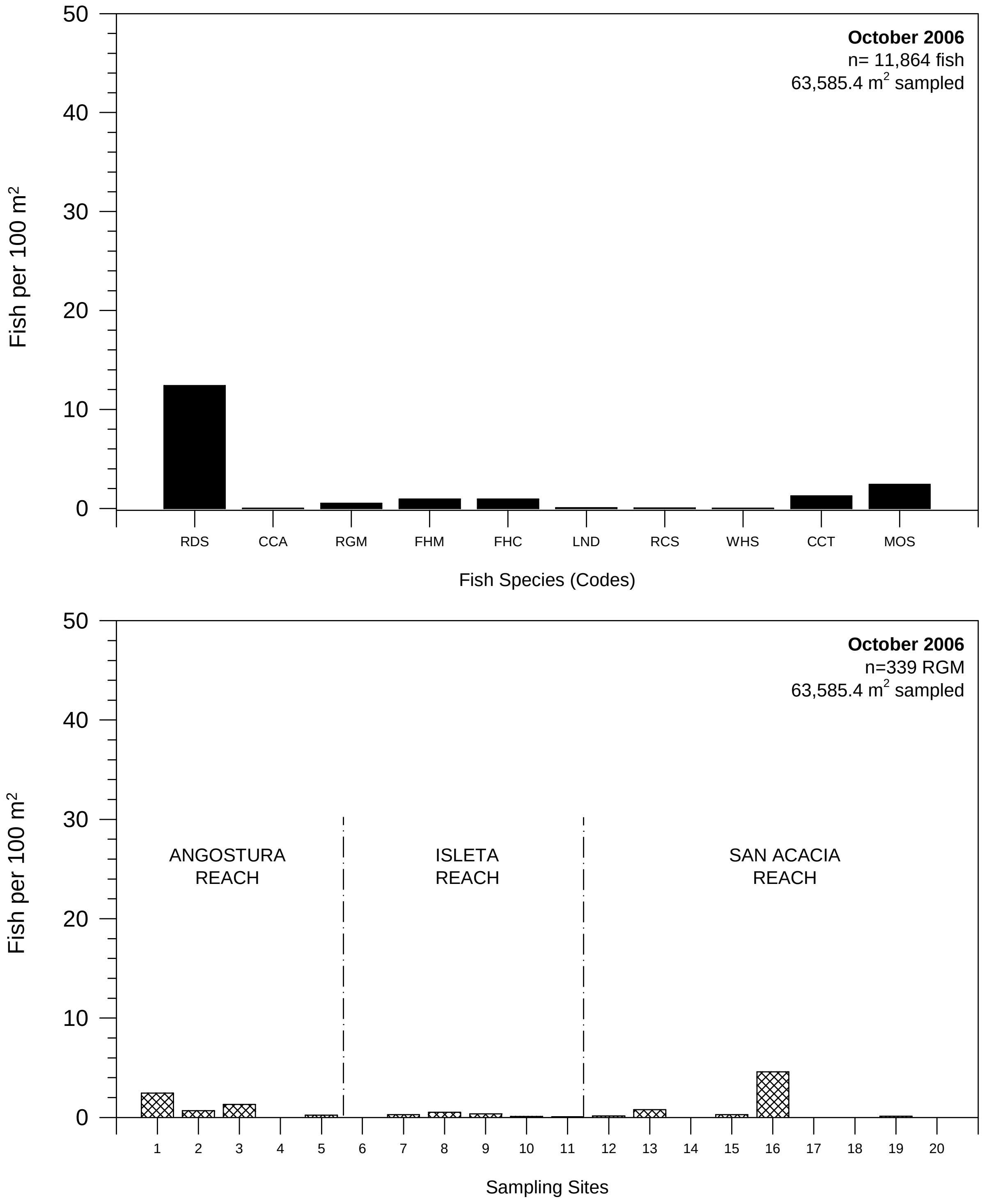


Figure 7. Catch rates for ten focal species (upper graph*), including Rio Grande silvery minnow, (RGM; lower graph*) during October 2006 at Rio Grande silvery minnow Population Estimation Program sampling segments (see Table 2 for fish species codes).

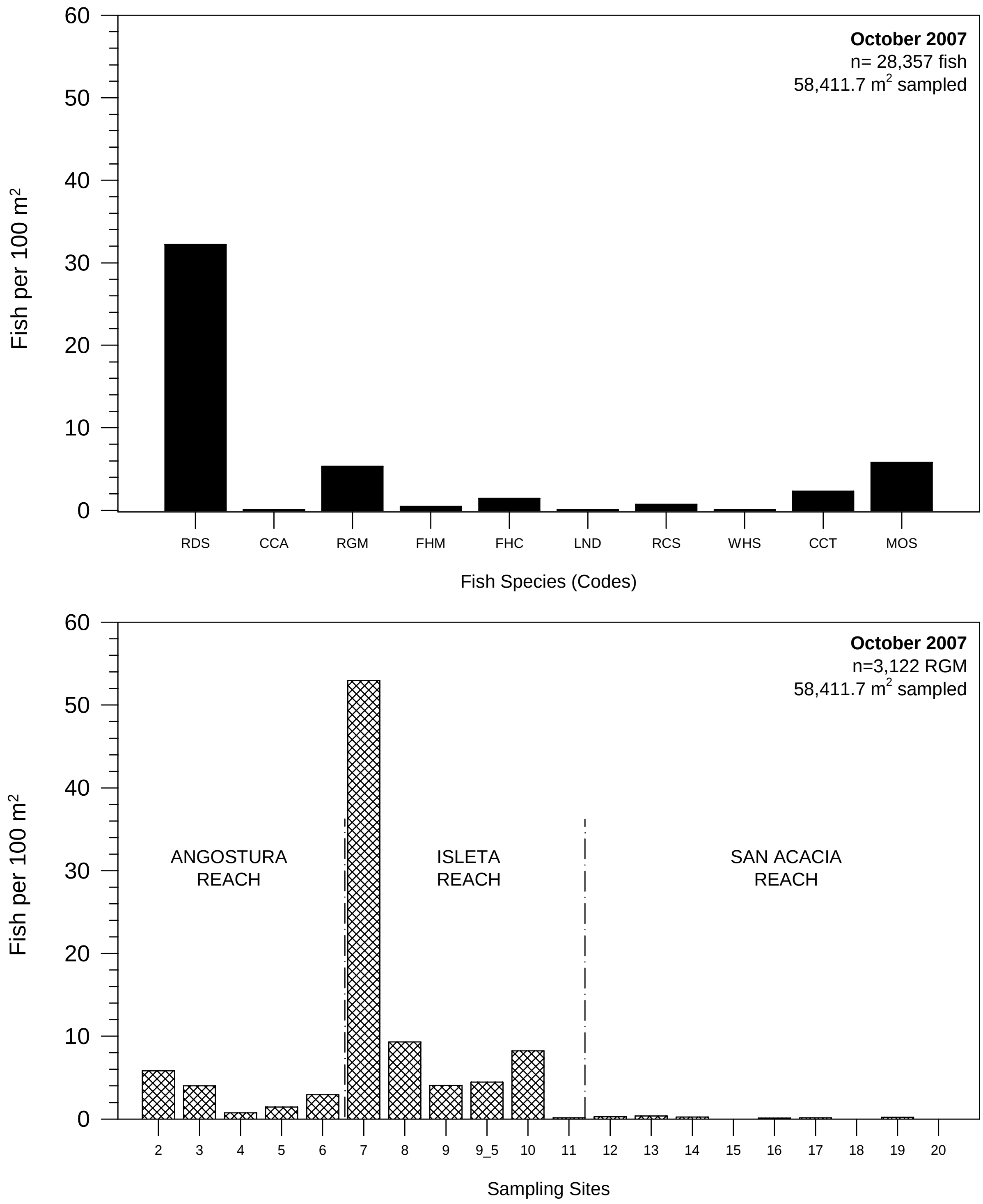
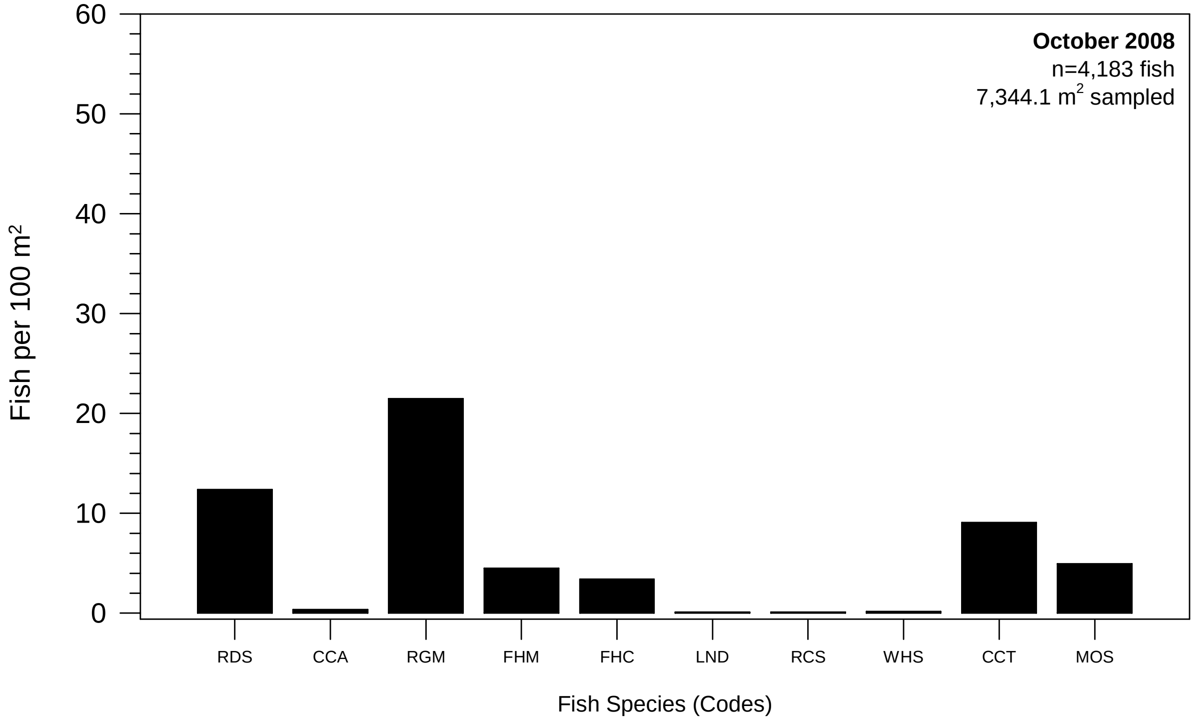


Figure 8. Catch rates for ten focal species (upper graph), including Rio Grande silvery minnow, (RGM; lower graph) during October 2007 at Rio Grande silvery minnow Population Estimation Program sampling units (see Table 2 for fish species codes).



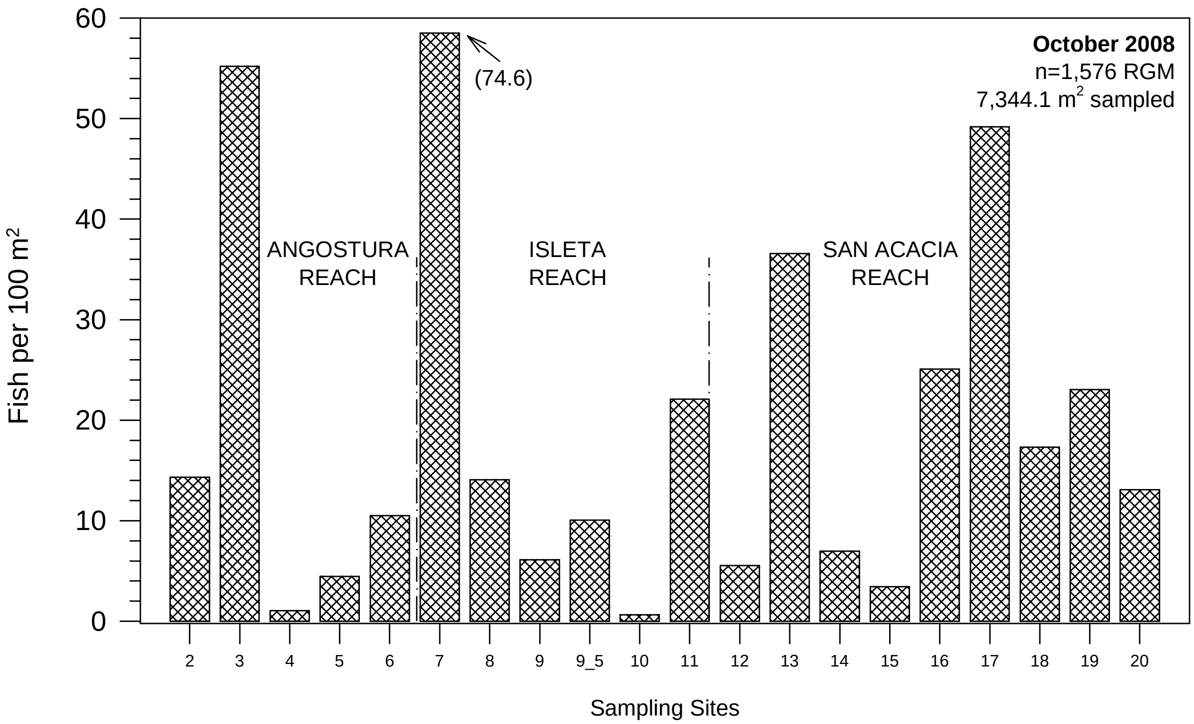


Figure 9. Catch rates for ten focal species (upper graph), including Rio Grande silvery minnow, (RGM; lower graph) during October 2008 at Rio Grande silvery minnow Population Estimation Program sampling units (see Table 2 for fish species codes).

Table 9. Rio Grande silvery minnow depletion removal analysis and modeling results for seining and electrofishing data collected from multiple mesohabitat types and locations in the Middle Rio Grande (2006).

RGSM seining data

Models	AICc	Delta AICc	AICc Weights	Model Likelihood	Number of Parameters	Deviance
A-{*Mesohabitat**Huggins}	312.6662	0	0.9822	1	4	697.2313
B-{Location*Huggins}	320.6828	8.0166	0.0178	0.0182	20	672.5193
C-{Huggins}	360.5569	47.8907	0	0	1	751.1543

A-{*Mesohabitat**Huggins}	Capture Probability Estimate	Standard Error of Estimate	Lower 95% CI of Estimate	Upper 95% CI of Estimate
BW	0.2412	0.0715	0.1288	0.4061
PO	0.2565	0.2100	0.0383	0.7492
SHPO	0.8231	0.0438	0.7207	0.8936
SHRU	0.7192	0.0760	0.5506	0.8427

RGSM electrofishing data

Models	AICc	Delta AICc	AICc Weights	Model Likelihood	Number of Parameters	Deviance
A-{*Huggins*}	140.3446	0	0.5230	1	1	196.4434
B-{*Mesohabitat**Huggins}	140.5698	0.2252	0.4673	0.8935	3	192.6048
C-{Location*Huggins}	148.3263	7.9817	0.0097	0.0185	12	181.4148

A-{*Huggins*}	Capture Probability Estimate	Standard Error of Estimate	Lower 95% CI of Estimate	Upper 95% CI of Estimate
p	0.4234	0.0667	0.3007	0.5564

B-{*Mesohabitat**Huggins}	Capture Probability Estimate	Standard Error of Estimate	Lower 95% CI of Estimate	Upper 95% CI of Estimate
BW	0.4381	0.0791	0.2934	0.5941
SHPO	0.2466	0.1638	0.0549	0.6482
SHRU	0.7299	0.1514	0.3750	0.9241

Table 10. Rio Grande silvery minnow depletion removal analysis and modeling results for seining data collected from multiple mesohabitat types and locations in the Middle Rio Grande (2007).

RGSM depletion data

Models	AICc	Delta AICc	AICc Weights	Model Likelihood	Number of Parameters	Deviance
A-{Mesohabitat}	312.6662	0	0.9822	1	4	697.2313
B-{Mesohabitat+Location}	320.6828	8.0166	0.0178	0.0182	20	672.5193
C-{Groups}	360.5569	47.8907	0	0	1	751.1543

A-{Mesohabitat}	Capture Probability Estimate	Standard Error of Estimate	Lower 95% CI of Estimate	Upper 95% CI of Estimate
BW	0.2412	0.0715	0.1288	0.4061
PO	0.6878	0.0509	0.5806	0.7780
SHPO	0.8231	0.0438	0.7207	0.8936
SHRU	0.7192	0.0760	0.5506	0.8427

units combined. However, there were also differences in the densities of Rio Grande silvery minnow among sampling units. The most appropriate comparison, given the above observation, was between open and closed samples made at an individual sampling unit. This comparison (interaction of sampling unit and sampling technique) yielded a significant difference ($F = 6.61$; $p < 0.0001$); the mean density of Rio Grande silvery minnow was higher in the closed samples than in the open samples (correction factor = 4.26). However, there were exceptions to this trend when comparing individual sampling units (i.e., sometimes the open sampling method yielded more fish than did the closed sampling method). For all sampling units combined, the open sampling method yielded a lower density of Rio Grande silvery minnow (N = 284, mean density = 1.60/100m^2, SD = 5.23) than did the closed sampling method (N = 276, mean density = 6.80/100m^2, SD = 21.74). When examining the difference between open and closed samples for the different age-classes, a similar pattern emerged. Age-0 individuals had lower ($F = 6.37$; $p < 0.0001$) densities in open samples (N = 284, mean density = 1.55/100m^2, SD = 5.13) than in closed samples (N = 276, mean density = 6.69/100m^2, SD = 21.63). Age-1 individuals also had lower ($F = 4.08$; $p < 0.0001$) densities in open samples (N = 284, mean density = 0.06/100m^2, SD = 0.37) than in closed samples (N = 276, mean density = 0.11/100m^2, SD = 1.08). Based on differences between the open and closed samples, we used only the closed sample data to estimate the densities of Rio Grande silvery minnow in runs in 2007. To facilitate a general comparison among the 2006 and 2007 Population Estimate Program data sets, we used the correction factor of 4.26 (based on the statistical comparison of open vs. closed sampling in runs during 2007) to adjust observed densities of Rio Grande silvery minnow in open run samples during 2006.

Additional experiments were conducted in 2007 to further refine the capture probability estimates in the non-run (BW, PO, SHPO, SHRU) mesohabitats. However, comparisons between open and closed sampling efforts produced inconclusive results from the three sampling units. Two of the three localities (Population Monitoring sampling units [#2 and #7]) did not yield adequate numbers of Rio Grande silvery minnow (in either open or closed habitats) to conduct a rigorous comparison of population estimates using the open or closed sampling methods. The other locality (Population Estimation sampling unit [#7]) yielded modest numbers of Rio Grande silvery minnow. The AIC_C model results suggest that the sampling method (open vs. closed) was having an effect on the estimate of *p* (Table 11). The most parsimonious model with method as an effect (Model B) yielded a beta parameter estimate that did not overlap with zero (indicating a significant effect). While Model C exhibited a high but nonsignificant estimate because of the confounding effect of captures within the various habitats, the other two models (Models D and E) demonstrated a significant effect of sampling method on the estimate of p. The large differences among locations resulted in a far lower AIC_C model (Model B = 1,141.71) with a method effect than the other possible models with a method effect (Models C = 1,165.73, D = 1,166.62, and E = 1,172.84). Despite a sampling method effect on the estimate of *p*, individual comparison of population estimates based on sampling method did not demonstrate a consistent pattern. Of the 12 comparisons between mesohabitat patches that yielded estimates of >5 individuals total, five were nonsignificant, four had a significantly higher estimate for the closed habitats, and three had a significantly higher estimate for the open habitats.

The capture probability estimates for hatchery Rio Grande silvery minnow in 2007 were higher for all mesohabitats as compared to wild Rio Grande silvery minnow (Table 12). The AIC_C model suggested strong differences among sample location and between the interaction of type (hatchery and wild) and mesohabitat. The largest significant difference (based on a comparison of the upper and lower confidence intervals) in capture probability between hatchery and wild fish (0.7417 and 0.2412, respectively) was for backwater mesohabitat. The other significant difference was for pool mesohabitat (hatchery = 0.8585 and wild = 0.6878). While capture probabilities in both shoreline pools and runs were slightly higher for hatchery fish than for wild fish, neither of these

Table 11. Rio Grande silvery minnow depletion removal analysis and modeling results for open and closed sampling data collected from multiple mesohabitat types and locations at Population Estimation sampling unit #7 (2007).

RGSM open vs. closed depletion data

Models	AICc	Delta AICc	AICc Weights	Model Likelihood	Number of Parameters	Deviance
A-{Groups}	1136.3690	0	0.9170	1	33	2734.3322
B-{Location+Method}	1141.1730	4.8040	0.0830	0.0905	14	2777.7410
C-{Habitat*Method}	1165.7341	29.3651	0	0	5	2820.4205
D-{Habitat+Method}	1166.6194	30.2504	0	0	4	2823.3125
E-{Method}	1172.8402	36.4712	0	0	2	2833.5424

Models with a Method Effect	Beta Estimate	Standard Error of Estimate	Lower 95% CI of Estimate	Upper 95% CI of Estimate
B-{Location+Method}	1.7135	0.3313	1.0642	2.3628
C-{Habitat*Method}	4.7626	221.7005	-429.7704	439.2955
D-{Habitat+Method}	1.4639	0.2768	0.9215	2.0063
E-{Method}	1.3611	0.2765	0.8192	1.9030

Table 12. Wild vs. hatchery Rio Grande silvery minnow depletion removal analysis and modeling results for seining data collected from multiple mesohabitat types and locations in the Middle Rio Grande (2007).

RGSM depletion data (Wild vs. Hatchery)

Models	AICc	Delta AICc	AICc Weights	Model Likelihood	Number of Parameters	Deviance
A-{Location}	**1121.2497**	**0**	**1**	**1**	**31**	**5370.6024**
B-{Type*Mesohabitat}	**1159.8802**	**38.6305**	**0**	**0**	**8**	**5455.4859**
C-{Type+Mesohabitat}	**1167.9860**	**46.7363**	**0**	**0**	**5**	**5469.6033**
D-{Type}	**1218.3405**	**97.0908**	**0**	**0**	**2**	**5525.9643**
E-{Mesohabitat}	**1225.3781**	**104.1284**	**0**	**0**	**4**	**5528.9980**

B-{Type*Mesohabitat}	Capture Probability Estimate	Standard Error of Estimate	Lower 95% CI of Estimate	Upper 95% CI of Estimate
Type=Wild RGSM				
BW	**0.2412**	**0.0715**	**0.1288**	**0.4061**
PO	**0.6878**	**0.0509**	**0.5806**	**0.7780**
SHPO	**0.8231**	**0.0438**	**0.7207**	**0.8936**
SHRU	**0.7192**	**0.0760**	**0.5506**	**0.8427**
Type=Hatchery RGSM				
BW	**0.7417**	**0.0236**	**0.6928**	**0.7851**
PO	**0.8585**	**0.0307**	**0.7872**	**0.9087**
SHPO	**0.9059**	**0.0373**	**0.8033**	**0.9578**
SHRU	**0.7766**	**0.0353**	**0.6998**	**0.8382**

comparisons was significantly different. A total of 200 marked Rio Grande silvery minnow were released into each of the 10 mesohabitats used in this experiment. However, problems were encountered with stocked fish schooling into the corners of the block nets that were set in areas with any measurable water velocity (even after the acclimation period). This precluded making an accurate estimation of population size for habitats where there was flow. The only area where this did not occur was in a backwater where there was no perceptible water velocity. The population estimate for this habitat was 194.1469 (SE = 0.3921) with a 95% LCI of 194.0086 and UCI of 196.5067.

Based on results from the 2006 and 2007 depletion experiments, only closed mesohabitat depletion sampling with electrofishing was used in 2008. Multiple depletion passes within discrete mesohabitats were used to generate depletion model estimates using closed habitat electrofishing data collected from 2008 to 2010 (Table 13). The best model for the mesohabitat-specific depletion data (based on the lowest AIC_C value) was by mesohabitat and location (for BW, PO, SHPO, and SHRU) and was supported by a high model weight. Riffles (RI) did not yield Rio Grande silvery minnow and so capture probability could not be estimated in this mesohabitat. Debris piles (DE) almost invariably formed pools along the shoreline of the main bank or islands and so the capture probability estimate for SHPO was used for this mesohabitat; low densities in DE mesohabitat precluded a separate calculation. The second best model (for BW, PO, SHPO, and SHRU) was by mesohabitat only but the model weight was substantially lower than the mesohabitat and location model. The best model for RU mesohabitat samples was by mesohabitat only and the second best model was by mesohabitat and location. For habitats where capture probabilities varied by location, a Bayesian hierarchical was used to estimate the mean across locations, with this mean used as the habitat-specific capture probability. The capture probability estimates (i.e., proportion of fish removed per depletion pass) for the different mesohabitats ranged from 0.6858 (shoreline pools) to 0.8444 (runs). The associated standard errors for estimates were consistent among mesohabitats and ranged from 0.0157 to 0.0382.

Occupancy Rates from Past Population Monitoring Data

The encounter history for Rio Grande silvery minnow (Tables 14 to 17) during November (2005 to 2008) was dominated by two types of sampling categories (0000 [always absent] and 1111 [always present]). The most common encounter history was 0000 in 2006 (58.9%) and 2007 (46.25%). In contrast, the 1111 encounter history was most common in 2005 (27.1%) and 2008 (27.5%). The other sampling encounter categories (i.e., not 0000 or 1111) had lower and relatively even probability distributions for most years.

Probability of detection estimates were calculated for all Rio Grande silvery minnow and for the respective age-classes from 2005 to 2008. However, there were generally inadequate numbers of putative age-2 individuals to warrant further analysis of that age-class. Age-0 Rio Grande silvery minnow usually dominated the relative abundance of age-classes and so there were often very minor differences between the calculations for this age-class and for all age-classes combined. The probability of detection estimates ranged widely among years and followed a similar pattern as the encounter histories (i.e., highest in 2005 (0.6814) and 2008 (0.6670) but lowest in 2006 (0.4034) and 2007 (0.4485)).

The probability of occupancy estimate was generated after the collection of three years of data. In 2007, the occupancy estimate for all Rio Grande silvery minnow was 0.5923 while the estimate for age-0 individuals was 0.5827. In 2008, the probability of occupancy estimate for all Rio Grande silvery minnow was 0.8302 while the estimate for age-0 individuals was 0.8251. The occupancy estimates for age-1 and age-2 individuals were either quite low or led to spurious results because of the low sample size.

Table 13. Rio Grande silvery minnow multiple depletion removal analysis and modeling results using all comparable closed habitat electrofishing data collected from multiple mesohabitat types and locations in the Middle Rio Grande (2008 to 2010).

RGSM depletion data

Models*	AICc	Delta AICc	AICc Weights	Model Likelihood	Number of Parameters	Deviance
BW - {Mesohabitat+Location}	**-5190.4048**	**0.0000**	**1.0000**	**1.0000**	**38.0000**	**59.6253**
BW - {Mesohabitat}	**-5084.6569**	**105.7479**	**0.0000**	**0.0000**	**39.0000**	**163.2597**
PO - {Mesohabitat+Location}	**-416.5693**	**0.0000**	**0.95776**	**1.0000**	**6.0000**	**4.6590**
PO - {Mesohabitat}	**-410.3267**	**6.2426**	**0.04224**	**0.0441**	**4.0000**	**15.2269**
RU - {Mesohabitat}	**-211.1987**	**0.0000**	**0.99774**	**1.0000**	**8.0000**	**6.6372**
RU - {Mesohabitat+Location}	**-199.0208**	**12.1779**	**0.00226**	**0.0023**	**14.0000**	**2.9928**
SHPO - {Mesohabitat+Location}	**-1392.1697**	**0.0000**	**1.0000**	**1.0000**	**32.0000**	**32.1484**
SHPO - {Mesohabitat}	**-1342.7764**	**49.3933**	**0.0000**	**0.0000**	**17.0000**	**114.2733**
SHRU - {Mesohabitat+Location}	**-2771.7221**	**0.0000**	**1.0000**	**1.0000**	**76.0000**	**70.1683**
SHRU - {Mesohabitat}	**-2692.2084**	**79.5137**	**0.0000**	**0.0000**	**39.0000**	**231.6219**

{Mesohabitat}	Capture Probability Estimate	Standard Error of Estimate	Lower 95% CI of Estimate	Upper 95% CI of Estimate
BW	**0.7037**	**0.0191**	**0.6649**	**0.9010**
PO	**0.7153**	**0.0376**	**0.6363**	**0.8826**
RU	**0.8444**	**0.0382**	**0.7543**	**0.9800**
SHPO	**0.6858**	**0.0276**	**0.6294**	**0.8604**
SHRU	**0.7361**	**0.0157**	**0.7042**	**0.9385**

Table 14. Rio Grande silvery minnow encounter history summaries and the probability of detection estimates based on repeated sampling efforts in November 2005.

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RGSM encounter history (all age-classes)

Encounters*	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0000	79	23.30	79	23.30
0001	17	5.01	96	28.32
0010	11	3.24	107	31.56
0011	12	3.54	119	35.10
0100	8	2.36	127	37.46
0101	7	2.06	134	39.53
0110	8	2.36	142	41.89
0111	19	5.60	161	47.49
1000	11	3.24	172	50.74
1001	7	2.06	179	52.80
1010	10	2.95	189	55.75
1011	6	1.77	195	57.52
1100	18	5.31	213	62.83
1101	17	5.01	230	67.85
1110	17	5.01	247	72.86
1111	92	27.14	339	100.00

***0=absence and 1=presence over four repeated sampling efforts (e.g., 0101 = absent on days 1 and 3 but present on days 2 and 4).**

RGSM probability of detection estimates

Parameter	Probability of Detection Estimate	Standard Error of Estimate	Lower 95% CI of Estimate	Upper 95% CI of Estimate
p: All RGSM	0.6814	0.0151	0.6511	0.7101
p: Age-0 RGSM	0.6740	0.0152	0.6436	0.7031

Table 15. Rio Grande silvery minnow encounter history summaries and the probability of detection estimates based on repeated sampling efforts in November 2006.

RGSM encounter history (all age-classes)

Encounters*	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0000	235	58.90	235	58.90
0001	17	4.26	252	63.16
0010	12	3.01	264	66.17
0011	5	1.25	269	67.42
0100	20	5.01	289	72.43
0101	8	2.01	297	74.44
0110	10	2.51	307	76.94
0111	2	0.50	309	77.44
1000	29	7.27	338	84.71
1001	5	1.25	343	85.96
1010	10	2.51	353	88.47
1011	5	1.25	358	89.72
1100	10	2.51	368	92.23
1101	7	1.75	375	93.98
1110	9	2.26	384	96.24
1111	15	3.76	399	100.00

***1=presence and 0=absent over four repeated sampling efforts (e.g., 1011 = present on days 1, 3, and 4 but absent on day 2).**

RGSM probability of detection estimates

Parameter	Probability of Detection Estimate	Standard Error of Estimate	Lower 95% CI of Estimate	Upper 95% CI of Estimate
p: All RGSM	0.4034	0.0230	0.3593	0.4491
p: Age-0 RGSM	0.3629	0.0292	0.3078	0.4218
p: Age-1 RGSM	0.2957	0.0282	0.2435	0.3538

Table 16. Rio Grande silvery minnow encounter history summaries, probability of detection estimates, and probability of occupancy estimates based on repeated sampling efforts in November 2007.

RGSM encounter history (all age-classes)

Encounters*	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0000	185	46.25	185	46.25
0001	17	4.25	202	50.5
0010	29	7.25	231	57.75
0011	8	2	239	59.75
0100	19	4.75	258	64.5
0101	5	1.25	263	65.75
0110	1	0.25	264	66
0111	10	2.5	274	68.5
1000	30	7.5	304	76
1001	16	4	320	80
1010	14	3.5	334	83.5
1011	5	1.25	339	84.75
1100	15	3.75	354	88.5
1101	10	2.5	364	91
1110	7	1.75	371	92.75
1111	29	7.25	400	100

*1=present and 0=absent over four repeated sampling efforts (e.g., 1011 = present on days 1, 3, and 4 but absent on day 2).

RGSM probability of detection and probability of occupancy estimates

Parameter	Estimate	Standard Error of Estimate	Lower 95% CI of Estimate	Upper 95% CI of Estimate
***p*: All RGSM**	0.4485	0.01976	0.4101	0.4874
***p*: Age-0 RGSM**	0.4515	0.01988	0.4130	0.4907
***p*: Age-1 RGSM**	0.0050	0.00183	0.0025	0.0100
***p*: Age-2 RGSM**	0.3067E-04	0.2189E-04	0.7578E-05	0.1242E-03
ψ: All RGSM	0.5923	0.0288	0.5349	0.6473
ψ: Age-0 RGSM	0.5827	0.0287	0.5257	0.6377
ψ: Age-1 RGSM	0.9999	0.0000	0.9999	0.9999
ψ: Age-2 RGSM	0.1482E-05	0.0000	0.1482E-05	0.1482E-05

*Where *p*=detection probability and ψ(psi)=probability of occupancy.

Table 17. Rio Grande silvery minnow encounter history summaries, probability of detection estimates, and probability of occupancy estimates based on repeated sampling efforts in November 2008.

RGSM encounter history (all age-classes)

Encounters*	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0000	72	18.00	72	18.00
0001	13	3.25	85	21.25
0010	9	2.25	94	23.50
0011	11	2.75	105	26.25
0100	13	3.25	118	29.50
0101	7	1.75	125	31.25
0110	5	1.25	130	32.50
0111	11	2.75	141	35.25
1000	31	7.75	172	43.00
1001	8	2.00	180	45.00
1010	12	3.00	192	48.00
1011	23	5.75	215	53.75
1100	33	8.25	248	62.00
1101	17	4.25	265	66.25
1110	25	6.25	290	72.50
1111	110	27.50	400	100.00

*1=present and 0=absent over four repeated sampling efforts (e.g., 1011 = present on days 1, 3, and 4 but absent on day 2).

RGSM probability of detection and probability of occupancy estimates

Parameter	Estimate	Standard Error of Estimate	Lower 95% CI of Estimate	Upper 95% CI of Estimate
p: All RGSM	0.6670	0.0136	0.6398	0.6932
p: Age-0 RGSM	0.6673	0.0137	0.6400	0.6936
p: Age-1 RGSM	0.2112	0.0462	0.1346	0.3155
p: Age-2 RGSM	0.1657	0.1002	0.0458	0.4513
ψ: All RGSM	0.8302	0.0195	0.7885	0.8651
ψ: Age-0 RGSM	0.8251	0.0198	0.7830	0.8605
ψ: Age-1 RGSM	0.1509	0.0325	0.0976	0.2262
ψ: Age-2 RGSM	0.0339	0.0199	0.0106	0.1036

*Where *p*=detection probability and ψ(psi)=probability of occupancy.

The availability of data from 2005 to 2008 allowed for a preliminary calculation of the probability of occupancy for all sampling units combined based on collections within each sampling unit over time (Table 18). This was different than the preceding analysis (i.e., Tables 14 to 17) in that the variable of interest was the sampling unit vs. individual mesohabitats within a sampling unit. The minimum AIC_c model had constant occupancy (psi, ψ), extinction (epsilon, ε), and colonization (gamma, γ) parameters across the two intervals, but detection probabilities (*p*) varying by year (*y*) and discharge (*d*). Note that the "group" variable (*g*) is the age-class category (N = 4, for 0, 1, 2, and all age classes combined). The site occupancy estimate was 1.0 for all age-classes combined and for age-0 individuals but was lower for age-1 (0.5726) and age-2 (0.5125) individuals. Estimates of the probability of extinction were relatively low for all age-classes (0.0172) and age-0 (0.0697) individuals. The probability of extinction was higher for both age-1 and age-2 individuals (0.2236 and 0.1242, respectively). Estimates of the probability of colonization were relatively high for age-0 (0.5877) and age-1 (0.7414) individuals. However, because a site for all age-classes never went from unoccupied to occupied, the colonization estimate for this group was zero. Estimates of the probability of occupancy varied among years and age-classes but were most variable for groups with fewer data (i.e., age-1 and age-2 individuals). Detailed Rio Grande silvery minnow detection probability estimates among years and for individual sampling occasions (for all sampling units combined) are provided in Appendix E.

Population Estimation of Rio Grande Silvery Minnow

Population estimates from October data (2006 to 2008)

Average population estimates of Rio Grande silvery minnow were calculated for each of the 20 segments and varied among years and reaches (Tables 19 to 21). The average population estimate for all reaches was 48.45 in 2006, 524.48 in 2007, and 947.38 in 2008. The highest average population estimate was recorded in the Angostura Reach during 2006 (78.79) and 2008 (1,561.98) but in the Isleta Reach during 2007 (990.74). The number of segments used to calculate total population size was similar between Isleta (N=421) and San Acacia (N=474); the shortest reach was Angostura (N=275). The total population estimate was highest in the Angostura Reach during 2006 (N = 21,668) and highest in the Isleta Reach during 2007 (N = 417,099) and 2008 (N = 453,267). The standard errors associated with population estimates for the three reaches varied within and among years.

An analysis was also conducted for only unmarked Rio Grande silvery minnow. The average population size estimate was relatively unchanged for the Isleta and San Acacia reaches in 2006. However, the average population estimate in the Angostura Reach (35.50) in 2006 was less than half of what it was when considering both marked and unmarked individuals (78.79). The total population estimate for unmarked Rio Grande silvery minnow was 609,712 in 2007. There was no change in the population estimate in the Angostura Reach (between the marked-unmarked vs. unmarked-only) because there were no marked individuals collected in that reach during 2007. There were no marked individuals collected in 2008 (unlike in 2006 or 2007). All of the population estimates are therefore the same for the marked-unmarked vs. unmarked-only categories in 2008.

Population estimates were also generated for the different age-classes of Rio Grande silvery minnow for all years of the study (Table 22 to 24). The overall population estimates for age-0 (N=31,010) and age-1 (N=25,361) Rio Grande silvery minnow were comparable in 2006. The highest numbers of age-0 Rio Grande silvery minnow in 2006 were recorded in the Angostura Reach (N=14,058) while the highest numbers of age-1 individuals were recorded in the San Acacia Reach (N=9,816). The overall population estimate for age-0 (N = 605,855) Rio Grande silvery minnow was significantly higher than for age-1 (N = 7,783) individuals in 2007. However, the overall proportion of

Table 18. Rio Grande silvery minnow site occupancy analysis among years for all sampling units combined (from Population Monitoring Program) in the Middle Rio Grande based on repeated sampling efforts in November (2005 to 2008).

RGSM Site Occupancy Models

Models*	AIC_c	Delta AIC_c	AIC_c Weights	Model Likelihood	Number of Parameters	Deviance
A: {ψ(*g*) ε(*g*) γ(*g*) *p*(*g**y*+*d*)}	684.0304	0.0000	0.64043	1.0000	29	620.0304
B: {ψ(*g*) ε(*g*) γ(*g*) *p*(*g**y*)}	686.2819	2.2515	0.20776	0.3244	28	624.7011
C: {ψ(*g*) ε(*g**y*) γ(*g*) *p*(*g**y*)}	687.2178	3.1874	0.13012	0.2032	36	605.8043
D: {ψ(*g*) ε(*g*) γ(*g*) *p*(*g**y*+*y**d*)}	691.2336	7.2032	0.01747	0.0273	32	619.8747
E: {ψ(*g*) ε(*g**y*) γ(*g**y*) *p*(*g**y*)}	694.1516	10.1212	0.00406	0.0063	40	602.3953

Parameter Estimates from Minimum AIC_c Model (A)**

Label*	Estimate	SE	LCI	UCI
ψ All Fish	1.0000	0.0000	1.0000	1.0000
ψ Age-0	1.0000	0.0000	1.0000	1.0000
ψ Age-1	0.5726	0.1712	0.2538	0.8407
ψ Age-2	0.5125	0.2651	0.1161	0.8938
ε All Fish	0.0172	0.0171	0.0024	0.1125
ε Age-0	0.0697	0.0353	0.0251	0.1790
ε Age-1	0.2236	0.0926	0.0919	0.4504
ε Age-2	0.1242	0.2093	0.0033	0.8603
γ All Fish	0.0000	0.0000	0.0000	0.0000
γ Age-0	0.5877	0.2270	0.1852	0.8994
γ Age-1	0.7414	0.1993	0.2721	0.9565
γ Age-2	1.0000	1.0000	0.0000	1.0000

Estimates of ψ by Year from Minimum AIC_c Model (A)

Group	Year	Estimate	SE	LCI	UCI
All Fish	2005	1.0000	0.0000	1.0000	1.0000
All Fish	2006	0.9828	0.0171	0.9493	1.0163
All Fish	2007	0.9658	0.0336	0.9000	1.0317
All Fish	2008	0.9492	0.0495	0.8521	1.0462
Age-0	2005	1.0000	0.0000	1.0000	1.0000
Age-0	2006	0.9303	0.0353	0.8610	0.9996
Age-0	2007	0.9064	0.0471	0.8141	0.9987
Age-0	2008	0.8982	0.0535	0.7934	1.0031
Age-1	2005	0.5726	0.1712	0.2371	0.9081
Age-1	2006	0.7614	0.0810	0.6028	0.9201
Age-1	2007	0.7681	0.0708	0.6292	0.9069
Age-1	2008	0.7683	0.0711	0.6290	0.9076
Age-2	2005	0.5125	0.2651	-0.0071	1.0322
Age-2	2006	0.4489	0.1663	0.1228	0.7749
Age-2	2007	0.3931	0.1369	0.1248	0.6614
Age-2	2008	0.3443	0.1613	0.0282	0.6604

*Where ψ(psi)=probability of occupancy, ε(epsilon)=probability of extinction, γ(gamma)=probability of colonization, *p*=detection probability, *y*=year, *d*=discharge, and *g*(group)=age-class: group 1 = All Fish, group 2 = Age-0, group 3 = Age-1, and group 4 = Age-2.
**Detailed estimates of *p* by year and sampling occasion are provided in Appendix E.

Table 19. Rio Grande silvery minnow population estimation results for all sampling reaches and the overall study area in the Middle Rio Grande (all individuals and for unmarked individuals only) during October 2006.

Rio Grande silvery minnow (all individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	78.79	110.22	275	21,667.84	12,239.17	7,724.64	60,778.89
Isleta	27.56	27.77	421	11,604.69	5,197.74	5,019.51	26,829.07
San Acacia	39.83	63.72	474	18,880.53	9,971.76	7,141.59	49,915.23
Combined	48.45	74.22	1,170	56,690.41	19,253.09	29,666.97	108,329.31

Rio Grande silvery minnow (unmarked individuals only)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	35.50	18.84	275	9,761.52	2,094.91	6,440.08	14,795.97
Isleta	26.74	28.63	421	11,255.64	5,359.29	4,640.75	27,299.31
San Acacia	36.99	60.88	474	17,535.55	9,528.58	6,470.73	47,521.00
Combined	33.98	42.96	1,170	39,757.15	11,144.46	23,190.25	68,159.30

Table 20. Rio Grande silvery minnow population estimation results for all sampling reaches and the overall study area in the Middle Rio Grande (all individuals and for unmarked individuals only) during October 2007.

Rio Grande silvery minnow (all individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	682.11	803.55	275	187,579.25	98,086.57	71,562.81	491,679.66
Isleta	990.74	1,497.65	421	417,099.24	255,618.37	137,899.82	1,261,580.87
San Acacia	12.24	11.85	474	5,799.78	1,865.89	3,135.26	10,728.74
Combined	524.48	1,001.87	1,170	613,638.34	259,983.21	276,726.69	1,360,736.12

Rio Grande silvery minnow (unmarked individuals only)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	682.11	803.55	275	187,579.25	98,086.57	71,562.81	491,679.66
Isleta	981.36	1,499.30	421	413,151.56	255,898.43	135,224.47	1,262,302.73
San Acacia	11.64	10.77	474	5,519.06	1,697.22	3,061.89	9,948.11
Combined	521.12	1,001.19	1,170	609,711.88	259,804.52	273,798.97	1,357,742.79

Table 21. Rio Grande silvery minnow population estimation results for all sampling reaches and the overall study area in the Middle Rio Grande (all individuals and for unmarked individuals only) during October 2008.

Rio Grande silvery minnow (all individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	1,561.98	1,803.85	275	429,544.58	220,215.92	166,651.59	1,107,151.46
Isleta	1,076.64	1,598.78	421	453,266.74	272,899.71	152,384.15	1,348,242.14
San Acacia	519.75	463.48	474	246,362.30	72,666.71	139,867.89	433,940.80
Combined	947.38	1,280.40	1,170	1,108,430.23	332,470.15	623,544.06	1,970,378.12

Rio Grande silvery minnow (unmarked individuals only)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	1,561.98	1,803.85	275	429,544.58	220,215.92	166,651.59	1,107,151.46
Isleta	1,076.64	1,598.78	421	453,266.74	272,899.71	152,384.15	1,348,242.14
San Acacia	519.75	463.48	474	246,362.30	72,666.71	139,867.89	433,940.80
Combined	947.38	1,280.40	1,170	1,108,430.23	332,470.15	623,544.06	1,970,378.12

Table 22. Rio Grande silvery minnow population estimation results for all sampling reaches and the overall study area in the Middle Rio Grande (age-0 and age-1 individuals) during October 2006.

Rio Grande silvery minnow (age-0 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	51.12	87.62	275	14,057.87	9,729.75	4,124.67	47,912.55
Isleta	10.25	6.95	421	4,315.60	1,302.34	2,419.59	7,697.36
San Acacia	19.12	34.35	474	9,064.82	5,375.14	3,091.17	26,582.52
Combined	26.50	53.04	1,170	31,010.16	13,759.53	13,509.73	71,180.53

Rio Grande silvery minnow (age-1 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	26.76	28.23	275	7,359.91	3,135.16	3,305.82	16,385.74
Isleta	17.31	23.29	421	7,289.09	4,358.73	2,466.22	21,543.45
San Acacia	20.71	53.80	474	9,815.71	8,419.73	2,289.83	42,076.49
Combined	21.68	39.45	1,170	25,361.09	10,232.73	11,846.32	54,294.05

Table 23. Rio Grande silvery minnow population estimation results for all sampling reaches and the overall study area in the Middle Rio Grande (age-0 and age-1 individuals) during October 2007.

Rio Grande silvery minnow (age-0 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	**678.79**	**805.24**	**275**	**186,667.39**	**98,292.34**	**70,790.36**	**492,223.96**
Isleta	**973.54**	**1,502.20**	**421**	**409,860.95**	**256,393.69**	**132,879.37**	**1,264,199.23**
San Acacia	**12.24**	**11.85**	**474**	**5,799.78**	**1,865.89**	**3,135.26**	**10,728.74**
Combined	**517.83**	**1,001.25**	**1,170**	**605,855.37**	**259,820.43**	**270,781.80**	**1,355,559.11**

Rio Grande silvery minnow (age-1 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	**3.32**	**2.92**	**275**	**911.87**	**356.25**	**435.63**	**1,908.75**
Isleta	**17.19**	**17.85**	**421**	**7,238.29**	**3,062.55**	**3,267.41**	**16,034.95**
San Acacia	**0**	**0**	**474**	**0**	**0**	**-**	**-**
Combined	**6.65**	**12.51**	**1,170**	**7,782.96**	**3,258.53**	**3,540.39**	**17,109.55**

Table 24. Rio Grande silvery minnow population estimation results for all sampling reaches and the overall study area in the Middle Rio Grande (age-0 and age-1 individuals) during October 2008.

Rio Grande silvery minnow (age-0 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	1,304.90	1,465.53	275	358,848.19	179,036.46	142,426.57	904,129.21
Isleta	840.20	1,208.55	421	353,725.15	206,302.61	122,482.80	1,021,543.34
San Acacia	513.21	468.02	474	243,259.79	73,376.20	136,420.79	433,770.58
Combined	809.23	1,017.46	1,170	946,798.09	264,312.60	553,441.39	1,619,731.83

Rio Grande silvery minnow (age-1 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	233.87	373.41	275	64,314.82	45,608.78	18,407.84	224,708.36
Isleta	225.58	395.30	421	94,967.95	67,510.54	27,113.27	332,638.25
San Acacia	6.55	15.83	474	3,102.51	2,501.64	774.97	12,420.58
Combined	129.09	289.01	1,170	151,031.28	75,070.86	60,130.23	379,350.74

each age-class in 2007 exhibited a similar pattern among the three reaches (i.e., populations were highest in the Isleta Reach, moderate in the Angostura Reach, and lowest in the San Acacia Reach). In 2008, the overall population estimate for age-0 (N = 946,798) Rio Grande silvery minnow was significantly higher than for age-1 (N = 151,031) individuals. The overall proportion of each age-class in 2008 exhibited a similar pattern among the three reaches (i.e., populations were highest in the Isleta and Angostura reaches and lowest in the San Acacia Reach).

Comparison of RGSM estimates from Population Monitoring and Population Estimation data

Population estimates were also generated using October data (2006 to 2008) from the Population Monitoring Program sampling efforts (Tables 25 to 27). The 2006 population estimate was 91,336 and had a standard error [S.E.] of 33,917.53. In 2007, the population estimate was 245,467 (S.E. = 68,783.96). The overall population estimate using the 2008 data (N = 544,170) was the highest of the study and had a standard error [SE] of 90,271.14.

In 2006, the highest average population estimate per segment was recorded in the Angostura Reach (189.82) while the lowest was in the Isleta Reach (52.42). The highest average population estimate per sampling unit in 2007 was recorded in the Angostura Reach (493.37) while the lowest was in the San Acacia Reach (91.37). In 2008, the highest average population estimates per sampling unit were recorded in the Isleta and San Acacia Reaches (496.54 and 583.36, respectively) while the lowest was in the Angostura Reach (214.51). Overall population estimates were highest in the Angostura Reach during 2006 (52,202), in the Isleta Reach during 2007 (135,678), and in the San Acacia Reach during 2008 (276,512).

An analysis was also conducted for only unmarked Rio Grande silvery minnow using Population Monitoring Program data. The total population estimate for unmarked Rio Grande silvery minnow was 69,660 in 2006 and 269,175 in 2007. Marked individuals were only collected in the Angostura Reach during 2006 and only in the Isleta and San Acacia reaches during 2007. There were no marked individuals collected in 2008 (unlike in 2006 or 2007). All of the population estimates are therefore the same for the “all individuals” vs. “unmarked individuals only” categories in 2008.

Population estimates were also generated, using the Population Monitoring Program data, for the different age-classes of Rio Grande silvery minnow for all years of the study (Tables 28 to 30). In 2006, the overall population estimate of Rio Grande silvery minnow using Population Monitoring Program data was 54,262 for age-0 individuals and 37,074 for age-1 individuals. The overall population estimate for Rio Grande silvery minnow in 2007 was 279,722 for age-0 individuals and 1,416 for age-1 individuals. The highest overall population estimate for Rio Grande silvery minnow using Population Monitoring Program data was recorded in 2008 (age-0 = 501,716 and age-1 = 42,279).

DISCUSSION

In contrast to population monitoring that provides year-round documentation of trends (i.e., monthly or bimonthly sampling) for the entire ichthyofaunal community, the Population Estimation Program supplements the current Population Monitoring Program by providing an annual estimate of the Rio Grande silvery minnow population during a single time-period (e.g., October). Systematic population monitoring activities provide an assessment of recruitment success over short time periods, a basis for comparing the changes in monthly recruitment success among years, insight to seasonal mortality rates, timely information about the status of the species during periods of reduced abundance, and a valuable tool to assess the real-time effectiveness of adaptive

Table 25. Rio Grande silvery minnow population estimation results (**using Population Monitoring Program data**) for all sampling reaches and the overall study area in the Middle Rio Grande (all individuals and for unmarked individuals only) during October 2006.

Rio Grande silvery minnow (all individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	189.82	231.99	275	52,201.77	28,586.64	19,131.63	142,435.55
Isleta	52.42	36.64	421	22,067.53	6,355.22	12,690.49	38,373.27
San Acacia	33.07	39.37	474	15,677.45	6,209.78	7,418.54	33,130.83
Combined	78.06	129.58	1,170	91,335.91	33,917.53	45,153.84	184,751.70

Rio Grande silvery minnow (unmarked individuals only)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	115.72	178.32	275	31,822.52	21,958.40	9,365.67	108,125.99
Isleta	52.42	36.64	421	22,067.53	6,355.22	12,690.49	38,373.27
San Acacia	33.07	39.37	474	15,677.45	6,209.78	7,418.54	33,130.83
Combined	59.54	94.23	1,170	69,659.80	24,691.25	35,493.27	136,715.71

Table 26. Rio Grande silvery minnow population estimation results (**using Population Monitoring Program data**) for all sampling reaches and the overall study area in the Middle Rio Grande (all individuals and for unmarked individuals only) during October 2007.

Rio Grande silvery minnow (all individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	493.37	346.05	275	135,677.67	42,453.45	74,534.58	246,978.38
Isleta	252.77	181.99	421	106,414.77	31,124.33	60,691.50	186,584.66
San Acacia	81.95	168.14	474	38,845.24	23,939.20	12,775.14	118,116.30
Combined	236.05	273.12	1,170	276,180.52	71,114.79	168,080.78	453,803.71

Rio Grande silvery minnow (unmarked individuals only)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	493.37	346.05	275	135,677.67	42,453.45	74,534.58	246,978.38
Isleta	236.06	200.40	421	99,380.56	34,257.56	51,531.69	191,658.69
San Acacia	79.79	168.56	474	37,818.24	23,997.26	12,093.73	118,261.24
Combined	230.06	276.94	1,170	269,175.14	72,102.31	160,680.40	450,927.80

Table 27. Rio Grande silvery minnow population estimation results (**using Population Monitoring Program data**) for all sampling reaches and the overall study area in the Middle Rio Grande (all individuals and for unmarked individuals only) during October 2008.

Rio Grande silvery minnow (all individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	214.51	228.08	275	58,991.04	27,857.49	24,483.06	142,136.75
Isleta	496.54	437.48	421	209,044.46	75,221.46	105,491.13	414,248.90
San Acacia	583.36	283.72	474	276,512.41	45,307.70	200,984.23	380,423.46
Combined	465.10	344.49	1,170	544,170.27	90,271.14	393,990.38	751,595.22

Rio Grande silvery minnow (unmarked individuals only)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	214.51	228.08	275	58,991.04	27,857.49	24,483.06	142,136.75
Isleta	496.54	437.48	421	209,044.46	75,221.46	105,491.13	414,248.90
San Acacia	583.36	283.72	474	276,512.41	45,307.70	200,984.23	380,423.46
Combined	465.10	344.49	1,170	544,170.27	90,271.14	393,990.38	751,595.22

Table 28. Rio Grande silvery minnow population estimation results (**using Population Monitoring Program data**) for all sampling reaches and the overall study area in the Middle Rio Grande (age-0 and age-1 individuals) during October 2006.

Rio Grande silvery minnow (age-0 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	142.53	152.47	275	39,195.79	18,792.38	16,071.03	95,595.01
Isleta	16.31	35.28	421	6,866.31	6,064.37	1,550.01	30,416.73
San Acacia	13.00	27.97	474	6,164.34	4,410.06	1,748.41	21,733.51
Combined	46.38	93.79	1,170	54,261.81	24,515.95	23,314.31	126,289.14

Rio Grande silvery minnow (age-1 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	47.29	89.07	275	13,005.97	10,960.48	3,094.56	54,662.18
Isleta	36.11	37.70	421	15,201.22	6,491.41	6,815.42	33,905.01
San Acacia	20.07	31.33	474	9,513.10	4,934.79	3,654.22	24,765.67
Combined	31.69	50.91	1,170	37,074.10	13,334.23	18,714.59	73,444.77

Table 29. Rio Grande silvery minnow population estimation results (**using Population Monitoring Program data**) for all sampling reaches and the overall study area in the Middle Rio Grande (age-0 and age-1 individuals) during October 2007.

Rio Grande silvery minnow (age-0 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	493.17	345.72	275	135,622.67	42,413.58	74,527.12	246,802.87
Isleta	248.90	184.00	421	104,786.90	31,466.01	58,910.86	186,388.30
San Acacia	81.95	168.14	474	38,845.24	23,939.20	12,775.14	118,116.30
Combined	234.84	273.26	1,170	274,764.82	71,152.88	166,762.21	452,714.72

Rio Grande silvery minnow (age-1 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	0.20	0.45	275	55.00	54.50	10.87	278.20
Isleta	3.87	5.65	421	1,627.87	965.30	555.10	4,773.85
San Acacia	0.00	0.00	474	0.00	0.00	0.00	0.00
Combined	1.21	3.41	1,170	1,415.70	885.82	458.87	4,367.68

Table 30. Rio Grande silvery minnow population estimation results (**using Population Monitoring Program data**) for all sampling reaches and the overall study area in the Middle Rio Grande (age-0 and age-1 individuals) during October 2008.

Rio Grande silvery minnow (age-0 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	102.24	58.78	275	28,115.41	7,292.80	17,050.35	46,361.30
Isleta	469.15	438.96	421	197,512.90	75,423.08	95,839.12	407,050.33
San Acacia	583.36	283.72	474	276,512.41	45,307.70	200,984.23	380,423.46
Combined	428.82	353.87	1,170	501,715.64	92,636.65	350,432.57	718,308.18

Rio Grande silvery minnow (age-1 individuals)

Reach	Average Pop. Est. per sampled segment	Standard Dev. of Pop. Est. per sampled segment	Total number of segments	Total Pop. Est	Standard Error of Pop. Est.	Lower 95% CI	Upper 95% CI
Angostura	112.08	236.89	275	30,820.63	28,895.88	6,498.49	146,174.18
Isleta	27.06	37.87	421	11,391.22	6,512.27	4,017.05	32,302.34
San Acacia	0.00	0.00	474	0.00	0.00	0.00	0.00
Combined	36.14	119.81	1,170	42,279.13	31,111.41	11,645.70	153,492.26

management activities. This study complements the ongoing population monitoring activities and furnishes valuable information necessary to gauge recovery of Rio Grande silvery minnow in the three principal downstream reaches of the Middle Rio Grande (i.e., Angostura, Isleta, and San Acacia). However, a long-term commitment to monitoring populations of Rio Grande silvery minnow will be necessary to ensure that insight gained from this study will have lasting value.

Estimating population size is conducted with statistical techniques that require a series of assumptions. Hence, any estimate of the number of Rio Grande silvery minnow must be presented within the context of those assumptions, especially given inherent variation in densities of organisms in the environment. A series of units, selected at random, were sampled to develop population estimates based on densities of Rio Grande silvery minnow in different mesohabitats. The relative proportional availability of mesohabitat types, combined with actual density estimates in mesohabitats, was used to generate the population estimate at each unit. Density estimates were calculated for each sampling unit and were used to estimate population size for each reach and for the entire Rio Grande study area. A relatively large number of units were sampled intensively in an effort to maintain a high degree of statistical confidence.

Estimation of the abundance of organisms has received considerable theoretical and applied study (for review, see Seber 1992; Schwarz and Seber, 1999). Estimating the number of organisms in the environment is of great interest to biologists studying spatiotemporal population changes. The abundance of different species is of interest to government agencies charged with managing populations of rare organisms (i.e., federally threatened or endangered). Monitoring changes in populations requires estimating species-specific abundance over time, usually from multiple sites.

The use of catch-per-unit-effort (CPUE) to monitor the status of fish populations is well established in fisheries science. Some of the first important theoretical contributions were provided by the mid-1900s (Ricker 1940, 1944; Zippin 1956, 1958). Constant effort on each pass simplifies the CPUE estimator to the standard removal estimator (Otis et al. 1978). The relationship between CPUE and abundance has received considerable attention in the literature (see reviews by Otis et al. 1978, Bannerot and Austin 1983). Experimental and statistical treatment of the issue has demonstrated that CPUE is a valid estimator of abundance and that the relationship appears to be one of strict proportionality for single species (Richards and Schnute, 1986). The work of Richards and Schnute (1986, 1992) and other researchers using CPUE in fisheries applications has appeared in international reviews on the general topic of estimating animal abundance (Seber 1992). Extensive reviews of the various methods for estimating animal abundance identify CPUE as one of the most widely used and well-researched techniques in fisheries science (e.g., Seber 1992, Schwarz and Seber 1999). CPUE provides a metric by which to gauge the relative increases or decreases (trends) in populations over time and space.

However, there are some instances where knowledge of the actual population size is desirable. Management of federally protected species may require the use of some benchmark by which to gauge the potential success or failure of various management actions (e.g., a target number of individuals may be required to ensure the genetic viability of a population). Managers can determine if the goal has been met or exceeded in any year by referring to a population estimate and its associated confidence interval.

Techniques utilized in this study demonstrated that statistically robust population estimates of Rio Grande silvery minnow, even during periods of relatively lower abundance, can be obtained when sampling over a large geographical area. A high degree of precision was obtained in mapping mesohabitats and determining the areas and densities of this species in specific mesohabitats. The methodology employed allowed for calculations of population size of Rio Grande silvery minnow among reaches and age-classes. The sampling of 20 randomly selected units yielded overall population estimates with seemingly reasonable associated measures of variance given the substantial variability in the abundance of Rio Grande silvery minnow observed since 1993 (Dudley and Platania, 2009) and the widely variable observed densities of Rio Grande silvery minnow among sampling units. The large number of samples taken from each sampling unit reduced the sampling variation in density among mesohabitats while the large number of sampling units reduced sampling variation of density across study reaches and over the entire study area. There were constraints on the number of sampling units and the amount of sampling allocated per unit based on the extensive sampling effort required and the limitations inherent within the scope of this project. However, a power analysis of existing data revealed that even doubling the sampling effort (i.e., adding 20 sampling units) would likely only result in a modest decrease in the variation associated with existing population estimates (unpubl. data).

Depletion sampling techniques were used to obtain an estimate of density within each mesohabitat. The overall low values of standard error for the capture probability estimates suggested that multiple sampling depletion efforts were consistent within and among mesohabitat types. Electrofishing (using seines and dipnets to remove stunned fish) appeared to be the most appropriate technique for depletion sampling across the range of conditions encountered in October (2006 to 2008). Electrofishing was possible in nearly all mesohabitats except for the deepest run habitats (because of safety reasons), which only occurred in a small fraction of the river during times of elevated discharge.

Capture probability estimates from closed mesohabitats were used to correct density estimates in the open mesohabitats that had first-pass seining data in 2006 for run and non-run mesohabitats and in 2007 for non-run mesohabitats. This method was applied because it was reasoned that fish in non-run mesohabitats were more likely to be missed during first-pass sampling than to flee from the area just prior to sampling. There were several reasons for this including: 1) the sampling crew moved at a swift pace (ca. 1.5 to 2.0 m/s), 2) instream visibility was always <10 cm and frequently <5 cm, 3) water temperatures ranged between 9 and 15^{o}C.

Additional depletion sampling (including random [open or closed] sampling at the same mesohabitat location between days) was implemented in 2007 to further address this question by quantifying the relative importance of this bias. While intensive open and closed sampling in non-run mesohabitats (e.g., shoreline pools, backwaters etc.) was conducted at three sampling localities, there were no consistent patterns in the estimates of Rio Grande silvery minnow population using either open or closed sampling. However, the low densities of Rio Grande silvery minnow (documented by both techniques) at two of the three sampling localities reduced the statistical power of the comparisons. The problems encountered with developing a statistically reliable correction factor for open sampling ultimately led to the decision to implement a closed depletion sampling technique for all run and non-run mesohabitats in 2008.

Discrete sampling of hatchery and wild Rio Grande silvery minnow in closed mesohabitats was conducted in 2007 to determine how estimates of capture probability might differ between the two groups. Several significant differences were documented between hatchery and wild fish for specific mesohabitat types. In all cases, hatchery fish were more easily captured than were wild fish. One possible reason for this observation could be that wild fish have the advantage of long-term acclimation to the local environment. In contrast, the hatchery fish were exposed to native river conditions for less than a day before being subjected to capture experiments. It is possible that hatchery fish that are stocked and allowed to acclimate to river conditions over a several week or month period would not show a similar effect. It was determined that changing capture probability estimates for marked fish would not be prudent based on the possible effects of acclimation period, age, and flow. Further study would be required to investigate the relative impact of these factors on capture probability estimates. However, it was noted that population estimates in closed mesohabitats closely matched the known number of Rio Grande silvery minnow placed into those habitats. While this comparison was based on limited data, it indicates that closed habitat depletion methods to calculate mesohabitat-specific capture probability estimates are relatively accurate.

The lack of Rio Grande silvery minnow collected in runs precluded development of a robust capture probability estimate in this mesohabitat in 2006. It was reasoned that shoreline runs would be the most similar mesohabitat to runs. If one were to assume that fish were fleeing in great numbers just prior to being sampled, then the estimate of population for this rather large mesohabitat category could be too low. Intensive closed mesohabitat sampling was conducted in runs during October 2007 to provide additional and more precise data on capture probabilities and estimated densities. The overall density estimates in closed runs were higher than in open runs. While a capture probability estimate was applied to open runs prior to calculating population size in 2007, the corrected values were still lower than those documented in the closed runs. Low densities of Rio Grande silvery minnow in run habitats meant that the population size estimates for sampled areas were not very different (i.e., non-run habitats account for the majority of the total number of individuals collected). However, the extensive availability of run habitat at most of the sampling units meant that any resulting population estimate could be too low. While a correction factor was developed for open vs. closed sampling in run habitat (and applied to run habitats sampled in 2006), it is likely that this correction would be subject to change based on other factors (e.g., spatial and temporal differences in flow conditions of runs) over time. Recalculating a correction factor periodically (based on open vs. closed sampling in run habitat) would require a substantial amount of field effort. The field effort required to generate a correction factor, possible biases associate with using a uniform correction factor, and the observed difference between sampling methods in the run habitats ultimately led to the decision to use the closed depletion sampling technique for runs in 2008.

Probability of detection values were used to estimate both the proportion of mesohabitat locations occupied and the proportion of sampling units occupied by Rio Grande silvery minnow during population monitoring efforts from 2005 to 2008 (based on November repeated sampling efforts). There are numerous benefits to documenting the estimated site occupancy rate of species over time. Probability of detection estimates can provide insight to patterns of site occupancy of Rio Grande silvery minnow both within and among sampling units. Site occupancy models can be developed over time to incorporate changes in the probability of detection and the presence/absence patterns at a particular site.

Site occupancy rates at the mesohabitat level were generated using techniques developed by MacKenzie et al. (2002, 2003, and 2006). The large decline in the abundance of Rio Grande silvery minnow from 2005 to 2006 was reflected in changes in the site occupancy rates at the established Population Monitoring Program sampling units. There was a noticeable decline in the percentage of sites occupied by age-0 Rio Grande silvery minnow between 2005 and 2006 (Dudley et al. 2007). Probability of detection estimates for Rio Grande silvery minnow (all age-classes combined) in 2008 were similar to those recorded in 2005 and significantly higher than those recorded in 2006 or 2007. Site occupancy estimates for 2008 reflected consistency in the encounter histories and were significantly higher than those recorded in 2006 or 2007.

More detailed site occupancy models at the sampling unit level were generated based on the availability of extensive data spanning four years (2005-2008). The most parsimonious model suggested that the occupancy, extinction, and colonization estimates were constant but that detection probabilities varied by year and with discharge. Additional data from future years will likely result in some changes to the structure of the model since it is based on a relatively short-term data set. For example, the influence of discharge on the detection probabilities was likely retained as an important parameter in the model because of the lower estimate of p in 2006 compared with the other years (2005, 2007-2008). It is unknown if this pattern will remain consistent over time as 2006 was also the year with the lowest discharge. Parameter estimates from the model suggest that site occupancy is highest for age-0 fish and lowest for age-2 fish. However, the low number of age-2 individuals adds notable variation to the estimates for these age-classes. The overall site extinction probability of Rio Grande silvery minnow is relatively low (0.0172) based on data collected over the past four years. Estimates of site occupancy suggest a minor decline from 2005 to 2008 but this was not supported with any statistically significant differences among years. Based on data collected over the past decade, it is likely that parameter estimates could change dramatically over a short time period based on flow conditions. Thus, the long-term site extinction probability should not be based on recently collected data during a period of relatively stable discharge (i.e., modest spring runoff and the avoidance of massive river drying).

There were differences in the relative variance in population estimates among reaches and between all-fish and unmarked-only categories (the patchy distribution of marked Rio Grande silvery minnow appears, in part, to be affecting these values) in 2006. It is likely that recently stocked silvery minnow have not had adequate time to redistribute within or among sampling reaches. It is also possible that these fish were more likely to school together than with wild individuals, which could further contribute to their relatively clumped distribution. It was notable that relative measures of variance (i.e., coefficient of variation) dropped considerably when marked individuals were removed from the analysis. This was not an issue in 2007 because of the few marked Rio Grande silvery minnow collected or in 2008 because no marked Rio Grande silvery minnow were collected.

While large numbers of Rio Grande silvery minnow have been periodically stocked into the river since 2002, there was no significant positive correlation between recent stocking numbers and population estimates from 2006-2007 (unpubl. data). While populations of Rio Grande silvery minnow have increased or decreased over several orders of magnitude in the past few years, this variation was explained almost entirely from critical aspects of the annually dynamic hydraulic regime (Dudley and Platania, 2009) as opposed to the periodic input of hatchery fish. No Rio Grande silvery minnow were stocked in 2008 and none of the sampling units of this study yielded marked individuals. Mortality rate of Rio Grande silvery minnow stocked in the previous spring would be expected to be high, especially if those individuals had spawned. However, the young of those marked fish would be included in our population estimate as wild fish. Increased sampling in the areas where stocked fish were spot-released would result in higher population estimates of marked fish. However, the purpose of this study was to estimate the population of wild Rio Grande silvery minnow (i.e., marked fish were noted so that they could be removed from the estimate of population size). Further, only wild individuals (unmarked) are counted toward recovery of the Rio Grande silvery minnow (U. S. Department of the Interior, 2007).

A large number of Rio Grande silvery minnow are salvaged from drying portions of the river each year but the number of individuals released into upstream reaches appears to have had little effect on inter- or intra-annual population fluctuations, based on results from population monitoring (Dudley and Platania, 2009). It is possible that the stresses inflicted on fish during the capture, handling, and transport activities could result in high rates of initial mortality (C. Caldwell, NMSU, pers. comm.). In addition, many of the salvaged individuals are collected earlier in the year than this study was conducted. These smaller life stages are expected to have higher rates of mortality and it is likely many of these fish perished before recruiting into the population.

There were inadequate numbers of age-2 or age-2+ Rio Grande silvery minnow to conduct separate analyses for either population estimates or for the site occupancy models. The age-class structure of these larger Rio Grande silvery minnow is not well understood. While some data suggest that the largest Rio Grande silvery minnow collected over a century ago may survive up to five years (Cowley et al. 2006), it is unclear how well those data relate to current conditions. Despite these uncertainties, sampling efforts completed during this project resulted in the capture of the full range of sizes (or ages) of Rio Grande silvery minnow presumed to be present in the wild at this time of year (range = 30 to 80 mm SL).

The population estimates from October 2008 data were generated following a period of improved Rio Grande silvery minnow spawning and recruitment as compared with 2006 (Dudley and Platania, 2008). There have been multiple substantial changes in the abundance of Rio Grande silvery minnow within a relatively short period (1999-2008). Recent changes (i.e., within the past five years) have been some of the most dramatic during the period of record; populations have changed by about an order of magnitude (10X) nearly every year since 2003 (Dudley and Platania, 2008). October population monitoring samples illustrate that there was a substantial decline from 2005 to 2006 following by a substantial increase from 2006 to 2007. The mean CPUE (catch per unit effort) of Rio Grande silvery minnow dropped from 36.99 in 2005 to 1.38 in 2006 but rebounded to 10.85 in 2007. Short-term increases and decreases in abundance are indicative of a population dominated by the youngest age-classes (i.e., age-0 and age-1 individuals).

Elevated and extended spring runoff in the Rio Grande during 2004, 2005, 2007, and 2008 contrasted with the low-flow conditions observed throughout the Middle Rio Grande during spring of 2002, 2003, and 2006. Portions of the Rio Grande between Isleta Diversion Dam and the southern terminus of the Bosque del Apache National Wildlife Refuge (NWR) were dried sporadically over the period of record. During periods of low flow, the lower section of the San Acacia Reach of the Rio Grande (downstream of Bosque del Apache NWR) was supplemented by water pumped from the Low Flow Conveyance Channel into the Rio Grande. This strategy prevented river drying but flow in this area of the Rio Grande remained low during summer.

The population estimates generated using the Population Estimation Program and Population Monitoring Program data showed a similar increasing population trend from 2006 to 2008. However, the actual estimates were consistently lower when using the Population Monitoring Program data as compared with the Population Estimation Program data. Numerous methodological differences in how the estimates were calculated likely resulted in a substantial underestimate of the population based on the Population Monitoring Program data (see Methods). The conservative approach to estimating population size using the Population Monitoring Program data (based on the lack of depletion data and habitat mapping data) meant that capture probability estimates were much higher than would be expected and that mesohabitat availability was much lower than would be expected. The combination of these factors apparently resulted in a subtantially lower estimate based on the Population Monitoring Program data and is the reason that these data were not compared statistically with those based on the Population Estimation Program data.

The 2006-2008 estimates of Rio Grande silvery minnow population size should be viewed cautiously as they are only a few data points and are preceded by the long-term Population Monitoring Program that was initiated in 1993. There have been numerous periods of rapidly expanding and contracting population size that have occurred over the past 15 years. While estimates from a few years provide a useful starting point for long-term monitoring, its importance (both statistically and from a resource management standpoint) will only be realized after multiple years of population estimation data are collected and analyzed.

The site occupancy data should be used in combination with population estimate data to provide a more complete understanding of the conservation status of Rio Grande silvery minnow. It is well known that simply having large numbers of a particular species in an area doesn't ensure its long-term survival. This is particularly true for short-lived species such as Rio Grande silvery minnow. The vast changes in populations of this species within short time periods underscore the need to ensure the presence of individuals over a broad geographical range. Changing environmental conditions within a particular region (either natural or manmade) can have rapid and severe impacts to local populations of Rio Grande silvery minnow. Large populations within these affected regions can be decimated within days because of river dewatering. Alternatively, the lack of spring runoff can inhibit spawning and limit recruitment to such a degree that populations decline several orders of magnitude within a year. The short life span of this species means that, following periods of low recruitment, total population size is not well buffered by surviving age-classes. For these reasons, it is imperative that populations of Rio Grande silvery minnow are established at multiple locations within its current and historical range to ensure its long-term persistence in the wild.

The success of this project will be evaluated annually but insight into the efficacy of estimating the population size of Rio Grande silvery minnow will require a multi-year commitment. Data from future year's efforts will provide additional information that will supplement recent population estimation activities and furnish valuable information necessary to gauge recovery of Rio Grande silvery minnow in the three principal reaches of the Middle Rio Grande. Ultimately, these data will be used to evaluate progress towards meeting Rio Grande silvery minnow recovery goals, following both management actions and stochastic environmental events.

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Appendix A.

Middle Rio Grande sampling units for the October (2006 to 2008) Rio Grande silvery minnow Population Estimation Program

Table A-1. Sampling unit localities for the October (2006 to 2008) Rio Grande silvery minnow Population Estimation Program.

Sampling Unit #	Sampling Unit Locality

ANGOSTURA REACH SITES

1 New Mexico, Sandoval County, Rio Grande, ca. 2.0 miles downstream of US Highway 550 Bridge crossing, Rio Rancho.
River Mile 202.0 (upper), 201.9 (lower) BERNALILLO QUADRANGLE
UTM Easting (upper): 356983 UTM Northing (upper): 3907801 Zone: 13
UTM Easting (lower): 356812 UTM Northing (lower): 3907696 Zone: 13

2 New Mexico, Bernalillo County, Rio Grande, ca. 0.4 miles upstream of Paseo del Norte Bridge crossing, Albuquerque.
River Mile 191.6 (upper), 191.5 (lower) LOS GRIEGOS QUADRANGLE
UTM Easting (upper): 349942 UTM Northing (upper): 3895288 Zone: 13
UTM Easting (lower): 349847 UTM Northing (lower): 3895111 Zone: 13

3 New Mexico, Bernalillo County, Rio Grande, ca. 1.2 miles downstream of Paseo del Norte Bridge crossing, Albuquerque.
River Mile 189.9 (upper), 189.8 (lower) LOS GRIEGOS QUADRANGLE
UTM Easting (upper): 348954 UTM Northing (upper): 3892935 Zone: 13
UTM Easting (lower): 348801 UTM Northing (lower): 3892807 Zone: 13

4 New Mexico, Bernalillo County, Rio Grande, ca. 1.6 miles upstream of Rio Bravo Blvd. Bridge crossing, Albuquerque.
River Mile 179.9 (upper), 179.8 (lower) ALBUQUERQUE WEST QUADRANGLE
UTM Easting (upper): 348261 UTM Northing (upper): 3879455 Zone: 13
UTM Easting (lower): 348133 UTM Northing (lower): 3879297 Zone: 13

5 New Mexico, Bernalillo County, Rio Grande, ca. 0.6 miles downstream of Rio Bravo Blvd. Bridge crossing, Albuquerque.
River Mile 177.6 (upper), 177.5 (lower) ALBUQUERQUE WEST QUADRANGLE
UTM Easting (upper): 347381 UTM Northing (upper): 3876106 Zone: 13
UTM Easting (lower): 347291 UTM Northing (lower): 3875933 Zone: 13

6 New Mexico, Bernalillo County, Rio Grande, ca. 1.0 miles downstream of Rio Bravo Blvd. Bridge crossing, Albuquerque.
River Mile 177.3 (upper), 177.2 (lower) ALBUQUERQUE WEST QUADRANGLE
UTM Easting (upper): 347155 UTM Northing (upper): 3875786 Zone: 13
UTM Easting (lower): 346986 UTM Northing (lower): 3875681 Zone: 13

ISLETA REACH SITES

7 New Mexico, Valencia County, Rio Grande, ca. 4.0 miles upstream of Los Lunas Bridge crossing (NM State Highway 49), Los Lunas.
River Mile 164.8 (upper), 164.7 (lower) LOS LUNAS QUADRANGLE
UTM Easting (upper): 342969 UTM Northing (upper): 3857901 Zone: 13
UTM Easting (lower): 343003 UTM Northing (lower): 3857710 Zone: 13

Table A-1. Sampling unit localities for the October (2006 to 2008) Rio Grande silvery minnow Population Estimation Program (continued).

Sampling Unit #	Sampling Unit Locality

ISLETA REACH SITES (continued)

8 New Mexico, Valencia County, Rio Grande, ca. 2.9 miles upstream of NM 6 bridge crossing, Belen.
River Mile 152.4 (upper), 152.3 (lower) TOME QUADRANGLE
UTM Easting (upper): 340193 UTM Northing (upper): 3840028 Zone: 13
UTM Easting (lower): 340242 UTM Northing (lower): 3839829 Zone: 13

9 New Mexico, Valencia County, Rio Grande, ca. 0.2 miles downstream of NM State Highway 346 Bridge crossing, Jarales.
River Mile 140.6 (upper), 140.5 (lower) VEGUITA QUADRANGLE
UTM Easting (upper): 338117 UTM Northing (upper): 3823765 Zone: 13
UTM Easting (lower): 338057 UTM Northing (lower): 3823577 Zone: 13

9_5 New Mexico, Socorro County, Rio Grande, ca. 1.0 miles downstream of US Highway 60 bridge crossing, Bernardo.
River Mile 130.0 (upper), 129.9 (lower) ABEYTAS QUADRANGLE
UTM Easting (upper): 333822 UTM Northing (upper): 3808522 Zone: 13
UTM Easting (lower): 333704 UTM Northing (lower): 3808335 Zone: 13

10 New Mexico, Socorro County, Rio Grande, ca. 3.7 miles downstream of US Highway 60 Bridge crossing, Bernardo.
River Mile 126.9 (upper), 126.8 (lower) ABEYTAS QUADRANGLE
UTM Easting (upper): 330997 UTM Northing (upper): 3805306 Zone: 13
UTM Easting (lower): 330850 UTM Northing (lower): 3805171 Zone: 13

11 New Mexico, Socorro County, Rio Grande, ca. 1.7 miles upstream of San Acacia Diversion Dam, San Acacia.
River Mile 117.9 (upper), 117.8 (lower) LA JOYA QUADRANGLE
UTM Easting (upper): 328767 UTM Northing (upper): 3792883 Zone: 13
UTM Easting (lower): 328699 UTM Northing (lower): 3792691 Zone: 13

SAN ACACIA REACH SITES

12 New Mexico, Socorro County, Rio Grande, ca. 0.8 miles downstream of San Acacia Diversion Dam, San Acacia.
River Mile 115.4 (upper), 115.3 (lower) SAN ACACIA QUADRANGLE
UTM Easting (upper): 325363 UTM Northing (upper): 3791796 Zone: 13
UTM Easting (lower): 325288 UTM Northing (lower): 3791608 Zone: 13

13 New Mexico, Socorro County, Rio Grande, ca. 4.5 miles upstream of US Highway 380 Bridge crossing, San Antonio.
River Mile 91.6 (upper), 91.5 (lower) SAN ANTONIO QUADRANGLE
UTM Easting (upper): 328199 UTM Northing (upper): 3760830 Zone: 13
UTM Easting (lower): 328206 UTM Northing (lower): 3760627 Zone: 13

Table A-1. Sampling unit localities for the October (2006 to 2008) Rio Grande silvery minnow Population Estimation Program (continued).

Sampling Unit #	Sampling Unit Locality
	SAN ACACIA REACH SITES (continued)
14	New Mexico, Socorro County, Rio Grande, ca. 1.5 miles downstream of US Highway 380 Bridge crossing, San Antonio. River Mile 85.7 (upper), 85.6 (lower) SAN ANTONIO QUADRANGLE UTM Easting (upper): 329256 UTM Northing (upper): 3752209 Zone: 13 UTM Easting (lower): 329312 UTM Northing (lower): 3752018 Zone: 13
15	New Mexico, Socorro County, Rio Grande, ca. 0.2 miles downstream of the south boundary of the Bosque del Apache National Wildlife Refuge. River Mile 73.6 (upper), 73.5 (lower) SAN MARCIAL QUADRANGLE UTM Easting (upper): 322489 UTM Northing (upper): 3732572 Zone: 13 UTM Easting (lower): 322331 UTM Northing (lower): 3732455 Zone: 13
16	New Mexico, Socorro County, Rio Grande, ca. 2.2 miles downstream of the south boundary of the Bosque del Apache National Wildlife Refuge. River Mile 71.6 (upper), 71.5 (lower) SAN MARCIAL QUADRANGLE UTM Easting (upper): 320044 UTM Northing (upper): 3730043 Zone: 13 UTM Easting (lower): 319924 UTM Northing (lower): 3729881 Zone: 13
17	New Mexico, Socorro County, Rio Grande, ca. 0.9 miles upstream of San Marcial Railroad Bridge crossing, San Marcial. River Mile 69.5 (upper), 69.4 (lower) SAN MARCIAL QUADRANGLE UTM Easting (upper): 316840 UTM Northing (upper): 3728978 Zone: 13 UTM Easting (lower): 316652 UTM Northing (lower): 3729038 Zone: 13
18	New Mexico, Socorro County, Rio Grande, ca. 5.0 miles downstream of San Marcial Railroad Bridge crossing, San Marcial. River Mile 63.6 (upper), 63.5 (lower) PARAJE WELL QUADRANGLE UTM Easting (upper): 313417 UTM Northing (upper): 3721520 Zone: 13 UTM Easting (lower): 313255 UTM Northing (lower): 3721407 Zone: 13
19	New Mexico, Socorro County, Rio Grande, ca. 0.9 miles downstream of the former confluence with the Low Flow Conveyance Channel. River Mile 59.8 (upper), 59.7 (lower) PARAJE WELL QUADRANGLE UTM Easting (upper): 308328 UTM Northing (upper): 3717266 Zone: 13 UTM Easting (lower): 308230 UTM Northing (lower): 3717093 Zone: 13
20	New Mexico, Socorro County, Rio Grande, ca. 1.1 miles downstream of the former confluence with the Low Flow Conveyance Channel. River Mile 59.6 (upper), 59.5 (lower) PARAJE WELL QUADRANGLE UTM Easting (upper): 308118 UTM Northing (upper): 3716920 Zone: 13 UTM Easting (lower): 308016 UTM Northing (lower): 3716750 Zone: 13

Appendix B.

Mesohabitat and fish sampling figures for all sampling units mapped during the October (2006 to 2008) Rio Grande silvery minnow Population Estimation Program

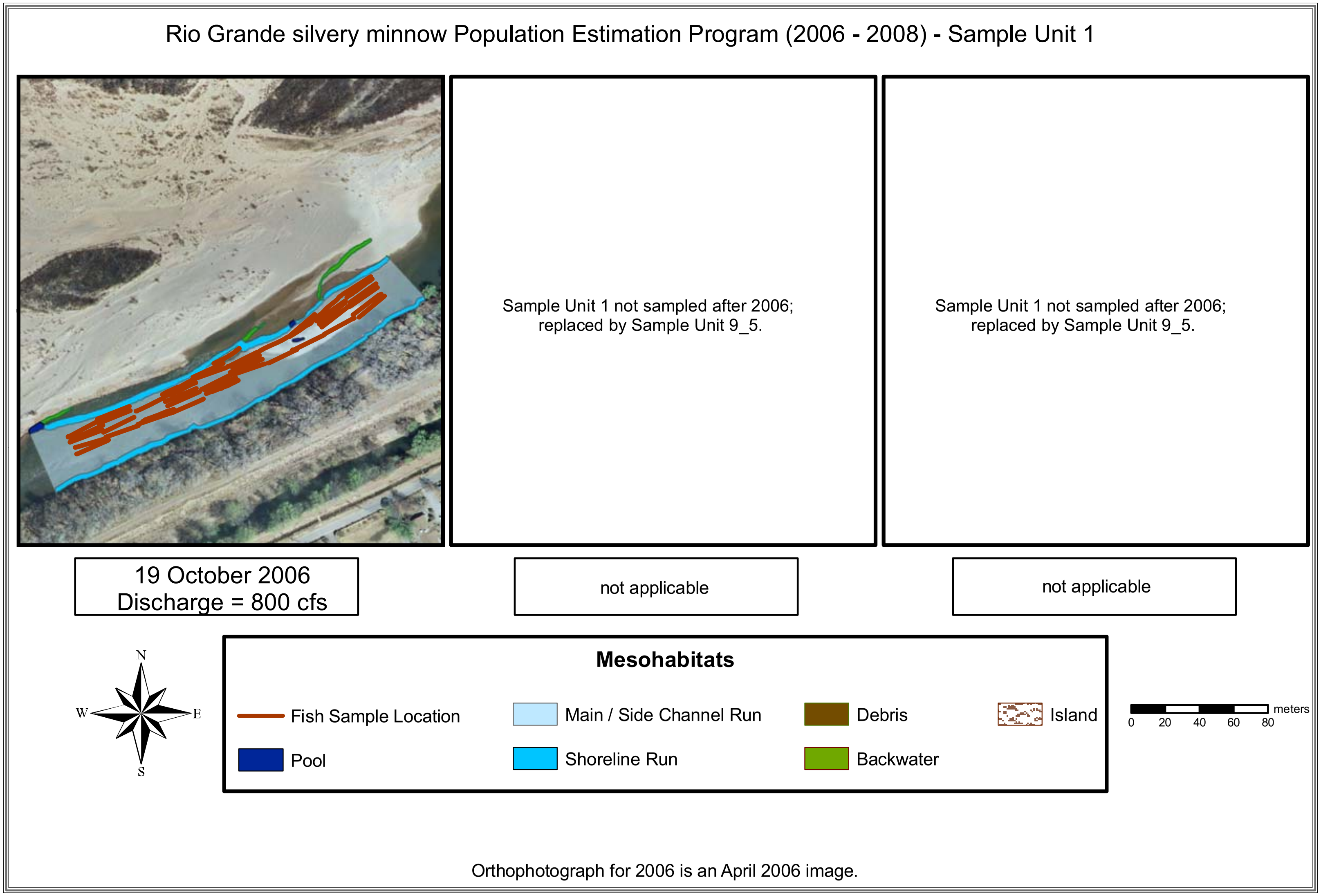

Figure B-1. Map of sampling unit #1 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats in October 2006.

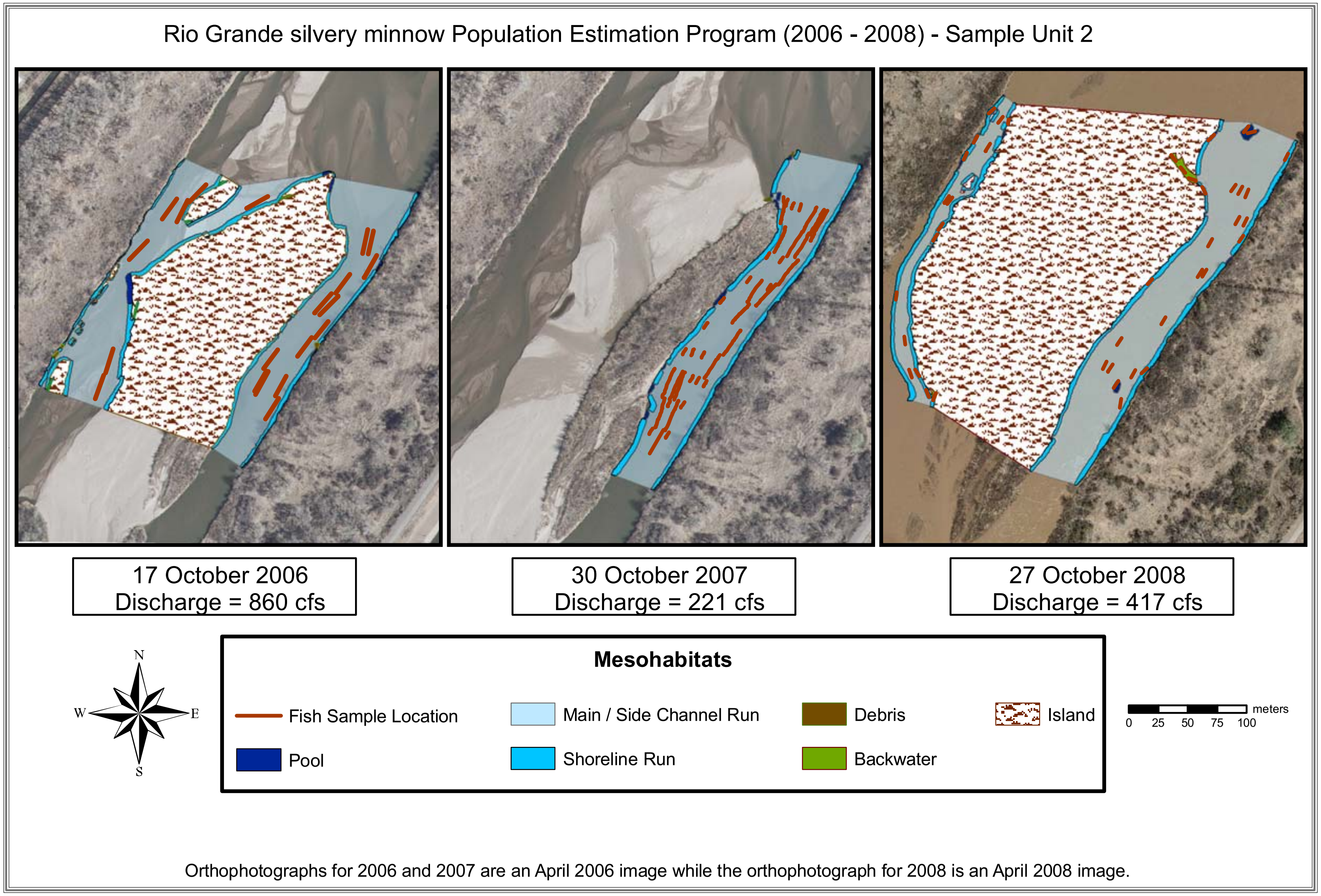

Figure B-2. Map of sampling unit #2 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

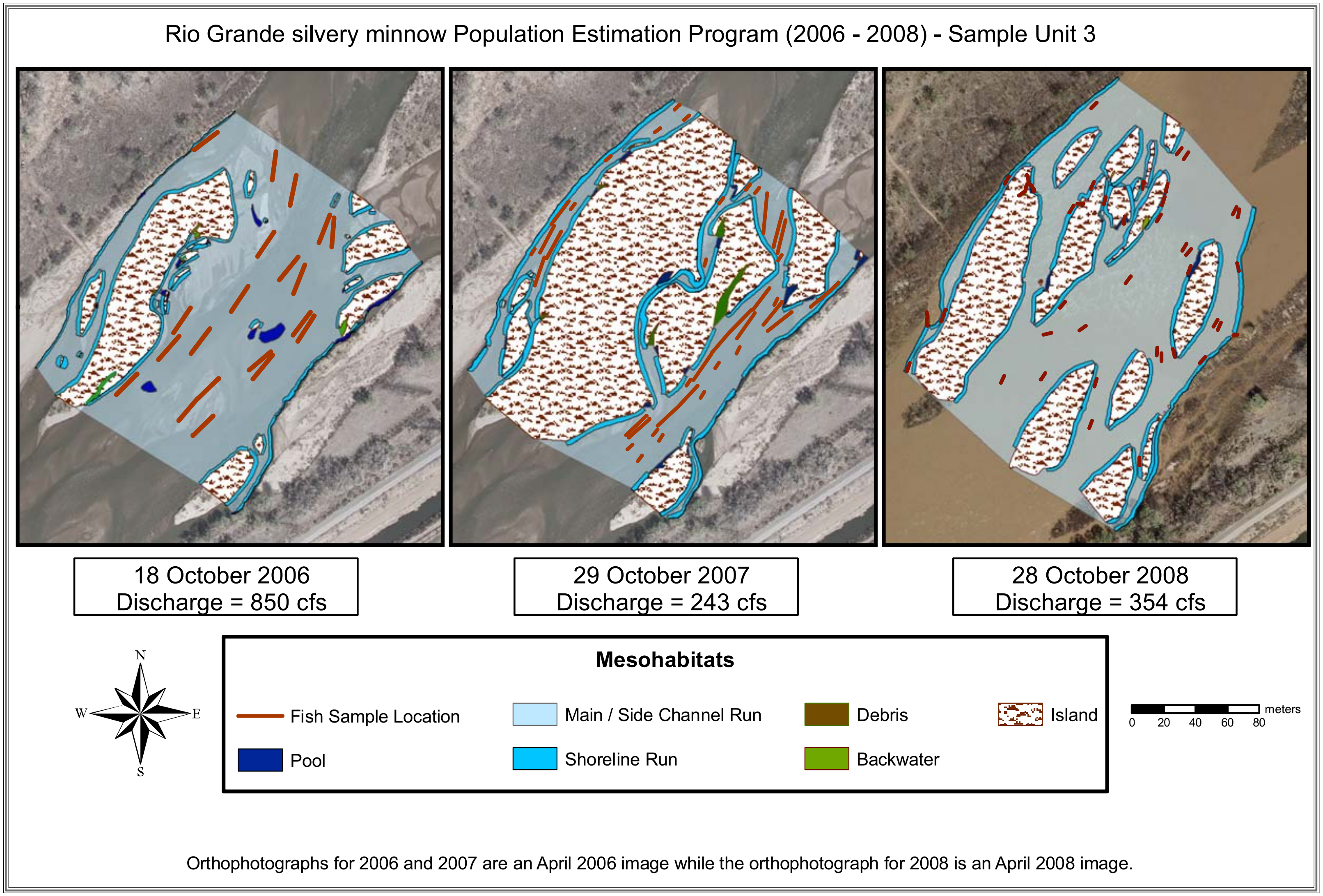

Figure B-3. Map of sampling unit #3 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

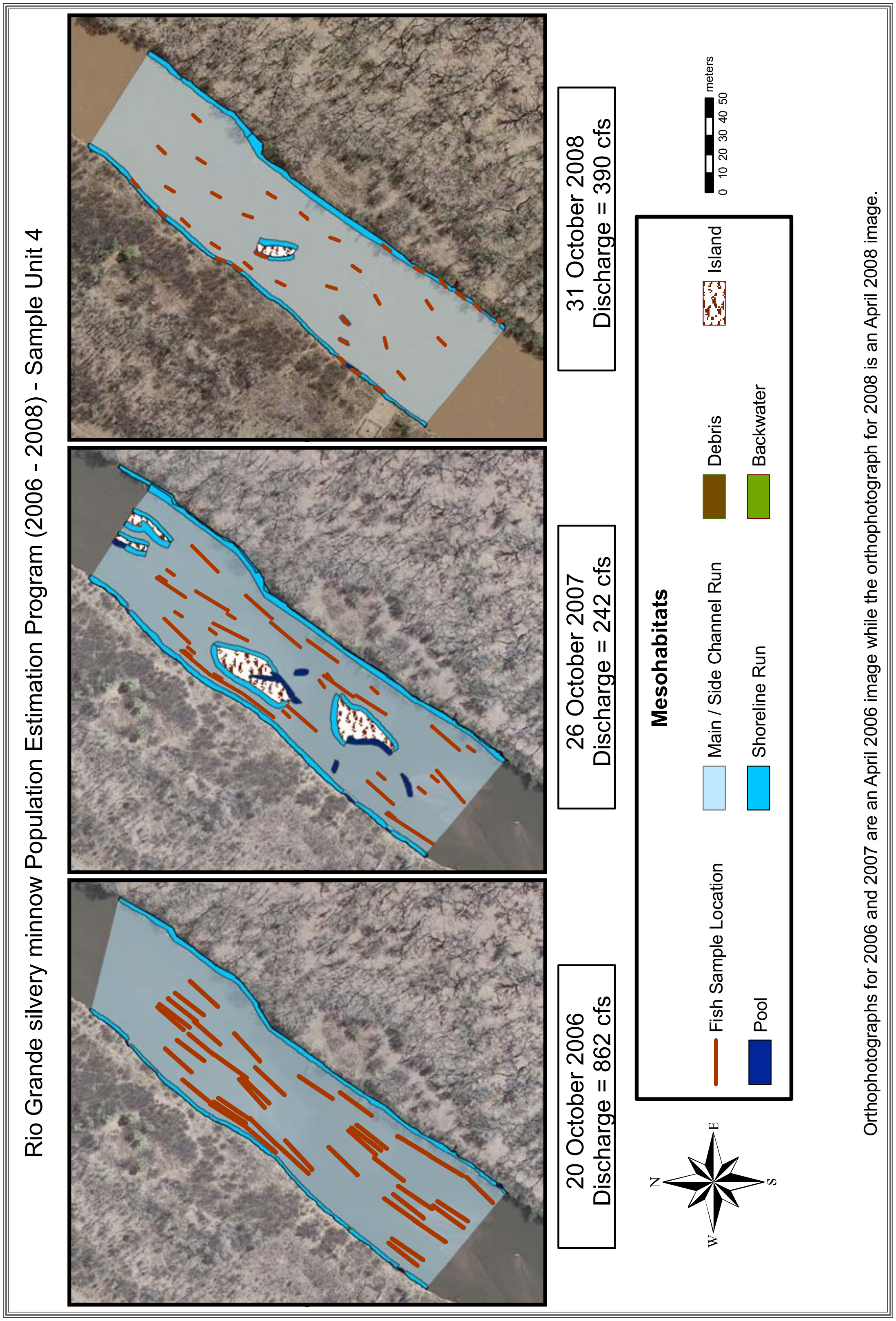

Figure B-4. Map of sampling unit #4 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

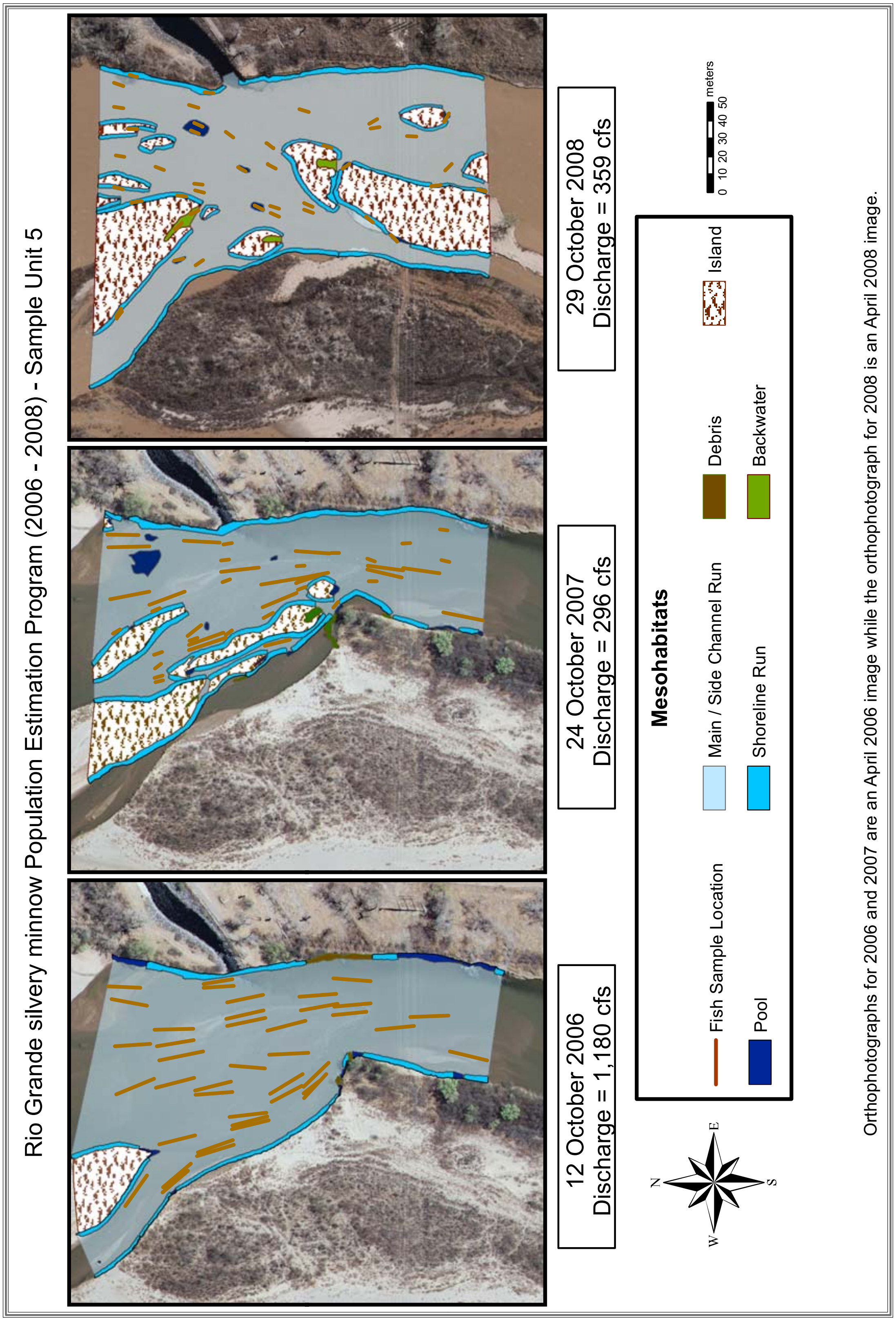

Figure B-5. Map of sampling unit #5 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

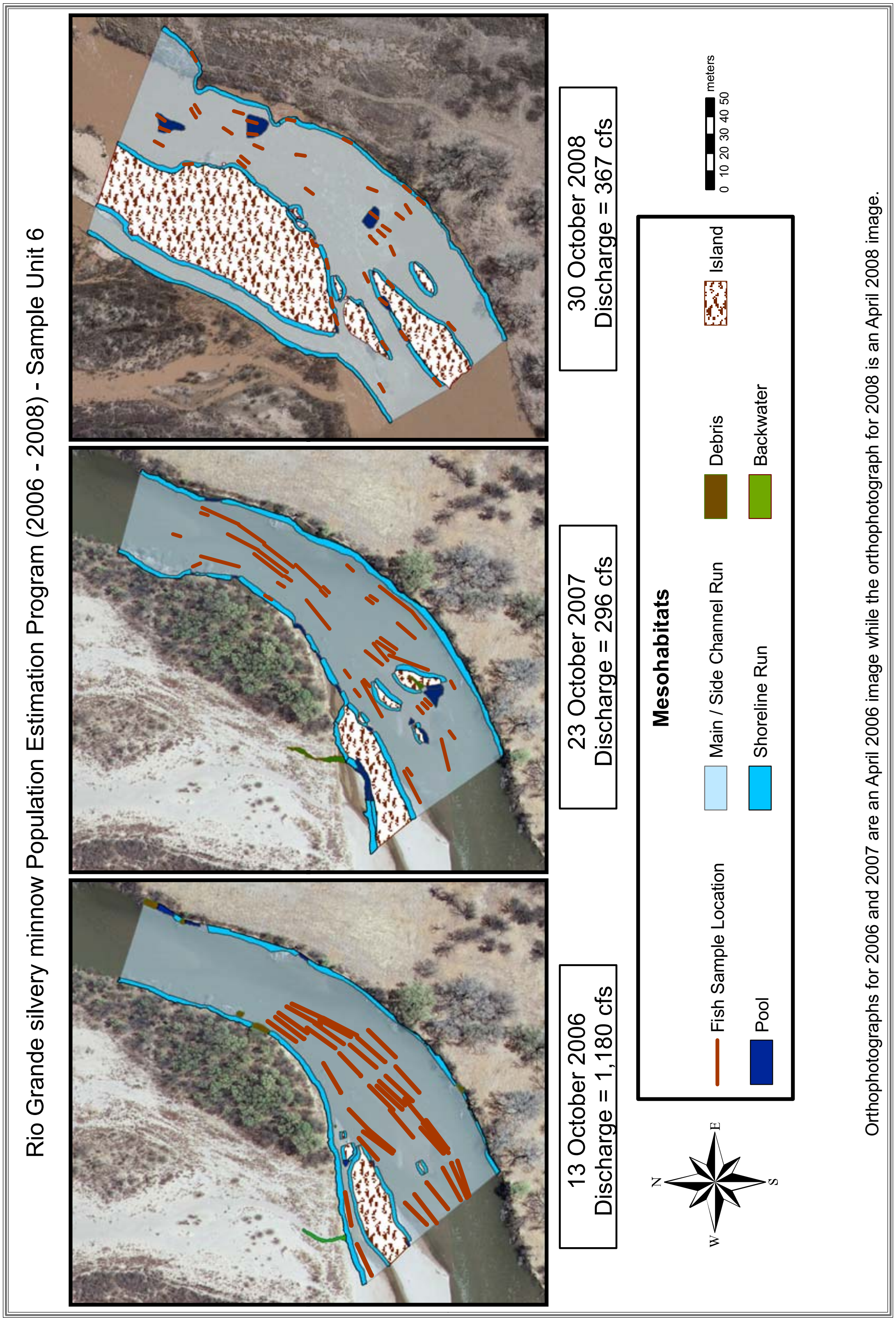

Figure B-6. Map of sampling unit #6 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

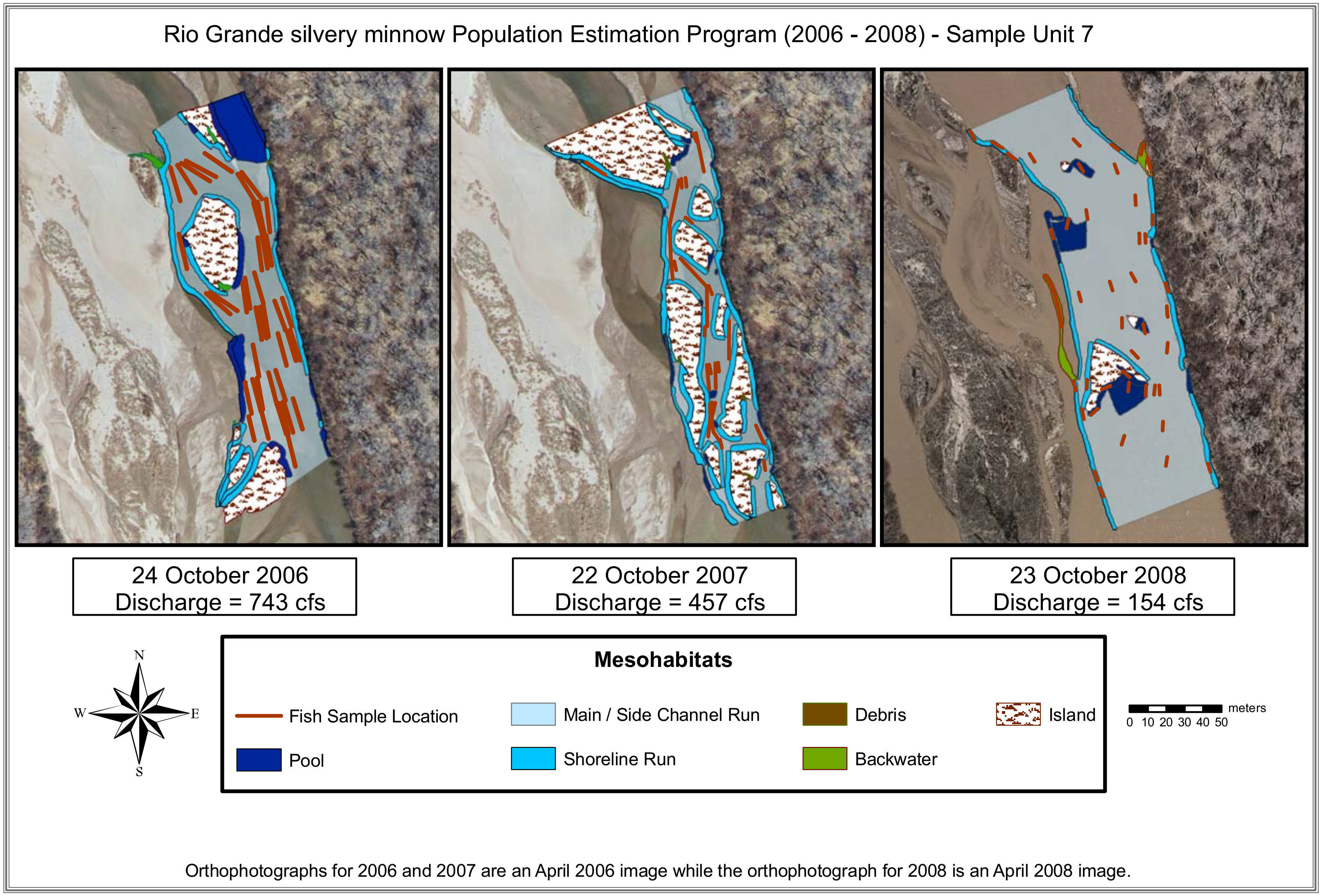

Figure B-7. Map of sampling unit #7 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

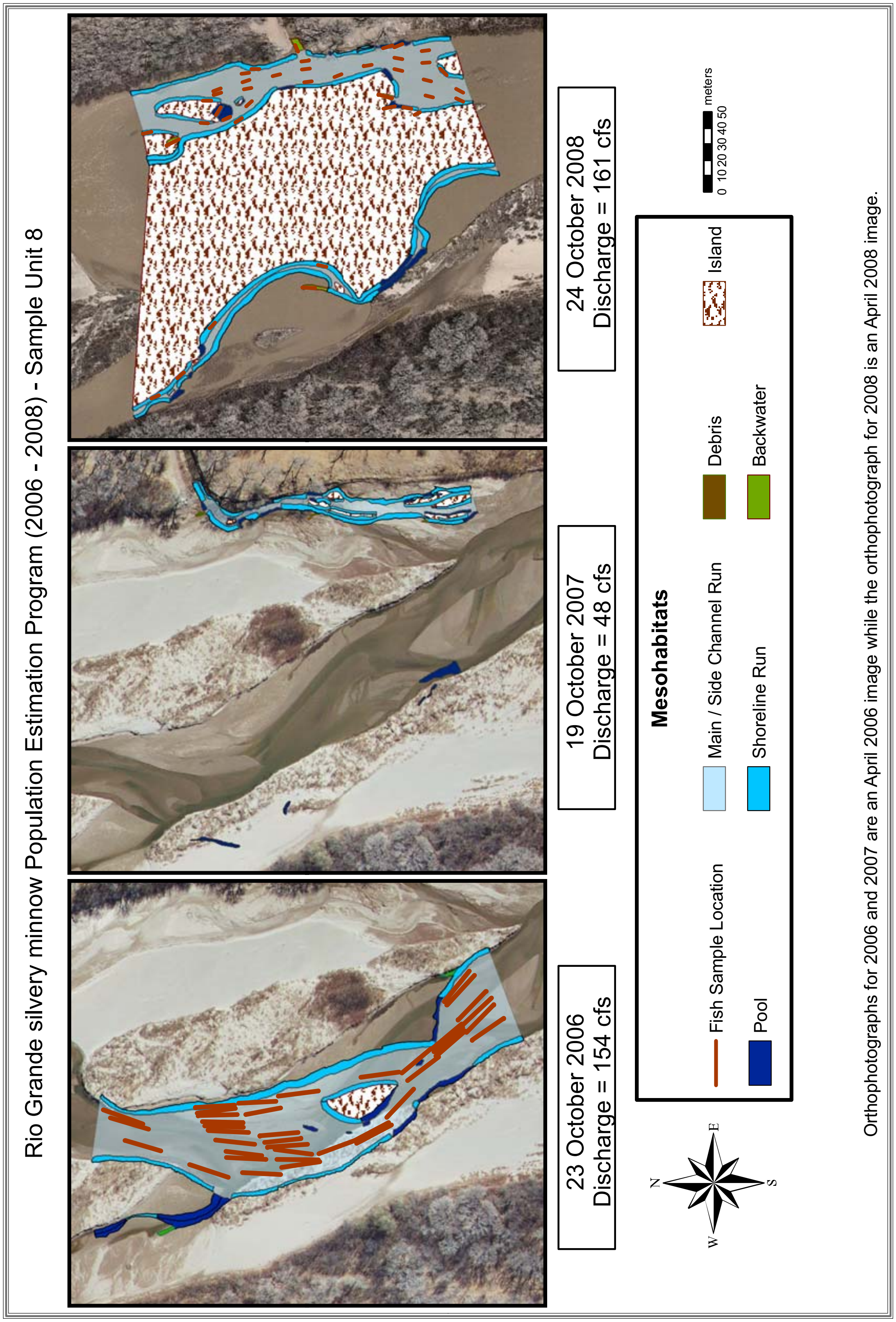

Figure B-8. Map of sampling unit #8 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

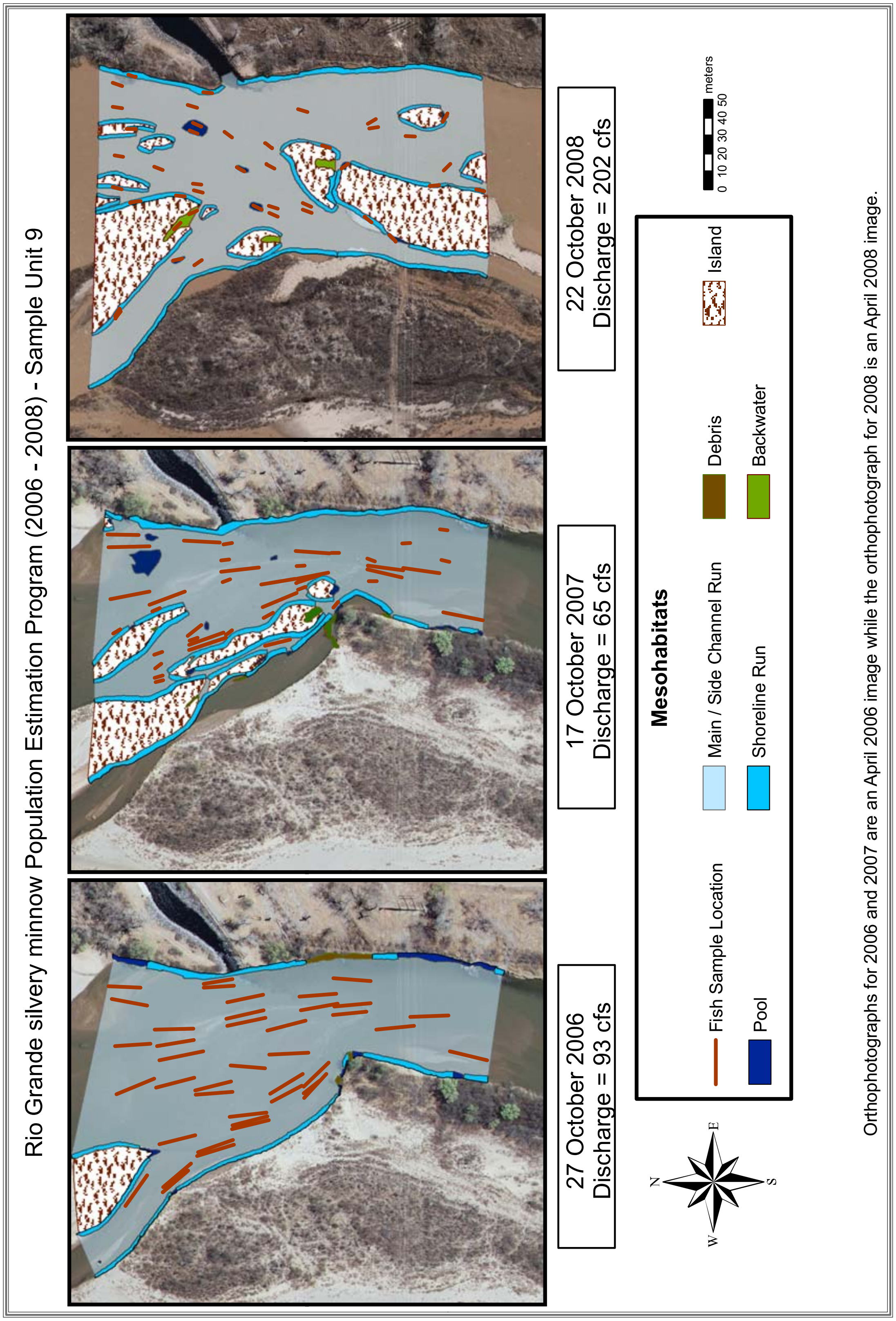

Figure B-9. Map of sampling unit #9 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

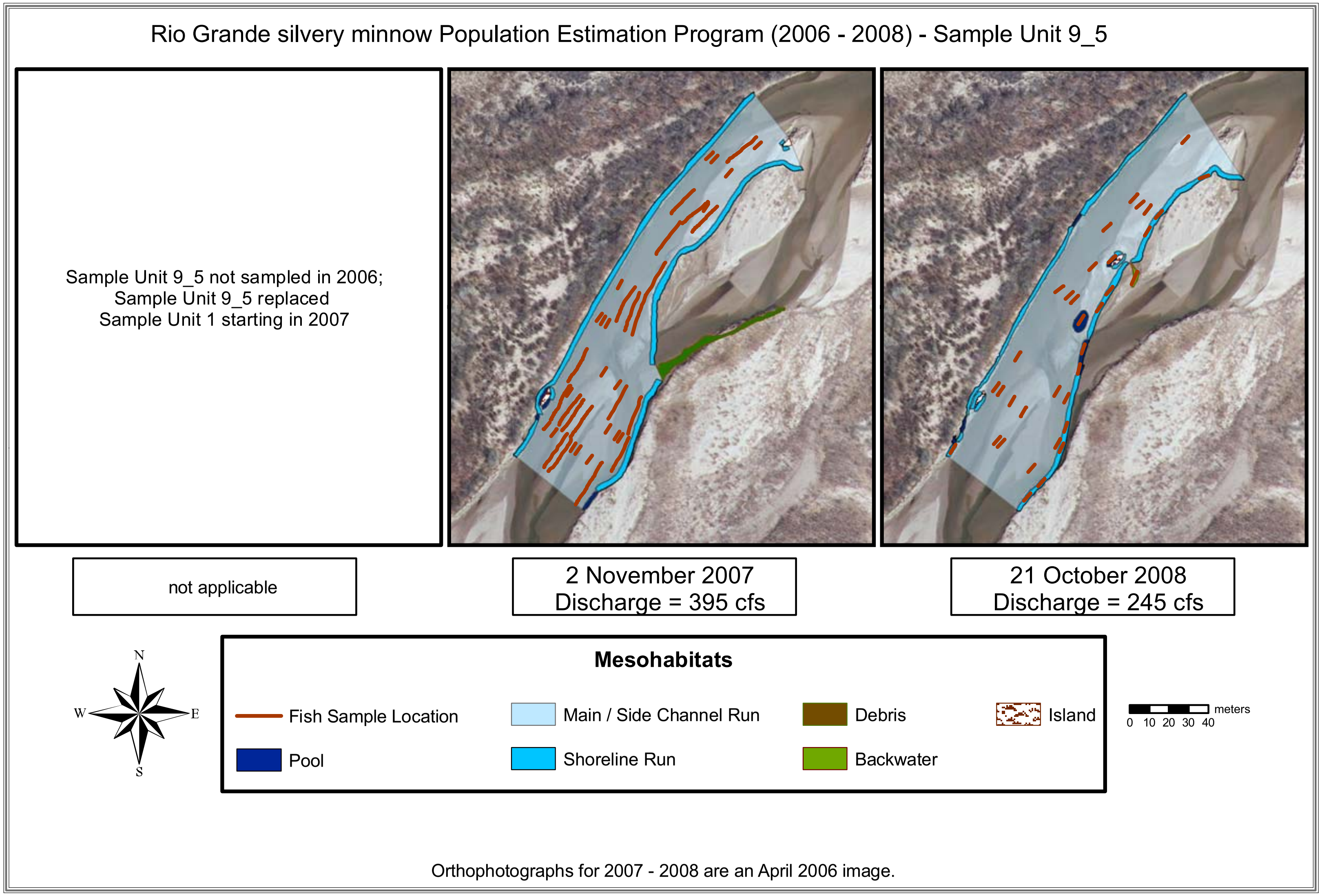

Figure B-10. Map of sampling unit #9_5 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

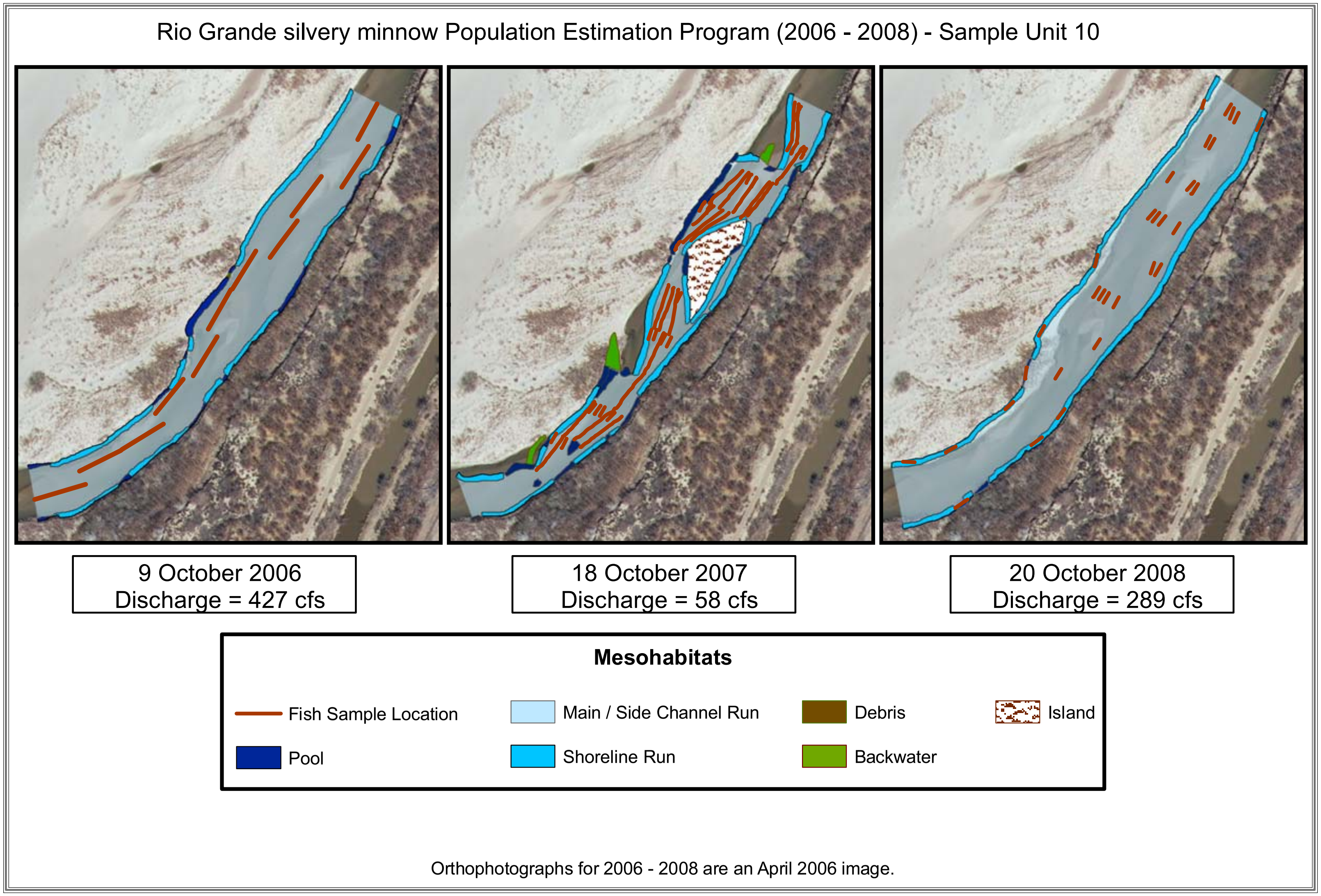

Figure B-11. Map of sampling unit #10 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

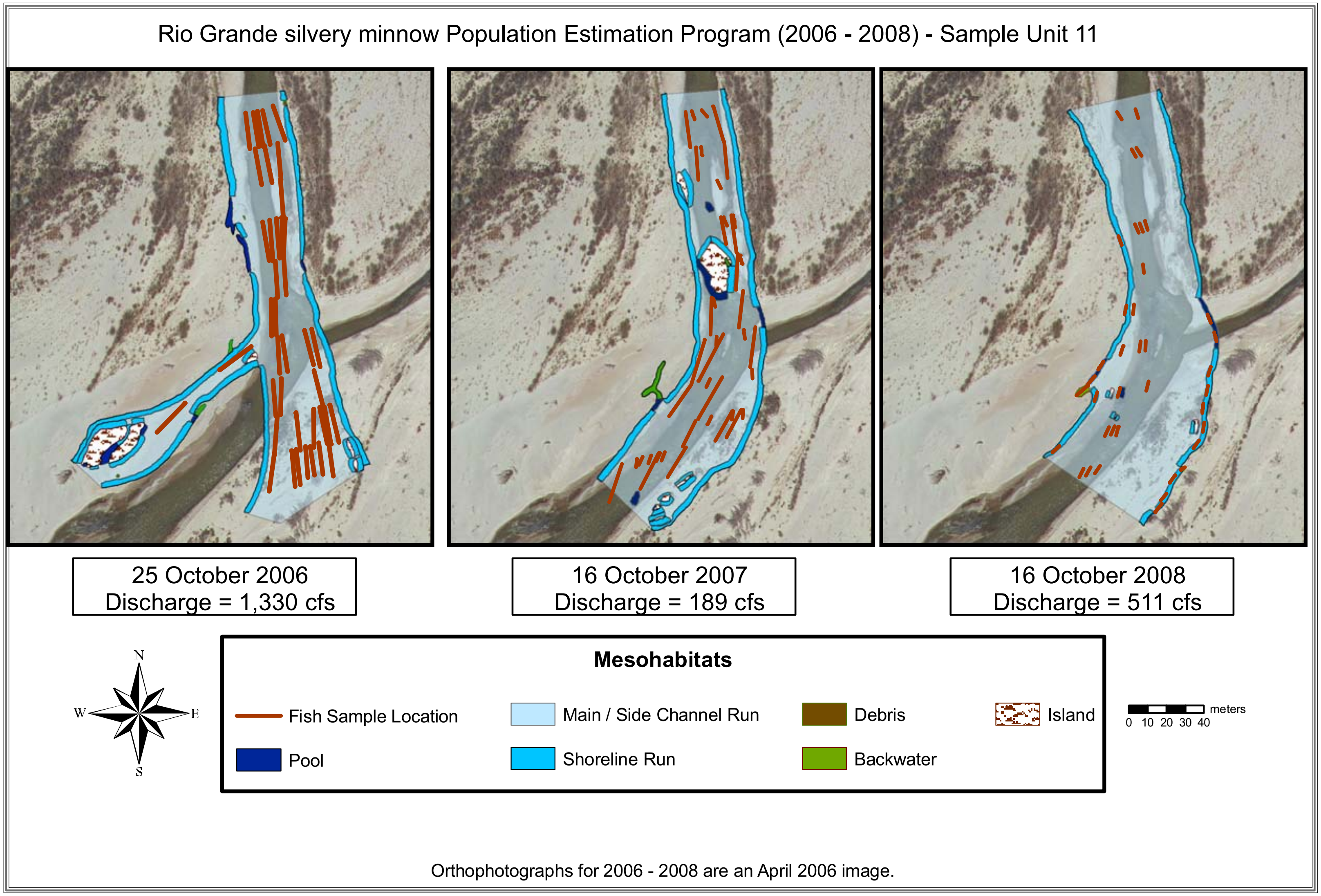

Figure B-12. Map of sampling unit #11 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

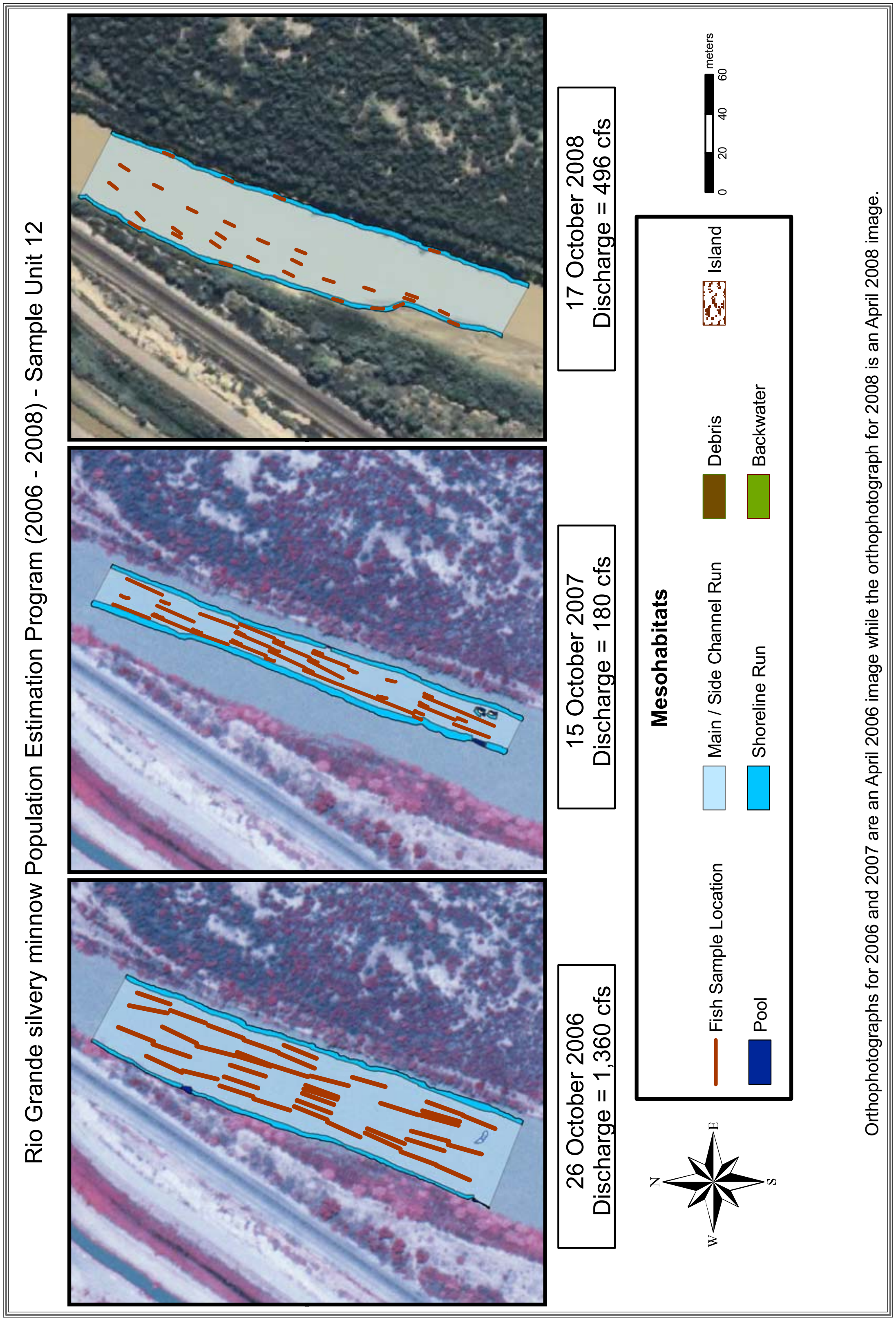

Figure B-13. Map of sampling unit #12 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

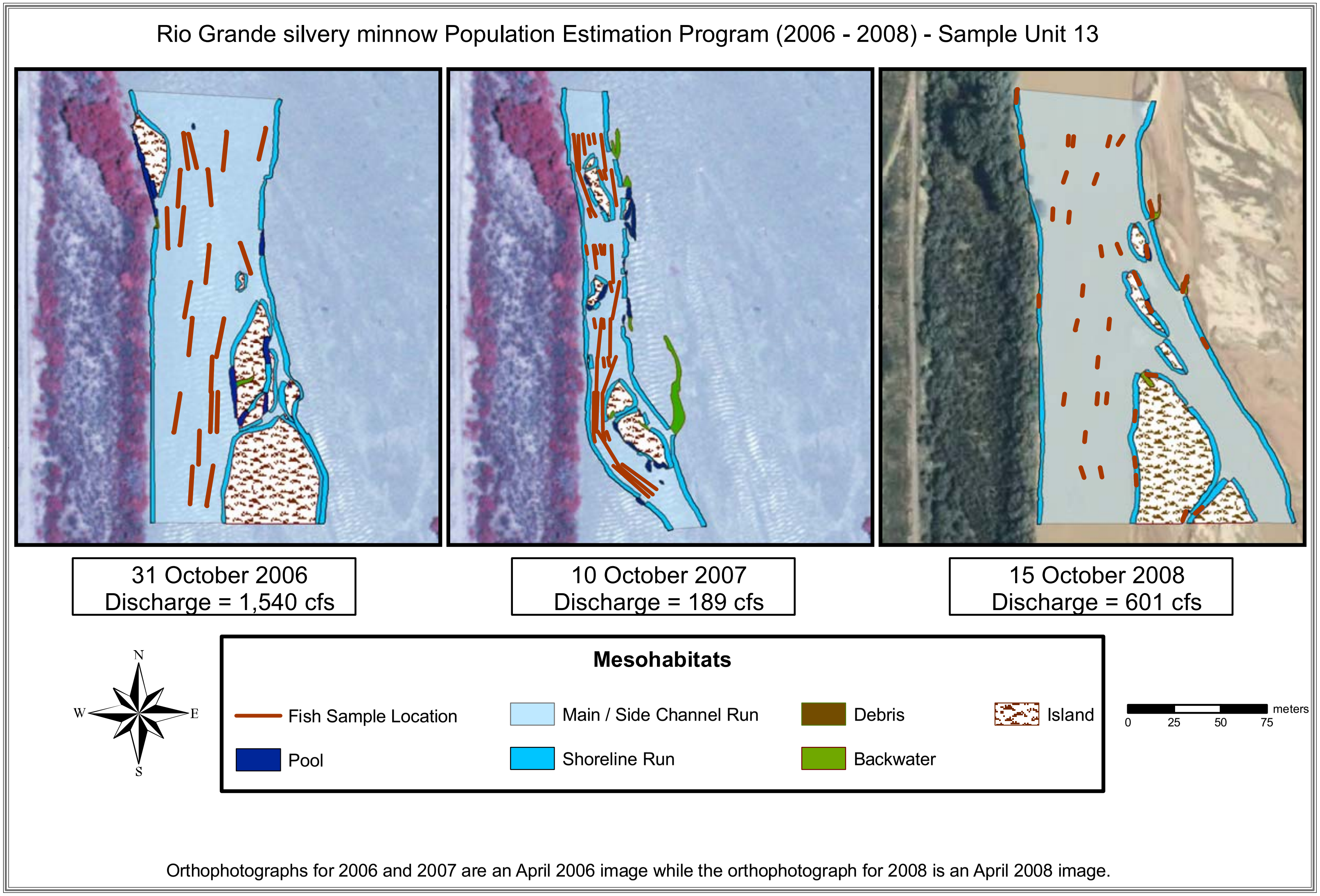

Figure B-14. Map of sampling unit #13 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

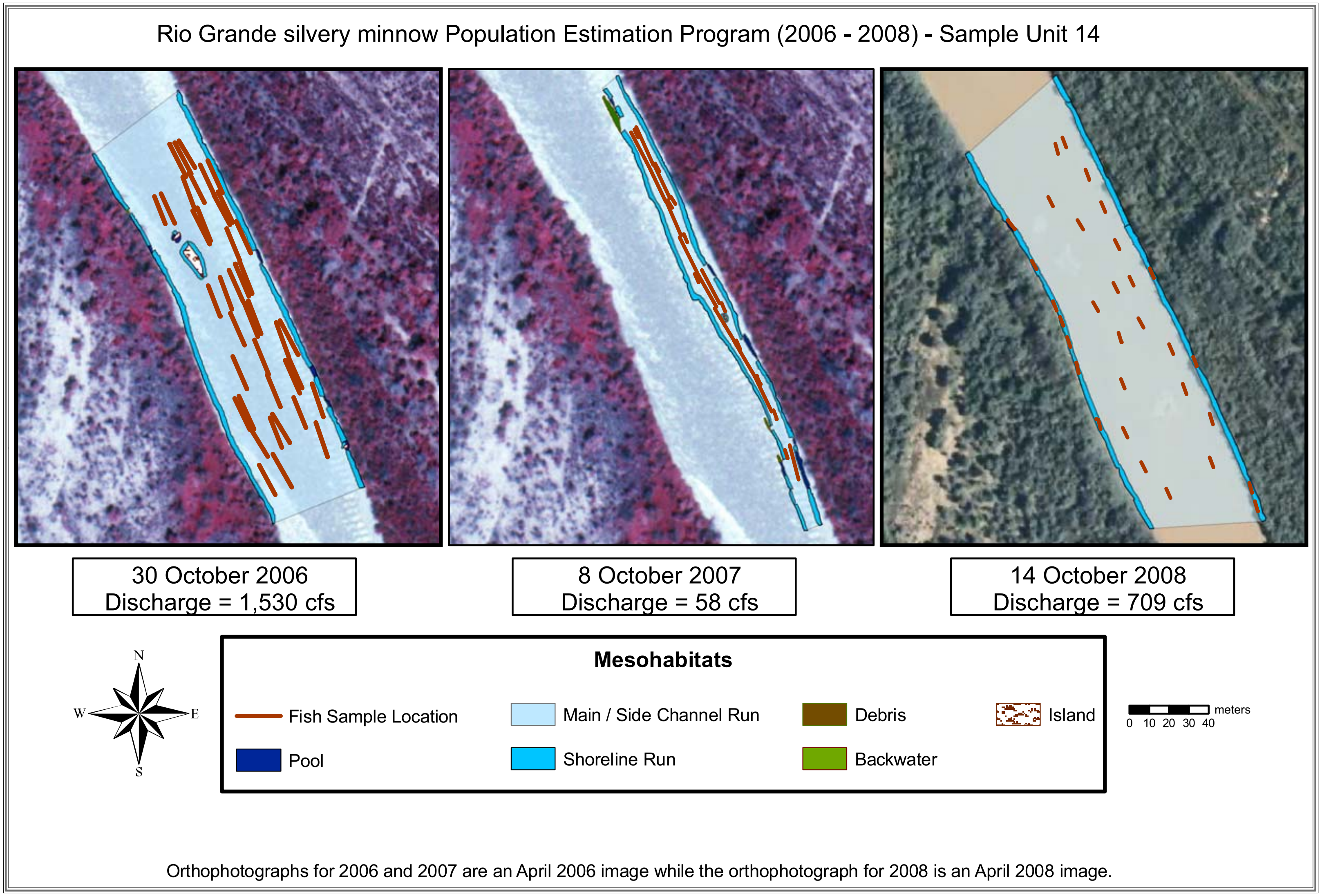

Figure B-15. Map of sampling unit #14 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

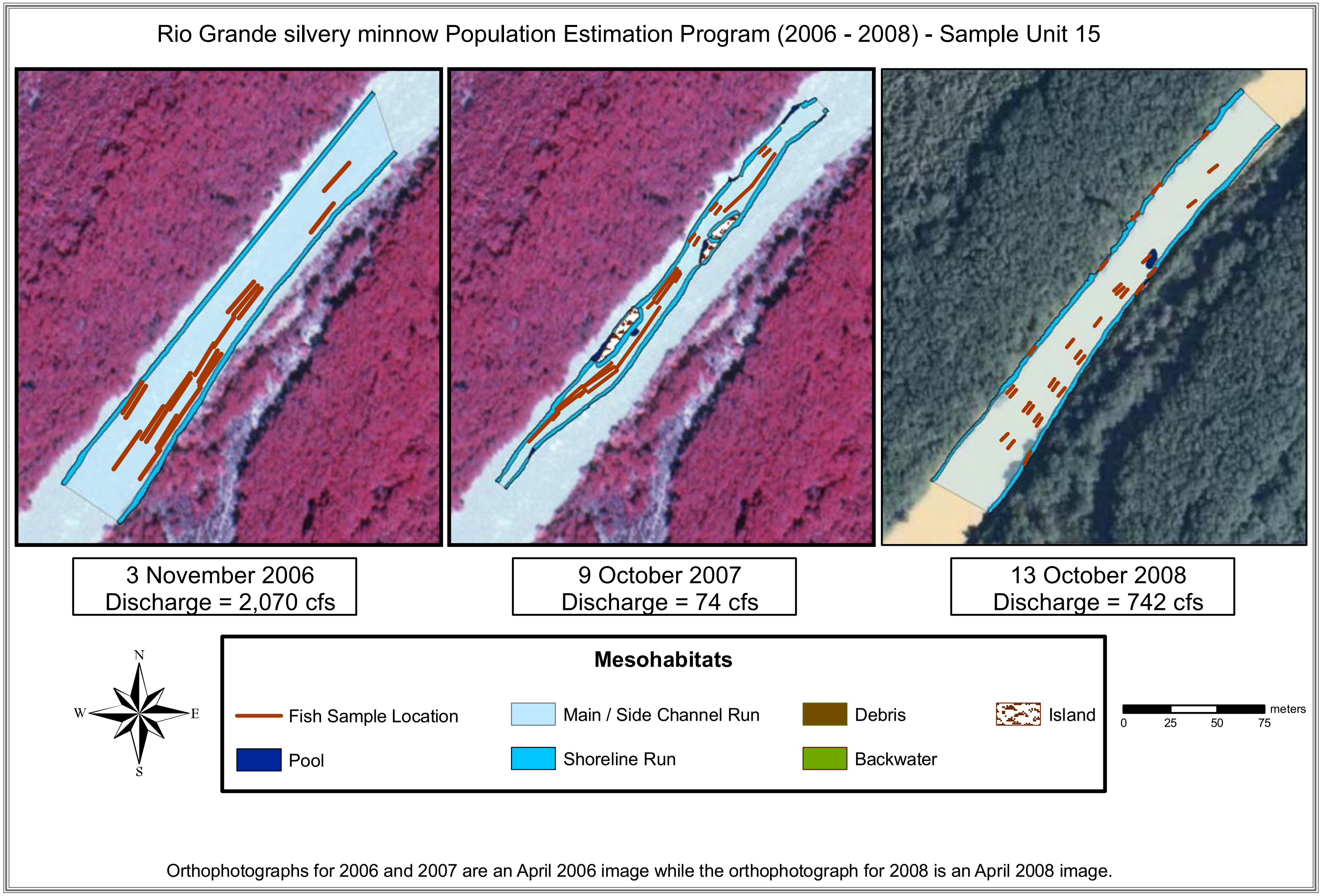

Figure B-16. Map of sampling unit #15 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

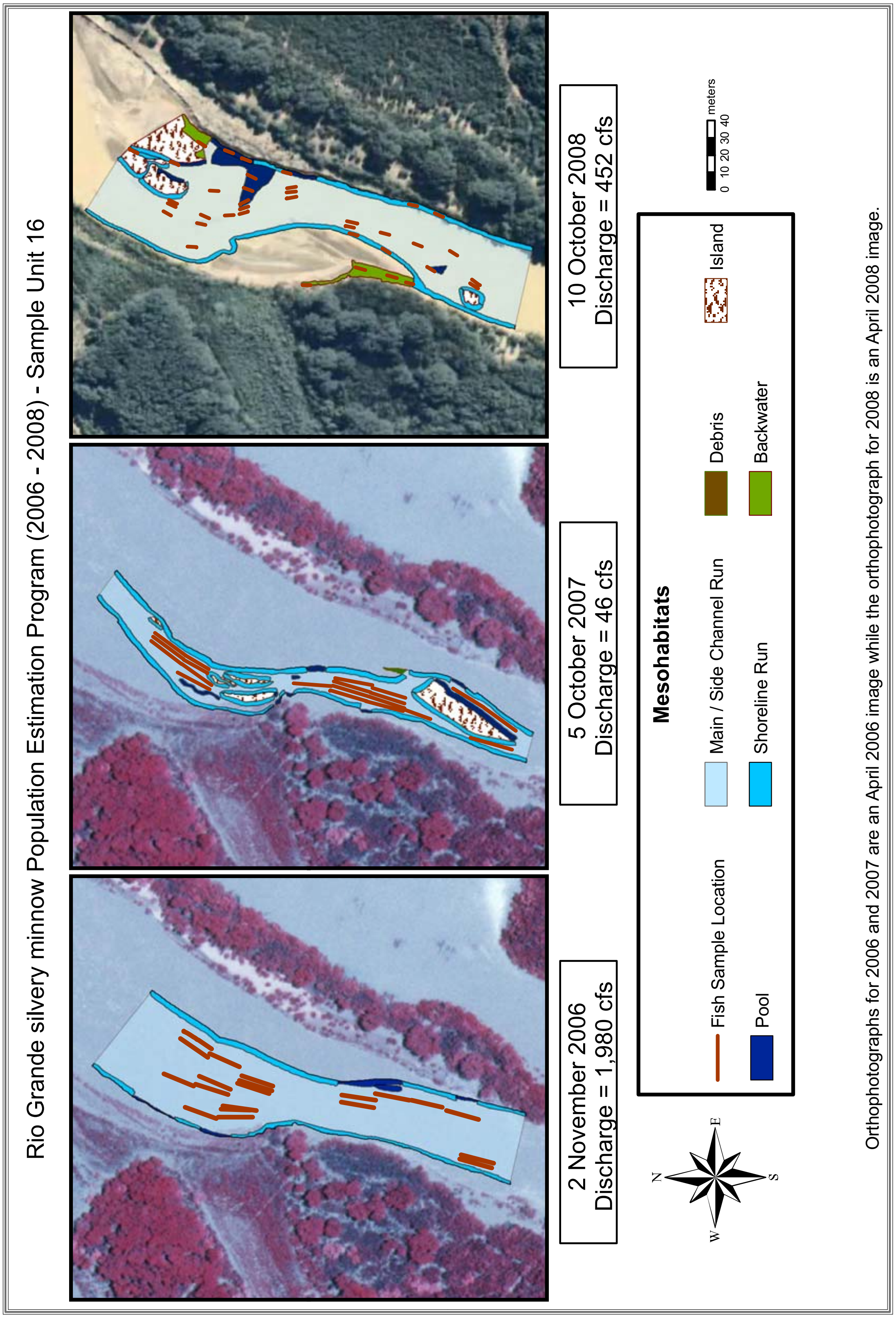

Figure B-17. Map of sampling unit #16 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

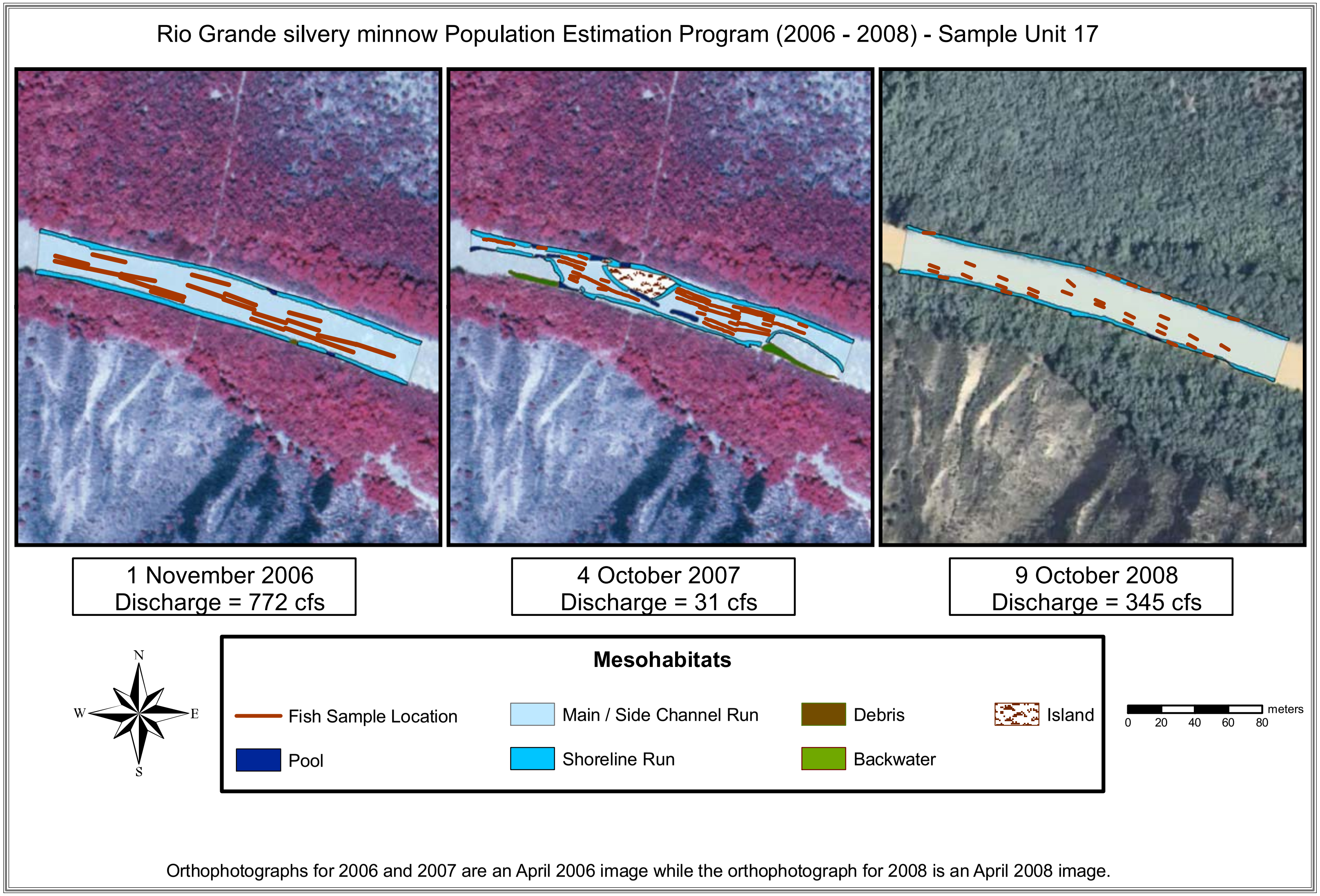

Figure B-18. Map of sampling unit #17 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

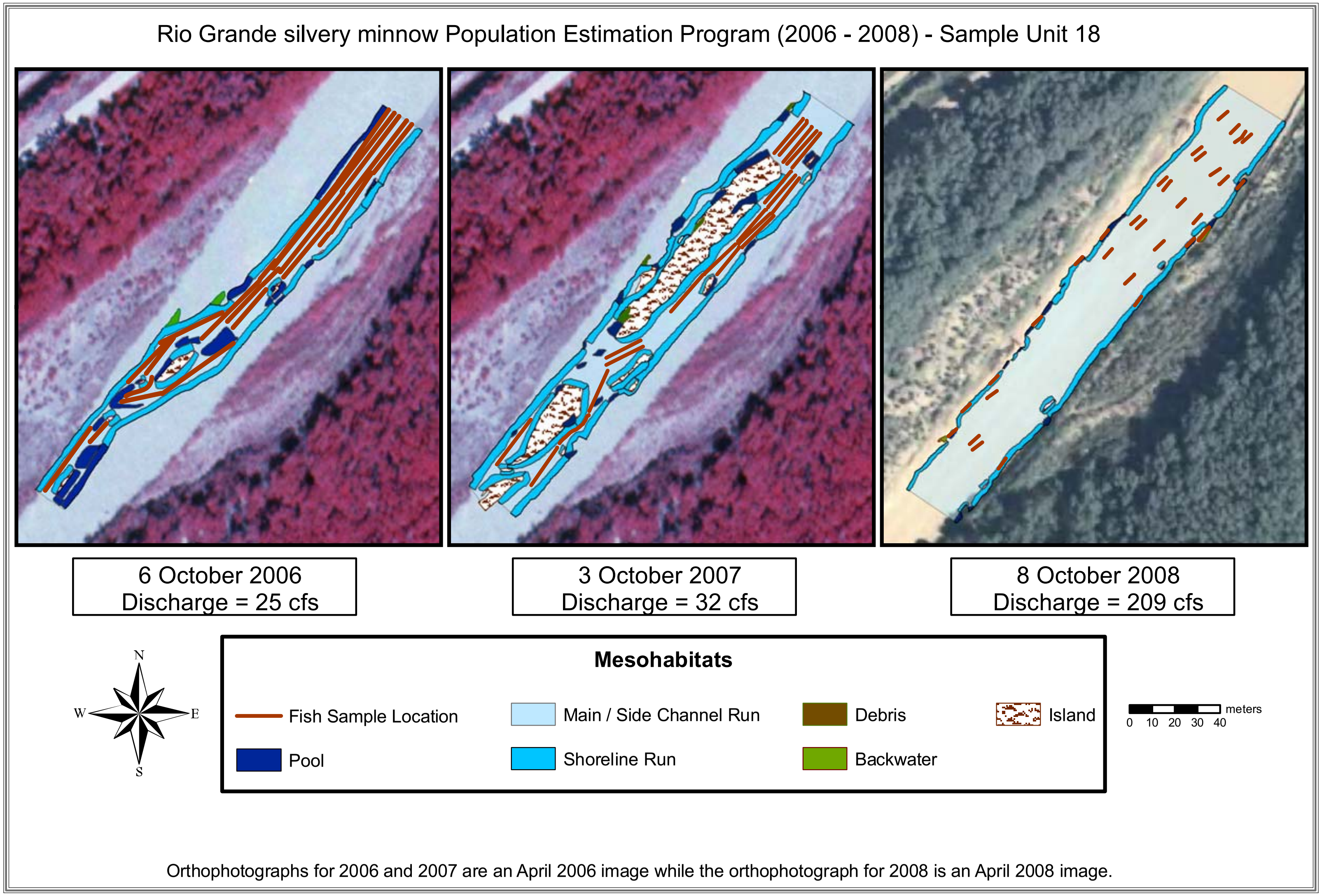

Figure B-19. Map of sampling unit #18 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

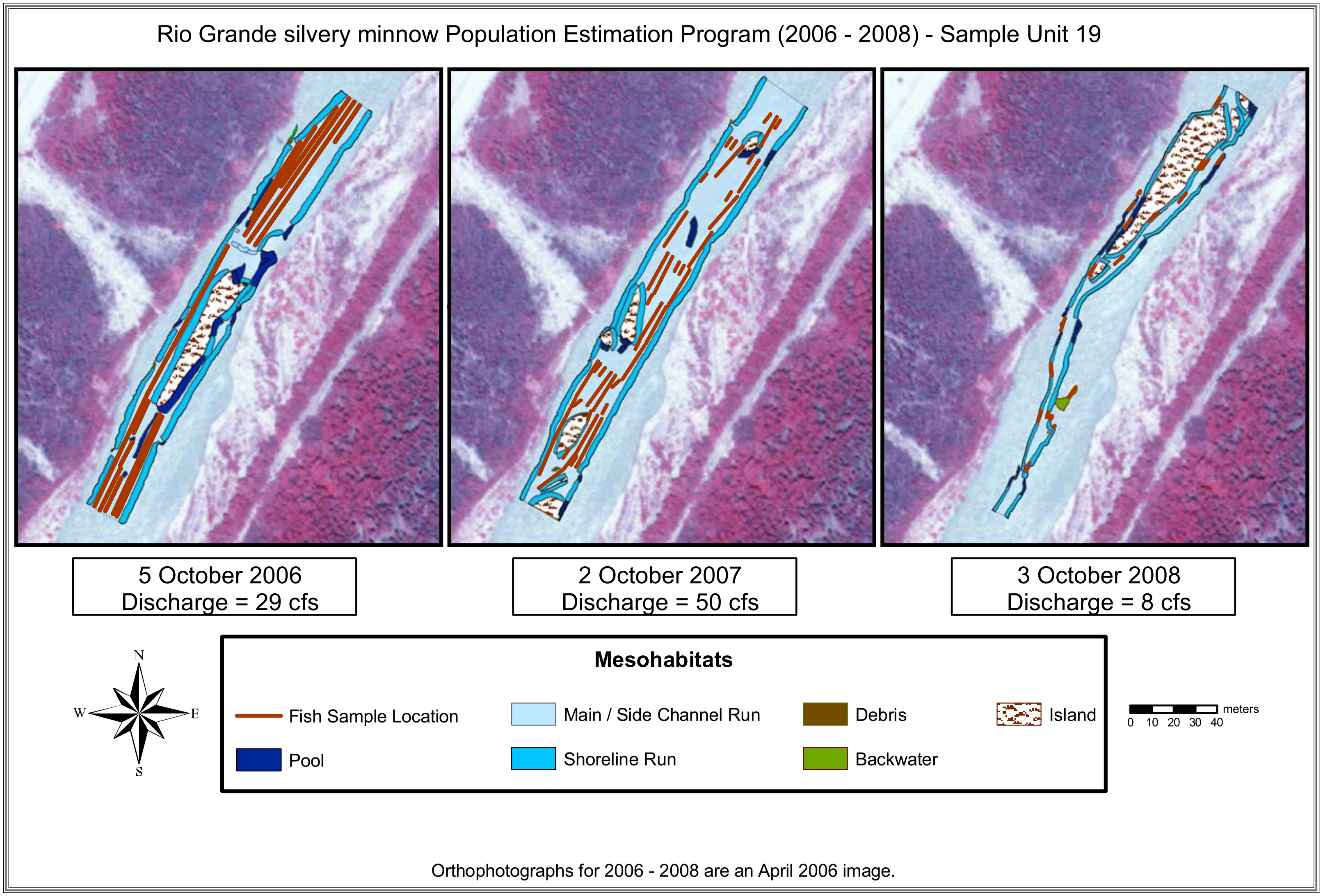

Figure B-20. Map of sampling unit #19 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

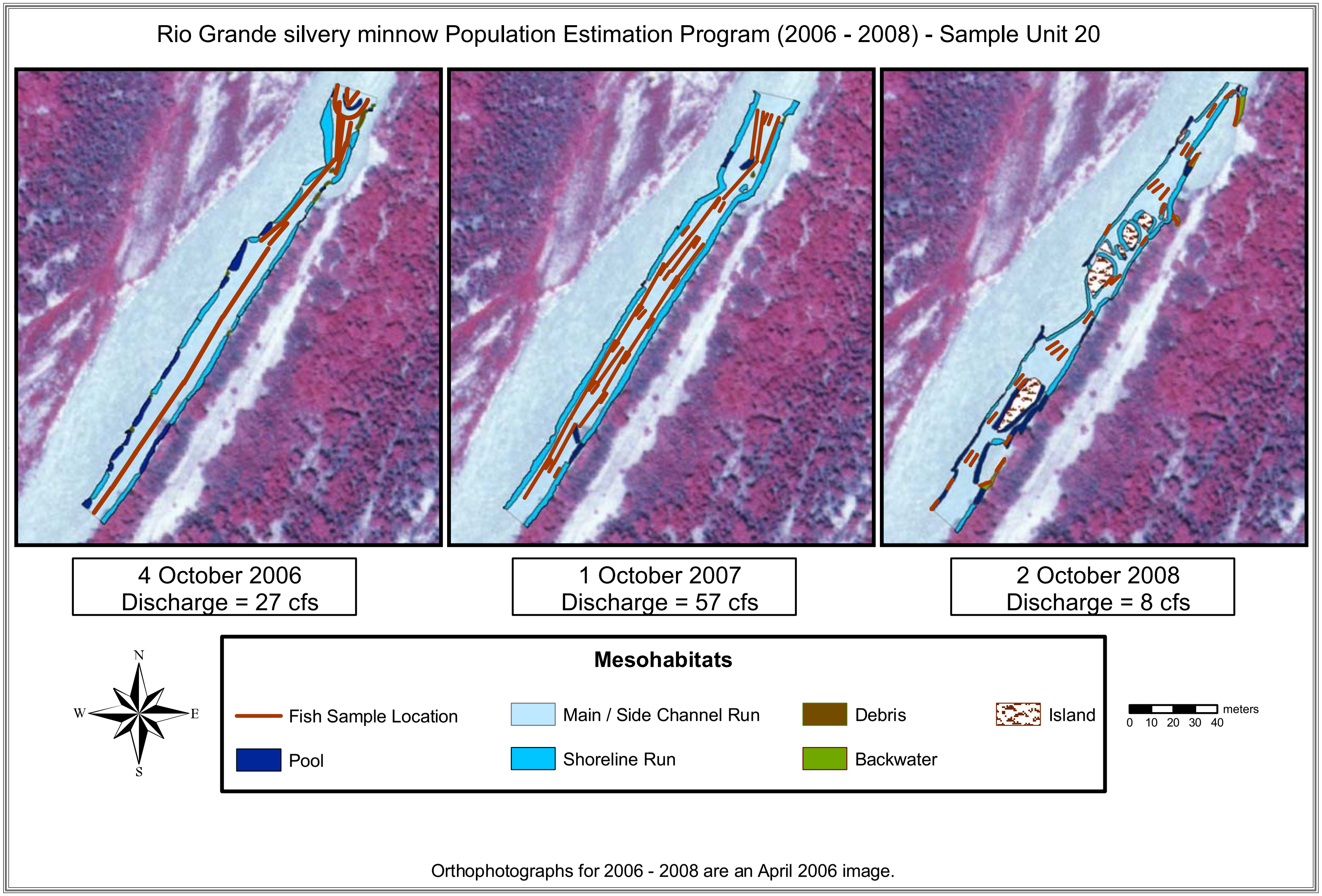

Figure B-21. Map of sampling unit #20 in the Middle Rio Grande, including all fish samples in run habitats and all available mesohabitats from October (2006 to 2008).

Appendix C.

Middle Rio Grande sampling units for the Population Monitoring Program

Table C-1. Sampling unit localities for the Rio Grande silvery minnow Population Monitoring Program.

Sampling Unit #	Sampling Unit Locality
	ANGOSTURA REACH SITES
0	New Mexico, Sandoval County, Rio Grande, directly below Angostura Diversion Dam, Algodones. River Mile 209.7 SAN FELIPE PUEBLO QUADRANGLE UTM Easting: 363811 UTM Northing: 3916006 Zone: 13
1	New Mexico, Sandoval County, Rio Grande, at NM State Highway 44 bridge crossing, Bernalillo. River Mile 203.8 BERNALILLO QUADRANGLE UTM Easting: 358543 UTM Northing: 3909722 Zone: 13
2	New Mexico, Sandoval County, Rio Grande, ca. 4.0 miles downstream of NM State Highway 44 bridge crossing, at Rio Rancho Wastewater Treatment Plant, Rio Rancho. River Mile 200.0 BERNALILLO QUADRANGLE UTM Easting: 354772 UTM Northing: 3905355 Zone: 13
3	New Mexico, Bernalillo County, Rio Grande, at Central Avenue bridge crossing (US Highway 66), Albuquerque. River Mile 183.4 ALBUQUERQUE WEST QUADRANGLE UTM Easting: 346840 UTM Northing: 3884094 Zone: 13
4	New Mexico, Bernalillo County, Rio Grande, at Rio Bravo Boulevard bridge crossing, (NM State Highway 500), Albuquerque. River Mile 178.3 ALBUQUERQUE WEST QUADRANGLE UTM Easting: 347554 UTM Northing: 3877163 Zone: 13
	ISLETA REACH SITES
5	New Mexico, Valencia County, Rio Grande at Los Lunas bridge crossing (NM State Highway 49), Los Lunas. River Mile 161.4 LOS LUNAS QUADRANGLE UTM Easting: 342898 UTM Northing: 3852531 Zone: 13
6	New Mexico, Valencia County, Rio Grande, ca. 1.0 miles upstream of NM State Highway 309/6 bridge crossing, Belen. River Mile 151.5 TOME QUADRANGLE UTM Easting: 339972 UTM Northing: 3837061 Zone: 13
7	New Mexico, Valencia County, Rio Grande, ca. 2.2 miles upstream of NM State Highway 346 bridge crossing, Jarales. River Mile 143.2 VEGUITA QUADRANGLE UTM Easting: 338136 UTM Northing: 3827329 Zone: 13
8	New Mexico, Socorro County, Rio Grande, at US Highway 60 bridge crossing, Bernardo. River Mile 130.6 ABEYTAS QUADRANGLE UTM Easting: 334604 UTM Northing: 3809726 Zone: 13
9	New Mexico, Socorro County, Rio Grande, ca. 3.5 miles downstream of US Highway 60 bridge crossing, Bernardo. River Mile 127.0 ABEYTAS QUADRANGLE UTM Easting: 331094 UTM Northing: 3805229 Zone: 13

Table C-1. Sampling unit localities for the Rio Grande silvery minnow Population Monitoring Program (continued).

Sampling Unit #	Sampling Unit Locality
	ISLETA REACH SITES (continued)
9.5	New Mexico, Socorro County, Rio Grande, ca. 0.6 miles upstream of San Acacia Diversion Dam, San Acacia River Mile 116.8 LA JOYA QUADRANGLE UTM Easting: 327902 UTM Northing: 3792603 Zone: 13
	SAN ACACIA REACH SITES
10	New Mexico, Socorro County, Rio Grande, directly below San Acacia Diversion Dam, San Acacia. River Mile 116.2 SAN ACACIA QUADRANGLE UTM Easting: 326162 UTM Northing: 3791977 Zone: 13
11	New Mexico, Socorro County, Rio Grande, ca. 1.5 miles downstream of San Acacia Diversion Dam, San Acacia. River Mile 114.6 LEMITAR QUADRANGLE UTM Easting: 325263 UTM Northing: 3790442 Zone: 13
12	New Mexico, Socorro County, Rio Grande, east of Socorro, 0.5 miles upstream of the Socorro Low Flow Conveyance Channel bridge; east and upstream of Socorro Wastewater Treatment Plant, Socorro. River Mile 99.5 LOMA DE LAS CANAS QUADRANGLE UTM Easting: 327097 UTM Northing: 3771043 Zone: 13
13	New Mexico, Socorro County, Rio Grande, ca. 4.0 miles upstream of US Highway 380 bridge crossing, San Antonio. River Mile 91.7 SAN ANTONIO QUADRANGLE UTM Easting: 328140 UTM Northing: 3761283 Zone: 13
14	New Mexico, Socorro County, Rio Grande, at US Highway 380 bridge crossing, San Antonio. River Mile 87.1 SAN ANTONIO QUADRANGLE UTM Easting: 328914 UTM Northing: 3754471 Zone: 13
15	New Mexico, Socorro County, Rio Grande, directly east of Bosque del Apache National Wildlife Refuge Headquarters, San Antonio. River Mile 79.1 SAN ANTONIO, SE QUADRANGLE UTM Easting: 327055 UTM Northing: 3740839 Zone: 13
16	New Mexico, Socorro County, Rio Grande, at San Marcial Railroad bridge crossing, San Marcial. River Mile 68.6 SAN MARCIAL QUADRANGLE UTM Easting: 315284 UTM Northing: 3728347 Zone: 13
17	New Mexico, Socorro County, Rio Grande, at its former confluence with the Low Flow Conveyance Channel; ca. 8 miles downstream of San Marcial Railroad bridge crossing. River Mile 60.5 PARAJE WELL QUADRANGLE UTM Easting: 309487 UTM Northing: 3718178 Zone: 13

Table C-1. Sampling unit localities for the Rio Grande silvery minnow Population Monitoring Program (continued).

Sampling Unit #	Sampling Unit Locality
	SAN ACACIA REACH SITES
18	New Mexico, Socorro County, Rio Grande, ca. 10 miles downstream of San Marcial Railroad bridge crossing. River Mile 57.7 PARAJE WELL QUADRANGLE UTM Easting: 307380 UTM Northing: 3714740 Zone: 13

Appendix D.

Report D-1. Ichthyofaunal composition of the October (2006 to 2008) Rio Grande silvery minnow Population Estimation Program sampling efforts

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Sandoval Co., Rio Grande Drainage
Rio Grande, ca. 2.0 miles downstream of US Highway 550 Bridge crossing, Rio — Sampling Unit: 1
19 October 2006 — **RKD06-321** — River Mile: 202.0
UTM Easting: 356983 UTM Northing: 3907801 Zone: 13 Quad: Bernalillo
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, N.B. Zerbe — Effort: 3,104.8 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	33
76	*Hybognathus amarus**	76
76	*Pimephales promelas*	55
76	*Platygobio gracilis*	115
76	*Rhinichthys cataractae*	8
81	*Catostomus commersoni*	3
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	9
212	*Gambusia affinis*	531

*** *Hybognathus amarus* by age class:**

age-0: 69
age-1: 7
age-2:

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 0.4 miles upstream of Paseo del Norte Bridge crossing, Albuquerque. Sampling Unit: 2
17 October 2006 **RKD06-319** River Mile: 191.6
UTM Easting: 349942 UTM Northing: 3895288 Zone: 13 Quad: Los Griegos
R.K. Dudley, M.A. Farrington,W.H. Brandenburg, L.E. Renfro, N.B. Zerbe Effort: 3,856.8 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	157
76	*Hybognathus amarus**	26
76	*Pimephales promelas*	22
76	*Platygobio gracilis*	63
76	*Rhinichthys cataractae*	8
81	*Carpiodes carpio*	3
93	*Ictalurus punctatus*	42
212	*Gambusia affinis*	116

*** *Hybognathus amarus* by age class:**

age-0: 13
age-1: 13
age-2:

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 1.2 miles downstream of Paseo del Norte Bridge crossing, Sampling Unit: 3
18 October 2006 **RKD06-320** River Mile: 189.8
UTM Easting: 348954 UTM Northing: 3892935 Zone: 13 Quad: Los Griegos
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, L.E. Renfro, N.B. Zerbe Effort: 4,339.7 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	126
76	*Hybognathus amarus**	56
76	*Pimephales promelas*	33
76	*Platygobio gracilis*	182
76	*Rhinichthys cataractae*	22
81	*Carpiodes carpio*	3
81	*Catostomus commersoni*	2
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	55
212	*Gambusia affinis*	61

*** *Hybognathus amarus* by age class:**

age-0: 31
age-1: 23
age-2: 2

New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 1.6 miles upstream of Rio Bravo Blvd. Bridge crossing, Albuquerque. Sampling Unit: 4
20 October 2006 **RKD06-322** River Mile: 179.8
UTM Easting: 348261 UTM Northing: 3879455 Zone: 13 Quad: Albuquerque West
R.K. Dudley, W.H. Brandenburg, L.E. Renfro, N.B. Zerbe Effort: 2,556.9 sq. m

FAMILY		N
93	*Ameiurus natalis*	2
93	*Ictalurus punctatus*	2

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 0.6 miles downstream of Rio Bravo Blvd. Bridge crossing, Sampling Unit: 5
12 October 2006 **RKD06-317** River Mile: 177.6
UTM Easting: 347381 UTM Northing: 3876106 Zone: 13 Quad: Albuquerque West
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, L.E. Renfro Effort: 3,220.8 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	41
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	7
76	*Pimephales promelas*	4
76	*Platygobio gracilis*	15
81	*Carpiodes carpio*	1
81	*Catostomus commersoni*	1
93	*Ictalurus punctatus*	119
212	*Gambusia affinis*	12
294	*Pomoxis annularis*	1

*** *Hybognathus amarus* by age class:**

age-0: 3
age-1: 4
age-2:

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 1.0 miles downstream of Rio Bravo Blvd. Bridge crossing, Sampling Unit: 6
13 October 2006 **RKD06-318** River Mile: 177.3
UTM Easting: 347155 UTM Northing: 3875786 Zone: 13 Quad: Albuquerque West
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, N.B. Zerbe Effort: 2,915.5 sq. m

FAMILY		**N**
76	*Cyprinella lutrensis*	66
76	*Hybognathus amarus**	1
76	*Pimephales promelas*	21
76	*Platygobio gracilis*	15
81	*Carpiodes carpio*	1
81	*Catostomus commersoni*	2
93	*Ameiurus natalis*	2
93	*Ictalurus punctatus*	352
212	*Gambusia affinis*	243

*** *Hybognathus amarus* by age class:**

age-0:
age-1: 1
age-2:

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Valencia Co., Rio Grande Drainage

Rio Grande, ca. 4.0 miles upstream of Los Lunas Bridge crossing (NM State Highway 49), Los Lunas.

Sampling Unit: 7

River Mile: 164.8

24 October 2006 **RKD06-324**

UTM Easting: 342969 UTM Northing: 3857901 Zone: 13 Quad: Los Lunas

R.K. Dudley, W.H. Brandenburg, M.A. Farrington, N.B. Zerbe, M.D. Porter

Effort: 4,993.3 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	1492
76	*Cyprinus carpio*	2
76	*Hybognathus amarus**	13
76	*Pimephales promelas*	111
76	*Platygobio gracilis*	9
81	*Carpiodes carpio*	1
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	31
212	*Gambusia affinis*	251
294	*Lepomis macrochirus*	1
294	*Micropterus salmoides*	1
294	*Pomoxis annularis*	1

*** *Hybognathus amarus* by age class:**

age-0: 4

age-1: 9

age-2:

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Valencia Co., Rio Grande Drainage
Rio Grande, ca. 2.9 miles upstream of NM 6 bridge crossing, Belen. Sampling Unit: 8
23 October 2006 **RKD06-323** River Mile: 152.4
UTM Easting: 340193 UTM Northing: 3840028 Zone: 13 Quad: Tome
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, L.E. Renfro, N.B. Zerbe Effort: 3,769.1 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	799
76	*Cyprinus carpio*	3
76	*Hybognathus amarus**	19
76	*Pimephales promelas*	209
76	*Platygobio gracilis*	7
76	*Rhinichthys cataractae*	1
81	*Carpiodes carpio*	4
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	29
212	*Gambusia affinis*	226

*** *Hybognathus amarus* by age class:**

age-0: 8
age-1: 11
age-2:

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Valencia Co., Rio Grande Drainage
Rio Grande, ca. 0.2 miles downstream of NM State Highway 346 Bridge crossing, Jarales.
Sampling Unit: 9
River Mile: 140.6
27 October 2006 **RKD06-327**
UTM Easting: 338117 UTM Northing: 3823765 Zone: 13 Quad: Veguita
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, L.E. Renfro, N.B. Zerbe
Effort: 2,602.3 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	1891
76	*Cyprinus carpio*	3
76	*Hybognathus amarus**	9
76	*Pimephales promelas*	110
76	*Platygobio gracilis*	12
81	*Carpiodes carpio*	1
93	*Ameiurus natalis*	3
93	*Ictalurus punctatus*	80
212	*Gambusia affinis*	53
294	*Lepomis macrochirus*	1

*** *Hybognathus amarus* by age class:**

age-0: 5
age-1: 4
age-2:

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 3.7 miles downstream of US Highway 60 Bridge crossing, Bernardo. Sampling Unit: 10
09 October 2006 **RKD06-316** River Mile: 126.9
UTM Easting: 330997 UTM Northing: 3805306 Zone: 13 Quad: Abevtas
R.K. Dudley, M.A. Farrington, L.E. Renfro Effort: 1,391.4 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	1006
76	*Hybognathus amarus**	1
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	2
81	*Carpiodes carpio*	1
93	*Ameiurus natalis*	2
93	*Ictalurus punctatus*	29
212	*Gambusia affinis*	31

*** *Hybognathus amarus* by age class:**

age-0: 1
age-1:
age-2:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 1.7 miles upstream of San Acacia Diversion Dam, San Acacia. Sampling Unit: 11
25 October 2006 **RKD06-325** River Mile: 117.9
UTM Easting: 328767 UTM Northing: 3792883 Zone: 13 Quad: La Joya
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, L.E. Renfro, N.B. Zerbe Effort: 3,988.0 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	39
76	*Hybognathus amarus**	2
76	*Platygobio gracilis*	116
76	*Rhinichthys cataractae*	3
81	*Carpiodes carpio*	4
93	*Ameiurus natalis*	2
93	*Ictalurus punctatus*	2
212	*Gambusia affinis*	7

*** *Hybognathus amarus* by age class:**

age-0: 2
age-1:
age-2:

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.8 miles downstream of San Acacia Diversion Dam, San Acacia. Sampling Unit: 12
26 October 2006 **RKD06-326** River Mile: 115.4
UTM Easting: 325363 UTM Northing: 3791796 Zone: 13 Quad: San Acacia
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, N.B. Zerbe Effort: 2,810.5 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	62
76	*Hybognathus amarus**	4
76	*Pimephales promelas*	2
76	*Platygobio gracilis*	27
81	*Carpiodes carpio*	1
93	*Ictalurus punctatus*	9
212	*Gambusia affinis*	1

*** *Hybognathus amarus* by age class:**

age-0: 4
age-1:
age-2:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 4.5 miles upstream of US Highway 380 Bridge crossing, San Antonio. Sampling Unit: 13
31 October 2006 **RKD06-329** River Mile: 91.6
UTM Easting: 328199 UTM Northing: 3760830 Zone: 13 Quad: San Antonio
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, L.E. Renfro, N.B. Zerbe Effort: 2,822.8 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	907
76	*Hybognathus amarus**	22
76	*Pimephales promelas*	7
93	*Ictalurus punctatus*	7
212	*Gambusia affinis*	5

*** *Hybognathus amarus* by age class:**

age-0: 7
age-1: 15
age-2:

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 1.5 miles downstream of US Highway 380 Bridge crossing, San Sampling Unit: 14
30 October 2006 **RKD06-328** River Mile: 85.7
UTM Easting: 329256 UTM Northing: 3752209 Zone: 13 Quad: San Antonio
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, L.E. Renfro, N.B. Zerbe Effort: 3,224.3 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	31
93	*Ictalurus punctatus*	1
212	*Gambusia affinis*	1

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.2 miles downstream of the south boundary of the Bosque del Apache National Wildlife Refuge. Sampling Unit: 15
River Mile: 73.6
03 November 2006 **RKD06-332**
UTM Easting: 322489 UTM Northing: 3732572 Zone: 13 Quad: San Marcial
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, L.E. Renfro Effort: 1,933.0 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	71
76	*Hybognathus amarus**	5
81	*Carpiodes carpio*	1
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	7

**** Hybognathus amarus* by age class:**

age-0: 2
age-1: 3
age-2:

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 2.2 miles downstream of the south boundary of the Bosque del Apache National Wildlife Refuge. Sampling Unit: 16
River Mile: 71.6
02 November 2006 **RKD06-331**
UTM Easting: 320044 UTM Northing: 3730043 Zone: 13 Quad: San Marcial
R.K. Dudley, M.A. Farrington, L.E. Renfro, N.B. Zerbe Effort: 1,969.9 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	483
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	90
76	*Pimephales promelas*	12
76	*Platygobio gracilis*	16
81	*Carpiodes carpio*	6
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	8

*** *Hybognathus amarus* by age class:**

age-0: 20
age-1: 70
age-2:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.9 miles upstream of San Marcial Railroad Bridge crossing, San Marcial. Sampling Unit: 17
River Mile: 69.5
01 November 2006 **RKD06-330**
UTM Easting: 316840 UTM Northing: 3728978 Zone: 13 Quad: San Marcial
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, L.E. Renfro, N.B. Zerbe Effort: 2,010.9 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	353
76	*Pimephales promelas*	1
93	*Ictalurus punctatus*	5

Rio Grande silvery minnow Population Estimation Program
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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 5.0 miles downstream of San Marcial Railroad Bridge crossing, San Marcial.
Sampling Unit: 18
River Mile: 63.6
06 October 2006 **RKD06-315**
UTM Easting: 313417 UTM Northing: 3721520 Zone: 13 Quad: Paraje Well
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, L.E. Renfro
Effort: 3,826.8 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	203
76	*Hybognathus amarus**	1
76	*Pimephales promelas*	2
76	*Platygobio gracilis*	1
81	*Carpiodes carpio*	2
81	*Catostomus commersoni*	2
93	*Ictalurus punctatus*	4

*** *Hybognathus amarus* by age class:**

age-0: 1
age-1:
age-2:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.9 miles downstream of the former confluence with the Low Flow Conveyance Channel.
Sampling Unit: 19
River Mile: 59.8
05 October 2006 **RKD06-314**
UTM Easting: 308328 UTM Northing: 3717266 Zone: 13 Quad: Paraje Well
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, L.E. Renfro
Effort: 5,581.6 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	82
76	*Hybognathus amarus**	6
76	*Pimephales promelas*	3
76	*Platygobio gracilis*	6
76	*Rhinichthys cataractae*	2
93	*Ameiurus natalis*	1
212	*Gambusia affinis*	7

*** *Hybognathus amarus* by age class:**

age-0: 6
age-1:
age-2:

Rio Grande silvery minnow Population Estimation Program
October 2006

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 1.1 miles downstream of the former confluence with the Low Flow Conveyance Channel. Sampling Unit: 20
River Mile: 59.6
04 October 2006 **RKD06-313**
UTM Easting: 308118 UTM Northing: 3716920 Zone: 13 Quad: Paraje Well
W.H. Brandenburg, M.A. Farrington, L.E. Renfro, N.B. Zerbe Effort: 2,667.2 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	43
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	1
76	*Platygobio gracilis*	1
93	*Ictalurus punctatus*	6
93	*Pylodictis olivaris*	1

*** *Hybognathus amarus* by age class:**

age-0: 1
age-1:
age-2:

Rio Grande silvery minnow Population Estimation Program
October 2007

New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 0.4 miles upstream of Paseo del Norte Bridge crossing, Albuquerque. Sampling Unit: 2
30 October 2007 **RKD07-192** River Mile: 191.6
UTM Easting: 349942 UTM Northing: 3895288 Zone: 13 Quad: Los Griegos
R.K. Dudley, W.H. Brandenburg, C.C. Mcbride, J.P. Larson, D.A. Helfrich Effort: 2,585.0 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	485
76	*Cyprinus carpio*	6
76	*Hybognathus amarus**	150
76	*Pimephales promelas*	21
76	*Platygobio gracilis*	33
81	*Carpiodes carpio*	13
81	*Catostomus commersoni*	1
93	*Ictalurus punctatus*	40
212	*Gambusia affinis*	73

*** *Hybognathus amarus* by age class:**

age-0: 149
age-1: 1

Rio Grande silvery minnow Population Estimation Program
October 2007

New Mexico: Bernalillo Co., Rio Grande Drainage

Rio Grande, ca. 1.2 miles downstream of Paseo del Norte Bridge crossing, Albuquerque. Sampling Unit: 3

29 October 2007 **RKD07-191** River Mile: 189.9

UTM Easting: 348954 UTM Northing: 3892935 Zone: 13 Quad: Los Griegos

R.K. Dudley, W.H. Brandenburg, J.P. Larson, C.C. McBride, T. Krabenhoff, D.A. Helfrich, A.L. Barkalow Effort: 6,319.2 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	632
76	*Cyprinus carpio*	3
76	*Hybognathus amarus**	254
76	*Pimephales promelas*	12
76	*Platygobio gracilis*	241
76	*Rhinichthys cataractae*	24
81	*Carpiodes carpio*	31
81	*Catostomus commersoni*	10
93	*Ictalurus punctatus*	102

*** *Hybognathus amarus* by age class:**

age-0: 253

age-1: 1

Rio Grande silvery minnow Population Estimation Program
October 2007

New Mexico: Bernalillo Co., Rio Grande Drainage

Rio Grande, ca. 1.6 miles upstream of Rio Bravo Blvd. Bridge crossing, Albuquerque. Sampling Unit: 4

26 October 2007 **RKD07-190** River Mile: 179.9

UTM Easting: 348261 UTM Northing: 3879455 Zone: 13 Quad: Albuquerque West

R.K. Dudley, S.P. Platania, W.H. Brandenburg, C.C. McBride Effort: 3,078.6 sq. m

FAMILY		**N**
76	*Cyprinella lutrensis*	742
76	*Cyprinus carpio*	4
76	*Hybognathus amarus**	23
76	*Pimephales promelas*	1
76	*Platygobio gracilis*	9
76	*Rhinichthys cataractae*	2
81	*Carpiodes carpio*	10
81	*Catostomus commersoni*	1
93	*Ictalurus punctatus*	120
212	*Gambusia affinis*	7

*** *Hybognathus amarus* by age class:**

age-0: 19

age-1: 4

Rio Grande silvery minnow Population Estimation Program
October 2007

New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 0.6 miles downstream of Rio Bravo Blvd. Bridge crossing, Albuquerque. Sampling Unit: 5
24 October 2007 **RKD07-188** River Mile: 177.6
UTM Easting: 347381 UTM Northing: 3876106 Zone: 13 Quad: Albuquerque West
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride Effort: 3,545.0 sq. m

FAMILY		**N**
76	*Cyprinella lutrensis*	665
76	*Hybognathus amarus**	51
76	*Pimephales promelas*	25
76	*Platygobio gracilis*	39
76	*Rhinichthys cataractae*	9
81	*Carpiodes carpio*	70
81	*Catostomus commersoni*	1
93	*Ictalurus punctatus*	127
212	*Gambusia affinis*	205
294	*Lepomis macrochirus*	1
294	*Pomoxis annularis*	1

*** *Hybognathus amarus* by age class:**

age-0: 46
age-1: 5

Rio Grande silvery minnow Population Estimation Program
October 2007

New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 1.0 miles downstream of Rio Bravo Blvd. Bridge crossing, Albuquerque. Sampling Unit: 6
23 October 2007 **RKD07-187** River Mile: 177.3
UTM Easting: 347155 UTM Northing: 3875786 Zone: 13 Quad: Albuquerque West
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, J.P. Larson Effort: 2,632.2 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	936
76	*Cyprinus carpio*	3
76	*Hybognathus amarus**	77
76	*Pimephales promelas*	81
76	*Platygobio gracilis*	35
76	*Rhinichthys cataractae*	1
81	*Carpiodes carpio*	128
81	*Catostomus commersoni*	10
93	*Ictalurus punctatus*	136
212	*Gambusia affinis*	127

*** *Hybognathus amarus* by age class:**

age-0: 76
age-1: 1

Rio Grande silvery minnow Population Estimation Program
October 2007

New Mexico: Valencia Co., Rio Grande Drainage

Rio Grande, ca. 4.0 miles upstream of Los Lunas Bridge crossing (NM State Highway 49), Los Lunas.

Sampling Unit: 7
River Mile: 164.8

22 October 2007 **RKD07-186**

UTM Easting: 342969 UTM Northing: 3857901 Zone: 13 Quad: Los Lunas

R.K. Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, J.P. Larson, A.L. Barkalow

Effort: 3,633.8 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	1435
76	*Cyprinus carpio*	3
76	*Hybognathus amarus**	1925
76	*Pimephales promelas*	12
76	*Platygobio gracilis*	12
76	*Rhinichthys cataractae*	1
81	*Carpiodes carpio*	32
93	*Ictalurus punctatus*	149
212	*Gambusia affinis*	83

*** *Hybognathus amarus* by age class:**

age-0: 1923
age-1: 2

Rio Grande silvery minnow Population Estimation Program
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New Mexico: Valencia Co., Rio Grande Drainage
Rio Grande, ca. 2.9 miles upstream of NM 6 bridge crossing, Belen. Sampling Unit: 8
19 October 2007 **RKD07-185** River Mile: 152.4
UTM Easting: 340193 UTM Northing: 3840028 Zone: 13 Quad: Tome
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride Effort: 1,205.9 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	1458
76	*Hybognathus amarus**	112
76	*Pimephales promelas*	19
81	*Carpiodes carpio*	59
81	*Catostomus commersoni*	1
93	*Ictalurus punctatus*	139
212	*Gambusia affinis*	1171
294	*Micropterus salmoides*	2

*** *Hybognathus amarus* by age class:**

age-0: 104
age-1: 8

Rio Grande silvery minnow Population Estimation Program
October 2007

New Mexico: Valencia Co., Rio Grande Drainage
Rio Grande, ca. 0.1 miles downstream of NM State Highway 346 Bridge crossing, Jarales.
Sampling Unit: 9
River Mile: 140.6

17 October 2007 **RKD07-183**
UTM Easting: 338117 UTM Northing: 3823765 Zone: 13 Quad: Veguita
R.K. Dudley, S.P. Platania, W.H. Brandenburg, M.A. Farrington, C.C. McBride, M. Cummer
Effort: 3,910.2 sq. m

FAMILY		**N**
76	*Cyprinella lutrensis*	3780
76	*Cyprinus carpio*	8
76	*Hybognathus amarus**	158
76	*Pimephales promelas*	45
76	*Platygobio gracilis*	12
81	*Carpiodes carpio*	33
93	*Ictalurus punctatus*	154
212	*Gambusia affinis*	947

*** *Hybognathus amarus* by age class:**

age-0: 151
age-1: 7

Rio Grande silvery minnow Population Estimation Program
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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 1.0 miles downstream of U.S. Highway 60 bridge crossing, Bernardo. Sampling Unit: 9.5
02 November 2007 **RKD07-193** River Mile: 130.0
UTM Easting: 333822 UTM Northing: 3808533 Zone: 13 Quad: Abeytas
R.K. Dudley, W.H. Brandenburg, C.C. McBride, A.L. Barkalow Effort: 2,274.8 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	3593
76	*Cyprinus carpio*	3
76	*Hybognathus amarus**	101
76	*Pimephales promelas*	39
81	*Carpiodes carpio*	14
93	*Ameiurus natalis*	2
93	*Ictalurus punctatus*	112
212	*Gambusia affinis*	408

*** *Hybognathus amarus* by age class:**

age-0: 97
age-1: 4

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 3.7 miles downstream of US Highway 60 Bridge crossing, Bernardo. Sampling Unit: 10
18 October 2007 **RKD07-184** River Mile: 126.9
UTM Easting: 330997 UTM Northing: 3805306 Zone: 13 Quad: Abeytas
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride Effort: 2,813.6 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	1742
76	*Cyprinus carpio*	2
76	*Hybognathus amarus**	231
76	*Pimephales promelas*	5
81	*Carpiodes carpio*	34
93	*Ictalurus punctatus*	114
212	*Gambusia affinis*	290

*** *Hybognathus amarus* by age class:**

age-0: 203
age-1: 28

Rio Grande silvery minnow Population Estimation Program
October 2007

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 1.7 miles upstream of San Acacia Diversion Dam, San Acacia. Sampling Unit: 11
16 October 2007 **RKD07-182** River Mile: 117.9
UTM Easting: 328767 UTM Northing: 3792883 Zone: 13 Quad: La Joya
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, J.P. Larson Effort: 3,084.6 sq. m

FAMILY		**N**
76	*Cyprinella lutrensis*	15
76	*Hybognathus amarus**	4
76	*Platygobio gracilis*	213
76	*Rhinichthys cataractae*	2
93	*Ictalurus punctatus*	6
212	*Gambusia affinis*	1

*** *Hybognathus amarus* by age class:**

age-0: 4
age-1:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.8 miles downstream of San Acacia Diversion Dam, San Acacia. Sampling Unit: 12
15 October 2007 **RKD07-181** River Mile: 115.4
UTM Easting: 325363 UTM Northing: 3791796 Zone: 13 Quad: San Acacia
R.K. Dudley, S.P. Platania, W.H. Brandenburg, M.A. Farrington, C.C. McBride, N.D. Zymonas Effort: 2,506.9 sq. m

FAMILY		**N**
76	*Cyprinella lutrensis*	176
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	7
76	*Pimephales promelas*	3
76	*Platygobio gracilis*	160
81	*Ictiobus bubalus*	1
93	*Ictalurus punctatus*	67
212	*Gambusia affinis*	3

*** *Hybognathus amarus* by age class:**

age-0: 7
age-1:

Rio Grande silvery minnow Population Estimation Program
October 2007

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 4.5 miles upstream of US Highway 380 Bridge crossing, San Antonio. Sampling Unit: 13
10 October 2007 **RKD07-180** River Mile: 91.6
UTM Easting: 328199 UTM Northing: 3760830 Zone: 13 Quad: San Antonio
R.K. Dudley, S.P. Platania, W.H. Brandenburg, M.A. Farrington, C.C. McBride Effort: 3,187.9 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	125
76	*Hybognathus amarus**	12
76	*Pimephales promelas*	2
76	*Platygobio gracilis*	5
81	*Carpiodes carpio*	2
93	*Ictalurus punctatus*	5
212	*Gambusia affinis*	4

*** *Hybognathus amarus* by age class:**

age-0: 12
age-1:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 1.5 miles downstream of US Highway 380 Bridge crossing, San Antonio. Sampling Unit: 14
08 October 2007 **RKD07-178** River Mile: 85.7
UTM Easting: 329256 UTM Northing: 3752209 Zone: 13 Quad: San Antonio
S.P. Platania, W.H. Brandenburg, M.A. Farrington, C.C. McBride, A.L. Barkalow, J.P. Larson Effort: 1,685.9 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	142
76	*Hybognathus amarus**	4
76	*Pimephales promelas*	2
81	*Carpiodes carpio*	1
93	*Ictalurus punctatus*	5
212	*Gambusia affinis*	3

*** *Hybognathus amarus* by age class:**

age-0: 4
age-1:

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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.2 miles downstream of the south boundary of the Bosque del Apache National Wildlife Refuge. Sampling Unit: 15
River Mile: 73.6
09 October 2007 **RKD07-179**
UTM Easting: 322489 UTM Northing: 3732572 Zone: 13 Quad: San Marcial
W.H. Brandenburg, M.A. Farrington, C.C. McBride, J.P. Larson Effort: 1,900.7 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	400
76	*Hybognathus amarus**	1
76	*Pimephales promelas*	6
76	*Platygobio gracilis*	14
93	*Ictalurus punctatus*	8
212	*Gambusia affinis*	47

*** *Hybognathus amarus* by age class:**

age-0: 1
age-1:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 2.2 miles downstream of the south boundary of the Bosque del Apache National Wildlife Refuge. Sampling Unit: 16
River Mile: 71.6
05 October 2007 **RKD07-177**
UTM Easting: 320044 UTM Northing: 3730043 Zone: 13 Quad: San Marcial
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride Effort: 2,917.6 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	507
76	*Hybognathus amarus**	3
76	*Platygobio gracilis*	38
93	*Ictalurus punctatus*	3

*** *Hybognathus amarus* by age class:**

age-0: 3
age-1:

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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.9 miles upstream of San Marcial Railroad Bridge crossing, San Marcial. Sampling Unit: 17
River Mile: 69.5
04 October 2007 **RKD07-176**
UTM Easting: 316840 UTM Northing: 3728978 Zone: 13 Quad: San Marcial
R.K. Dudley, S.P. Platania, W.H. Brandenburg, M.A. Farrington, C.C. McBride, L.E. Renfro
Effort: 2,485.9 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	482
76	*Hybognathus amarus**	3
76	*Platygobio gracilis*	2
81	*Carpiodes carpio*	1
93	*Ictalurus punctatus*	2
212	*Gambusia affinis*	8

*** *Hybognathus amarus* by age class:**

age-0: 3
age-1:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 5.0 miles downstream of San Marcial Railroad Bridge crossing, San Marcial.
Sampling Unit: 18
River Mile: 63.6
03 October 2007 **RKD07-175**
UTM Easting: 313417 UTM Northing: 3721520 Zone: 13 Quad: Paraje Well
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride
Effort: 3,669.0 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	1136
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	1
76	*Platygobio gracilis*	2
81	*Carpiodes carpio*	1
93	*Ictalurus punctatus*	18
212	*Gambusia affinis*	2

*** *Hybognathus amarus* by age class:**

age-0: 1
age-1:

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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.9 miles downstream of the former confluence with the Low Flow Conveyance Channel.
Sampling Unit: 19
River Mile: 59.8
02 October 2007 **RKD07-174**
UTM Easting: 308328 UTM Northing: 3717266 Zone: 13 Quad: Paraje Well
R.K. Dudley, S.P. Platania, W.H. Brandenburg, M.A. Farrington, C.C. McBride, J.P. Larson
Effort: 2,620.5 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	228
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	5
76	*Platygobio gracilis*	31
93	*Ictalurus punctatus*	28
212	*Gambusia affinis*	11

*** *Hybognathus amarus* by age class:**
age-0: 5
age-1:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 1.1 miles downstream of the former confluence with the Low Flow Conveyance Channel.
Sampling Unit: 20
River Mile: 59.6
01 October 2007 **RKD07-173**
UTM Easting: 308118 UTM Northing: 3716920 Zone: 13 Quad: Paraje Well
R.K. Dudley, S.P. Platania, W.H. Brandenburg, M.A. Farrington, C.C. McBride, J.P. Larson
Effort: 2,354.4 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	147
76	*Cyprinus carpio*	2
76	*Hybognathus amarus**	0
76	*Platygobio gracilis*	6
93	*Ictalurus punctatus*	16
212	*Gambusia affinis*	7

*** *Hybognathus amarus* by age class:**
age-0:
age-1:

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New Mexico: Bernalillo Co., Rio Grande Drainage

Rio Grande, ca. 0.4 miles upstream of Paseo del Norte Bridge crossing, Albuquerque. Sampling Unit: 2

27 October 2008 **RKD08-184** River Mile: 191.6

UTM Easting: 349942 UTM Northing: 3895288 Zone: 13 Quad: Los Griegos

R.K.Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, B.L. Christman, A.L. Barkalow, J.A. Bachus Effort: 328.4 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	15
76	*Cyprinus carpio*	5
76	*Hybognathus amarus**	47
76	*Pimephales promelas*	6
76	*Platygobio gracilis*	7
76	*Rhinichthys cataractae*	1
81	*Catostomus commersoni*	9
93	*Ameiurus melas*	1
93	*Ictalurus punctatus*	39
212	*Gambusia affinis*	9
294	*Pomoxis annularis*	1
295	*Sander vitreus*	1

*** *Hybognathus amarus* by age class:**

age-0: 26
age-1: 20
age-2: 1

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New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 1.2 miles downstream of Paseo del Norte Bridge crossing, Albuquerque.
Sampling Unit: 3
River Mile: 189.9
28 October 2008 **RKD08-185**
UTM Easting: 348954 UTM Northing: 3892935 Zone: 13 Quad: Los Griegos
R.K.Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, B.L. Christman
Effort: 317.1 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	43
76	*Cyprinus carpio*	5
76	*Hybognathus amarus**	175
76	*Pimephales promelas*	24
76	*Platygobio gracilis*	45
76	*Rhinichthys cataractae*	5
81	*Catostomus commersoni*	1
93	*Ameiurus melas*	1
93	*Ictalurus punctatus*	40
212	*Gambusia affinis*	88

*** *Hybognathus amarus* by age class:**

age-0: 157
age-1: 18
age-2:

Rio Grande silvery minnow Population Estimation Program
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New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 1.6 miles upstream of Rio Bravo Blvd. Bridge crossing, Albuquerque. Sampling Unit: 4
31 October 2008 **RKD08-188** River Mile: 179.9
UTM Easting: 348261 UTM Northing: 3879455 Zone: 13 Quad: Albuquerque West
R.K.Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, A.L. Barkalow Effort: 289.0 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	25
76	*Hybognathus amarus**	3
76	*Pimephales promelas*	11
76	*Platygobio gracilis*	2
81	*Carpiodes carpio*	1
81	*Catostomus commersoni*	1
93	*Ictalurus punctatus*	45
212	*Gambusia affinis*	5

***Hybognathus amarus* by age class:**

age-0: 3
age-1:
age-2:

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New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 0.6 miles downstream of Rio Bravo Blvd. Bridge crossing, Albuquerque.
Sampling Unit: 5
River Mile: 177.6
29 October 2008 **RKD08-186**
UTM Easting: 347381 UTM Northing: 3876106 Zone: 13 Quad: Albuquerque West
R.K.Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, B.L. Christman, A.L. Barkalow
Effort: 448.4 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	19
76	*Hybognathus amarus**	20
76	*Pimephales promelas*	24
76	*Platygobio gracilis*	17
76	*Rhinichthys cataractae*	3
81	*Catostomus commersoni*	1
93	*Ictalurus punctatus*	56
212	*Gambusia affinis*	7

*** *Hybognathus amarus* by age class:**

age-0: 19
age-1:
age-2: 1

Rio Grande silvery minnow Population Estimation Program
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New Mexico: Bernalillo Co., Rio Grande Drainage
Rio Grande, ca. 1.0 miles downstream of Rio Bravo Blvd. Bridge crossing, Albuquerque.
Sampling Unit: 6
River Mile: 177.3
30 October 2008 **RKD08-187**
UTM Easting: 347155 UTM Northing: 3875786 Zone: 13 Quad: Albuquerque West
R.K.Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, B.L. Christman
Effort: 323.9 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	19
76	*Cyprinus carpio*	2
76	*Hybognathus amarus**	34
76	*Pimephales promelas*	153
76	*Platygobio gracilis*	18
81	*Carpiodes carpio*	1
81	*Catostomus commersoni*	1
93	*Ictalurus punctatus*	36
212	*Gambusia affinis*	32
294	*Lepomis macrochirus*	1

*** *Hybognathus amarus* by age class:**

age-0: 32
age-1: 2
age-2:

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New Mexico: Valencia Co., Rio Grande Drainage
Rio Grande, ca. 4.0 miles upstream of Los Lunas Bridge crossing (NM State Highway 49), Los Lunas.
Sampling Unit: 7
River Mile: 164.8
23 October 2008 **RKD08-182**
UTM Easting: 342969 UTM Northing: 3857901 Zone: 13 Quad: Los Lunas
R.K.Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, B.L. Christman
Effort: 589.6 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	135
76	*Cyprinus carpio*	5
76	*Hybognathus amarus**	440
76	*Pimephales promelas*	32
76	*Platygobio gracilis*	4
81	*Carpiodes carpio*	1
93	*Ameiurus natalis*	3
93	*Ictalurus punctatus*	26
212	*Gambusia affinis*	38
294	*Lepomis macrochirus*	1

*** *Hybognathus amarus* by age class:**

age-0: 415
age-1: 25
age-2:

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New Mexico: Valencia Co., Rio Grande Drainage
Rio Grande, ca. 2.9 miles upstream of NM 6 bridge crossing, Belen. Sampling Unit: 8
24 October 2008 **RKD08-183** River Mile: 152.4
UTM Easting: 340193 UTM Northing: 3840028 Zone: 13 Quad: Tome
W.H. Brandenburg, C.C. McBride, B.L. Christman, A.L. Barkalow Effort: 540.5 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	57
76	*Hybognathus amarus**	76
76	*Pimephales promelas*	28
76	*Platygobio gracilis*	1
81	*Carpiodes carpio*	3
93	*Ictalurus punctatus*	11
212	*Gambusia affinis*	47
294	*Pomoxis annularis*	1

*** *Hybognathus amarus* by age class:**

age-0: 65
age-1: 10
age-2: 1

New Mexico: Valencia Co., Rio Grande Drainage
Rio Grande, ca. 0.1 miles downstream of NM State Highway 346 Bridge crossing, Jarales. Sampling Unit: 9
River Mile: 140.6
22 October 2008 **RKD08-181**
UTM Easting: 338117 UTM Northing: 3823765 Zone: 13 Quad: Veguita
M.A. Farrington, W.H. Brandenburg, C.C. McBride, B.L. Christman, A.L. Barkalow Effort: 436.9 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	66
76	*Hybognathus amarus**	26
76	*Pimephales promelas*	4
81	*Carpiodes carpio*	1
93	*Ameiurus melas*	2
93	*Ictalurus punctatus*	9
212	*Gambusia affinis*	15

*** *Hybognathus amarus* by age class:**

age-0: 21
age-1: 3
age-2: 2

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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 1.0 miles downstream of U.S. Highway 60 bridge crossing, Bernardo. Sampling Unit: 9.5
21 October 2008 **RKD08-180** River Mile: 130.0
UTM Easting: 333822 UTM Northing: 3808533 Zone: 13 Quad: Abeytas
R.K.Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, B.L. Christman Effort: 407.3 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	178
76	*Hybognathus amarus**	41
76	*Pimephales promelas*	19
76	*Platygobio gracilis*	4
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	49
212	*Gambusia affinis*	10

*** *Hybognathus amarus* by age class:**

age-0: 40
age-1: 1
age-2:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 3.7 miles downstream of US Highway 60 Bridge crossing, Bernardo. Sampling Unit: 10
20 October 2008 **RKD08-179** River Mile: 126.9
UTM Easting: 330997 UTM Northing: 3805306 Zone: 13 Quad: Abeytas
R.K. Dudley, M.A. Farrington, C.C. Mcbride, B.L. Christman, A.L. Barkalow Effort: 316.5 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	102
76	*Cyprinus carpio*	2
76	*Hybognathus amarus**	2
76	*Platygobio gracilis*	1
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	40
212	*Gambusia affinis*	6

*** *Hybognathus amarus* by age class:**

age-0: 1
age-1: 1
age-2:

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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 1.7 miles upstream of San Acacia Diversion Dam, San Acacia. Sampling Unit: 11
16 October 2008 **RKD08-177** River Mile: 117.9
UTM Easting: 328767 UTM Northing: 3792883 Zone: 13 Quad: La Joya
R.K.Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, B.L. Christman, A.L. Barkalow Effort: 453.0 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	8
76	*Hybognathus amarus**	100
76	*Pimephales promelas*	15
76	*Platygobio gracilis*	55
93	*Ictalurus punctatus*	41
212	*Gambusia affinis*	25

*** *Hybognathus amarus* by age class:**

age-0: 97
age-1: 2
age-2: 1

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.8 miles downstream of San Acacia Diversion Dam, San Acacia. Sampling Unit: 12
17 October 2008 **RKD08-178** River Mile: 115.4
UTM Easting: 325363 UTM Northing: 3791796 Zone: 13 Quad: San Acacia
M.A. Farrington, W.H. Brandenburg, C.C. McBride, B.L. Christman, A.L. Barkalow Effort: 325.4 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	11
76	*Hybognathus amarus**	18
76	*Pimephales promelas*	8
76	*Platygobio gracilis*	41
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	43
212	*Gambusia affinis*	10

*** *Hybognathus amarus* by age class:**

age-0: 17
age-1: 1
age-2:

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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 4.5 miles upstream of US Highway 380 Bridge crossing, San Antonio. Sampling Unit: 13
15 October 2008 **RKD08-176** River Mile: 91.6
UTM Easting: 328199 UTM Northing: 3760830 Zone: 13 Quad: San Antonio
R.K. Dudley, M.A. Farrington, C.C. Mcbride, B.L. Christman, A.L. Barkalow Effort: 456.6 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	25
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	167
76	*Pimephales promelas*	4
76	*Platygobio gracilis*	23
93	*Ameiurus natalis*	1
93	*Ictalurus punctatus*	17
212	*Gambusia affinis*	31

*** *Hybognathus amarus* by age class:**

age-0: 167
age-1:
age-2:

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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 1.5 miles downstream of US Highway 380 Bridge crossing, San Antonio. Sampling Unit: 14
River Mile: 85.7
14 October 2008 **RKD08-175**
UTM Easting: 329256 UTM Northing: 3752209 Zone: 13 Quad: San Antonio
R.K.Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, B.L. Christman Effort: 316.4 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	1
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	22
76	*Platygobio gracilis*	15
81	*Carpiodes carpio*	1
93	*Ameiurus natalis*	2
93	*Ictalurus punctatus*	121
212	*Gambusia affinis*	1

*** *Hybognathus amarus* by age class:**

age-0: 21
age-1: 1
age-2:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.2 miles downstream of the south boundary of the Bosque del Apache National Wildlife Refuge. Sampling Unit: 15
River Mile: 73.6
13 October 2008 **RKD08-174**
UTM Easting: 322489 UTM Northing: 3732572 Zone: 13 Quad: San Marcial
R.K.Dudley, W.H. Brandenburg, C.C. McBride, B.L. Christman, A.L. Barkalow Effort: 291.5 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	70
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	10
93	*Ictalurus punctatus*	38
212	*Gambusia affinis*	13

*** *Hybognathus amarus* by age class:**

age-0: 10
age-1:
age-2:

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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 2.2 miles downstream of the south boundary of the Bosque del Apache National Wildlife Refuge.
Sampling Unit: 16
River Mile: 71.6
10 October 2008 **RKD08-173**
UTM Easting: 320044 UTM Northing: 3730043 Zone: 13 Quad: San Marcial
R.K. Dudley, M.A. Farrington, C.C. Mcbride, B.L. Christman, A.L. Barkalow
Effort: 422.7 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	20
76	*Cyprinus carpio*	3
76	*Hybognathus amarus**	106
76	*Platygobio gracilis*	2
93	*Ictalurus punctatus*	7

*** *Hybognathus amarus* by age class:**

age-0: 106
age-1:
age-2:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.9 miles upstream of San Marcial Railroad Bridge crossing, San Marcial.
Sampling Unit: 17
River Mile: 69.5
09 October 2008 **RKD08-172**
UTM Easting: 316840 UTM Northing: 3728978 Zone: 13 Quad: San Marcial
R.K.Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride, B.L. Christman
Effort: 327.4 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	48
76	*Hybognathus amarus**	161
76	*Platygobio gracilis*	3
93	*Ictalurus punctatus*	15
93	*Pylodictis olivaris*	1

*** *Hybognathus amarus* by age class:**

age-0: 161
age-1:
age-2:

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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 5.0 miles downstream of San Marcial Railroad Bridge crossing, San Marcial. Sampling Unit: 18
River Mile: 63.6
08 October 2008 **RKD08-171**
UTM Easting: 313417 UTM Northing: 3721520 Zone: 13 Quad: Paraje Well
R.K.Dudley, W.H. Brandenburg, C.C. McBride, B.L. Christman, A.L. Barkalow Effort: 317.4 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	8
76	*Hybognathus amarus**	55
76	*Platygobio gracilis*	5
81	*Carpiodes carpio*	1
93	*Ictalurus punctatus*	27

*** *Hybognathus amarus* by age class:**

age-0: 55
age-1:
age-2:

New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 0.9 miles downstream of the former confluence with the Low Flow Conveyance Channel. Sampling Unit: 19
River Mile: 59.8
03 October 2008 **RKD08-170**
UTM Easting: 308328 UTM Northing: 3717266 Zone: 13 Quad: Paraje Well
R.K.Dudley, W.H. Brandenburg, M.A. Farrington, C.C. McBride Effort: 156.2 sq. m

FAMILY		N
76	*Cyprinella lutrensis*	24
76	*Hybognathus amarus**	36
76	*Platygobio gracilis*	7
93	*Ictalurus punctatus*	2
93	*Pylodictis olivaris*	6
212	*Gambusia affinis*	1

*** *Hybognathus amarus* by age class:**

age-0: 36
age-1:
age-2:

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New Mexico: Socorro Co., Rio Grande Drainage
Rio Grande, ca. 1.1 miles downstream of the former confluence with the Low Flow Conveyance Channel.
Sampling Unit: 20
River Mile: 59.6
02 October 2008 **RKD08-169**
UTM Easting: 308118 UTM Northing: 3716920 Zone: 13 Quad: Paraje Well
R.K. Dudley, W.H. Brandenburg, M.A. Farrington, C.C. Mcbride, B.L. Christman
Effort: 275.4 sq. m

FAMILY		N
69	*Dorosoma cepedianum*	8
76	*Cyprinella lutrensis*	17
76	*Cyprinus carpio*	1
76	*Hybognathus amarus**	36
76	*Platygobio gracilis*	1
93	*Ictalurus punctatus*	4
93	*Pylodictis olivaris*	6
212	*Gambusia affinis*	6
283	*Morone chrysops*	1

*** *Hybognathus amarus* by age class:**

age-0: 36
age-1:
age-2:

Appendix E

Table E-1. Rio Grande silvery minnow detection probability estimates among years for all sampling units combined (from Population Monitoring Program data) in the Middle Rio Grande based on repeated sampling efforts in November (2005 to 2008).

Detection Probability Estimates from Minimum AIC$_c$ Model (A)				
Label*	**Estimate**	**SE**	**LCI**	**UCI**
***p* 2005 All Fish Day 1**	**0.9753**	**0.0172**	**0.9067**	**0.9938**
***p* 2005 All Fish Day 2**	**0.9753**	**0.0173**	**0.9065**	**0.9938**
***p* 2005 All Fish Day 3**	**0.9752**	**0.0173**	**0.9062**	**0.9938**
***p* 2005 All Fish Day 4**	**0.9750**	**0.0175**	**0.9053**	**0.9937**
***p* 2005 Age-0 Day 1**	**0.9792**	**0.0150**	**0.9177**	**0.9950**
***p* 2005 Age-0 Day 2**	**0.9759**	**0.0169**	**0.9082**	**0.9940**
***p* 2005 Age-0 Day 3**	**0.9756**	**0.0171**	**0.9070**	**0.9939**
***p* 2005 Age-0 Day 4**	**0.9747**	**0.0177**	**0.9043**	**0.9937**
***p* 2005 Age-1 Day 1**	**0.3335**	**0.1023**	**0.1688**	**0.5521**
***p* 2005 Age-1 Day 2**	**0.3327**	**0.1021**	**0.1683**	**0.5513**
***p* 2005 Age-1 Day 3**	**0.3267**	**0.1013**	**0.1644**	**0.5447**
***p* 2005 Age-1 Day 4**	**0.3066**	**0.0992**	**0.1505**	**0.5246**
***p* 2005 Age-2 Day 1**	**0.0243**	**0.0268**	**0.0027**	**0.1851**
***p* 2005 Age-2 Day 2**	**0.0246**	**0.0271**	**0.0028**	**0.1872**
***p* 2005 Age-2 Day 3**	**0.0248**	**0.0273**	**0.0028**	**0.1885**
***p* 2005 Age-2 Day 4**	**0.0251**	**0.0276**	**0.0028**	**0.1901**
***p* 2006 All Fish Day 1**	**0.8829**	**0.0368**	**0.7897**	**0.9380**
***p* 2006 All Fish Day 2**	**0.8827**	**0.0368**	**0.7893**	**0.9379**
***p* 2006 All Fish Day 3**	**0.8823**	**0.0369**	**0.7888**	**0.9377**
***p* 2006 All Fish Day 4**	**0.8812**	**0.0372**	**0.7871**	**0.9371**
***p* 2006 Age-0 Day 1**	**0.8388**	**0.0491**	**0.7187**	**0.9137**
***p* 2006 Age-0 Day 2**	**0.8174**	**0.0532**	**0.6900**	**0.9000**
***p* 2006 Age-0 Day 3**	**0.8150**	**0.0538**	**0.6863**	**0.8987**
***p* 2006 Age-0 Day 4**	**0.8098**	**0.0554**	**0.6778**	**0.8961**
***p* 2006 Age-1 Day 1**	**0.6996**	**0.0547**	**0.5829**	**0.7951**
***p* 2006 Age-1 Day 2**	**0.6989**	**0.0548**	**0.5822**	**0.7945**
***p* 2006 Age-1 Day 3**	**0.6931**	**0.0552**	**0.5759**	**0.7897**
***p* 2006 Age-1 Day 4**	**0.6730**	**0.0584**	**0.5503**	**0.7759**
***p* 2006 Age-2 Day 1**	**0.1101**	**0.0613**	**0.0350**	**0.2967**
***p* 2006 Age-2 Day 2**	**0.1113**	**0.0620**	**0.0354**	**0.2996**
***p* 2006 Age-2 Day 3**	**0.1121**	**0.0624**	**0.0356**	**0.3014**
***p* 2006 Age-2 Day 4**	**0.1132**	**0.0630**	**0.0360**	**0.3038**
***p* 2007 All Fish Day 1**	**0.9870**	**0.0129**	**0.9136**	**0.9982**
***p* 2007 All Fish Day 2**	**0.9870**	**0.0129**	**0.9134**	**0.9982**
***p* 2007 All Fish Day 3**	**0.9870**	**0.0130**	**0.9132**	**0.9982**
***p* 2007 All Fish Day 4**	**0.9868**	**0.0131**	**0.9124**	**0.9981**
***p* 2007 Age-0 Day 1**	**0.9890**	**0.0111**	**0.9243**	**0.9985**
***p* 2007 Age-0 Day 2**	**0.9873**	**0.0127**	**0.9148**	**0.9982**
***p* 2007 Age-0 Day 3**	**0.9871**	**0.0129**	**0.9136**	**0.9982**
***p* 2007 Age-0 Day 4**	**0.9866**	**0.0133**	**0.9111**	**0.9981**
***p* 2007 Age-1 Day 1**	**0.1154**	**0.0441**	**0.0530**	**0.2331**
***p* 2007 Age-1 Day 2**	**0.1150**	**0.0439**	**0.0528**	**0.2325**
***p* 2007 Age-1 Day 3**	**0.1123**	**0.0430**	**0.0515**	**0.2277**
***p* 2007 Age-1 Day 4**	**0.1034**	**0.0406**	**0.0466**	**0.2138**
***p* 2007 Age-2 Day 1**	**0.0000**	**0.0000**	**0.0000**	**0.0000**
***p* 2007 Age-2 Day 2**	**0.0000**	**0.0000**	**0.0000**	**0.0000**
***p* 2007 Age-2 Day 3**	**0.0000**	**0.0000**	**0.0000**	**0.0000**
***p* 2007 Age-2 Day 4**	**0.0000**	**0.0000**	**0.0000**	**0.0000**

*Where *p*=detection probability and Day is the sampling occasion sequence for a particular year.

Appendix E (continued)

Table E-1. (conintued) Rio Grande silvery minnow detection probability estimates among years for all sampling units combined (from Population Monitoring Program data) in the Middle Rio Grande based on repeated sampling efforts in November (2005 to 2008).

Detection Probability Estimates from Minimum AIC$_c$ Model (A)				
Label*	**Estimate**	**SE**	**LCI**	**UCI**
***p* 2008 All Fish Day 1**	**1.0000**	**0.0000**	**1.0000**	**1.0000**
***p* 2008 All Fish Day 2**	**1.0000**	**0.0000**	**1.0000**	**1.0000**
***p* 2008 All Fish Day 3**	**1.0000**	**0.0000**	**1.0000**	**1.0000**
***p* 2008 All Fish Day 4**	**1.0000**	**0.0000**	**1.0000**	**1.0000**
***p* 2008 Age-0 Day 1**	**1.0000**	**0.0000**	**1.0000**	**1.0000**
***p* 2008 Age-0 Day 2**	**1.0000**	**0.0000**	**1.0000**	**1.0000**
***p* 2008 Age-0 Day 3**	**1.0000**	**0.0000**	**1.0000**	**1.0000**
***p* 2008 Age-0 Day 4**	**1.0000**	**0.0000**	**1.0000**	**1.0000**
***p* 2008 Age-1 Day 1**	**0.6294**	**0.0800**	**0.4644**	**0.7689**
***p* 2008 Age-1 Day 2**	**0.6286**	**0.0800**	**0.4636**	**0.7682**
***p* 2008 Age-1 Day 3**	**0.6222**	**0.0804**	**0.4573**	**0.7629**
***p* 2008 Age-1 Day 4**	**0.6001**	**0.0829**	**0.4327**	**0.7470**
***p* 2008 Age-2 Day 1**	**0.2918**	**0.1363**	**0.1016**	**0.6002**
***p* 2008 Age-2 Day 2**	**0.2945**	**0.1370**	**0.1028**	**0.6033**
***p* 2008 Age-2 Day 3**	**0.2962**	**0.1375**	**0.1036**	**0.6052**
***p* 2008 Age-2 Day 4**	**0.2984**	**0.1381**	**0.1045**	**0.6077**

*Where *p*=detection probability and Day is the sampling occasion sequence for a particular year.