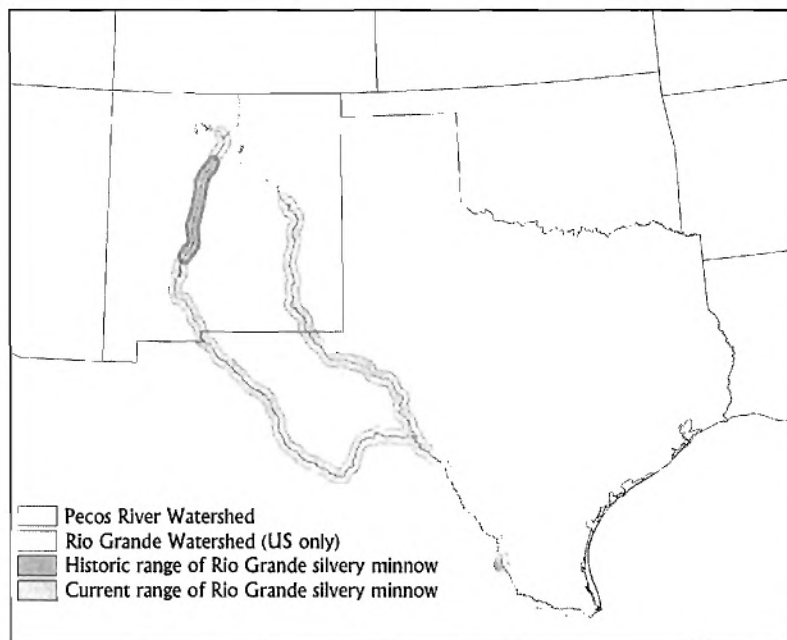


**SUMMARY OF THE BIOLOGY OF RIO GRANDE SILVERY MINNOW,
AN ENDANGERED SPECIES IN THE
MIDDLE RIO GRANDE, NEW MEXICO**



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Frontispiece: Historical and current distribution of Rio Grande silvery minnow.

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*RESTORATION OF THE RIO GRANDE BOSQUE
THE ROLE OF THE RIO GRANDE SILVERY MINNOW*

A Project of the Office of the Governor, State of New Mexico,
the Honorable Bill Richardson
and
The McCune Foundation

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EXECUTIVE SUMMARY

Rio Grande silvery minnow was, historically, relatively widespread and abundant in the Rio Grande Basin occurring from near Embudo, New Mexico, to the Gulf of Mexico. Studies during the past 20 years have documented the 90-95% reduction in the range of Rio Grande silvery minnow and threats to its continued persistence in its remaining range (the Middle Rio Grande of New Mexico). The decline of this species throughout the basin and threats to its survival in the Middle Rio Grande resulted in the 1994 listing of this endemic minnow as a Federal Endangered Species. The restriction of Rio Grande silvery minnow to a 174 mile reach of river between Cochiti Dam and Elephant Butte Reservoir, fragmentation of that range due to diversion dam structures (Angostura, Isleta, and San Acacia), and frequent de-watering of the river were deemed threats to the species survival. In 2003, the U. S. Fish and Wildlife Service designated a major portion (157 miles; 90%) of this species remaining range in the Middle Rio Grande as Critical Habitat.

The Middle Rio Grande formerly possessed the characteristics distinctive of a Great Plains aquatic ecosystem, including a unique and highly adapted fish fauna. The river used to undergo extensive braiding and meandering as it flowed through an extremely wide floodplain over a shifting sand substrate. Likewise, the river was relatively shallow throughout most of the year but subjected to periods of high flow. Intense localized summer rainstorms, which often caused severe flash-flooding, were important in maintaining perennial flow in the river. The diverse fish fauna of the Middle Rio Grande included shovelnose sturgeon, blue catfish, and at least five unique minnow species. Of the aforementioned species, the two big-river fishes (sturgeon and blue catfish) and two minnow species (speckled chub and Rio Grande shiner) have been extirpated from the Middle Rio Grande and two minnows (Rio Grande bluntnose shiner and phantom shiner) are now extinct. Rio Grande silvery minnow is the only surviving member of the unique Great Plains River fish fauna that once inhabited the Middle Rio Grande.

The group of four extirpated minnows from the Middle Rio Grande shared similar ecological attributes with Rio Grande silvery minnow. All were small, short-lived fishes that occupied mainstem habitats. Four of those species fed on a variety of plants and animals while Rio Grande silvery minnow was the only one to feed primarily on vegetation. In addition to the aforementioned shared traits, all five minnow species were members of a group of Great Plains River fishes characterized by pelagic spawning during elevated flows and the production of semibuoyant eggs. This spawning strategy and egg type was advantageous prior to dams and diversions structures. However, placement of those structures was detrimental to those fishes because it prevented the upstream movement of fish to reaches where they had been spawned. Fish eggs and drifting larvae transported downstream from one reach to another are never able to return upstream past the barriers.

Rio Grande silvery minnow recovery efforts must concentrate on reducing the deleterious effects that changes in river connectivity, flow patterns, and habitat heterogeneity have had on downstream displacement of silvery minnow eggs and larvae. Eliminating or redesigning the diversion structures to allow unfettered upstream passage of individuals to reaches previously occupied by parental stocks would greatly aid in the recovery of this species. Recovery of Rio Grande silvery minnow and the Middle Rio Grande ecosystem is very possible but will require broad scale commitment, shared sacrifice, and cooperation that, heretofore, has not been a hallmark of Rio Grande Basin inhabitants.

BACKGROUND

The purpose of this synthesis report is to present summary information regarding the biology of federally endangered Rio Grande silvery minnow (U. S. Department of the Interior 1994). There have been numerous studies performed on this fish and the associated fish community in the Rio Grande during the past 20 years. This report is not intended to be a detailed scientific synthesis that includes all information acquired during that period. Instead its primary goal is to convey, in general terms, some overall information regarding this species. This approach will result in the loss of some information but will hopefully better facilitate a general understanding of the biology of this fish and the reasons that have led to its decline. Individuals interested in study specifics or more detailed information are directed to the original reports many of which are available on the world-wide web site prepared for this symposium (the specific symposium web site address was not available at the time of submission of this report. The following temporary address will either redirect interested parties to the aforementioned web page can access or provide updated information: <http://home.comcast.net/~splatania/rgsm/template/index.html>).

The research summarized in this document is presented in five major sections: DISTRIBUTION AND ABUNDANCE, HABITAT, REPRODUCTION AND EARLY LIFE-HISTORY, GROWTH, and MOVEMENT. Within the DISTRIBUTION AND ABUNDANCE section, historical information has been presented regarding this fishes occurrence in the Rio Grande (New Mexico, Texas, and Mexico) and Pecos River (New Mexico and Texas). The most detailed information on the distribution and abundance of Rio Grande silvery minnow is for the Middle Rio Grande (current range of the species) from 1994 through 2000. A general presentation of the habitat occupied by Rio Grande silvery minnow is provided as well as discussion of habitat use during different seasons and by various life stages. The section on REPRODUCTION AND EARLY LIFE-HISTORY contains a wealth of information regarding spawning, reproductive behavior, egg physiology, larval fish behavior and development, and timing and magnitude of spawning. Data regarding growth, age class structure of the population, and food of Rio Grande silvery minnow are contained in the section: GROWTH. The final section (MOVEMENT) presents data regarding movement of Rio Grande silvery minnow from a recent study in the San Acacia Reach of the river.

Scientific reporting requires presentation of most values in the metric terms (i.e., mm, cm, m, km) . In an effort to make this report more readable, we have included the English equivalent (inches, feet, yards, miles) followed by the metric value (in parenthesis). The use of some scientific nomenclature can not be avoided and in those cases, the definition of the terms follow immediately. Common names of organisms are used almost exclusively in the body of the text.

This document does not attempt to summarize the information regarding the history of or resulting litigation that has been generated in reference to Rio Grande silvery minnow. Likewise, we have specifically avoided delving into aspects regarding water law as that is outside of our realm of expertise, is extremely complicated, and is best dealt with by other parties. In fact, every effort has been made to avoid references to such legal documents and decisions. The few legal documents that are included in the body of the text and bibliography are those related to the listing of this fish as endangered and the designation of critical habitat as required by the Endangered Species Act.

Finally, similar questions continue to be annually posed regarding this fish and the Middle Rio Grande. The most frequently asked questions have been selected and we attempt to answer them (final section of this report) and the underlying assumptions that seem to have been responsible for the development of the question.

INTRODUCTION

The reach of the Rio Grande between Cochiti Dam and Elephant Butte Reservoir (Middle Rio Grande) has been greatly modified over the last 50 years (Lagasse 1980). Historically, this section of the river gradually meandered through a wide floodplain in a vegetated valley. Extensive braiding of the river as it flowed over the shifting sand substrate was common and flow was generally perennial except during times of severe or extended drought (Scurlock 1998). The Middle Rio Grande was relatively shallow throughout most of the year because of regionally low precipitation levels (Gold and Denis 1985) but was subjected to periods of high flow. Flow was generally greatest during the annual spring snow melt runoff (April-June), however intense localized summer rainstorms (monsoonal events) often caused severe flooding and were important in maintaining perennial flow in the river. Historically, the Middle Rio Grande possessed all the characteristics distinctive of a Great Plains aquatic ecosystem (i.e., rivers in the Great Plains region of the United States).

The historical Middle Rio Grande fish fauna was also reflective of a Great Plains river. At least five types of cyprinid (=minnow) that can be characterized as Great Plains river fishes formerly occurred in the Middle Rio Grande (Platania and Altenbach 1998). Of the aforementioned minnows two (speckled chub and Rio Grande shiner) have been extirpated from the Middle Rio Grande. Two more (phantom shiner and Rio Grande bluntnose shiner) are now extinct (Bestgen and Platania 1990). Rio Grande silvery minnow is the only extant (=surviving) member of the unique Great Plains River cyprinid fish fauna fish that inhabited the Middle Rio Grande (Bestgen and Platania 1991; Platania 1991).

The group of extirpated and extinct cyprinids from the Middle Rio Grande (speckled chub, Rio Grande shiner, phantom shiner, and Rio Grande bluntnose shiner) shared similar ecological attributes with Rio Grande silvery minnow. All were small, (generally less than 4 inches long, [< 100 mm]), short-lived (2-5 years), fishes that occupied mainstem habitats. Four of the species are characterized as omnivorous (feed on a variety of plants and animals) while Rio Grande silvery minnow is herbivorous (feed on vegetation). In addition to the aforementioned shared traits, all five fish were members of a reproductive guild (=group) characterized by pelagic spawning and production of semibuoyant eggs.

Rio Grande silvery minnow has, at times during the last 15 years, been very abundant in selected reaches of the Middle Rio Grande, indicating that environmental and habitat conditions were suitable. This fish has a high reproductive potential and appears able to survive the modified general flow pattern of the Rio Grande in most years. It spawns during the high runoff of late spring or early summer which coincides with large dam releases of snowmelt runoff. One potential negative impact of these high releases is the loss of low-velocity habitats due to constriction of the river channel. Since 1935, there has been an approximate 50% reduction in the width of the river channel (Crawford et al. 1993).

Future efforts should focus on reducing the deleterious effects that changes in river connectivity, flow patterns, and habitat heterogeneity have on the downstream displacement of Rio Grande silvery minnow eggs and larvae. Eliminating diversion structures would allow upstream passage of individuals to reaches of their parental stock. Repopulating upstream reaches of the Middle Rio Grande through natural recolonization would greatly aid in the recovery of this species. Efforts to improve degraded riverine habitats could include returning the flow regime to a more historical pattern (i.e., allowing passage of large flow events) and removing or relocating structures that inhibit the lateral movement of the Rio Grande (e.g., jetty-jacks, levees, and water conveyance ditches). The long-term recovery of Rio Grande silvery minnow will depend on taking management actions that attempt to restore the natural processes of this river.

RIO GRANDE SILVERY MINNOW BIOLOGY REVIEW

I. DISTRIBUTION AND ABUNDANCE OF RIO GRANDE SILVERY MINNOW (BACKGROUND)

The Rio Grande silvery minnow, whose scientific name is *Hybognathus amarus*, is a small, short-lived, mainstream cyprinid (minnow) that use to occur in the Rio Grande from a point near Embudo (New Mexico) downstream to Brownsville (Texas/Mexico) and in the Pecos River from near Santa Rosa (New Mexico) downstream to the Pecos River-Rio Grande confluence in Texas (Figure 1). Prior to 1950, this fish occupied almost 2,400 combined river miles in these two systems where, besides being a very widespread species, it was also one of the most abundant fishes in collections (Bestgen and Platania 1991). There are very few records of this fish from Rio Grande or Pecos River tributary streams and most of those samples were taken with a few miles of the tributary-mainstem confluence. Likewise, despite extensive collection efforts in Mexican tributaries to the Rio Grande, the only records of Rio Grande silvery minnow from the Republic of Mexico are from the mainstem of the Rio Grande (Edwards et al. 2003).

Today, Rio Grande silvery minnow occurs only in a 174 river mile reach of the Rio Grande located in the Middle Rio Grande Valley of New Mexico which translates to between 5-10% of its former range. This narrow river reach is bounded to the north by Cochiti Dam and to the south by Elephant Butte Reservoir, is fragmented by three river-wide diversion dams (Angostura, Isleta, and San Acacia Diversion Dams) that divide the river into four discrete reaches (Cochiti to Angostura, 22.3 miles [35.9 km]; Angostura to Isleta, 40.4 miles [65.0 km]; Isleta to San Acacia, 53.1 miles [85.5 km]; and San Acacia to Elephant Butte Reservoir, 58.2 miles [93.7 km]). The river also flows through the sovereign nations of at least six Native American Pueblos and several large municipalities including Albuquerque (Figure 2). A major portion (157 miles; 90%) of this river reach was designated as critical habitat for the Rio Grande silvery minnow by the U. S. Fish and Wildlife Service on 21 March 2003 (U. S. Department of the Interior 2003).

The complicated history of the extirpation of Rio Grande silvery minnow from portions of its range outside of the Middle Rio Grande Valley was reconstructed using all available historical fish collection samples from the Rio Grande Basin. Unfortunately, the number of samples taken during any given period (years to decades) in the vast river reaches that this fish formerly occurred varied markedly and it was often decades between sampling attempts in a given region. The year that Rio Grande silvery minnow was last collected from a selected river reach was determined from the aforementioned historical fish collections (Table 1). In all cases, there were numerous samples taken subsequent to the date during which this species was last taken in a specific river reach thereby providing validation of the "date last collected." It should be noted that the date a species was last collected is not comparable with the date of its extirpation.

DISTRIBUTION AND ABUNDANCE OF RIO GRANDE SILVERY MINNOW (WITHIN SPECIFIC REACHES)

RIO GRANDE--- In the Rio Grande drainage of New Mexico, Rio Grande silvery minnow occurred in the lower portions of the Rio Chama and throughout the Rio Grande downstream to El Paso, Texas. There are also single records of this species from the lower Jemez River (1958) and Rio Chama (1949). Recent (1998-2000) sampling efforts in the lower Jemez River (from Jemez Canyon Dam downstream to its confluence with the Rio Grande; ca. 2.8 miles) produced 26 Rio Grande silvery minnow (U. S. Fish and Wildlife Service, personal communication). Collections of Rio Grande silvery minnow upstream of present-day Cochiti Reservoir were from 1874 (at Otowi Bridge) to 1978 (southwest of Velarde; Sublette et al. 1990). Numerous post-1983 sampling efforts in the Rio Grande

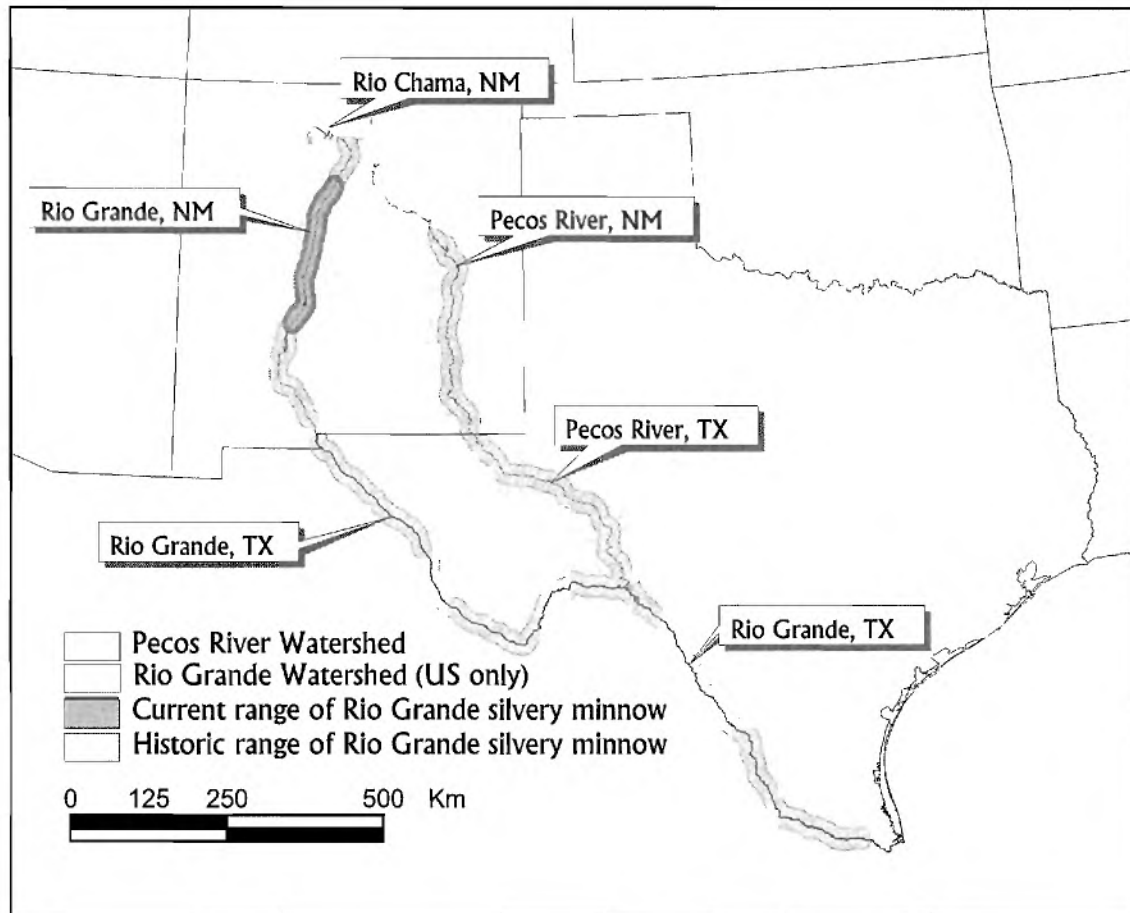


Figure 1. Historical and current distribution of Rio Grande silvery minnow. Rio Grande Basin tributaries originating in the Republic of Mexico are not shown as records of this species do not exist from those watersheds.

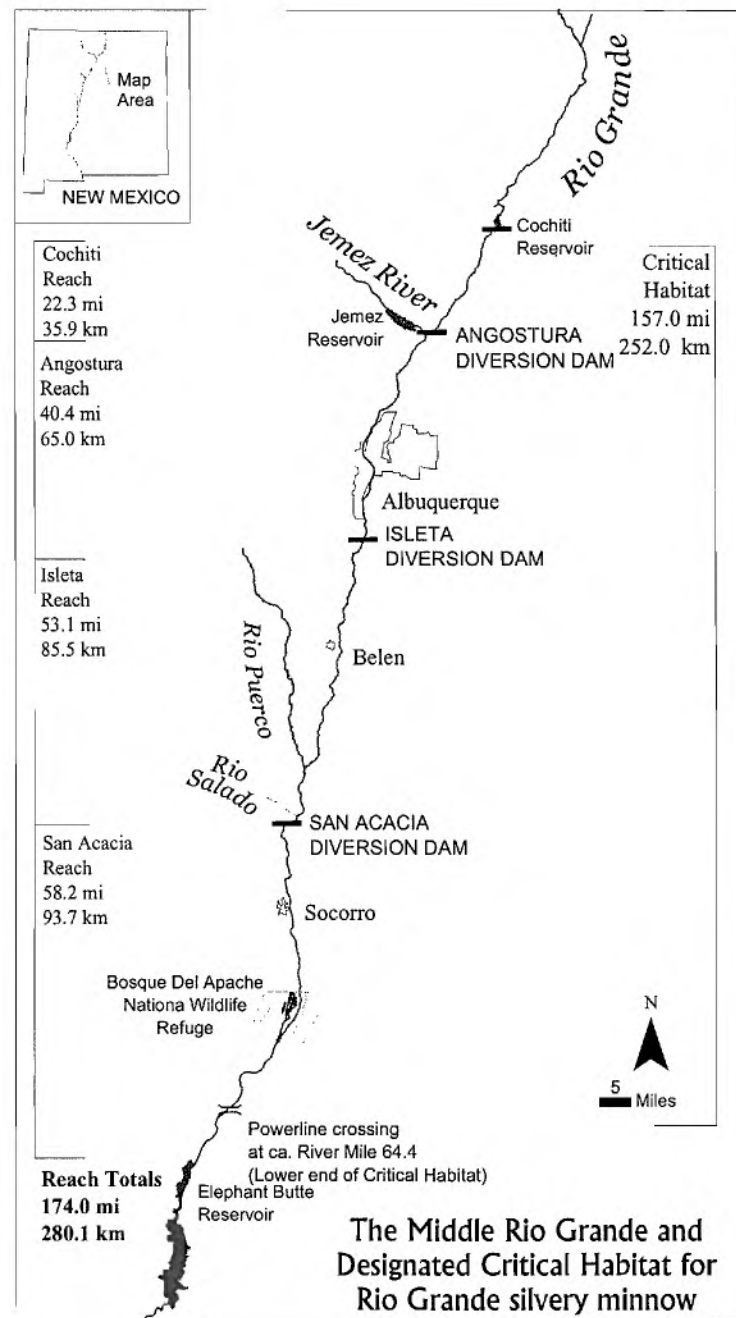


Figure 2. Map of the Middle Rio Grande, New Mexico. Included on this map are the major diversion structures, length of individual river reaches, and delineation of Rio Grande silvery minnow critical habitat.

RIVER or RIVER REACH	REACH LENGTH		Last Collected
	Miles	Kilometers	
RIO GRANDE, NEW MEXICO			
UPPER RIO GRANDE, NM			
Embudo to Cochiti Reservoir	40	64	1978
MIDDLE RIO GRANDE, NM			
Cochiti Reach	22	36	present (1995)
Angostura Reach	40	65	present
Isleta Reach	53	86	present
San Acacia Reach	58	94	present
LOWER RIO GRANDE, NM			
Elephant Butte Reservoir to El Paso, TX	134	216	1944
RIO GRANDE, TEXAS			
El Paso to Presidio	284	454	no specimens exist
Presidio to Amistad Reservoir	312	500	1960
Amistad Reservoir to Falcon Reservoir	299	481	late 1950s
Falcon Reservoir to Brownsville	275	442	late 1950s
PECOS RIVER, NEW MEXICO			
Santa Rosa Reservoir to Sumner Reservoir	55	89	1939
Sumner Reservoir to Brantley Reservoir	223	359	1968
Brantley Reservoir to Red Bluff Reservoir	74	119	no specimens exist
PECOS RIVER, TEXAS			
Red Bluff Reservoir to Amistad Reservoir	405	652	1940
RIO CHAMA, NEW MEXICO			
Abiquiu to confluence with the Rio Grande	20	32	1949

Table 1. Year that Rio Grande silvery minnow was last collected in a specific river or reach of river.

between Cochiti and Embudo and in the Rio Chama downstream of Abiquiu Dam have failed to produce specimens of Rio Grande silvery minnow. The species is therefore presumed to be extirpated from the Rio Grande drainage upstream of Cochiti Dam.

Although Rio Grande silvery minnow likely historically inhabited the Rio Grande between Elephant Butte Dam and Caballo Reservoir, there are no museum records to confirm its occurrence there. Propst et al. (1987) did not find the species in this reach during their survey in 1985 and it is considered extirpated from this area.

In the Rio Grande from Caballo Reservoir downstream to the Texas-New Mexico border, only four collections and 16 specimens of Rio Grande silvery minnow were taken between 1938 and 1944. No specimens of Rio Grande silvery minnow have been taken in this reach since the 1940s despite intensive sampling as recently as 1999 and 2000.

There are very few (less than five) historical fish collections from the Texas/Mexico reach of the mainstem Rio Grande between El Paso and Presidio and none that contain Rio Grande silvery minnow. Those collections that do exist are very incomplete and much of the data associated with the remaining samples has been lost. Given that Rio Grande silvery minnow were present in historical fish collections up-and-downstream of that reach of the river, the absence of this fish from those partial collections is not considered indicative of their distribution. There were no physical barriers in that reach of the Rio Grande that would have prevented this or other small bodied fishes from dispersing into that reach from either up or downstream locations.

Seven collections made between 1938 and 1960 in the Rio Grande and its tributaries in Big Bend National Park, Texas/Mexico document the historical occurrence of Rio Grande silvery minnow in this region. The species has not been found in that area since 1960, despite extensive sampling from 1977 to present. There are no records of this fish from the Rio Conchos (Mexico) in historical or recent collections (Edwards et al. 2003).

In the lower Rio Grande of Texas, Rio Grande silvery minnow formerly occurred from the confluence of the Rio Grande and Pecos River (present-day Amistad Reservoir) to the Gulf of Mexico (Pflieger 1980). Collections prior to 1960 indicate that Rio Grande silvery minnow was moderately common and one of the most widespread species in the lower Rio Grande (Trevino-Robinson 1959). Previously, the last known collection of the species in this reach was just downstream of Falcon Reservoir in 1961 (Bestgen and Platania 1991), but re-examination of that specimen revealed that it was plains minnow (Bestgen and Propst 1996). Thus, the last known collection of Rio Grande silvery minnow from the Lower Rio Grande, Texas, was in the late 1950s (Trevino-Robinson 1959). The few specimens available from this reach during that period did not indicate that hybridization was responsible for the extirpation of Rio Grande silvery minnow (Bestgen and Propst 1996). The loss of Rio Grande silvery minnow from this reach of the Rio Grande was documented by Edwards and Contreras-Balderas (1991). They also reported that there is no evidence that Rio Grande silvery minnow ever inhabited larger tributaries of the Rio Grande in the Republic of Mexico.

PECOS RIVER--- The Pecos River in New Mexico historically supported populations of Rio Grande silvery minnow from Santa Rosa downstream to the Texas-New Mexico border. This species was also reported from the Rio Felix, a small tributary to the Pecos River located just south of Roswell. Collection records suggest that reduction in the range of Rio Grande silvery minnow in the Pecos River first occurred upstream of Sumner Reservoir. It was taken in only one of five samples made in that reach from 1939 to 1955 and subsequently has not been collected there.

Rio Grande silvery minnow was historically common in the Pecos River from Sumner Reservoir downstream to Avalon Reservoir and was the second most abundant species in the six collections taken in that reach between 1939-1955. Five collections, made from 1963 through 1965 between Sumner Reservoir and Lake McMillan (now inundated by Brantley Reservoir), suggest that Rio Grande silvery minnow was widespread and common at that time.

In the Pecos River, downstream of Avalon Dam, New Mexico, Rio Grande silvery minnow may have been historically uncommon; only 14 specimens from two collections are known. The preponderance of pool habitats and intrusions of saline water were probably responsible for the paucity of Rio Grande silvery minnow in this reach.

The only documented collections of Rio Grande silvery minnow from the Pecos River drainage in Texas were nine specimens collected in a Pecos River drainage canal near Fort Stockton in 1928, 68 individuals from the Pecos River in 1940 just upstream of its confluence with the Rio Grande, and 80 specimens from the Pecos River above the mouth of Junagus Springs in 1954. It is likely that silvery minnow historically occupied more of the Pecos River in Texas than these collections suggest. The last collection of Rio Grande silvery minnow in the Pecos River was near Roswell in 1968. These collections also included the first verified specimens of plains minnow from the Pecos River (Cowley 1979).

MIDDLE RIO GRANDE---. For this seminar, we have chosen to concentrate on the recent collections using data from the Rio Grande silvery minnow population monitoring effort. Detailed information of the distribution and abundance of this species in the Middle Rio Grande prior to 1992 and data from the 1992 sampling inventory are available in text that we previously provided for the Rio Grande silvery minnow Recovery Plan (U. S. Fish and Wildlife Service 1999) and remain unchanged. In addition, there is an extremely complex myriad of over 1,200 miles of irrigation canals and ditches and water conveyance systems in the Middle Rio Grande that will not be directly address in the main body of this work. The results of a fish survey in a portion of those canals is in Lang and Altenbach (1994).

In 1992, the most extensive sampling effort in the Middle Rio Grande was conducted at over 100 sampling localities between Cochiti Dam and Elephant Butte Reservoir. Those sites were sampled twice (summer and autumn) during that year and generated over 200 samples. The 1992 fish inventory information is the baseline data set that provides documentation of the recent distribution and abundance of Rio Grande silvery minnow.

A subset of those 100 sampling sites was selected, starting in 1994, as sites to be sampled under a Rio Grande silvery minnow population monitoring program. While sites were initially sampled quarterly (1994-1997), the marked decline of Rio Grande silvery minnow recorded in 1996-1997 necessitated an increase in the frequency of sampling (bimonthly from 1999-2001, monthly since 2002). Unfortunately, the lack of timely issuance of Federal Endangered Species Permits, due to major administrative changes in the federal endangered species permitting procedures, precluded sampling in 1998.

The purpose of the abbreviated synthesis that follows is to briefly illustrate the marked decline in the abundance of Rio Grande silvery minnow during the past several years following low flow and stream drying events using past and recent Middle Rio Grande population monitoring data (1994-2002). Annual Rio Grande silvery minnow population monitoring reports have been prepared, many of which are available in electronic format (Dudley and Platania 1999, 2000, 2001, 2002; Dudley et al. 2003).

1994-2002 POPULATION MONITORING SUMMARY---. The decline in the abundance of Rio Grande silvery minnow in the Middle Rio Grande between 1994 and present has been well

documented (Figure 3). There were few changes in the cumulative catch rate (number of fish per surface m² of water sampled) of Rio Grande silvery minnow between 1994 and 1996. However, the marked decline in Rio Grande silvery minnow cumulative catch rate between 1996 and 1997 was likely a manifestation of the massive losses incurred during spring and summer drying events of 1996. The marked decline in the cumulative catch rate of this species continued between 1999 and 2000 and remains exceedingly low today.

Rio Grande silvery minnow continue to be disproportionately distributed throughout the Middle Rio Grande. The 1994-2002 population monitoring data continue to indicate that the majority of individuals occur in the San Acacia Reach with the fewest silvery minnow being in the Angostura and Isleta reaches, respectively (Figure 3). This reach-specific longitudinal distribution (increasing numbers from up-to-downstream reaches) was predicted given the reproductive strategy of this species (which results in the production of large quantities of semibuoyant eggs released into the water column and dispersed downstream).

In 1999, over 98% of the Rio Grande silvery minnow catch, by number, was from the San Acacia Reach indicating that a significant portion of the population resides in that reach (which does not mean that 98% of the population was in that reach). Such values are indicative of the relative importance of the San Acacia Reach to the continued survival of this species. Understandably, the proportion of the silvery minnow population inhabiting the upstream two reaches (Angostura and Isleta) will increase as segments of the San Acacia Reach dry (as occurred in 2002). Regardless of the metric used to calculate or illustrate the reach specific distribution of this species, there can be little question that, since at least 1994, the vast majority of the Rio Grande silvery minnow population occurred in the San Acacia Reach. Likewise, site specific annual catch rate data provide a thorough documentation of the history of decline of Rio Grande silvery minnow (Figure 4).

DISTRIBUTION AND ABUNDANCE OF RIO GRANDE SILVER MINNOW DURING 2002

2002 POPULATION MONITORING SUMMARY—The number of Rio Grande silvery minnow collected exhibited a steady decline throughout calendar year 2002. The highest number of individuals were taken during the first 2002 sampling effort (January; n=548) while the fewest specimens were taken during the October 2002 sampling effort (October; n=11). These numbers of fish are extremely low and were not observed during pre-2000 study years. The number of Rio Grande silvery minnow collected in October 2002 (n=11) is one of the lowest every taken during the tenure of the 1994-2002 population monitoring study and is indicative of alarmingly low population levels.

As has been well documented over the years, catch rate (number of fish per m² sampled) of Rio Grande silvery minnow during 2002 continued to be highest in the San Acacia Reach (the most downstream section of river and first reach to be eliminated by lack of flow) and lowest in the Angostura Reach (the most upstream reach of the river). Absence of continuous flow through the San Acacia Reach eliminated a disproportionately greater proportion of silvery minnow than absence of water flow in the Angostura or Isleta reaches.

Close examination of the 2002 population monitoring efforts indicate that spawning success of Rio Grande silvery minnow (during 2002) was very poor. Collections from May-June 2002 (the period immediately after spawning occurs) produced few age 0 (=fish hatched during 2002) individuals. This lack of age 0 fish indicates that few larval Rio Grande silvery minnow survived the summer low flow conditions and river drying in the Middle Rio Grande. The low number of Rio Grande silvery minnow present in late summer and autumn 2002 population monitoring efforts and dearth of age 0 individuals suggest the marked decline of this species will continue as there will be few silvery minnow alive from the 2002 spawn to comprise the population during 2003.

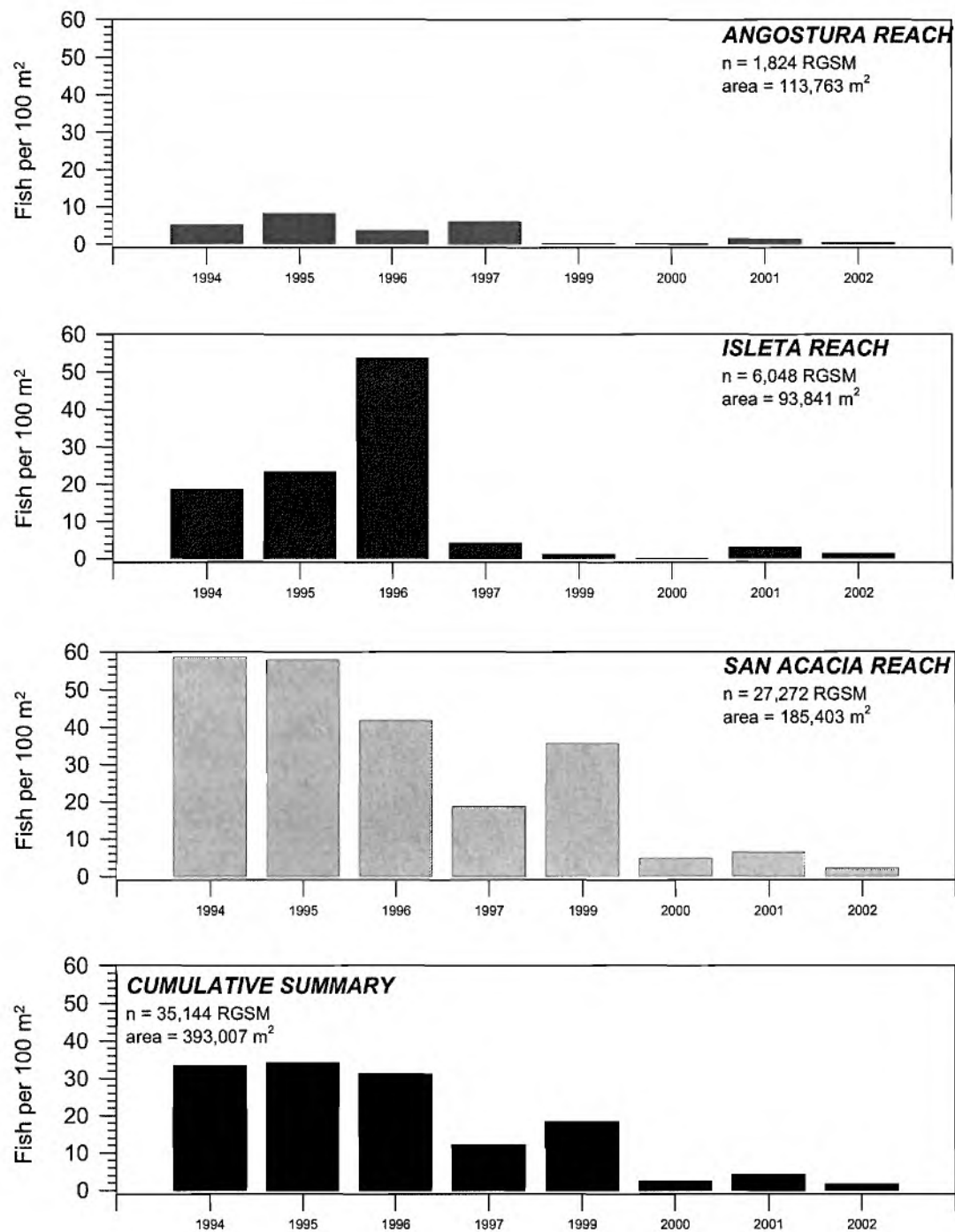


Figure 3. Reach specific and cumulative annual Rio Grande silvery minnow catch rates from 1994 through 2002.

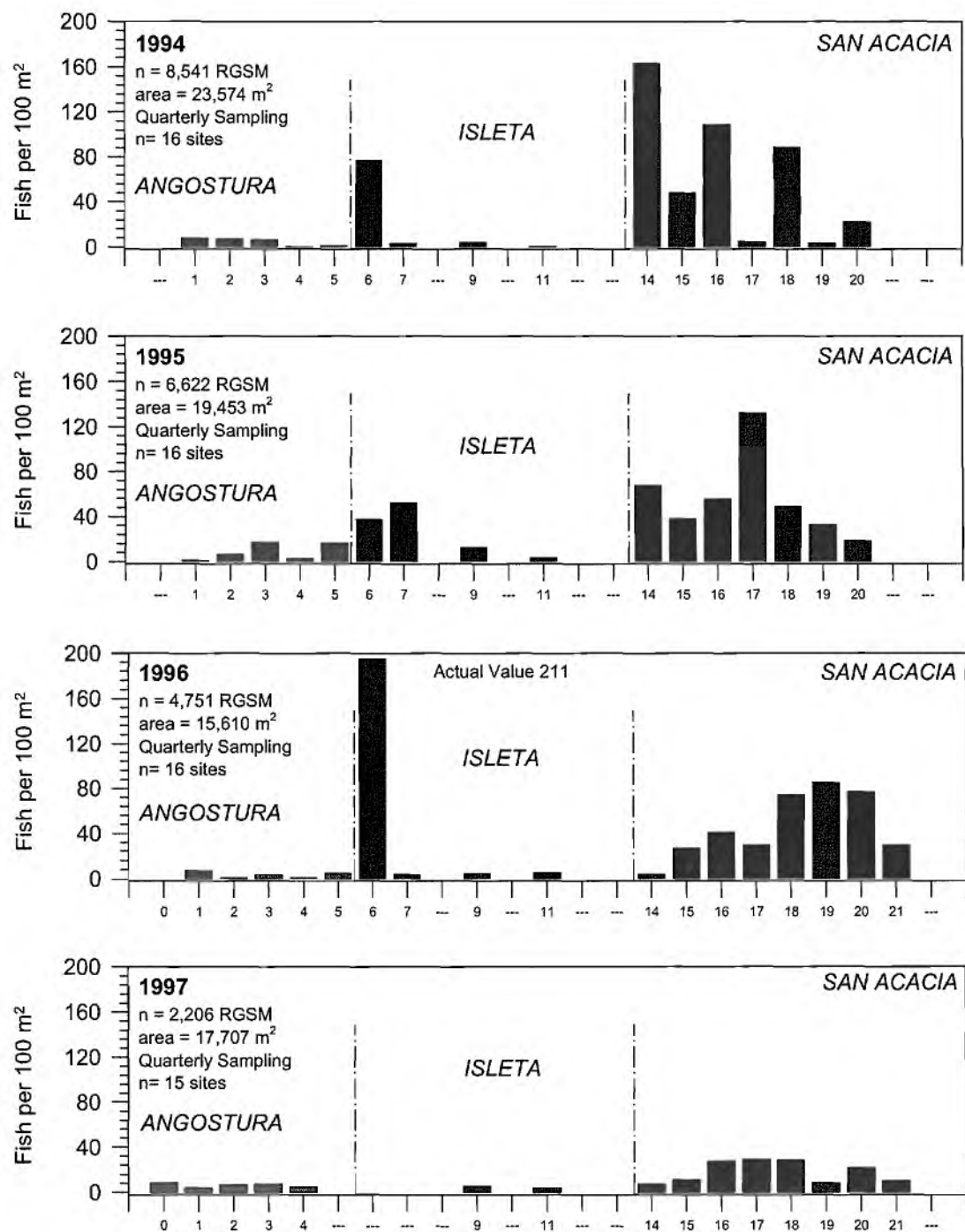


Figure 4. Cumulative annual Rio Grande silvery minnow (RGSM) catch rates by reach during the study period (*Note: High catch of RGSM at site 6 in 1996 due to their confinement in isolated pools during April river drying events).

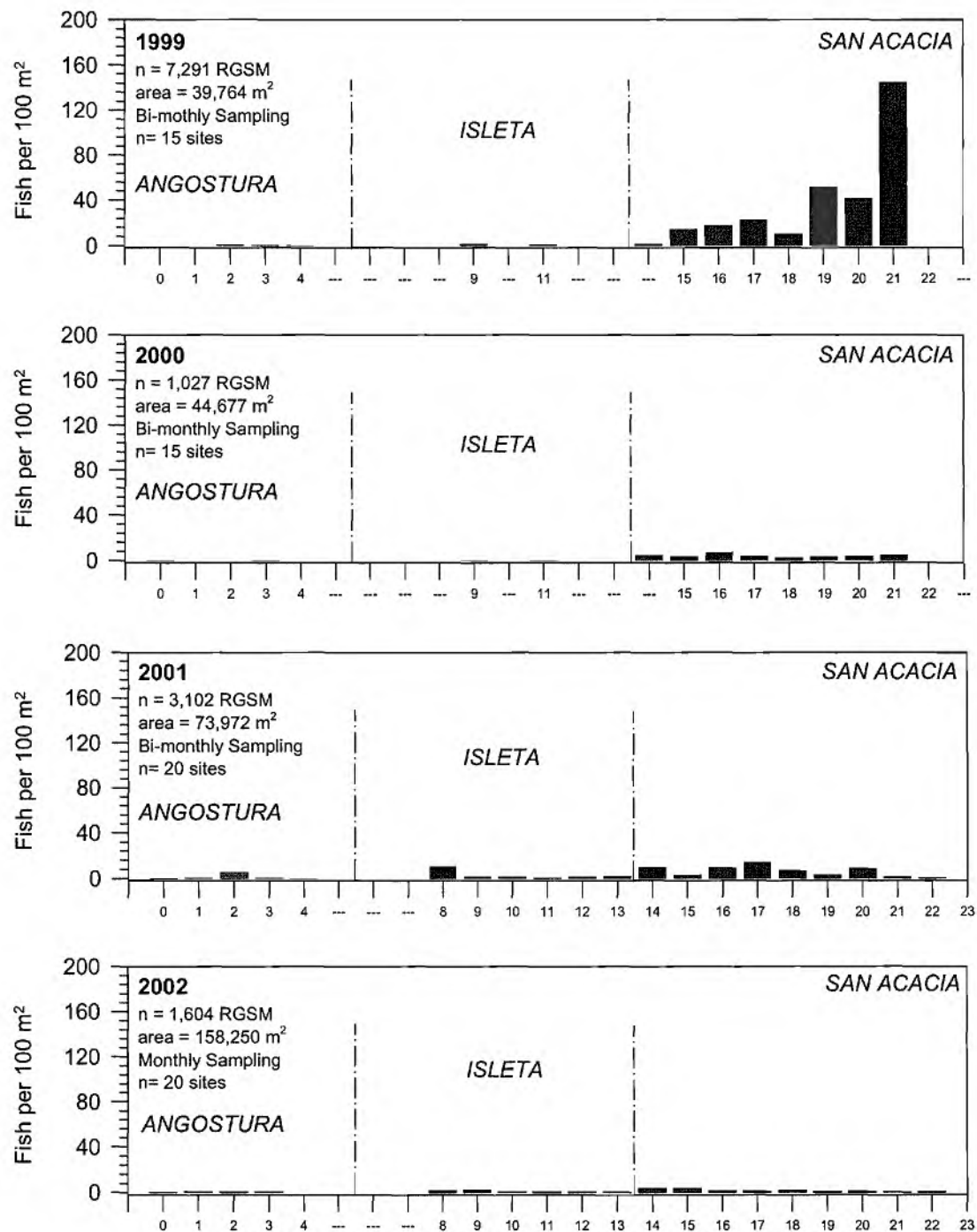


Figure 4. Cumulative annual Rio Grande silvery minnow catch rates by reach during the study period (continued).

Efforts to maintain flow throughout the Middle Rio Grande are critical as further losses of Rio Grande silvery minnow could result in the extirpation of this species from the wild. The barrier to upstream movement imposed by the three Middle Rio Grande Diversion Dams and downstream transport of silvery minnow eggs and larvae into Elephant Butte Reservoir continue to adversely impact populations of this species. The effects of these problems have been synergistic and now become especially critical as densities of individuals for calendar year 2002 were the lowest ever recorded (Dudley et al. 2003).

II. HABITAT OF RIO GRANDE SILVER MINNOW

Investigations of fish habitat use in the Middle Rio Grande during 1987-1992 demonstrated that most minnows use a very small portion of the available aquatic habitat (Platania 1993). Likewise, a 1994-1996 Rio Grande silvery minnow habitat use study found that this species did not occupy the most commonly available aquatic habitats in proportion to its availability (Dudley and Platania 1997; Figure 5). Rio Grande silvery minnow is most abundant in areas of low or moderate water velocity and rare in habitats with high water velocities. The habitat types that Rio Grande silvery minnow occupy indicate their preference for low-velocity areas. Silvery minnow used relatively rare habitats such as eddies formed by debris piles, pools, and backwaters most frequently. Conversely, main channel runs, the most abundant habitat in the Middle Rio Grande, were generally avoided by Rio Grande silvery minnow.

HABITAT USE BY DIFFERENT LIFE-STAGES--- Habitats used by larval Rio Grande silvery minnow were, almost without exception, relatively shallow areas with low or no water velocity and a fine particulate substrate (i.e., silt or silt/sand mixture). These habitat conditions were most frequently encountered in habitats not directly associated with the main river channel (i.e., backwaters and secondary channels pools). The overall shift in depth, velocity, and substrate use by Rio Grande silvery minnow as they grew larger was supported by habitat use shifts from low to moderate velocity areas. The small size-classes of this fish were collected almost exclusively in backwaters, pools, and along shoreline habitats. Larger individuals were in a broader spectrum of habitats which included areas of flowing water such as main and side channel runs. The generalized decline, as Rio Grande silvery minnow grew, in the percent of individuals that occupied lower velocity habitats (debris piles and shoreline habitats) suggested their movement to slightly higher-velocity habitats. Despite shifts in habitat use, the majority of size-classes still predominantly occupied low-velocity habitats.

SEASONAL HABITAT USE--- Habitats selected by Rio Grande silvery minnow differed between summer (April-September) and winter (October-March) with most changes occurring after the seasonal decline in water temperatures. The onset of the drop in water temperatures generally occurs near the beginning of autumn or winter and does not rise substantially until late spring or summer. In winter, Rio Grande silvery minnow moved from (summer) habitats such as pools and backwaters to habitats with instream debris piles. The majority of Rio Grande silvery minnow collected in the winter were in or adjacent to instream debris piles (i.e., tumbleweeds) even though instream debris was one of the rarest habitats present in the river. The diminished water velocity in debris piles appeared a major factor influencing the habitat selection of the fishes in winter. Rio Grande silvery minnow also occupied deeper waters in the winter, than summer, but these areas were still typified by low water velocities. Individuals occurred almost exclusively over silt and sand substrata in both winter and summer.

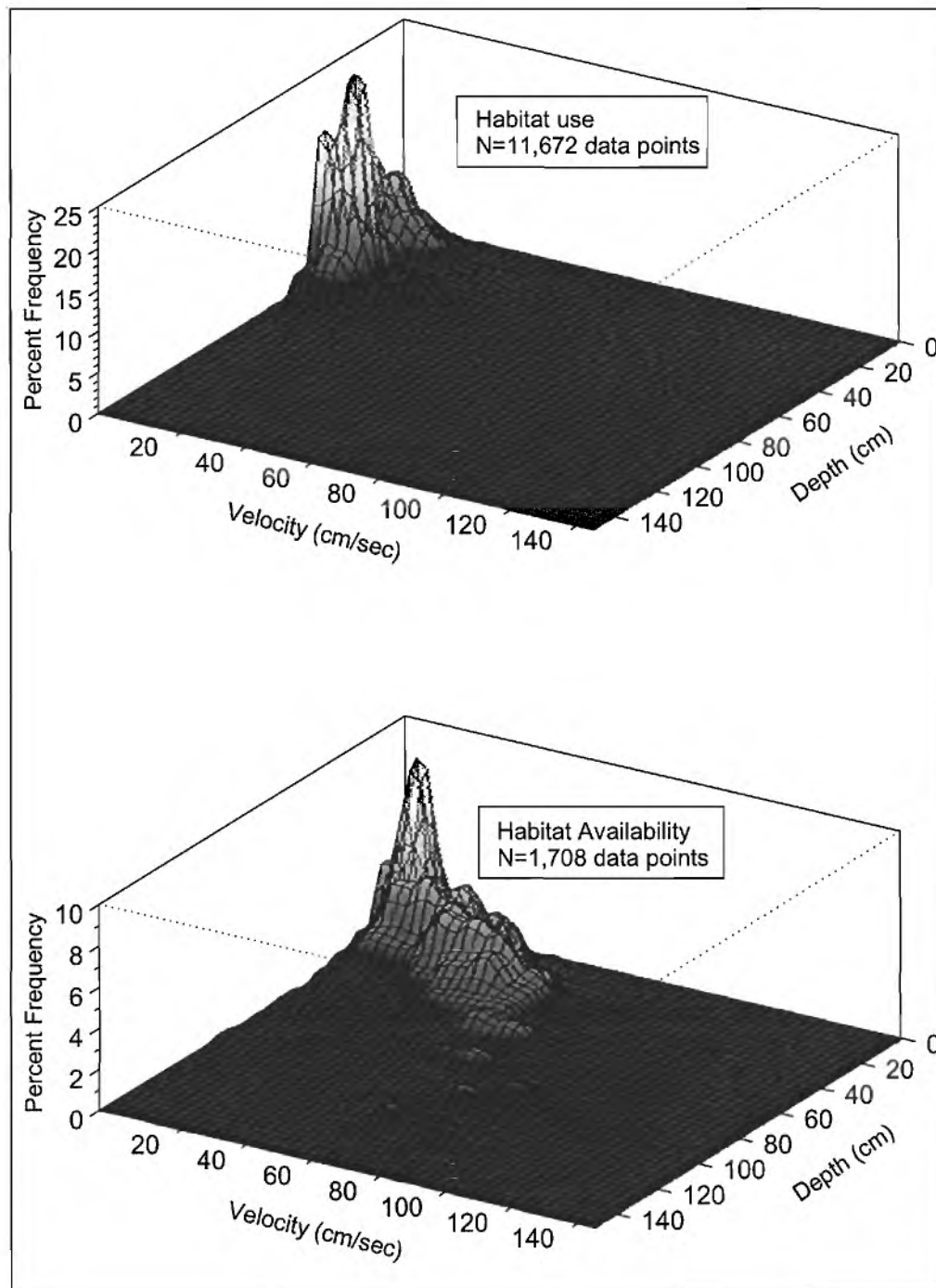


Figure 5. Comparison of habitat availability parameters (depth and velocity) with habitat (depth and velocity) used by Rio Grande silvery minnow in the San Acacia Reach of the Rio Grande (at Socorro) during 1994-1996.

Many species of fish seek areas of cover during winter primarily because these areas have reduced water velocities and provide protection from predators. Occupying areas of low water velocity in winter is critical since fish, such as Rio Grande silvery minnow, rarely feed during that period and would not have the energy reserves necessary to occupy habitats with elevated water velocities for extended periods. A U. S. Army Corps of Engineers funded study to examine the winter habitat of Rio Grande silvery minnow reported that over 70% of Rio Grande silvery minnow were taken in or adjacent to debris piles (Dudley and Platania 1996).

III. REPRODUCTION AND EARLY LIFE-HISTORY

Prior to the 1990s, little was known of the life history and ecology of Rio Grande silvery minnow (e.g., Sublette et al. 1990). Much of the following information is derived from studies undertaken during the mid-1990s and represents a summary of that information. Rio Grande silvery minnow is a member of a reproductive guild (=group) defined by being pelagic broadcast spawners that produce nonadhesive, semibuoyant eggs. This reproductive behavior and egg physiology was common to many fishes inhabiting the Rio Grande and Pecos River including four fish taxa that have been eliminated from the Middle Rio Grande (Platania and Altenbach 1998).

Reproductive biology studies on Rio Grande silvery minnow resulted in the successful spawning of this species in aquaria and rearing of their larvae to the juvenile developmental stage. That study (Platania 1995) revealed spawning behavior and demonstrated that this species is a pelagic spawner that may produce over 3,000 semibuoyant, nonadhesive eggs during a spawning season. The eggs are about 1/16 inch (1.6 mm) diameter upon fertilization but quickly swell to 1/8 inch (3.0 mm) and remain suspended in the water column during development. Egg hatching time was temperature dependent but rapid and generally to occurred in 24-48 hours (Platania 2000). The higher the water temperature, the more rapid the development and hatching of eggs (Figure 6). Recently hatched larval fish attempt to remain a part of the drift by swimming vertically (swim-up stage) in the water column. About three days after hatching, the gas bladder of the larval fish develops, the yolk-sac is almost completely absorbed, and protolarvae (=earliest [first of four] stage of development in larval fish) begin feeding (Figure 7). These physiological developments correspond with a shift in swimming behavior as the protolarvae end their swim up period, moved horizontally, and appeared to actively seek low-velocity habitats.

Larvae are about 9/16 inch (3.7 mm) in standard length (SL= standard length = a measure from the tip of the snout to the base [versus end] of the tail) upon hatching and grew about 1/170th of an inch (0.15 mm) per day during proto-and mesolarval stages. The first mesolarval (=second [of four] stage of development in larval fish) Rio Grande silvery minnow (15/64 of an inch; 5.9 mm SL) was observed seven days after hatching but protolarvae numerically dominated the samples until 16 days after hatching (Platania 1995). The first metalarvae silvery minnow (=third [of four] stage of development in larval fish) was 3/8 inch long (9.9 mm SL) and collected on day 22 and the first juvenile (5/8 inch; 16.4 mm SL) was taken 48 days after hatching. Growth for the first 41 days appeared to be allometric (1/150th of an inch/day; 0.17 mm/day) and seemed to shift to isometric between days 41-48 (9/32nd inch/day; 0.71 mm/day).

Additional laboratory investigation revealed that reproduction in Rio Grande silvery minnow consisted of multiple spawning events with between 100-200 eggs expelled per spawn and the fecundity of an Age II female being over 5,000 eggs (Platania and Altenbach 1996). The duration between spawning events and high level of spawning achieved by

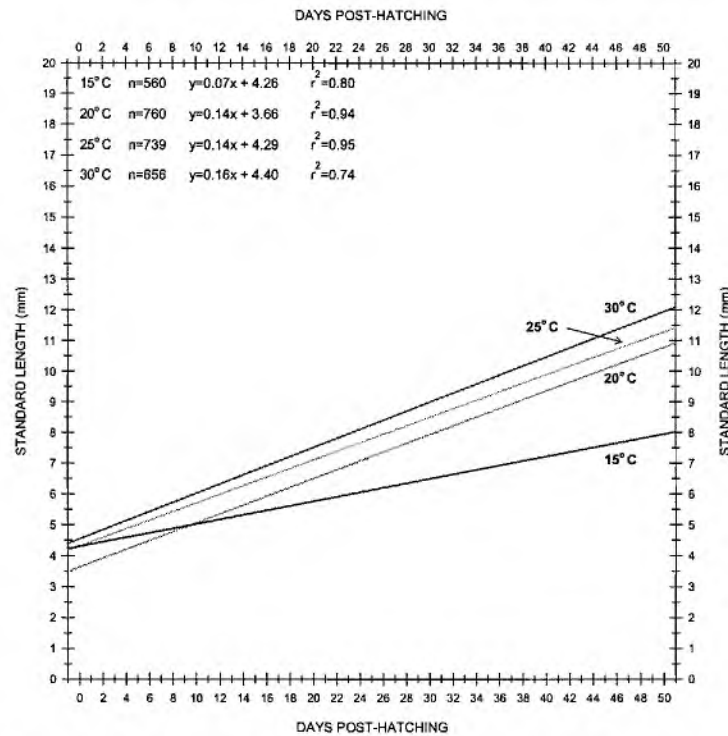


Figure 6. Comparison of laboratory reared larval Rio Grande silvery minnow growth rates, using mean daily lengths, when raised under different temperature treatments.

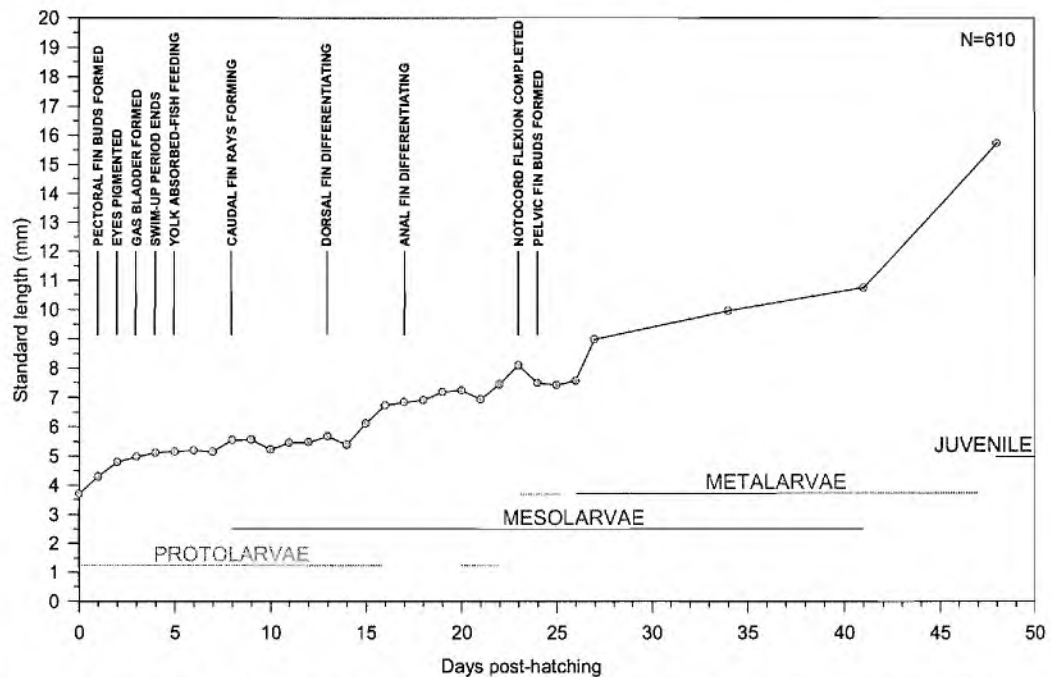


Figure 7. Summary of Rio Grande silvery minnow growth and development through the larval stage. Dots represent mean daily length. Horizontal lines represent range of ages over which the developmental stages occurred.

some individuals, especially during later trials, suggested that this species had the capability of releasing all eggs within a relatively short time frame. This ability, in combination with this species apparent schooling behavior, suggested a high probability for synchronous spawning within populations in selected reaches of the Rio Grande.

SPAWNING: TIMING, DURATION, AND MAGNITUDE--- Spawning by Rio Grande silvery minnow and other members of this reproductive guild is associated with high-flow events such as spring runoff or summer rainstorms. Rio Grande silvery minnow generally spawn over a relatively brief period (ca. 1 month) in late spring-early summer (May-June) which coincides with spring runoff. In 1999, 2001, 2002, and 2003 peak spawning by wild (=non-laboratory study) Rio Grande silvery minnow occurred soon after the initiation of spring snowmelt runoff or release of artificial "flow-spikes" from Cochiti Reservoir (Figure 8). The catch rate of Rio Grande silvery minnow eggs appear most closely correlated with increased flow and not absolute water volume. While spawning by Rio Grande silvery minnow appeared to be strongly associated with changes in flow and water temperature, its peak spawning period occurs over a very short time span (Platania and Dudley 2002, 2003). In 2001, over 98% of all Rio Grande silvery minnow eggs collected arrived over a three day period (8-10 May) while over 99% of the 2002 silvery minnow egg catch arrived during 17-19 May (Figure 9). The number of Rio Grande silvery minnow eggs retained for propagation efforts in 2002 was estimated to be over 900,000 with the vast majority of those eggs (85%, n=784,000) collected on 18 May 2002. The pattern of the 2003 Rio Grande silvery minnow spawn was the same as observed during 2001-2002 (peak 19-22 May) except that the magnitude of the was spawn considerably smaller than recorded in 2002.

V. GROWTH

Spawning exerts high mortality on Rio Grande silvery minnow. In general, by December of any given year, the vast majority (>98%) of surviving Rio Grande silvery minnow are age 0 (= spawned that previous summer). This ratio does not change appreciably between January (1 January is the nominal birth date) and June as age 1 fish constitute over 95% of the population just prior to spawning (Figure 10). Generally, the population consists of only two age-classes; either age 0 and age 1 or age 1 and age 2 (very few age 2). Rio Grande silvery minnow continue to grow through the winter months, albeit less rapidly than during the warmer months. Age 1 fish are 1.75 to 2 inches (45 to 49 mm) by the initiation of the spawning season. Age 0 and age 1 Rio Grande silvery minnow from the Angostura Reach (comparatively cool thermal regime) have greater lengths (7/64ths of an inch; ca. 3 mm) for a given date than those from the San Acacia Reach (comparatively warm thermal regime). Most growth occurs between June (post-spawning) and October. Maximum size attained by Rio Grande silvery minnow is about 3.5 inches (87 mm SL). Maximum longevity in the wild is about 25 months but very few fish survive more than 13 months. Conversely, it is not uncommon for Rio Grande silvery minnow in captivity to live beyond two years.

DIET--- Rio Grande silvery minnow has an elongated and coiled gastrointestinal tract which is typical of an herbivorous (=eats primarily vegetation) fish. The presence of sand and silt in the gut of wild captured specimens suggests that epipsammatic algae (=algae growing on the surface of sand) is an important food. Laboratory reared Rio Grande silvery minnow were observed grazing on algae growing in the aquaria (Platania 1995). In addition, reared study specimens were fed a dry commercially microparticulate diet of BioKyowa fry feed (Kyowa 250-A) which is comprised of various finely ground aquatic invertebrates, amino

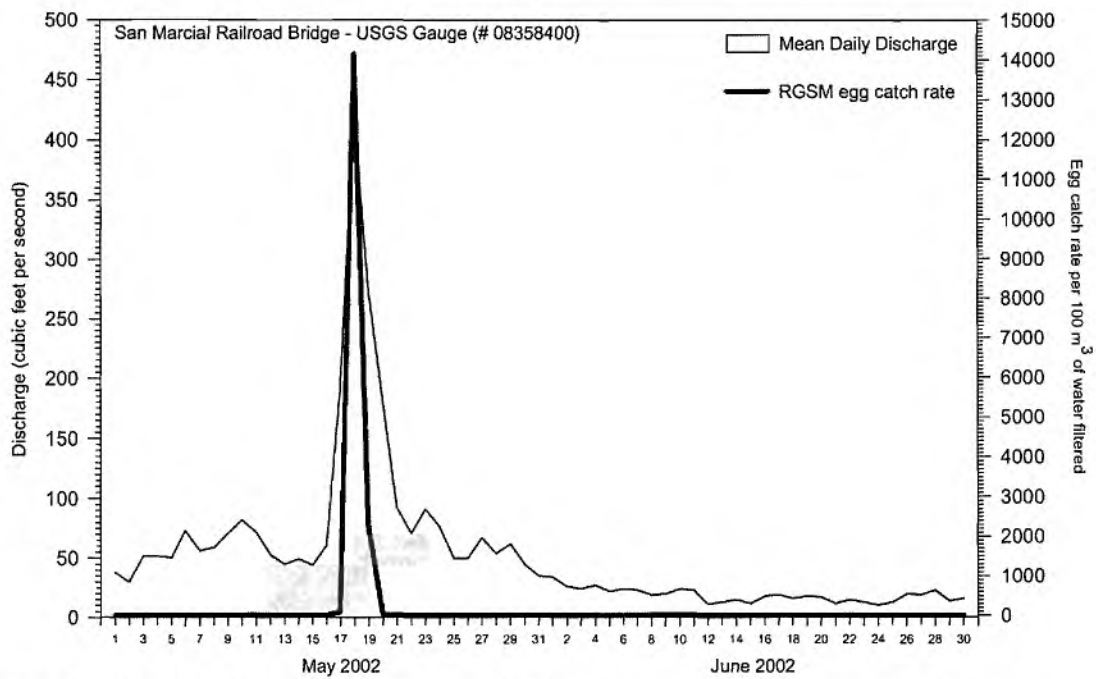


Figure 8. Rio Grande silvery minnow catch rates during the 2002 spawning period compared with mean daily discharge as recorded at the San Marcial Railroad Bridge Crossing Gauge.

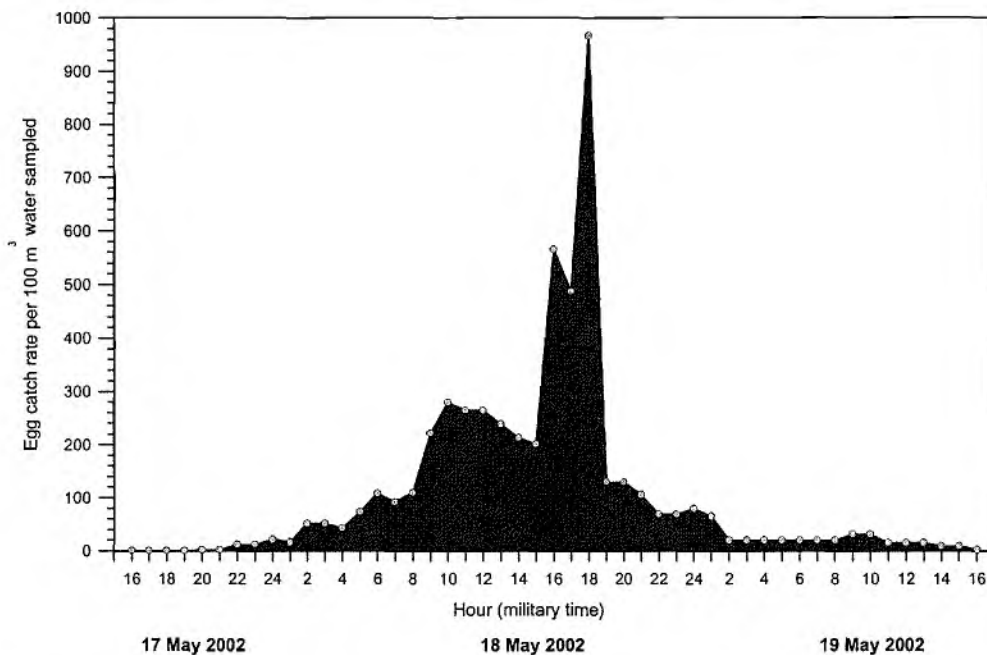


Figure 9. Hourly Rio Grande silvery minnow egg catch rates (single Egg Catcher) during the peak 2002 spawning event.

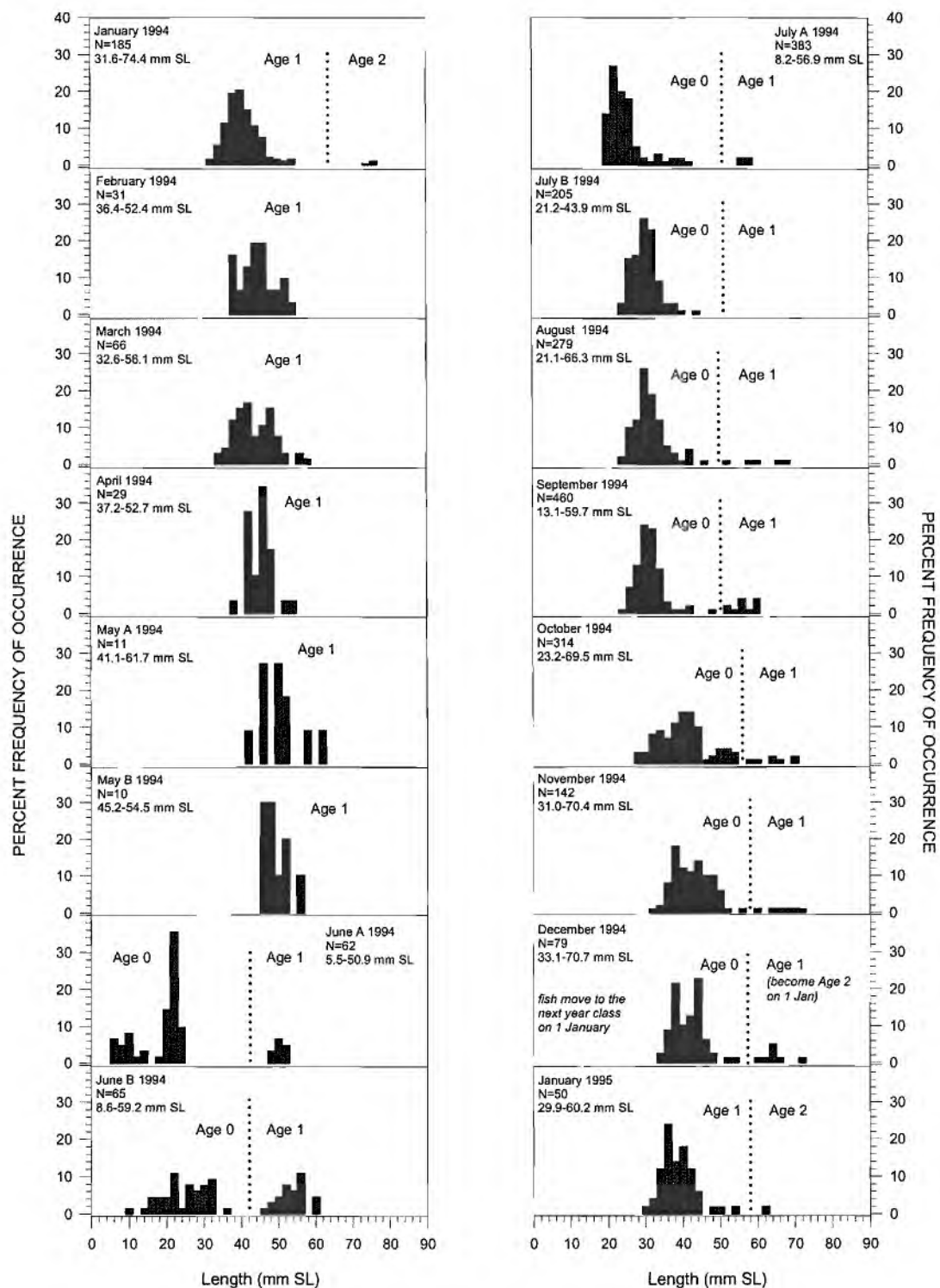


Figure 10. Length-frequency histograms of wild Rio Grande silvery minnow collected in the San Acacia Reach of the Rio Grande (at Socorro) January 1994 through January 1995. Dotted vertical line separates putative age classes.

acids, and other dietary supplements (Platania 1995, Platania and Altenbach 1996, Platania 2000). Studies of captive Rio Grande silvery minnow are currently in process to determine the diet necessary to maximize culture of this species.

VI. MOVEMENT OF RIO GRANDE SILVERY MINNOW

Among current suggestions designed to aid in the recovery of Rio Grande silvery minnow is removal or redesign of the three Middle Rio Grande diversion dams (Angostura, Isleta, San Acacia). Prior to initiation of any such construction activities, a suite of information is needed regarding Rio Grande silvery minnow. Research proposals designed to determine behavior and swimming ability of Rio Grande silvery minnow in reference to fish passage device have been completed (Bestgen et al. 2003). Likewise, initial data on movement of Rio Grande silvery minnow in the Rio Grande, acquired through a mark-recapture study, were also recently reported (Platania et al. 2003). The results of the mark-recapture investigation are summarized below (Figure 11).

In November and December 2001, approximately 12,000 captive reared Rio Grande silvery minnow ranging in length from 0.6 inches (15 mm) to 2.6 inches (65 mm) SL, were marked as part of a project that began as a pilot study designed to evaluate the utility of the Visible Implant fluorescent Elastomer (VIE) marking technique on a laboratory population of Rio Grande silvery minnow. An initial assessment of recapture ability and rate was also to be performed. A yellow tag (ca. 3/16 - 1/4 inch [5-6 mm]) was inserted on the left side (in front of the dorsal fin) of 4,600 silvery minnow while a green tag was placed (same location) in 7,300 silvery minnow. The two different lots (yellow marked and green marked) were maintained separately and ultimately released separately at two localities in the San Acacia Reach of the Rio Grande on 9 January 2002.

The 2001-2002 mark-recapture study of hatchery reared wild-produced Rio Grande silvery minnow resulted in the acquisition of extremely valuable information in the fields of fish marking techniques and behavior, and archetypal data regarding movement of a small-bodied Great Plains River fish. The study clearly demonstrated not only that a large number of Rio Grande silvery minnow can be marked in a relatively short time, but also that a substantial percentage of the marks are retained, that small fish can be successfully tagged, and that the combination of multiple colors and placement of VIE tags provides a system for hundreds of unique marks. A total of 66 tagged Rio Grande silvery minnow were recaptured during the tenure of this study. About half (47%) of the recaptured specimens were green-marked fish taken in samples in the upper portion of the San Acacia Reach. Slightly more (n=35) yellow-marked silvery minnow were recaptured, than green-marked, however 69% of the yellow-tagged silvery minnow were taken (collectively) in two samples and they were not nearly as equally distributed throughout the study area as green-tagged fish. Green-tagged fish were first recaptured 54 days after being released and last taken 133 days post-release.

This investigation also documented two very important facets of movement in Rio Grande silvery minnow. The study highlighted the propensity of hatchery reared silvery minnow to redistribute downstream and the ability of individuals to move extensive distances upstream in a relatively short time. Collectively, 67% of the marked fish moved downstream while 77% of the fish were collected either at or downstream of the release site. The distance traveled by recaptured fish ranged from 0.16 miles (0.26 km) to over 15.5 miles (25 km). The seven longest distances traveled were by Rio Grande silvery minnow containing a green VIE tag. In those seven samples, the distance of dispersal ranged from 2.09 miles (3,360 m) to 15.64 miles (25,170 m). In general, the recapture of marked fish was negatively correlated with distance from the respective release site.



Figure 11. Summary of 2002 Rio Grande silvery minnow recapture information from the San Acacia Reach of the Middle Rio Grande.

CONCLUSION

The unique ecological life history characters that served Rio Grande silvery minnow and other members of the semibuoyant egg reproductive guild so well prior to extensive anthropogenic (=man-made) modification of the river and associated floodplain are the inexorable links that provide unambiguous insight to reasons for the decline of this species and extirpation of other guild members. Spawning by Rio Grande silvery minnow during increased river flows, like spring runoff or summer rainstorms, was advantageous prior to dams and diversions. Such flow events would generally infuse a volume of water, to the aquatic ecosystems that traversed the Chihuahuan Desert environment, of sufficient magnitude and duration to trigger adult fish to produce a new generation. Instead of laying eggs in sand or gravel or attaching them to the substrate or vegetation, these unique fish would wait for high flow events before broadcasting gametes. The resulting propagules would be captured in the elevated flow and transported downstream.

Rapid development and hatching of eggs is also perceived as a strategy for the survival of fishes in systems characterized by erratic spring and summer flow events (=flashy flows). The development of the gas or swim bladder in larval fish about 4-5 days after fertilization allows them to actively escape the high flow event in which they are being carried thereby limiting the distance they are transported downstream of the parental home. Once they are free of the high flows, they seek shelter in low velocity habitats. These shallow protected habitats are chosen because they are typically devoid of predators and maintain water temperatures that are higher than adjacent main channel habitats. The warm water temperatures of the shallow habitats provide an abundant food source via primary productivity (growth of algae) that, in combination with the accelerated developmental rate of larval Rio Grande silvery minnow in warmer waters, result in its rapid progression through this vulnerable life stage.

Annually Rio Grande silvery minnow is one of the earliest spawning fish in the Middle Rio Grande and is only preceded in spawning by nonnative white sucker. Historical museum curated fish collections and information gleaned from Pecos River studies on this reproductive guild of fishes indicate that the other members of this group spawned later in the summer, more typically during storm events than spring runoff, than Rio Grande silvery minnow. Given that Rio Grande silvery minnow is the only nonpredacious fish (an omnivore) in the Middle Rio Grande, it is subjected to pressure of predation by other cyprinids (especially during the larval stages). Spawning before other species and its rapid growth rate allow age 0 Rio Grande silvery minnow to achieve large size relatively rapidly. By the time other Middle Rio Grande cyprinids have spawned and their larvae are actively feeding in habitats occupied by Rio Grande silvery minnow, the age 0 silvery minnow are generally too large to be preyed upon. In addition, there are few predaceous native fishes in the Middle Rio Grande large enough to eat juvenile or adult Rio Grande silvery minnow.

Another benefit of this unique reproductive and behavioral strategy may have been that it promoted recolonization of reaches impacted during periods of natural drought. The tendency of fish and other aquatic organisms to move upstream toward more permanent water sources can serve to concentrate diminished populations. Increased density of individuals in small upstream river reaches would be extremely important under a scenario of low downstream population levels as it would increase likelihood of spawning among the congregated individuals during a high flow event as well as provide subsequent access to productive flooded habitats for larval fish. However, the most critical component to success under each of the previously mentioned scenarios remains the ability of fish to move unimpeded to upstream reaches. Absent free upstream movement, not only do the

advantages of this formerly successful reproductive strategy disappear, they attain the dubious status of liabilities

River fragmentation and drying are two of the most immediate threats to remnant populations of Rio Grande silvery minnow. The drifting propagules of Rio Grande silvery minnow that historically dispersed throughout the free-flowing Rio Grande, are now subject to being transported considerable distances downstream and displaced over diversion dams or into a reservoir. There are currently three diversion structures between Cochiti Dam and Elephant Butte Reservoir that are barriers to upstream movement of fishes and effectively divide the Rio Grande into four discrete reaches. These diversion dams prevent the movement of fish to upstream reaches which means that a portion of the Rio Grande silvery minnow population is carried, on an annual basis, from each upstream reach to selected downstream segments. Any fish eggs and drifting protolarvae transported downstream from one reach to another are never able to return upstream past these barriers. Another important negative impact of the downstream transport of propagules is the presence of Elephant Butte Reservoir. Since this artificial environment is uninhabitable to most riverine fishes and is the downstream terminus of the range for Rio Grande silvery minnow, propagules carried into that system are forever lost from the population.

That water velocity is typically near its maximum rate during the spawning period of Rio Grande silvery minnow means a very high relative rate of downstream transport. Given the reproductive ecology of Rio Grande silvery minnow (spawning behavior, egg type, and early life history traits), the correlation between depressed developmental rates and low water temperatures, and drift dynamics of propagules, it is not surprising that this species is least common in the uppermost river reach (Angostura) and most abundant in the lowermost portion of its remaining range (San Acacia). This pattern was very apparent and consistent during the early and mid 1990s but, because of river drying, became less significant during recent years. (Data from the Cochiti Reach also follow the aforementioned pattern, however, due to the lack of recent systematic sampling of that reach, this discussion is limited to the three lowermost river reaches.)

In an effort to simplify the multidimensional interactions between Middle Rio Grande hydrology and Rio Grande silvery minnow biology and provide a general understanding of basic principals, the following discussion discounts river drying and instead conveys hypothesis based on a continuous river. Reach length (i.e., distance between dams) and habitat complexity are important factors determining the impact of downstream transport of eggs and larvae on population stability. The shorter the river reach, the more likely the chance that the eggs will be transported out of that reach (i.e., over the diversion structure). A simplistic (one-dimensional) drift model predicts that, over a relatively short period, the entire annual reproductive effort of Rio Grande silvery minnow is conveyed to Elephant Butte Reservoir. This is somewhat of a paradox because, if these predictions regarding drift were realized, the cumulative effect would have been the rapid extinction of this species decades ago.

There are two primary reasons that these predictions are not achieved. While such a model (one-dimensional) is a fundamentally valid initial attempt to quantify measures of drift rate, it remains an extremely simple representation of a complex system. Calculations used to determine a one-dimensional, linear, downstream transport (Y-plane) of eggs and larvae do not account for movement of propagules through the other two planes; horizontal movement across the river channel (X-plane) and vertical distribution through the water column (Z-plane). Three dimensional modeling is necessary to provide a more realistic understanding, than a unidirectional model, of the rate of downstream transport of Rio Grande silvery minnow propagules.

The other reason that the prediction of complete transport of eggs and larvae has not been met is that transport data from even a multidimensional model can not be ascribed to all propagules. There is no simple mechanism to account for the variation inherent in the distribution of eggs and larvae. Given the considerable number of eggs produced by a female Rio Grande silvery minnow (ca. 2,000-5,000), it should be expected that even though the percent of propagules that remain in a reach may be small, it can constitute a large absolute number of individuals.

Perhaps the most serious problem affecting organisms in the Middle Rio Grande Valley is the frequent drying of the river. While there may be some disagreement as to the extent and magnitude of the effects of water management practices on the Middle Rio Grande fish fauna, there should be no debate that an extremely serious impact is the drying of vast reaches of the river channel. In 1989 and 1990, as is typical in years of below average water supply and normal irrigation demand, extensive portions of the Rio Grande downstream of San Acacia Diversion Dam were completely de-watered. The result was that all fish trapped in those sections died. It required at least two years for fish populations in the dried reaches to return to pre-1989 levels. In April and May 1996, extensive reaches of the Rio Grande in the San Acacia reach were again de-watered resulting in the loss of thousands of gravid Rio Grande silvery minnow and other members of the fish community. As recently as the summer of 2003, much of the Isleta and San Acacia reaches of the Middle Rio Grande were de-watered resulting in further losses of the fish community within these areas.

Recovery efforts for Rio Grande silvery minnow will need to focus on reducing the deleterious effects that changes in river connectivity, flow patterns, and habitat heterogeneity have on the downstream displacement of their eggs and larvae. Eliminating diversion structures as barriers would allow upstream passage of individuals to reaches from which they were displaced as well as escape routes during periods of drying. Repopulating upstream reaches of the Middle Rio Grande through natural recolonization would greatly aid in the recovery of this species. Efforts to improve degraded riverine habitats could include returning the flow regime to a more historical pattern (i.e., allowing passage of large flow events) and removing or relocating structures that inhibit the lateral movement of the Rio Grande (e.g., jetty-jacks, levees, and water conveyance ditches). The long-term recovery of Rio Grande silvery minnow will depend on taking management actions that attempt to restore the natural processes of this river and ameliorating conditions that have led to the severe reduction and loss of the early life history stages.

The four mainstem cyprinids which had similar life-history strategies as Rio Grande silvery minnow and were historically sympatric (occurred in the same geographic region), were extirpated in the Middle Rio Grande of New Mexico by the early 1970s (Bestgen and Platania 1991). The synergistic effects of downstream displacement of reproductive products and dam-related modifications of flow and habitat have been identified as major factors responsible for the decline and demise of numerous cyprinids in both the Rio Grande Basin and other Great Plains streams. Given the loss from the Middle Rio Grande of four of the five members of this ecological guild, it is not unreasonable to presume that Rio Grande silvery minnow would likely be the next fish to be lost forever. If this preventable event does occur, it would mean the man-induced loss in little more than half a century of a total of five unique kinds of small freshwater fish that use to be abundant in the Middle Rio Grande of New Mexico.

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FREQUENTLY POSED QUESTIONS

QUESTION 1: *The Rio Grande use to go dry in the past but despite that fact the Rio Grande silvery minnow survived. Why is it now necessary to keep the river wet for the minnow to survive?*

An underlying assumption of this question has been that river drying events of those periods did not significantly impact the local fish communities. This assumption could not be more in error. On the contrary, fish collection information clearly demonstrates that those drying events had devastating impacts on local fish communities. That fact is clearly demonstrated by the extirpation of several fish species in the Middle Rio Grande during this time period. Interestingly, all of the fish species lost during that period were, like Rio Grande silvery minnow, members of the semibuoyant egg reproductive guild.

The question can be restated, once the aforementioned assumption debunked, as "Why or how did Rio Grande silvery minnow survive previous drought periods in the Middle Rio Grande, especially since river drying was so devastating to other fish species?"

We will never have all the answers to this question but have developed several reasons for the persistence of Rio Grande silvery minnow. Many aspects of Rio Grande hydrology have changed since the droughts of the 1960s and the extensive drying that use to occur throughout many reaches of the Middle Rio Grande. One very important fact is that the diversion structures that exist today are not the same as those that existed in the period being discussed. Cochiti Diversion Dam (Cochiti Dam and Reservoir did not exist at that time) and Angostura Diversion Dam were not the barrier to upstream movement they are now. Fish were able to move upstream past these diversion structures and maintain population levels in the upper reaches. That Rio Grande silvery minnow was present in much greater numbers in the Cochiti and Angostura reaches than they are at present attest to that fact. In addition, Rio Grande silvery minnow was also present in the Rio Grande upstream of current day Cochiti Dam (at least until 1978). These upstream populations were the source necessary to repopulate downstream reaches that had been diminished or eliminated during drying events. Once Cochiti Reservoir was in place, populations upstream of the reservoir could no longer provide individuals to downstream populations. While we do not have extensive collection records from the Cochiti Reach, we know that as recently as 1984 Rio Grande silvery minnow were relatively abundant in that section of the river. Gradual changes in river morphology associated with Cochiti Dam ultimately lead to the decline of this and other species in that reach. There are no records of the other four species (i.e., semibuoyant egg species that were eliminated from the Middle Rio Grande) upstream of Cochiti Dam during this time frame.

QUESTION 2: *Can Rio Grande silvery minnow or their eggs can survive in the mud during times when the Rio Grande stops flowing and doesn't this explain why they can persist in a desert river?*

Absolutely, positively, not. This is a rural and urban myth that began spreading about 10 years ago and, like most myths, refuses to die. No life stage of Rio Grande silvery minnow is able to aestivate (survive in the absence of water). That Rio Grande silvery minnow can not live without water should not be surprising to anybody. Silvery minnow is part of the largest Order (a scientific term for a group of fish of the same evolutionary lineage) of freshwater fishes in the world (comprised of 2,700 species worldwide) and none of the species in that Order are able to live without water - without water they simply die. The reason Rio Grande silvery minnow populations have been able to remain in the Rio Grande, even during times of drying, was because populations persisted either upstream or downstream of the reach that dried. With the return of water to the dry riverbed, fish from the up-or-downstream reaches repopulate the formerly dry habitats. (FYI: Lungfishes, which occur in South America, Africa, and Australia, are one of the very few groups of fishes that are able to survive in the absence of water, they aestivate in the mud.)

QUESTION 3: *What good is Rio Grande silvery minnow and why should we protect this species?*

There are a number of answers to this question including philosophical, practical, and religious. Lengthy books have been written on this subject and it is beyond the scope of this document to attempt to synthesize those works. One answer to the question is that need to protect species has been decided to be important by people of the United States and laws developed by elected politicians. The Endangered Species Act is the legislation that protects Rio Grande silvery minnow and other organisms in danger of extinction.

In that 1973 Act, Congress declared:

- (1) various species of fish, wildlife, and plants in the United States have been rendered extinct as a consequence of economic growth and development untempered by adequate concern and conservation;
- (2) other species of fish, wildlife, and plants have been so depleted in numbers that they are in danger of or threatened with extinction;
- (3) these species of fish, wildlife, and plants are of aesthetic, ecological, educational, historical, recreational, and scientific value to the Nation and its people;
- (4) the United States has pledged itself as a sovereign state in the international community to conserve to the extent practicable the various species of fish or wildlife and plants facing extinction.

QUESTION 4: *How many Rio Grande silvery minnow are there currently and how many are required for their future persistence?*

The ongoing Rio Grande silvery minnow population monitoring studies were not designed to estimate the size of the population but instead provide a measure by which general trends (either increasing or decreasing) can be detected. There are at least two principal reasons that there has not been an attempt to estimate the size of the Rio Grande silvery minnow population. The first is that determination of such a number would be extremely difficult, incredibly expensive, and have very wide confidence intervals (explained later). A mark-recapture study (like was used in the movement study discussed earlier in this report) is the generally preferred study design for determination of the size of a population. In such studies, a known number of individuals are marked and attempts are made to recollect those individuals. The ratio of recaptured marked fish to the total number of marked individuals are then incorporated into one of several mark-recapture models to determine population size.

The principal problems with performing such a study on Rio Grande silvery minnow is that it would require a monumental effort to mark and recapture enough fish to generate information that would be of any value. In mark-recapture studies, a recapture rate of 5% is generally considered minimum if one is to obtain a meaningful estimate of the population size. In the 2001-2002 mark-recapture study (Platania et al. 2003), almost 12,000 fish were marked in the San Acacia Reach of the river but the recapture rate was less than 0.6%. Even if enough fish could be marked and recaptured, the confidence intervals around the numbers generated from the models would be very large and render such estimates relatively meaningless.

A "confidence interval" provides a statistical range above and below the number generated by the model. For example, a model may generate a population estimate of 100,000 individuals with a confidence interval of + or - 30,000 individuals. That translates to a population estimate between 70,000 and 130,000 individuals. The higher the recapture rate the better the population estimate and smaller the confidence interval.

The other reason that such a study is not attempted is because, given the population dynamics of small, short-lived organisms, such estimates (even if accurate) would be of little value to management and resource agencies. The number of fish in any given reach varies markedly by seasons, especially between spring and summer (pre and post spawning) and summer and autumn. The unpredictability of continuous flow in the various reaches of the Middle Rio Grande injects additional complications to any attempts to estimate population size.
