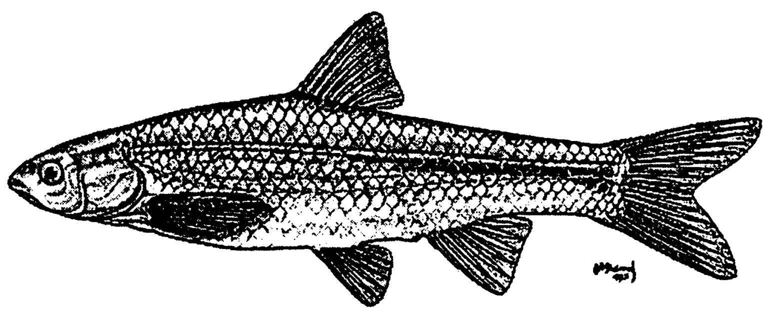
RIO GRANDE SILVERY MINNOW

RECOVERY PLAN



REGION 2
U. S. FISH AND WILDLIFE SERVICE
ALBUQUERQUE, NEW MEXICO

RIO GRANDE SILVERY MINNOW
(*Hybognathus amarus*)

RECOVERY PLAN

Region 2
U. S. Fish and Wildlife Service
Albuquerque, New Mexico

Approved: Nancy M. Kaufman
Regional Director, U. S. Fish and Wildlife Service

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RIO GRANDE SILVERY MINNOW
RECOVERY PLAN
Prepared by the Rio Grande silvery minnow Recovery Team

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Numerous other persons provided reviews and information for the preparation of this plan. The Service greatly appreciates the invaluable assistance provided by team members, consultants, and other individuals who contributed to the preparation of this Recovery Plan.

The Rio Grande Silvery Minnow Recovery Team was created by the Fish and Wildlife Service pursuant to the cooperative policy statement effective on July 1, 1994, to involve stakeholders in the development of recovery plans in order to minimize the social and economic impacts consistent with timely recovery of endangered species.

EXECUTIVE SUMMARY

Current Status:

The Rio Grande silvery minnow is federally listed as endangered and also listed as endangered in the states of New Mexico and Texas and the Republic of Mexico. Historically, this species occurred throughout the Rio Grande basin in New Mexico and Texas. Currently, the species is known to occur only in the Rio Grande from just downstream of Cochiti Dam to the headwaters of Elephant Butte Reservoir, New Mexico, occupying about five percent of its known historic range.

Habitat Requirements and Limiting Factors:

The Rio Grande silvery minnow occurs only in flowing plains streams of variable depth and velocity. The decline of the Rio Grande silvery minnow may be attributed in part to modification of stream discharge patterns and channel desiccation by impoundments, water diversion, stream channelization, competition and predation by introduced nonnative species and water quality degradation.

Recovery Objective:

The goals of this recovery plan are to: 1) stabilize and enhance populations of Rio Grande silvery minnow and its habitat in the middle Rio Grande valley and 2) reestablish the Rio Grande silvery minnow in at least three other areas of its historic range.

Recovery Criteria:

Population levels of Rio Grande silvery minnow vary within and between each of the four middle Rio Grande valley reaches but collectively are not currently considered of sufficient magnitude for recovery of this species. Recovery of Rio Grande silvery minnow will require that populations in some reaches of the middle Rio Grande valley be stabilized while others will require both stabilization and enhancement. Following accomplishment of these actions, recovery of Rio Grande silvery minnow in the middle Rio Grande valley will be considered achieved when there are no biologically significant declines in distribution, abundance, or levels of reproduction in the middle valley for a period of five consecutive years and when institutional mechanisms to assure adequate deliveries of water and restoration of aquatic and riparian habitat are in place to protect the species and its habitat.

The goal for reestablishing Rio Grande silvery minnow populations outside of the middle valley will be considered met when self-sustaining populations of Rio Grande silvery minnow have become established in at least three of the reaches identified in this document for reestablishment. For these populations to be considered reestablished, there should be no biologically significant declines in reproduction, distribution, and abundance for a period of five consecutive years and institutional mechanisms must be in place that will protect the species and its habitat.

The term "biologically significant decline" as used in the Recovery Criteria will be used to quantify whether recovery is progressing or has been achieved. The method used to determine biological significance is based upon a determination of the statistical deviation from the moving five-year mean of autumn population abundance and a minimum over-winter mortality rate. A detailed description of the process used to determine biological significance is given on page 42 of this document.

Actions needed:

The following action statements correspond to the major headings of the Narrative Outline, Part II - Recovery and Part III - Implementation Tasks, and are more fully described therein.

1. Restore and protect habitats within the middle Rio Grande valley necessary for the stabilization and enhancement of populations of Rio Grande silvery minnow.
2. Reestablish Rio Grande silvery minnow into suitable habitat within its historic range.
3. Design and implement a public awareness and education program.
4. Implement and maintain an adaptive management program and ensure appropriate research and management activities are carried out in order to attain recovery of the Rio Grande silvery minnow.

Costs:

The estimated costs of performing the activities described in this Recovery Plan over the next five years are summarized in the following table (in thousands of $'s). The costs of capital projects are not known and are not included. The total cost of water is not known, and only annual estimates are included.

Year	(1.) Habitat Restoration	(2.) Reestablishment	(3.) Public Information	(4.) Adaptive Management	TOTAL
2000	960.0	485.0	35.0	135.0	1,615.0
2001	990.0	685.0	35.0	135.0	1,845.0
2002	830.0	500.0	10.0	125.0	1,465.0
2003	475.0	250.0	10.0	125.0	860.0
2004	475.0	200.0	10.0	125.0	810.0
5-Yr. Total	3,730.0	2,120.0	100.0	645.0	6,595.0

All tasks and total costs required to implement actions identified as a result of research undertaken and data collected in accordance with this plan are not known. The ultimate time frame and total costs of implementing activities to achieve the objective of this recovery plan will be addressed through the adaptive management program. The performance of activities described in this Recovery Plan will be reviewed at least annually by the Recovery Team and evaluated at the end of the five-year period.

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PART I - INTRODUCTION

Status:

The Rio Grande silvery minnow, *Hybognathus amarus*, is one of seven species in the genus *Hybognathus* found in the United States (Pflieger 1980). The Rio Grande silvery minnow was historically found in the Rio Grande from Espanola, New Mexico, to the Gulf of Mexico (Bestgen and Platania 1991), and in the Pecos River from Santa Rosa downstream to its confluence with the Rio Grande (Pflieger 1980). Currently, the Rio Grande silvery minnow is found only in a 274 km (170 mi.) reach of the middle Rio Grande from just downstream of Cochiti Dam to the headwaters of Elephant Butte Reservoir, New Mexico (Bestgen and Platania 1991). It is federally listed as endangered (U. S. Fish and Wildlife Service 1994) and listed as endangered by New Mexico (19 NMAC 33.1) and Texas (Sections 65.171 - 65.184 of Title 31 T.A.C.) and the Republic of Mexico (SDS,1994). Critical habitat has been proposed in New Mexico from the State Highway 22 bridge crossing the Rio Grande immediately downstream from Cochiti Dam southward for approximately 262 km (163 mi.) to where the Burlington Northern and Santa Fe Railroad crosses the river near San Marcial, Socorro County (U. S. Fish and Wildlife Service 1993). Throughout much of its historic range, the decline of the Rio Grande silvery minnow may be attributed in part to modification of stream discharge patterns and channel desiccation by impoundments, water diversion, stream channelization (Bestgen and Platania, 1991, Cook et al., 1992), competition and predation by introduced nonnative species and water quality degradation.

Reasons for Decline:

The Rio Grande silvery minnow was determined to be an endangered species due to the impact of one or more of the following factors:

The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range. The only existing population of Rio Grande silvery minnow is threatened by annual dewatering of a large percentage of its habitat. This dewatering is primarily the result of diversion of the river for agriculture within the middle Rio Grande valley of New Mexico. During a below-average water year, the river channel may be dry from Isleta Diversion Dam downstream about 179 km (111mi) for two months for more. When two below-average flow years occur consecutively, a short-lived species such as Rio Grande silvery minnow can be severely impacted, if not completely eliminated from the dry reaches of the river. Diversion dams also entrain Rio Grande silvery minnow into irrigation canals and prevent migration to upstream habitat. It has been estimated that in 1996, approximately 70% of the known population of Rio Grande silvery minnow inhabited the river below the San Acacia Diversion Dam.

Mainstem dams permit the artificial regulation of flow, prevent flooding, trap nutrients, alter sediment transport, prolong flows, and create reservoirs that favor nonnative fish species. These changes may affect Rio Grande silvery minnow by reducing its food supply, altering its preferred habitat and preventing dispersal. Altering flow regimes may also improve conditions for other native fish species that occupy the same habitat as the Rio Grande silvery minnow and may thereby cause their populations to expand at the expense of the Rio Grande silvery minnow.

Channelization of the middle Rio Grande has resulted primarily from the jetty fields along the river, which are designed to protect the levees by retarding flood flows, trapping sediment, and promoting the establishment of vegetation. Meanders, oxbows and other components of historic aquatic habitat have been eliminated in order to pass water as efficiently as possible for agricultural and downstream deliveries. These changes affect Rio Grande silvery minnow by altering its habitat. Sandy substrate, which it prefers, has been replaced by gravel and cobble, and no backwater areas exist where the young can develop.

Growth of agriculture and cities along the Rio Grande during the last century may have adversely affected the quality of the river's water. During low-flow periods, a large percentage of the river's flow consists of municipal and agricultural discharge and less water is available to dilute pollutants. This degradation of water quality may affect the Rio Grande silvery minnow's survival.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes. It is not presently known if the species is being overutilized for commercial, recreational, scientific, or educational purposes. State agencies regulate scientific taking and commercial bait sales, although State regulations do not assure against the unintentional collection or distribution of the Rio Grande silvery minnow.

Disease or Predation. Rio Grande silvery minnow are more susceptible to both disease and predation when it is forced into confined habitats due to lack of streamflow. Nonnative species prey upon Rio Grande silvery minnow and may compete with Rio Grande silvery minnow for space and food. Rio Grande silvery minnow is also subject to predation by native fish species under these circumstances. Confining fish to pools causes stress that can often result in outbreaks of parasitic disease.

Inadequacy of Existing Regulatory Mechanisms. At the time Rio Grande silvery minnow was federally listed, the administration of water rights in New Mexico did not provide for protection of the habitat upon which the species depends. However, the March 27, 1998, Opinion of Attorney General Tom Udall concluded that New Mexico law permits the State Engineer to afford legal protection to instream flows for recreational, fish or wildlife, or ecological purposes. Nothing in the regulatory framework prohibits the acquisition of water rights for these purposes of use, provided that an application for transfer of a water right for instream purposes of use is submitted to and approved by the State Engineer.

Reestablishment Site Evaluation Process:

The Recovery Team recognizes the necessity of reestablishing Rio Grande silvery minnow in portions of its historic range outside of the middle Rio Grande in New Mexico, and is committed to this recovery action. An initial evaluation was made to identify reaches within the species' historic range that were deemed most suitable for reestablishment. The reach-by-reach evaluation was based on the experience and observations of Recovery Team members and the consideration of completed research. The principal criteria used in determination of reestablishment potential were: understanding of reasons for the species extirpation from the selected reach, the presence of other members of the reproductive guild (pelagic spawner; non-adhesive, semibuoyant eggs), habitat conditions (including susceptibility to river drying and presence of diversion structures), presence of congeners (i.e., other species of *Hybognathus*). Other criteria include: competitors, water quality and quantity issues, and presence, composition, and density of predators.

Based on the above criteria, a preliminary list of reaches deemed suitable for reestablishment of Rio Grande silvery minnow was produced (Appendix B). A thorough analysis of the reestablishment potential of specific riverine segments within the historic range of Rio Grande silvery minnow is necessary but not practical or possible until after approval of this Recovery Plan. The task of evaluating reestablishment potential of specific reaches is given a first priority under the implementation task table and identified in the narrative outline (Item 2.5, *Identify and evaluate potential reestablishment sites*).

The reaches absent from the preliminary list (Appendix B) have not been excluded from further consideration. All reaches will be reevaluated and reconsidered in the analysis identified in item 2.5. In addition, the order of priority of the list in Appendix B is preliminary and is also subject to reevaluation. There has been and will continue to be additional discussion of the potential to reestablish Rio Grande silvery minnow in subsections or portions of all reaches within its historic range.

<u>Ecosystem management:</u>

The U. S. Fish and Wildlife Service (Service) believes that a shift should be made from relying on reactive management to relying on preventative management (Angermire and Karr, 1994). Ecosystem management is defined by Grumbine (1994) as "The integration of scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term."

Ecological integrity in recovery planning is vitally important due to the obvious connection between the decline of ecosystems and the listing of endangered species. Incorporating an ecosystem approach into recovery efforts means protecting the processes and functions of ecosystems important for the conservation of listed species.

A natural part of any recovery strategy should be to identify ways to arrest and reverse conditions which led to the decline of the species resulting in protection under the Endangered Species Act. Section 2(b) of the Act states that its primary purpose is "to provide a means whereby the ecosystem upon which the endangered species and threatened species depend may be conserved."

HISTORIC DISTRIBUTION

Rio Grande silvery minnow was formerly one of the most widespread and abundant species in the Rio Grande basin of New Mexico, Texas, and Mexico (Bestgen and Platania 1991). This species was distributed from northern New Mexico (vicinity of Española) in the Rio Grande and Pecos River (vicinity of Santa Rosa) to the Gulf of Mexico (Pflieger 1980, see Figure 1). Despite extensive collection efforts in Mexican tributaries to the Rio Grande, the only records of this species from Mexico are from the mainstem Rio Grande. The species is no longer found in extensive portions of its historic range (Table 1).

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). 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 (N=62) in the Rio Grande 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 presumed extirpated from this area.

In the Rio Grande from Caballo Reservoir downstream to the Texas-New Mexico border, only four collections and 15 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.

The Pecos River in New Mexico historically supported populations of Rio Grande silvery minnow from Santa Rosa downstream to the Texas-New Mexico border. The 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

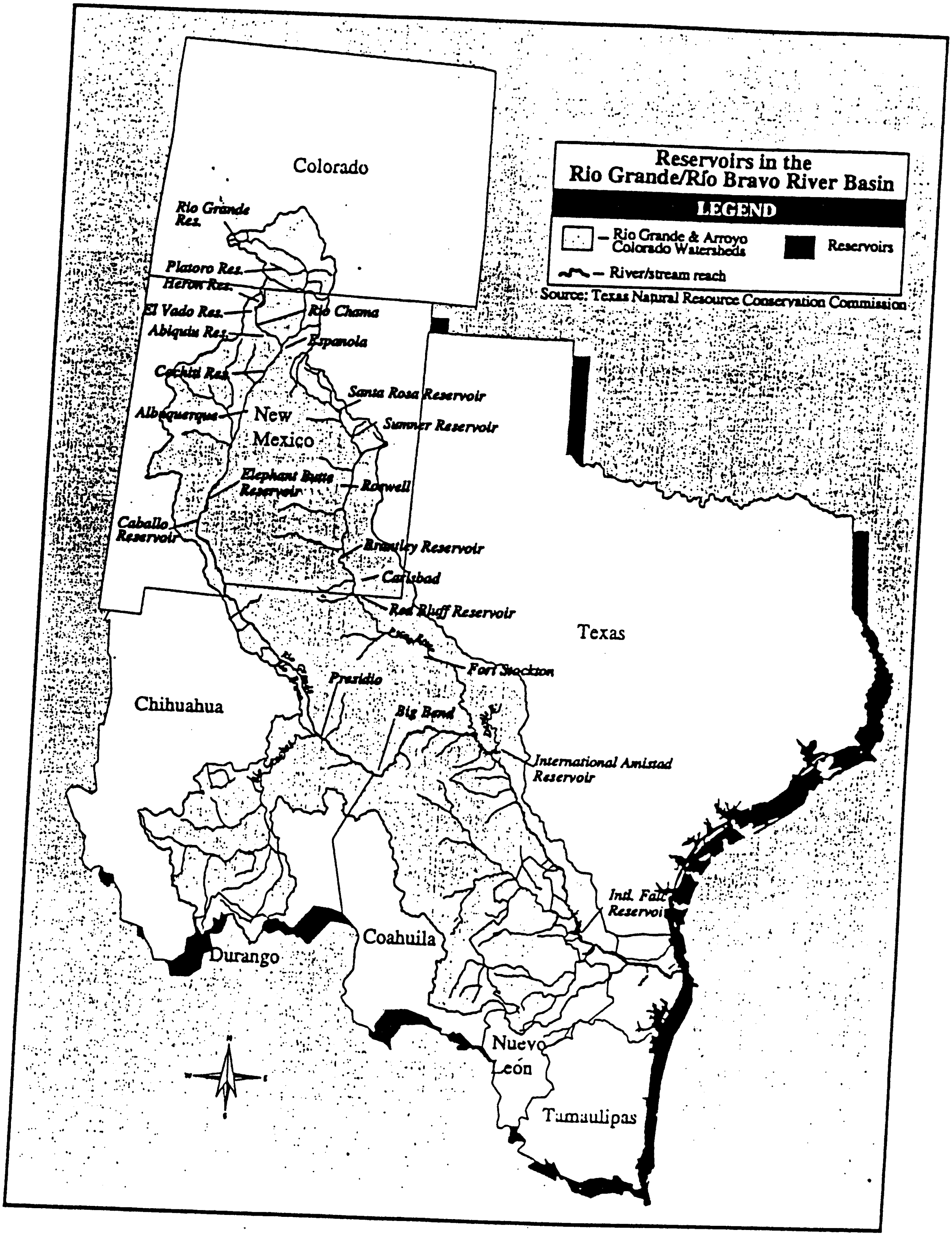

Figure 1. Map of Rio Grande drainage basin

Table 1. Dates Rio Grande silvery minnow was last collected.

RIVER REACH	REACH LENGTH (Kilometers)	(Miles)	DATE LAST COLLECTED[1]
RIO CHAMA	32	20	1949
RIO GRANDE			
Upstream of Cochiti Reservoir	64	40	1978[2]
MIDDLE RIO GRANDE, NEW MEXICO			
Cochiti Reach	34	21	still present
Angostura Reach	61	38	still present
Isleta Reach	90	56	still present
San Acacia Reach	76	47	still present
LOWER RIO GRANDE, NEW MEXICO			
Elephant Butte Reservoir to NM-TX border	216	134	1944
RIO GRANDE, TEXAS			
El Paso to Presidio	454	284	[3]
Presidio to Amistad Reservoir	500	312	1960
Amistad Reservoir to Falcon Reservoir	481	299	late 1950s
Falcon Reservoir to Gulf of Mexico	442	275	late 1950s
PECOS RIVER			
NEW MEXICO			
Santa Rosa Reservoir to Sumner Reservoir	89	55	1939
Sumner Reservoir to Brantley Reservoir	359	223	1968
Brantley Reservoir to Red Bluff Reservoir	119	74	[3]
TEXAS			
Red Bluff Reservoir to Amistad Reservoir	652	405	1940

[1] The last date of collection for a species is not comparable with the date of extirpation. It was often decades between sampling efforts in many river reaches of the Rio Grande basin. The lack of regular collecting efforts (i.e., yearly) makes it impossible to accurately determine a date of extirpation in selected reaches.

[2] Identification of specimens not verified.

[3] No museum records exist

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 Rio Grande silvery minnow historically occupied more of the Pecos River in Texas than these collections suggest.

The last known 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, *Hybognathus placitus*, from the Pecos River (Cowley 1979).

Seven collections made between 1938 and 1960 in the Rio Grande and its tributaries in Big Bend National Park, Texas document the historic 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 species from the Rio Conchos (Mexico) in either historic (taken primarily by University of Michigan Museum of Zoology biologists) or recent collections (made by Texas Parks and Wildlife).

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 involved in the extirpation of Rio Grande silvery minnow (Bestgen and Propst 1996). The extirpation 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 Mexican tributaries of the Rio Grande in Mexico.

CURRENT RANGE

The 181 fish collections made prior to 1990 in the Rio Grande between Cochiti Dam and Elephant Butte Reservoir (Figure 2) were composed of 36 species and 80,440 specimens, of which 16,563 were specimens of Rio Grande silvery minnow. In the decades between 1930 and 1969, the number of collections per decade ranged from 7 to 12 and averaged 8, with the lowest in the 1960s. Collecting efforts increased substantially in the 1970s and 1980s. All of the 21 collections taken in the 1930s and 1940s were either in the vicinity of Angostura or Isleta. The first collection in the vicinity of Cochiti was in 1958 while the first collection in the San Acacia area was in 1961. No fish collections were made in the Low-Flow Conveyance Channel prior to 1977.

The historic abundance of Rio Grande silvery minnow was determined by decade and river reach by examining fish collections from the middle Rio Grande (Figure 3). Rio Grande silvery minnow relative abundance was determined per decade as the percent of the total fish catch (the number of Rio Grande silvery minnow in a single collection as a proportion of the total number of individual fish taken in that collection). An additional measure of relative abundance of Rio Grande silvery minnow, per cent of the cyprinid (i. e., minnow) catch, was also derived. This latter measure of abundance was calculated by dividing the number of Rio Grande silvery minnow in a single catch by the total number of minnows (i. e., red shiner *Cyprinella lutrensis*, fathead minnow *Pimephales promelas*, flathead chub *Platygobio gracilis*, longnose dace *Rhinichthys cataractae*) present in the collection. This measure can often be an informative estimate of relative abundance.

Museum records indicate that Rio Grande silvery minnow was historically common in the Rio Grande between Cochiti Dam and Elephant Butte Reservoir (Figure 3). Rio Grande silvery minnow was present in 26 of 28 collections taken between 1926 and 1959 and was the most abundant species in half of these samples comprising 41.1% (N=3,739) of the total sample. Sample abundance ranged from 1 to 1,171 individuals.

There were relatively few fish (N=1,442) and no Rio Grande silvery minnow taken in the seven collections made during the 1960s (Figure 3). The Cochiti area collections (N=813 specimens) contained 56.4% of the specimens while the four collections in the San Acacia reach were 35.0% of the total catch.

The most extensive series of fish collections made in the Cochiti Dam-Elephant Butte Reservoir reach of the Rio Grande prior to 1990 were the 44 samples made in 1977 and 1978 by C. W. Painter. These samples were comprised of 16 species and 25,098 specimens from 23 mainstream stations between Cochiti Dam and San Marcial and 21 Low-Flow Conveyance Channel collections. Painter made an additional 50 collections in Middle Rio Grande Conservancy District canals. Rio Grande silvery minnow was cumulatively the most abundant cyprinid and second most common species in mainstream collections and was present in 19 of the 23 samples. Although Rio Grande silvery minnow was the most abundant species in three of these samples, it was represented by only eight individuals in seven of the 19 mainstem samples.

The 1980s were a period of intensive sampling in the Rio Grande between Cochiti Dam and Elephant Butte Reservoir. A series of 15 samples, including 11 from the mainstem Rio Grande, was taken between Cochiti Dam and the Valencia-Socorro

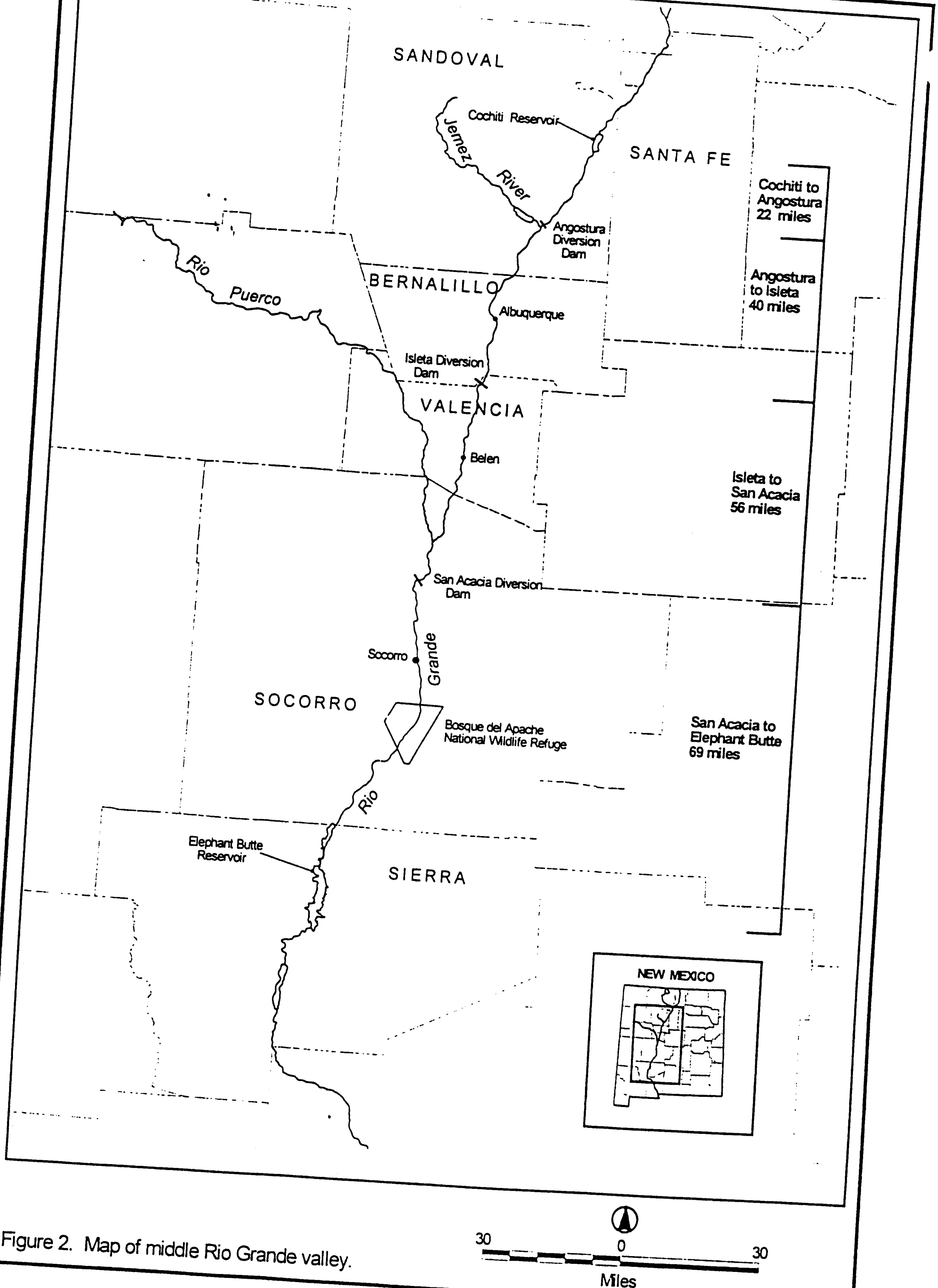

Figure 2. Map of middle Rio Grande valley.

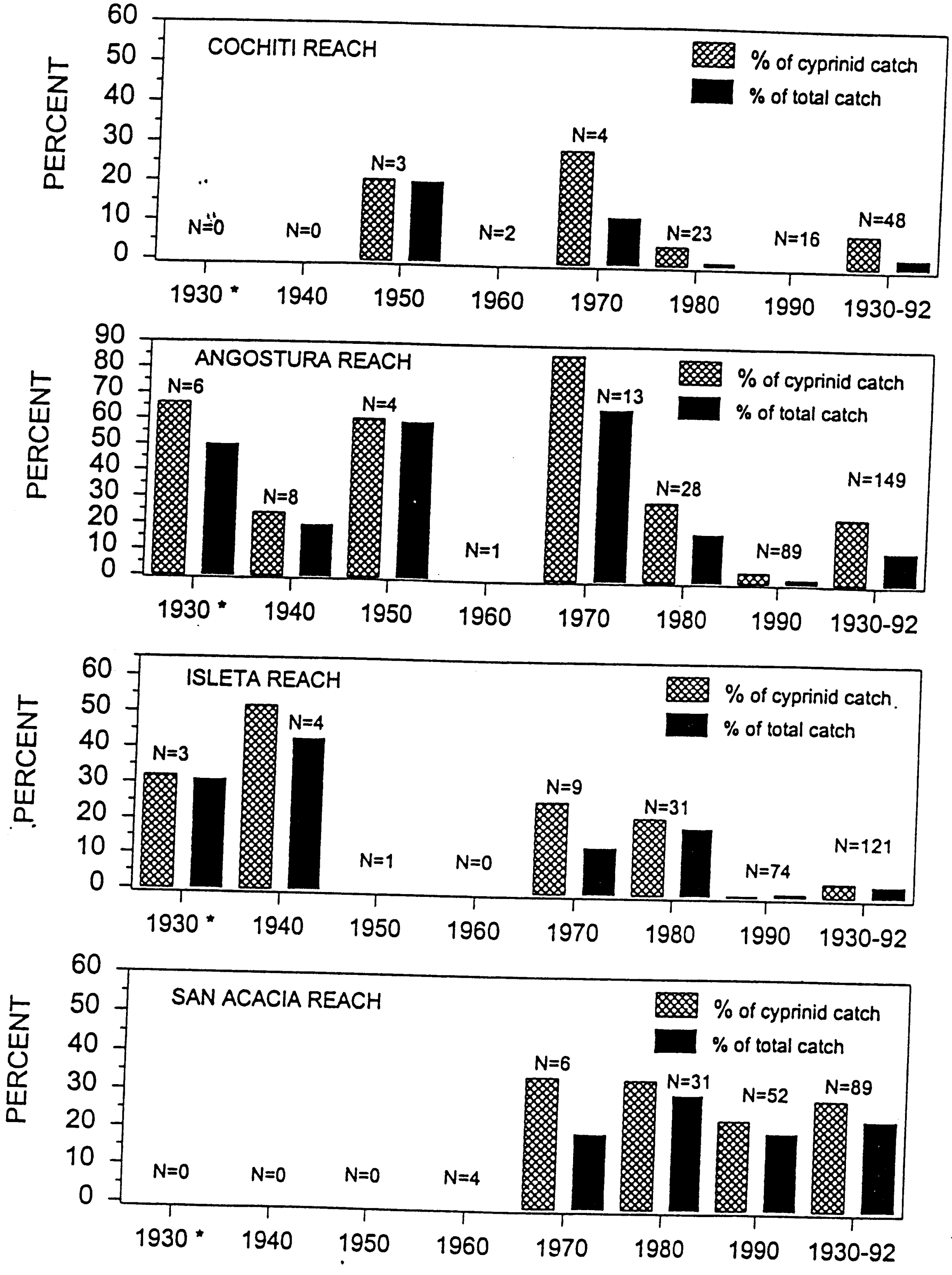

Figure 3. Relative abundance of Rio Grande silvery minnow by reach and decade. "N" values refer to the number of collections (* 1930 collections include single 1926 sample).

County line in 1984. From 1986 through 1989 there were 101 mainstem Rio Grande collections between Cochiti Dam and Elephant Butte Reservoir and 12 Low-Flow Conveyance Channel samples between San Acacia Diversion Dam and Elephant Butte Reservoir. Comparison between 1984 and 1986 through 1989 samples suggested a decrease in the abundance of Rio Grande silvery minnow in the northern portion of its range. While Rio Grande silvery minnow cumulatively comprised 29.4% of the 1984 collections and was the most abundant species in 11 mainstream collections, it had decreased to 8.1% of the 1986-1989 samples.

The records of the U. S. Geological Survey show that the water supply of the middle Rio Grande valley was above average during the middle 1980s. The annual flow of the Rio Grande below Cochiti Dam was above average each year during the 1982-1987 period. The 3-year (1985-87) average flow below Cochiti Dam was 160% of average. However, 1988 and 1989 were both below average years; the two-year (1988-89) average annual flow was only 78% of average. These streamflow data are presented here to describe the hydrologic conditions of the Rio Grande relative to abundance levels of Rio Grande silvery minnow during the 1980s.

<u>Current Distributional Status Extant Ichthyofauna</u>-Pecos River, New Mexico and Texas.

Pecos River--Santa Rosa Dam to Sumner Reservoir:

Currently, the Pecos River between Santa Rosa Dam and Sumner Reservoir (Figure 1) supports 15 fish species of which 12 are native and three are nonnative.

Pecos River--Sumner Dam to Brantley Reservoir:

The fish fauna of the Pecos River between Sumner Dam and Brantley Reservoir is currently composed of 38 species, 26 of which are native and 12 nonnative (Hoagstrom et al. 1995). Between 1986 and 1994, native fish represented 69% of the fish collected. Among native fish species, red shiner, Rio Grande shiner, and western mosquitofish were the most common specimens collected. Two nonnative fish species, plains minnow and Arkansas River shiner, were also common. Native Pecos bluntnose shiner, sand shiner, fathead minnow, and plains killifish were comparatively common (15%). Inland silverside, a nonnative, is rare in this reach.

Pecos River--Brantley Dam to Red Bluff Reservoir:

The fish fauna of the Pecos river between Brantley Dam and Red Bluff Reservoir is composed of more lentic adapted forms than occur in either of the upper two reaches. Thirty-five fish species currently occupy this reach; 24 are native and 11 nonnative.

Pecos River--Red Bluff Dam to International Amistad Reservoir:

The Pecos River between Red Bluff Dam and Amistad Reservoir is currently occupied by about 28 native fishes and at least six regularly collected nonnative fishes. Of these, Mexican tetra *Astyanax mexicanus*, red shiner, rainwater killifish *Lucania parva*, and western mosquitofish *Gambusia affinis* are comparatively common native species. Sheepshead minnow *Cyprinodon variegatus* and bullhead minnow *Pimephales vigilax* are the most common nonnatives.

Current Distributional Status of Extant Ichthyofauna-Rio Grande, Texas.

Rio Grande--New Mexico-Texas border to Presidio:

At least 15 species of fish were reported in the El Paso to Presidio reach of the Rio Grande between 1977-1988. Cyprinidae was the most species-rich of the seven families of fish in this reach. One species, red shiner, numerically dominated the collections, and was the most abundant of the five cyprinids in this reach, accounting for almost 90% of the catch of minnows. Speckled chub *Macrhybopsis aestivalis* was extremely rare in collections and was the only pelagic spawner that produces semi-buoyant eggs occurring in this reach.

Rio Grande--Presidio to International Amistad Reservoir:

Extensive sampling of this reach of the Rio Grande between 1991-1995 produced a total of 34 species. This reach of the Rio Grande is characterized by at least two major categories of fishes: large-bodied, long-lived, big-river fishes and small bodied, short-lived fishes. The former was well represented by river carpsucker *Carpiodes carpio*, blue sucker *Cycleptus elongatus*, smallmouth buffalo *Ictiobus bubalus*, and west Mexican redhorse *Moxostoma anisurum*. At least 12 species of minnow, 10 of which are native, occur in this reach of the Rio Grande. Two species that are pelagic spawners, producing semi-buoyant eggs (speckled chub and Rio Grande shiner), occur throughout much of this reach. This portion of the Rio Grande contains a somewhat different and more diverse fish fauna than upstream or downstream reaches.

Rio Grande—International Amistad Reservoir to International Falcon Reservoir:

Recent (1990-1994) fish collections in this reach of the Rio Grande documented the presence of at least 35 species. Cyprinidae was the most species-rich family with nine of the 12 cyprinid species being native. The two most numerous species (red shiner and blacktail shiner *Cyprinella venusta*) comprised the majority of both the cyprinid and overall catch in this reach of the river. Speckled chub and Rio Grande shiner were the only pelagic spawners that occurred between Amistad Reservoir and Falcon Reservoir. However, these two species were extremely rare, being represented by only five specimens each and taken at three separate locations.

There have been several changes in the ichthyofaunal composition of this reach of the Rio Grande since the 1950s. Most notable, among extant species, is the diminished range and abundance of Rio Grande shiner. Trevino-Robinson (1959) reported Rio Grande shiner from 42 of 45 stations (from the confluence of the Rio Grande and Pecos River downstream to near the mouth of the Rio Grande) and stated that it was one of the "most prevalent forms in the Rio Grande." The precipitous decline in the distribution and abundance of this species subsequent to the work of Trevino-Robinson (1959) and rarity of speckled chub suggest that members of its reproductive guild have been disproportionately affected by changes in the river.

Rio Grande--International Falcon Reservoir to Gulf of Mexico:

Edwards and Contreras-Balderas (1991) reported 114 species of fishes from this reach of the Rio Grande. They noted the decline and disappearance of several species during the last 100 years. Extirpated taxa included speckled chub, Rio Grande silvery minnow and Rio Grande shiner; all of which were pelagic spawners that produced semi-buoyant eggs. Several other species appeared to be absent or reduced in abundance throughout this reach.

Concurrent with the reduction in abundance and loss of several species was the increase in abundance of other taxa. The species exhibiting population increases (sheepshead minnow, gulf killifish *Fundulus grandis*, and mountain mullet *Angonostomus monticola*) were generally more tolerant of elevated salinity than were those species historically reported from the area.

<u>Current Distributional Status of Extant Ichthyofauna</u> - Rio Grande, New Mexico.

Extensive collecting activity has occurred since 1990 within the current range of Rio Grande silvery minnow (Figure 2). Forty-six collections were made between Cochiti Pueblo and Bosque del Apache National Wildlife Refuge from 1990 through April 1992. These collections produced 23 species and 38,501 specimens, but only 10 specimens of Rio Grande silvery minnow. Red shiner was the most frequently collected and abundant species, occurring in 42 collections and numerically comprising 51.9% of the sample. Fathead minnow, the second most abundant fish, was present in 39 collections and represented 34.0% of the total catch. Sites where Rio Grande silvery minnow had previously (1987-1988) numerically dominated the collections were sampled 2-3 times but no Rio Grande silvery minnow were found.

The most extensive and intensive survey of currently occupied Rio Grande silvery minnow range was in 1992 when 215 samples were taken between Angostura and Elephant Butte Reservoir, including the Low-Flow Conveyance Channel. Sample sites were linearly spaced roughly equidistant through the study reach. The summer portion of the survey was conducted 1 July-30 August 1992 and consisted of 104 sites and the autumn survey occurred 16 September-16 December and included the 104 summer sites and six additional localities. Multiple samples (N=3) were taken at one of the summer sites. Data from 13 summer and 15 autumn Low-Flow Conveyance Channel samples were treated separately from mainstream collections. All localities (N=61) sampled during the 1987 study (Bestgen and Platania 1991) were resurveyed during the 1992 study. This included 11 collections made in the Low-Flow Conveyance Channel.

The 215 collections made in 1992 produced 24 species of fish and 143,040 specimens compared to 23,353 specimens in 61 samples in 1987. There was little difference in the number of species and specimens during the two 1992 sampling periods with 24 species and 51.7% of the fish taken in summer collections and 21 species and 48.3% of the catch was from the autumn sample.

There was a substantial difference in the number and occurrence of Rio Grande silvery minnow between the two sampling periods with 49 summer samples and 23 autumn samples containing Rio Grande silvery minnow (2,825 and 472, respectively). Ten of the summer samples had more than 50 Rio Grande silvery minnow while only two autumn samples had more than 50 individuals. In addition, Rio Grande silvery minnow was unevenly distributed in the study area and there was a general increase in frequency of occurrence of Rio Grande silvery minnow in a downstream direction. Rio Grande silvery minnow was absent from eight collections taken during 1992 from the Cochiti reach, but the species was represented in 80% of the samples from the San Acacia portion of the study area. In addition, over 75% of all individuals of Rio Grande silvery minnow were taken in 36 samples at or downstream of San Acacia Diversion Dam.

The following is a detailed account of ichthyofaunal surveys on the Rio Grande and associated habitats between Cochiti Dam and Elephant Butte Reservoir made between 1990 and 1992.

Rio Grande-- Cochiti Reach[4]:

During summer and autumn 1992, this reach was sampled at eight locations. These collections yielded 2,113 specimens of 14 species. This reach had the lowest cumulative catch rate (4.64 fish/10m^2) in the study and was the only section that exhibited a large seasonal variation in catch; 75.5% of all specimens were taken during summer sampling. White sucker was the numerically dominant species comprising 42.3% of the total catch, and longnose dace was the most abundant cyprinid (N=418). Rio Grande silvery minnow was absent from the 1992 collections. In 1993, the Rio Grande in the vicinity of Cochiti Pueblo was intensively sampled, but no specimens of Rio Grande silvery minnow were found. These collections (N=15) yielded 17 species and 4,700 specimens. During 1994, sampling efforts in the Cochiti reach focused on the Pueblos of Santo Domingo and San Felipe. Among the 16 collections, 19 species and 6,915 specimens were obtained. Twenty-two (0.3%) were Rio Grande silvery minnow (0.05 fish/10m^2).

Several relatively recent physical changes have occurred in this reach of the Rio Grande. Since completion of Cochiti Dam (1973) average annual discharge has increased by about 18% (from 1,377 cfs to 1,624 cfs). While the presence of the dam is also believed to have ensured a more consistent flow, Bullard and Wells (1992) cautioned that such a conclusion may be an artifact of the short period of record since closure of Cochiti. Flow in the Rio Grande at Cochiti Dam is now generally clear, cool, and free of sediment. Substrate immediately downstream of the dam is often armored cobble. The relatively clear water and associated light penetration allows for algal growth throughout this reach

[4] Reach names reference the diversion structure that forms the upstream boundary of that river section.

of the Rio Grande. There is relatively little channel braiding in this reach of the river and depositional areas with reduced velocity and sand or silt substrata were uncommon. The fish community in this reach of the Rio Grande is comprised of cool-water minnows and suckers and several species of piscivourous nonnative gamefish. The changes in habitat that occurred after closure of the dam, in addition to the alteration of the thermal regime of the river, allowed these species to become principal members of the fish community.

The rarity of Rio Grande silvery minnow in the Cochiti reach is probably not exclusively due to range fragmentation and their life-history attributes. Rather, it is the synergistic effect of these factors in addition to scouring of the riverbed, alterations in the flow and thermal regimes and introduction of nonnative fishes. These unfavorable conditions ultimately resulted in the reduced abundance of Rio Grande silvery minnow, extirpation of other native cyprinids and restructuring of the fish community in this reach.

Rio Grande--Angostura Reach:

The distribution of Rio Grande silvery minnow in the Angostura reach of the middle Rio Grande exhibited an up to downstream gradient of increasing abundance. This species is very rare immediately downstream of the Angostura Diversion Dam and is uncommon at Bernalillo. The abundance of Rio Grande silvery minnow between Bernalillo and Isleta Diversion Dam appears to fluctuate both seasonally and annually, depending on flow conditions. No where in this reach does this species achieve the comparatively high population levels observed in the reach between San Acacia Diversion Dam and Elephant Butte Reservoir.

Sixty-eight collections were made in the Angostura reach in 1992. The 33,562 specimens in these collections represented 22 species and were 23.5% of the total 1992 catch. This was the only reach where more fish were taken in autumn (55.9%) than summer. Total catch rate in this section was second highest (8.8 fish/10m^2) for the 1992 study and was similar between seasons.

The 645 Rio Grande silvery minnow taken in 11 samples in this reach represented 19.6% of the 1992 total Rio Grande silvery minnow catch. The two largest Rio Grande silvery minnow collections from this reach were both taken during summer and accounted for 89.1% (N=575) of the catch of the species in the Angostura reach. Catch rate of the Rio Grande silvery minnow ranged from 0.01 to 6.67 individuals/10m^2 with the highest concentration of individuals occurring near Rio Rancho.

Rio Grande silvery minnow was the eighth most abundant fish in this reach. Cyprinids accounted for 32.7% of the 1992 fish community in the Angostura reach with red shiner being 60.0% of that group. Fathead minnow and flathead chub, the next most abundant cyprinids, collectively represented 22.2% of the minnow guild.

Between 1987 and 1992, Rio Grande silvery minnow decreased in proportion of both the total catch and the cyprinid guild. Catch rates for Rio Grande silvery minnow were greater in summer 1992 than summer 1987 but less when autumn 1992 was compared to winter 1987. The difference between 1987 and 1992 collections in this reach was probably, in part, an artifact of the scale of sampling; the 1992 effort was a tenfold sampling increase over 1987.

The majority and most consequential point sources of discharges which affect water quality of the middle Rio Grande are in the Angostura reach. Major municipalities in this section of the river include Bernalillo, Rio Rancho, and Albuquerque. The principal sources of point discharge are the North and South Diversion Channels and Albuquerque Wastewater Treatment Plant. The two channels collect and transport storm runoff from the metropolitan Albuquerque area and empty into the Rio Grande either upstream of Corrales (North Diversion Channel) or near Tijeras Creek (South Diversion Channel). Most of the time these channels are dry, but the North Diversion Channel has carried 11,000 cfs (Bullard and Wells, 1992).

In contrast to the usually dry channels, the Albuquerque Wastewater Treatment Plant continuously discharges an average of about 80 cfs of water into the Rio Grande. The outfall for the plant is about 12.4 kilometers (7.7 miles) upstream of Isleta Diversion Dam and immediately upstream of the South Diversion Channel outfall. Flow is currently perennial through this reach of the river. This is due, in part, to water rights owned by the City of Albuquerque and their agreement with the Middle Rio Grande Conservancy District (MRGCD) to maintain a minimum flow of 250 cfs through the reach. This water is meant, in part, to dilute effluent discharge from Albuquerque's Wastewater Treatment Plant. Once that water reaches Isleta Diversion Dam, it is diverted by the MRGCD.

Rio Grande--Isleta Reach:

Despite being the second longest reach, the Isleta to San Acacia segment of the Rio Grande typically supports very few Rio Grande silvery minnow (Bestgen and Platania, 1991). The dearth of Rio Grande silvery minnow from this reach was believed due both to the extensive diversion of water at the Isleta Diversion dam and the limited downstream arrival of eggs and larvae from the small upstream populations. On those occasions when Rio Grande silvery minnow were found in moderate or large numbers in this reach, they were concentrated in habitats immediately downstream of Isleta Diversion dam. Leakage at the dam often provided the only available surface water for this portion of the Isleta reach. The congregation of fish at this locality may have been due to the drying of the river in more downstream portions of this reach or could have reflected an upstream migration of individuals.

Sampling effort in this reach in 1992 was similar to that in 1987. The Isleta collections produced 19 species and 65.4% of all individuals in the 1992 study with the number of fish collected each season about equal. There were more specimens collected in this reach (N=93,538) during 1992 than in the other three reaches combined. The large number of specimens and high catch rate was due, in part, to two samples taken directly below Isleta Diversion Dam. These two samples, while cumulatively representing only 3% of the sampling effort, contained 12.3% of the total number of fish collected in the Isleta reach. In addition, these two collections collectively resulted in a catch rate of 165.53 fish/10m^2; the highest catch rate during this study. If the two Isleta Diversion Dam collections are removed from the comparisons, the total catch rate for the Isleta reach is still the highest in the study area.

Despite the extensive sampling, high catch rate, and large number of fish collected, Rio Grande silvery minnow was represented by only 95 specimens in 22 collections. Capture rate for Rio Grande silvery minnow in the Isleta reach was the second lowest of the 1992 study reaches and ranged from 0.01-0.45 individuals/10 m^2. Only two collections contained more than six individuals of Rio Grande silvery minnow and the maximum number in any collection was 32.

Cyprinids numerically dominated the Isleta reach samples, comprising 85.2% of the catch. Red shiner achieved its greatest abundance in this reach and was 83.5% of the minnow population and 71.1% of the total catch. In 21 of the 33 autumn collections, red shiner comprised more than 90% of each of the samples. Rio Grande silvery minnow was the least abundant of the mainstream cyprinids and tenth most common species.

The greatest change between 1987 and 1992 in the abundance of Rio Grande silvery minnow was recorded in the Isleta reach. Differences observed in this reach were probably not an artifact of collecting effort. The decrease of Rio Grande silvery minnow was noted as declines in both the portions of the cyprinid and total fish community. One collection from directly below Isleta Diversion Dam in 1987 resulted in the greatest number of specimens in the reach for that study (808 Rio Grande silvery minnow). Two 1992 collections from Isleta Diversion Dam, with 4,943 and 6,546 specimens each, yielded only four specimens of Rio Grande silvery minnow.

Aquatic habitats in the Isleta reach of the middle Rio Grande are probably the most adversely impacted, due to water diversions, of any of the reaches. At Isleta Diversion Dam, up to 1,070 cfs of water can be diverted to east and west bank channels. Diverted water generally remains in the 445 miles of drains and canals in this reach as there are few points of return in the upper and middle segments. Many extensive portions of this reach (especially the upper section) of the river are frequently isolated during summer and autumn and eventually dry. Irrigation return flows and localized flooding in the Rio Puerco and Rio Salado and other smaller tributaries can provide substantial flow in the lower 10 miles of the Isleta reach.

Rio Grande--San Acacia Reach:

The San Acacia reach is the longest uninterrupted segment in the current range of Rio Grande silvery minnow and supports the largest population of this species. Individuals in this reach may have originated in any of the three upstream segments. Leakage at San Acacia Diversion Dam often provides the only flow for the upper portion of this segment. The San Acacia portion of the Rio Grande differs from Isleta in that there were, until 1996, no points for the return of diverted water to the river channel. This often left extensive portions of the San Acacia reach, especially downstream of San Antonio, dry. When present, late summer flow to this reach of the river is generally supplied by summer rainstorm events either in the upper (above Isleta) portion of the drainage or via inflow from the Rio Puerco or Rio Salado which often ensure survival of the fish community in the San Acacia reach of the middle Rio Grande.

About 39% of the 1987 and 22% of the 1992 sampling effort was expended in this reach of the Rio Grande. The 9,991 specimens and 16 species represented 6.98% of the total 1992 sample, with little difference in catch or catch rate recorded between seasons.

Over 75% of Rio Grande silvery minnow taken during the 1992 survey occurred in the San Acacia reach. This species was most abundant in the summer when it was taken at 20 of 21 sites and represented 36.3% (N=2072) of the specimens collected. Eight of the summer samples and two of the 15 autumn samples contained more than 50 specimens of Rio Grande silvery minnow. The highest individual, seasonal, and total capture rates for this species were recorded in this reach. Rio Grande silvery minnow comprised between 45-77% of seven summer and three autumn collections.

Habitats in the San Acacia reach are negatively impacted by water diversion from the Rio Grande. Prior to 1996, there was only one point in this section, at Brown Arroyo where diverted water could be returned to the river. This was significant because, as opposed to the Cochiti and Angostura reaches which maintain perennial flow and the Isleta reach which has downstream river outfalls for irrigation water, none of the water in canals at San Acacia could be diverted into the river. After its use, irrigation water from the Socorro Main Canal and water used by the Bosque del Apache National Wildlife Refuge was moved into the Low-Flow Conveyance Channel and transported directly to Elephant Butte Reservoir. These diversions of water and subsequent changes in river channel morphology have had marked effects on habitat availability in this reach of the middle Rio Grande.

In 1996, the United States Bureau of Reclamation opened a connection between the Low-Flow Conveyance Channel and the Rio Grande about 9.5 miles downstream of San Acacia Diversion Dam. The Bureau of Reclamation has the ability to control the amount of water being diverted from the Low-Flow Conveyance Channel (LFCC) back into the Rio Grande.

Rio Grande--Low-Flow Conveyance Channel:

Sixteen species and 3,836 specimens were obtained in the 28 Low-Flow Conveyance Channel collections made during the 1992 survey. Fathead minnow and red shiner were the most abundant species in both seasonal collections while cyprinids were 69.9% of the total catch. These two species were 64.8% of the total catch and 92.8% of the cyprinid guild. Western mosquitofish (N=777) was the only other species that accounted for more than 5% of the total Low-Flow Conveyance Channel catch.

A total of 73 Rio Grande silvery minnow was taken in three samples (two sites) in the Low-Flow Conveyance Channel in 1991. Most of the specimens (N=71) were collected at the southern boundary of the Bosque del Apache National Wildlife Refuge where a drainage culvert returned flow to the Low-Flow Conveyance Channel. The summer collection at this site produced 66 specimens while the autumn sample yielded 5 individuals. The latter collection was the only autumn Low-Flow Conveyance Channel sample that contained Rio Grande silvery minnow. The only other station in the Low-Flow Conveyance Channel that produced Rio Grande silvery minnow (N=2) was at the United States Geological Survey San Marcial gaging station. The 73 specimens from these three collections were all Age 0 fish and ranged in length from 31-61 mm SL.

Eleven species and 373 specimens were taken in the 11 Low-Flow Conveyance Channel samples during the 1987 study. Red shiner, fathead minnow, and western mosquitofish were the most abundant species during both study periods, cumulatively accounting for 96.0% of the 1987 and 85.1% of the 1992 collections. The absence of Rio Grande silvery minnow in the 1987 samples and the size and age of specimens, location of collection, and relatively low numbers of specimens from the 1992 study suggested that this species is not a perennial inhabitant of the Low-Flow Conveyance Channel. Since 1985, the LFCC has acted as a drain and no substantial amount of water has been diverted from the river into it at San Acacia since then.

Since 1995, studies have been conducted in the upper nine-mile reach of the Low Flow Conveyance Channel. As of February 1997, two subreaches within the nine-mile study area were sampled with a backpack electroshocker for a total of 52 hours. Sixteen species and 3,277 individuals have been collected since 1995. Fathead minnow was the most abundant native species, along with river carpsucker and longnose dace; common carp and white sucker were the dominant nonnative. Only eight Rio Grande silvery minnow were collected during this time period.

A description of the history of the construction and operation of the Low-Flow Conveyance Channel is presented in Appendix A.

Rio Grande--Irrigation Canals and Diversions:

The Middle Rio Grande Conservancy District (MRGCD) consists of four divisions (Cochiti, Albuquerque, Belen, and Socorro) encompassing about 150 river miles from Cochiti Dam to the northern boundary of Bosque del Apache National Wildlife Refuge (Figure 2). The Albuquerque and Belen divisions are bounded at their northern limits by low-head diversion dams, Cochiti Dam and Reservoir head the Cochiti Division, and the technical origin of the Socorro Division is just upstream of San Acacia Diversion Dam. About 834 miles of irrigation canals and 386 miles of interior and riverside drains provide a network of irrigation systems throughout the middle Rio Grande valley. Historic collections documented the occurrence of Rio Grande silvery minnow in both ephemeral and perennial canals and ditches of the MRGCD system (Lang and Altenbach, 1994).

Lang and Altenbach (1994) sampled 74 sites (July-August 1993) in this complex to characterize the distribution and relative abundance of its fish fauna. A total of 12,570 specimens representing 9 families and 27 species was collected in the study area. Nine native species accounted for 63.9% of the specimens collected; two native cyprinids, red shiner and fathead minnow, constituted 58.0% of all specimens. Eighteen introduced species accounted for 36.1% of the specimens. A total of 114 specimens of Rio Grande silvery minnow were collected during the Lang and Altenbach (1994) survey. The majority (N=106; 93%) of Rio Grande silvery minnow specimens were YOY individuals (20-37 mm SL) taken in the Belen Division. Of the seven Rio Grande silvery minnow taken in the Socorro Division canals, five were collected in the Low-Flow Conveyance Channel. There is no evidence that Rio Grande silvery minnow spawned in canals or drains within any division of the MRGCD.

ECOLOGY

Until recently, 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 ongoing studies and represents a summary of that information (Dudley and Platania, 1997). Information presented herein was acquired from two study sites on the Rio Grande between January 1993 and July 1995. One study site was located near the northern limits (Rio Rancho) of the current range of the species and the second was within the river reach where the species attains its greatest current abundance (San Acacia).

Life history:

Spawning by Rio Grande silvery minnow occurs over a brief period (ca. 1 month) in late spring-early summer (May-June) and coincides with spring runoff. Spawning takes place in the water column (i.e., pelagic spawning) when water temperature is 20 to 24°C. The majority of spawning individuals are Age 1 fish; Age 2 fish normally constitute <10% of the spawning population (Figures 4 and 5). Reproductively mature females are typically larger than males (Figure 6). Each female may produce 3 to 18 clutches of eggs in a 12-hr period. Mean clutch size is about 270 eggs. Age 2 females produce about twice as many eggs as Age 1 females. Following fertilization, the semi-buoyant, non-adhesive eggs drift with the current for up to 50 hrs. Time to hatching is temperature dependent and larvae are about 3.7 mm standard length (SL) upon hatching. Although larvae continue to drift for at least one day after hatching, young soon move to low-velocity habitats where food (mainly phyto- and zooplankton) is abundant. In low-velocity habitats (backwaters and embayments), growth is rapid and lengths of 39 to 41 mm are attained by late autumn.

Spawning exerts high mortality on Rio Grande silvery minnow. By December the large majority (>98%) of individuals are Age 0. 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. Generally, the population consists of only two age-classes. Rio Grande silvery minnow continue to grow through the winter months, albeit less rapidly than during the warmer months. Age 1 fish are 45 to 49 mm by the initiation of the spawning season. Age 0 and Age 1 Rio Grande silvery minnow from the Rio Rancho study site (comparatively cool thermal regime) have greater lengths (ca. 3 mm) for a given date than those from the San Acacia study site (comparatively warm thermal regime). Most growth occurs between June (post-spawning) and October. Maximum size attained by Rio Grande silvery minnow is about 87 mm SL. Maximum longevity is about 25 months and very few fish survive more than 13 months.

The elongated and coiled gastrointestinal tract of Rio Grande silvery minnow is indicative of its herbivorous diet: The presence of sand and silt in gut contents suggests that epipsammatic algae is an important food.

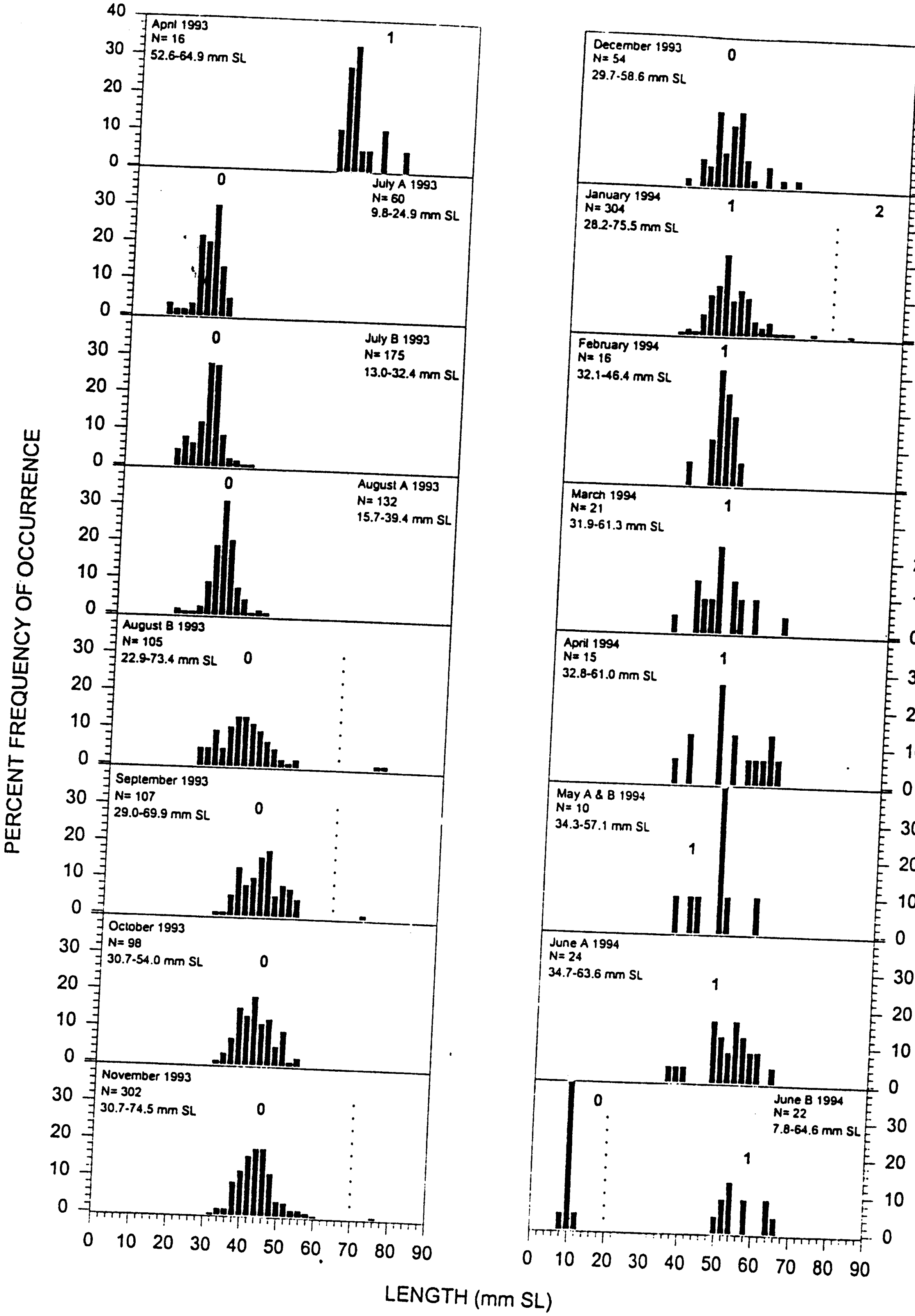

Figure 4a. Rio Grande silvery minnow length frequency histograms by collecting date at the Rio Rancho sampling locality on the Rio Grande (0,1,2 designate age-classes; broken line separates putative age-classes).

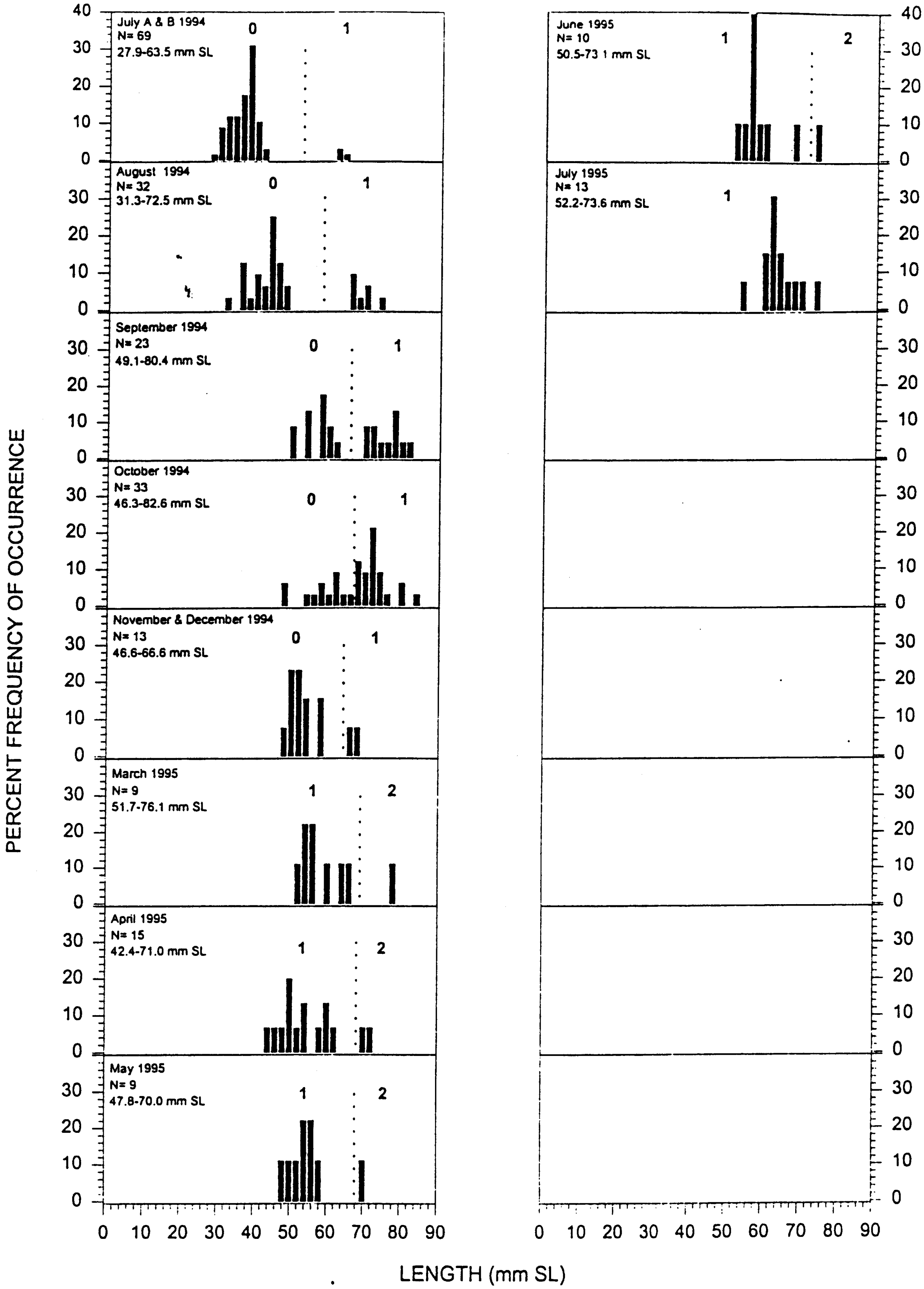

Figure 4b. Rio Grande silvery minnow length frequency histograms by collecting date at the Rio Rancho sampling locality in the Rio Grande (0,1,2 designate age-classes; broken line separates putative age-classes).

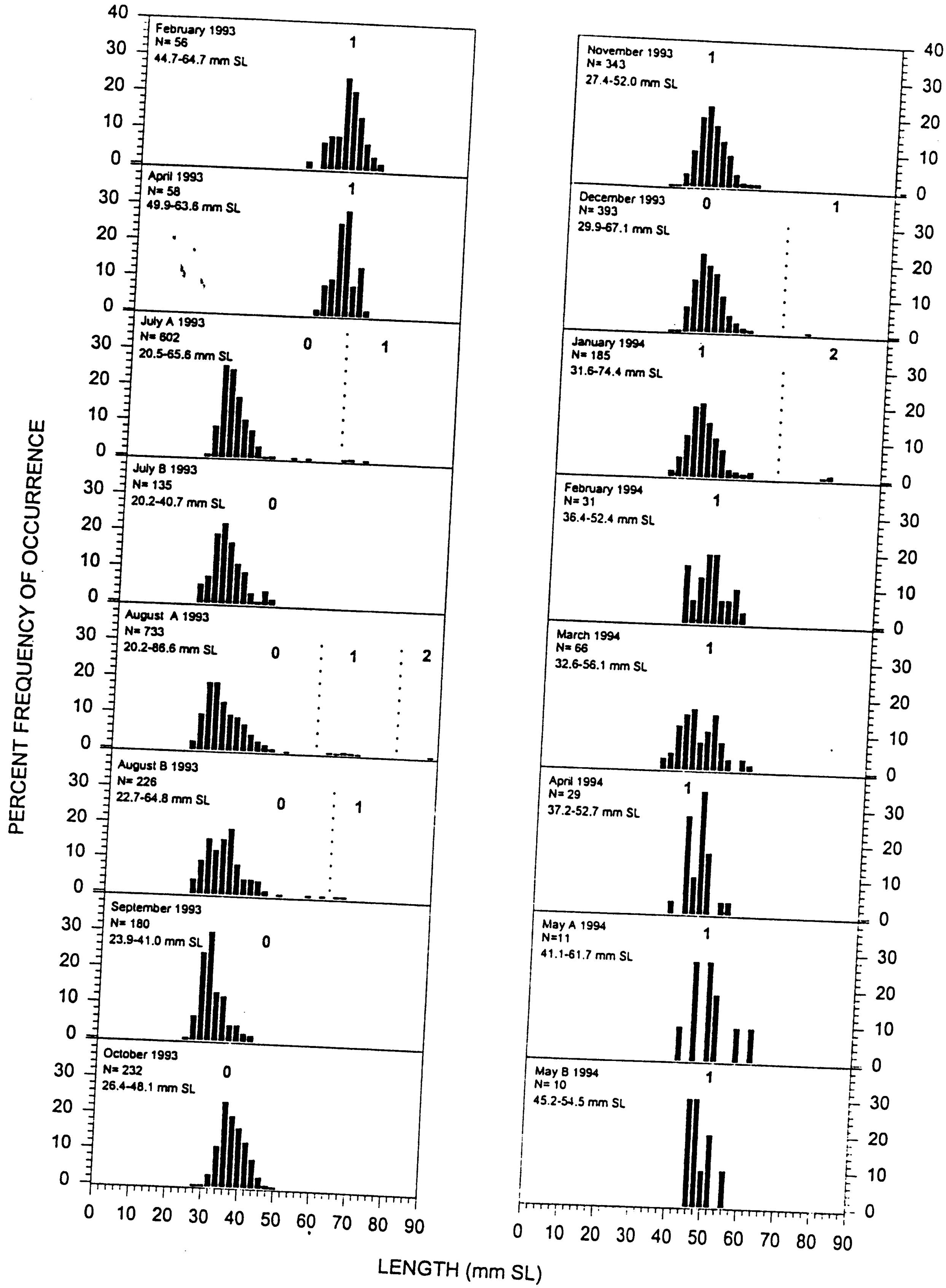

Figure 5a. Rio Grande silvery minnow length frequency histograms by collecting date at the Socorro sampling locality in the Rio Grande (0,1,2 designate age-classes; broken line separates putative age classes).

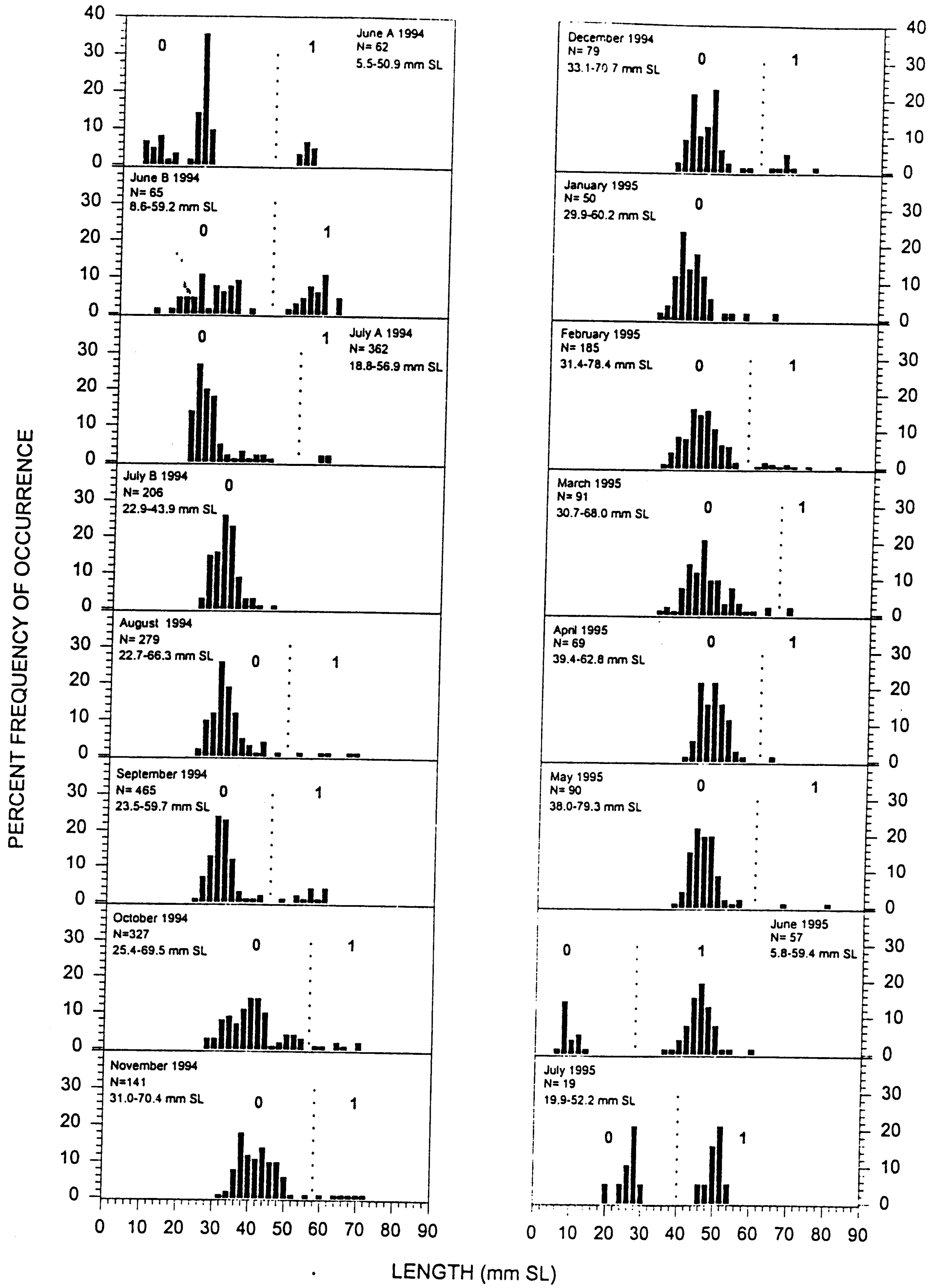

Figure 5b. Rio Grande silvery minnow length frequency histograms by collecting date at the Socorro sampling locality in the Rio Grande (0,1,2 designate age-classes; broken line separates putative age classes).

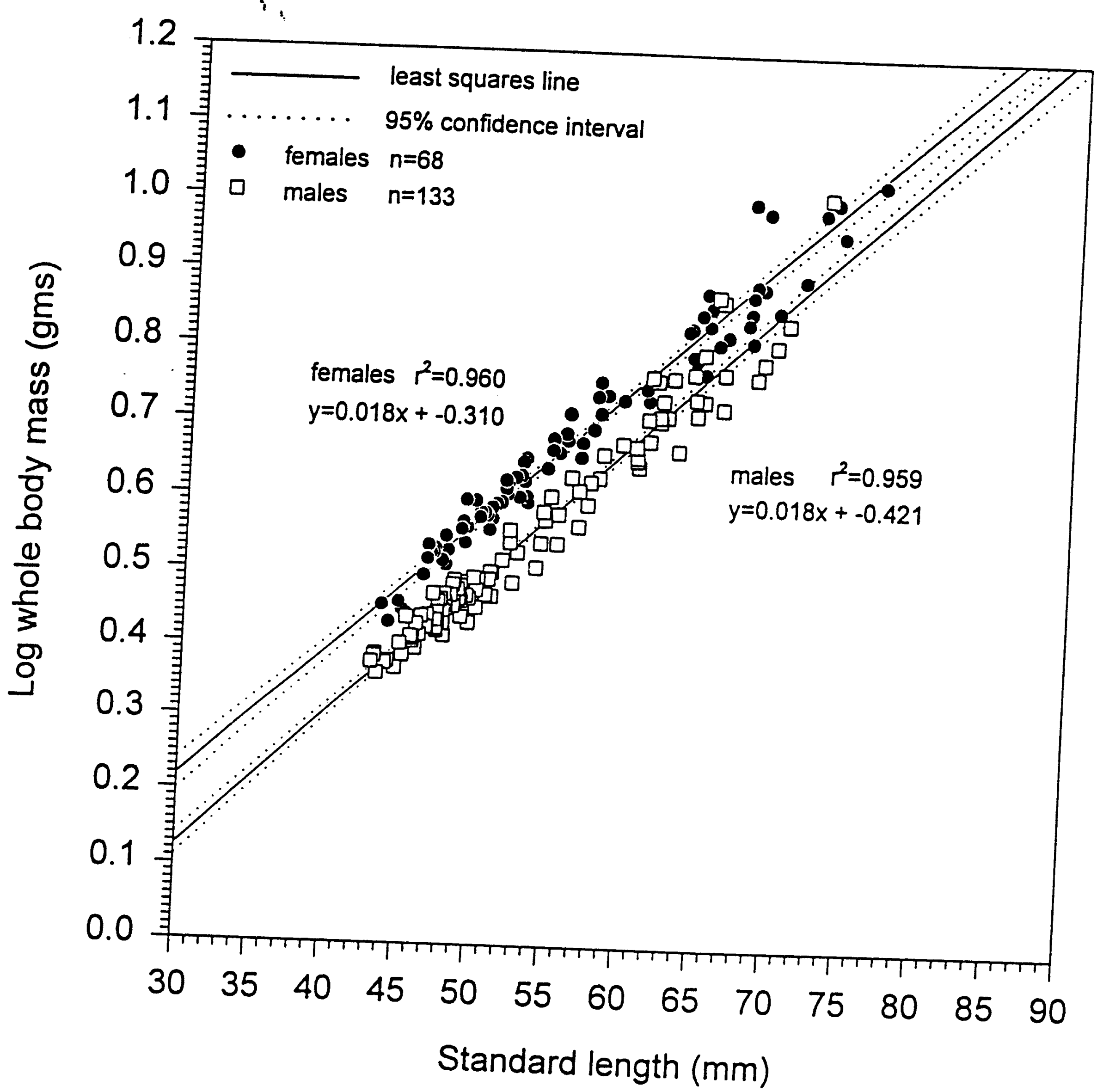

Figure 6. Standard length-whole body mass relationship for Rio Grande silvery minnow.

HABITAT

The habitats selected by Rio Grande silvery minnow were not the most commonly available (Dudley and Platania, 1997, see Figure 7). In addition, the mean depths and velocities occupied by this fish differed from their availability. There is a bimodal distribution in the histogram plot of depth use by Rio Grande silvery minnow with individuals most commonly collected in habitats with depths <20 cm or 31-40 cm. Few individuals utilized areas with depths >50 cm.

Rio Grande silvery minnow was abundant (86.5%) in areas with little or no water velocity (<10 cm/sec). Individuals were occasionally taken (11.0%) in areas of moderate velocity (11-30 cm/sec) but rarely (0.8%) in habitats with water velocities >40 cm/sec. Silt was the substrate over which most (91.3%) individuals were located. Sand was the second most common substrate (8.1%) associated with Rio Grande silvery minnow, while gravel and cobble collectively accounted for <1% of the substrata over which Rio Grande silvery minnow was taken. The mesohabitat types selected by individuals largely reflected their preference for low-velocity areas. The most frequently selected mesohabitat types were eddies formed by debris piles (40.5%), pools (35.9%) and backwaters (13.8%). Main channel runs were generally avoided by Rio Grande silvery minnow as only 1.3% utilized this, the most abundant habitat.

Statistical analyses of Rio Grande silvery minnow habitat use data are not presented in this document, but are available elsewhere (Dudley and Platania, 1997). Habitat use data were analyzed using a binary (presence/absence) weight. As such, measures of habitat had the same importance, in the statistical analyses, regardless of the number of fish present. Although CPUE (catch per unit effort) was determined for all samples, this measure was not used in statistical analyses of habitat use/selection. However, to ensure that there were no large discrepancies between the outcome of statistical analyses using the binary and CPUE weights, tests were run using both weights for comparative purposes. As there were no notable differences between analyses using either weighting methodology, the data presented here are based on the numerical frequency (not presence/absence) of Rio Grande silvery minnow for ease of interpretation.

Description of Study Sites:

The upper sample site is located about 6.4 km downstream of the NM State Highway 44 Bridge in the town of Rio Rancho, NM (Sandoval County; 35°16'58.9"N, 106°35'53.3"W). The lower site is located about 160 km downstream of the Rio Rancho site near the low-flow conveyance channel bridge at Socorro, NM (Socorro County, 34°04'04.5"N, 106°53'28.3"W). Streamflow data for the Rio Rancho sampling locality was recorded at the USGS gaging station Rio Grande at Albuquerque(# 0833000, 35°05'21"N, 106°40'48"W), while streamflow data for the Socorro sampling locality was recorded at the USGS gaging station Rio Grande Floodway at San Acacia (# 08354900, 34°15'23"N, 106°53'18"W). The general trend at both sites was an increase in flow in

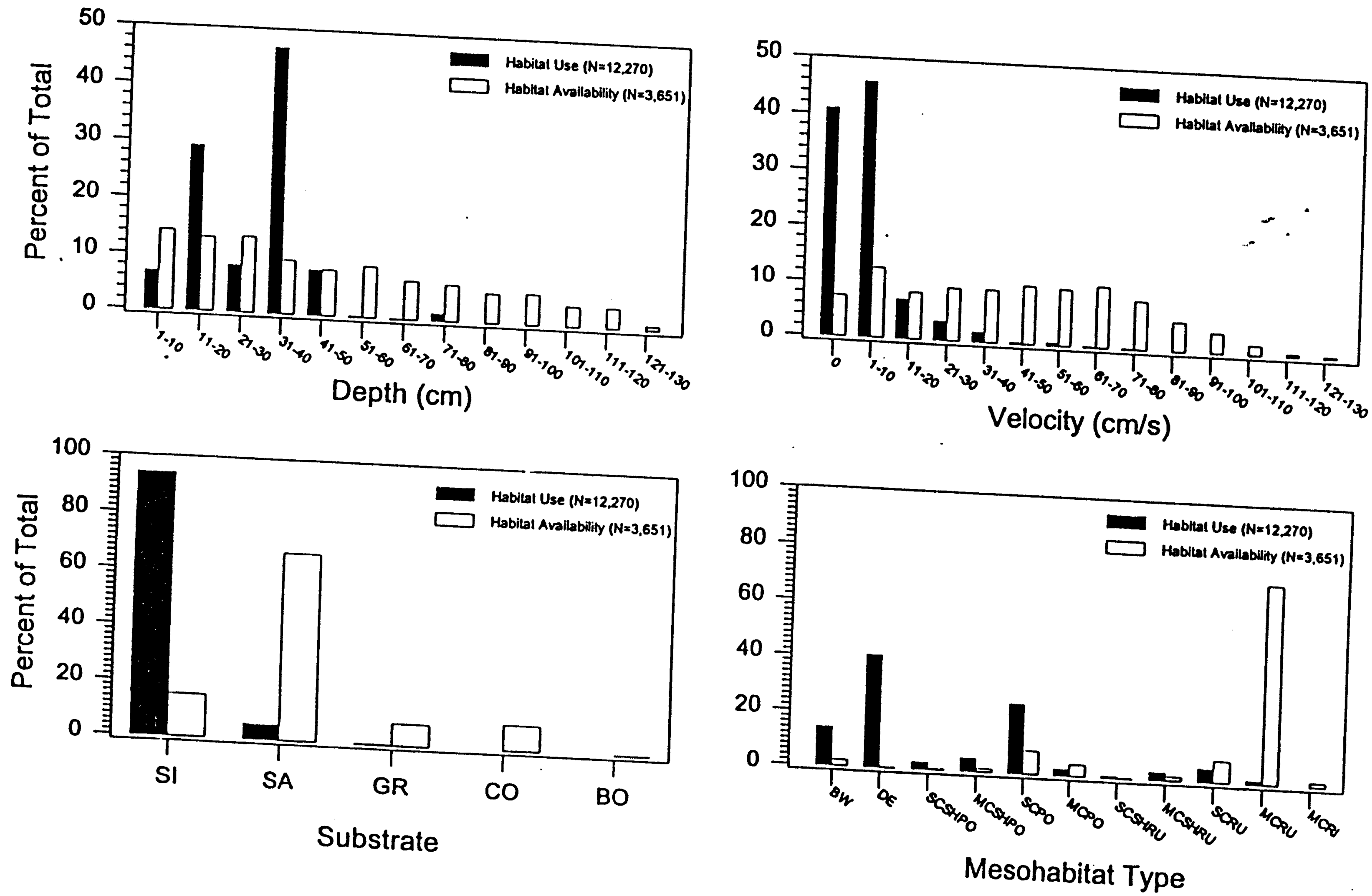

Figure 7. Comparison of mesohabitat use and availability by Rio Grande silvery minnow for both sampling locations in the Rio Grande. (Substrate and mesohabitat definitions are given on page 30).

spring (March-May) followed by a decrease in summer/autumn (July-October) of each year throughout the 1994-1996 study period. Highest flow generally occurred in spring as a result of snow-melt runoff and irrigation water releases. Lowest flow occurred during summer when most of the available discharge was diverted to agriculture. Winter flow (November-February) generally increased after the end of the irrigation season, but was notably lower than spring flow. The only exception to this pattern was in the spring of 1996 when flow in the river at both gages remained low due to drought and water diversions to agriculture. Flow at the Albuquerque gage (i.e., Rio Rancho site) was generally higher than flow below San Acacia Dam (i.e., Socorro site) throughout the year.

Ontogenetic Comparisons:

Examination of the habitats selected by each 10 mm SL size-class revealed the extent of ontogenetic shifts and the overall trends (Figure 8). The smallest individuals (11-20 mm SL) used shallow habitats ($\bar{x}$=14.9 cm) and were never taken in water depths >30 cm. Although the range of depths used by a single size-class did not vary considerably (all used depths <50 cm), larger individuals were found in deeper areas. This shift occurred over a narrow range of depths ($\bar{x}$ range=14.9 to 34.8 cm).

The ontogenetic shift in water velocities selected by different size-classes of Rio Grande silvery minnow was not as pronounced as that for depth. The most discernible break for water-velocity-size-classes was 60 mm standard length (SL). Rio Grande silvery minnow that were <60 mm SL were taken in slower water velocities ($\bar{x}$ range=4.01 to 4.63 cm/sec) than those fish >60 mm SL ($\bar{x}$ range=7.6 to 8.4 cm/sec). There was a positive correlation, among Rio Grande silvery minnow <50 mm SL, between increasing water velocity and increased length (11-20 mm SL, <20 cm/sec; 21-30 mm SL, <50 cm/sec; 31-40 mm SL, <70 cm/sec; 41-50 mm SL , <80 cm/sec).

The substrata over which different size-class Rio Grande silvery minnow were collected changed only moderately for larger individuals and seemed a function of the slow ontogenetic shift into higher velocity habitats. The smallest size-class was found exclusively over a silt substrata. The next larger size-classes (21-30 mm SL and 31-40 mm SL) were predominantly collected over silt (96.9% and 94.0% respectively), but were occasionally located over sand or gravel. All other size-classes were taken over silt, sand, gravel and cobble to varying degrees. There was a separation between individuals <50 mm SL using primarily habitats with silt substrata compared to individuals >50 mm SL which were primarily found over sand (i.e., slightly higher velocity habitats).

The overall ontogenetic shifts in depth, velocity and substrate use by Rio Grande silvery minnow was supported by mesohabitat use shifts from low to moderate velocity areas. Small size-classes were collected almost exclusively in backwaters, pools and along shoreline habitats. Larger individuals were found in a broader spectrum of habitats which included areas of flowing water such as main and side channel runs. The 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 higher-velocity habitats. Despite some shifts in mesohabitat use, the majority of all size-classes were found in low-velocity habitats. Moderate sized fish (30-70 mm SL) were found to occupy eddies formed by debris piles (this was primarily a winter phenomena).

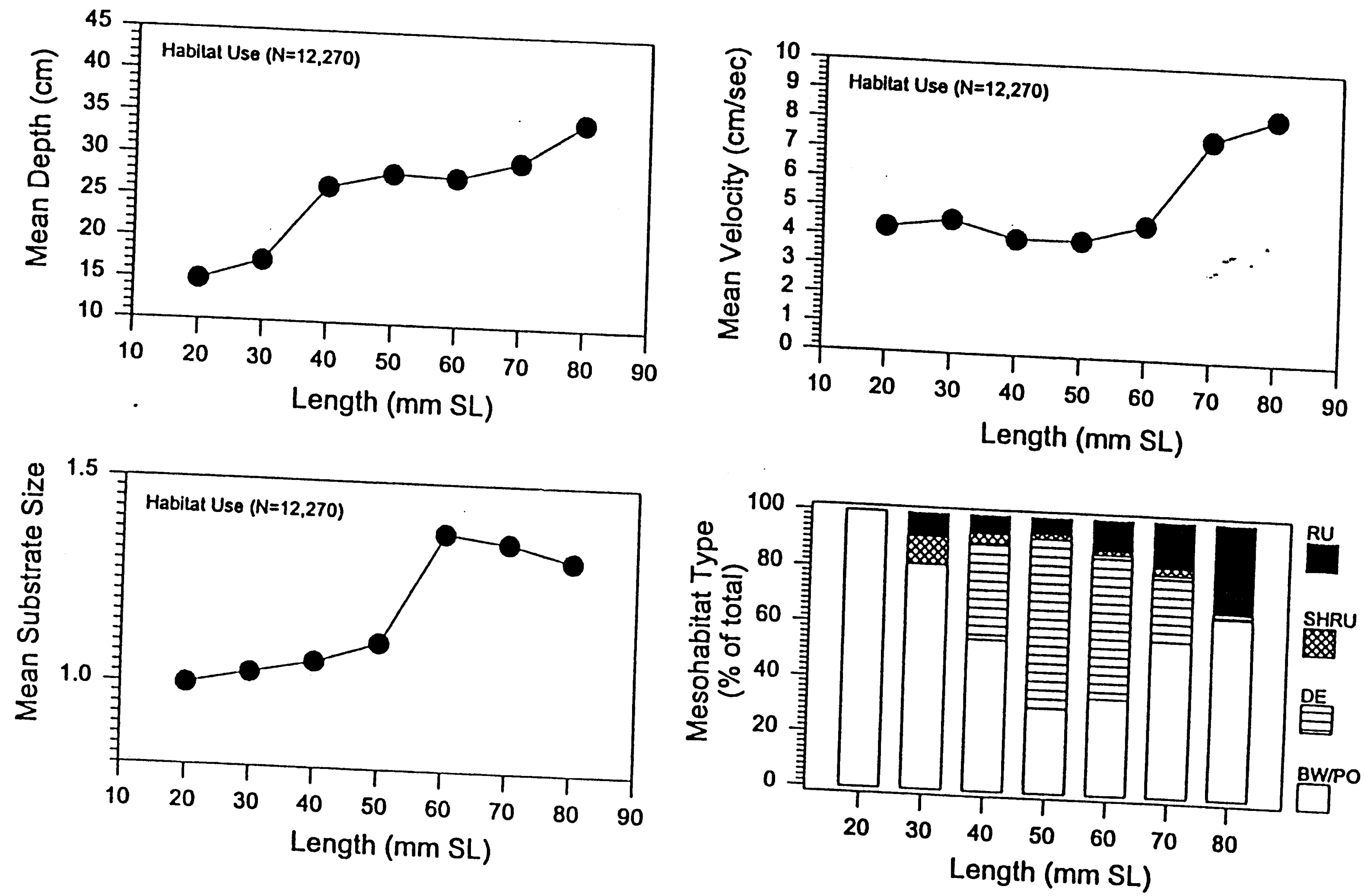

Figure 8. General trends in the ontogenetic shifts in habitat use by Rio Grande silvery minnow for both sampling localities in the Rio Grande. (Substrate codes and mesohabitat definitions are given on page 30).

Mesohabitat and substrate types, codes, and definitions used in Figures 7, 8 and 11.

Mesohabitat Types

Primary

MC - **Main channel**- the section of the river which carries the majority of the flow; there can be only one main channel.

SC **Secondary channel**- all channels not designated as the main channel; there can be zero or several secondary channels at a site.

Secondary

BW **Back water**- 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 **Eddy**- a pool with current moving opposite to that in the channel.

FL **Flats**- a region of uniform shallow depth, moderate velocity, and sand substrate.

IP **Isolated pool**- a pool which is not connected to the main or secondary channel; frequently a former backwater which is no longer connected to the main or secondary channel.

PO **Pool**- the portion of the river that is deep and with relatively little velocity compared to the rest of the channel.

RI **Riffle**- a shallow and high velocity habitat where the water surface is irregular and broken by waves; generally indicates gravel-cobble substrate.

RU **Run**- a reach of relatively fast velocity water with laminar flow and a non-turbulent surface.

SH **Shoreline**- usually a shallower, lower velocity area that is adjacent to shore. This designation precedes other mesohabitat types (i.e. SHRU= shoreline run or SHRI= shoreline riffle).

Substrate Types[1]

BO	**Boulder**- diameter > 256 mm	Numeric Code = 5
CO	**Cobble**- diameter between 64-256 mm	Numeric Code = 4
GR	**Gravel**- diameter between 2-64 mm	Numeric Code = 3
SA	**Sand**- diameter between 0.0625-2 mm	Numeric Code = 2
SI	**Silt**- diameter < 0.0625 mm	Numeric Code = 1

1 - Modified Wentworth classification for substrate particle size (Cummins, 1962)

Site Comparisons:

Three-dimensional graphs display the landscape of depth-velocity relationships for habitat use and availability at Rio Rancho and Socorro (Figures 9 and 10). The range of depths occupied by individuals was the same at both sites (<70 cm). The majority of individuals at Socorro were found at depths < 40 cm (90.4%) with nearly 30% at depths between 11-20cm. At Rio Rancho, individuals occupied deeper areas (>40 cm) more frequently (26.2%) than Socorro (9.7%). It was uncommon at either site to collect fish in depths <10 cm or in depths >60 cm. The majority of individuals taken at both sites selected low-velocity areas (<10 cm/sec). Some individuals at both sites (mostly larger size-classes) occupied areas of moderate current (>10 cm/sec), although this was more frequently observed at Rio Rancho than Socorro. Few individuals from either site selected the higher water velocity (>40 cm/sec) areas.

The substrata over which individuals were collected seemed correlated with its relative availability. There was an increased presence of gravel and cobble substrata at Rio Rancho, even in low-moderate velocity habitats, and fish were associated with these substrata more than at Socorro. At both sites, Rio Grande silvery minnow selected silt substrata more than would be predicted from its availability.

There were few between site differences in the mesohabitat type selected by Rio Grande silvery minnow. Individuals were most abundant in low-velocity mesohabitats (debris piles, backwaters and pools) and rarest in high velocity habitats (runs and riffles). While there were some shifts between sites in the exact mesohabitat occupied (i.e., side channel vs. main channel or shoreline vs. open water) the overall pattern in habitat selection was virtually the same.

Seasonal Comparisons:

Habitats selected by Rio Grande silvery minnow differed by season (Figure 11). Most differences occurred between summer (April-September) and winter (October-March). Rio Grande silvery minnow exhibited a shift to deeper waters in the winter, median depth occupied by Rio Grande silvery minnow shifted from 11-20 cm during summer to 31-40 cm in winter. Although individuals used deeper waters in winter, these areas were generally typified by lower water velocities. A higher percentage of the Rio Grande silvery minnow utilized lower water velocities (<10 cm/sec) in winter than summer. Despite this redistribution of fishes within stream habitats over the seasons, the range of water velocities occupied by Rio Grande silvery minnow was similar in the summer (0-70 cm/sec) and winter (0-80 cm/sec). Individuals were found almost exclusively over silt and sand substrata in winter and summer. All substrate classes were utilized to some degree in the summer and winter with the exception of boulders. The percent of individuals found in higher velocity mesohabitats (main and side channel runs) was higher in summer than winter. There also was a dramatic shift of individuals from pool and backwater habitats in summer to habitats with instream debris piles in winter. The majority of individuals collected in the winter were in or adjacent to instream debris; instream debris accounted for 0.1% of the available habitats.

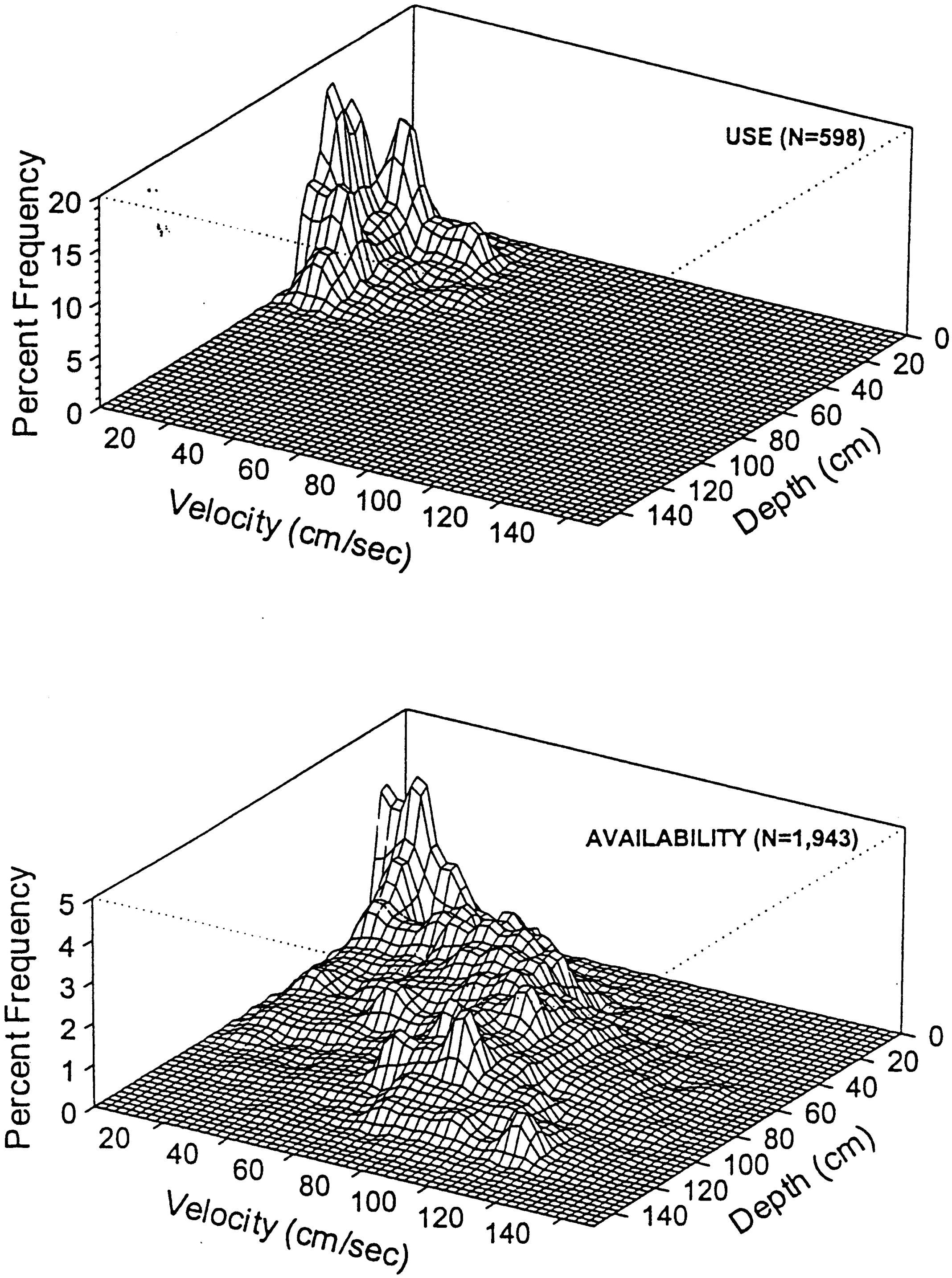

Figure 9. Comparison of depth-velocity availability and use by Rio Grande silvery minnow at the Rio Rancho sampling locality in the Rio Grande.

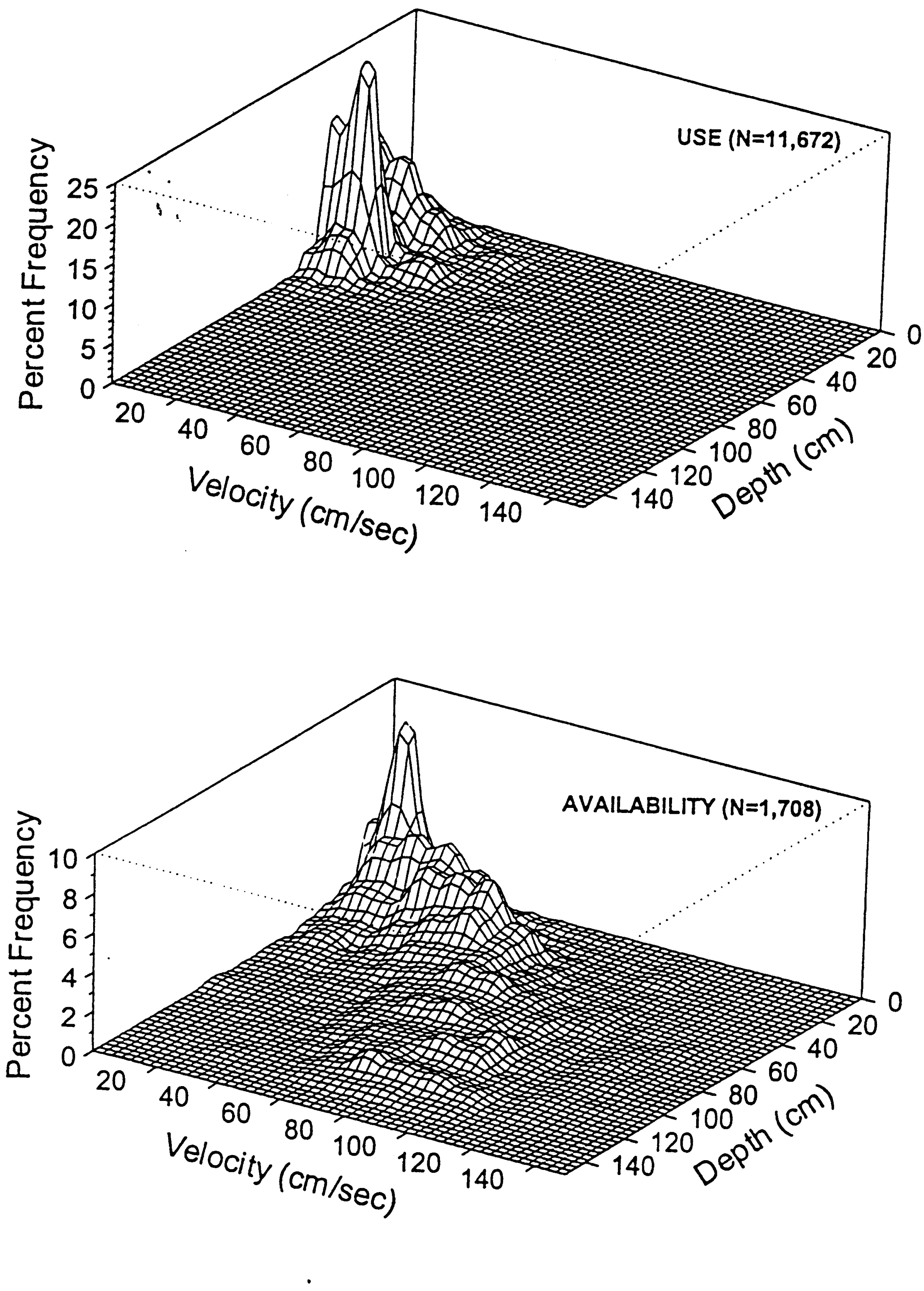

Figure 10. Comparison of depth-velocity availability and use by Rio Grande silvery minnow at the Socorro sampling locality in the Rio Grande.

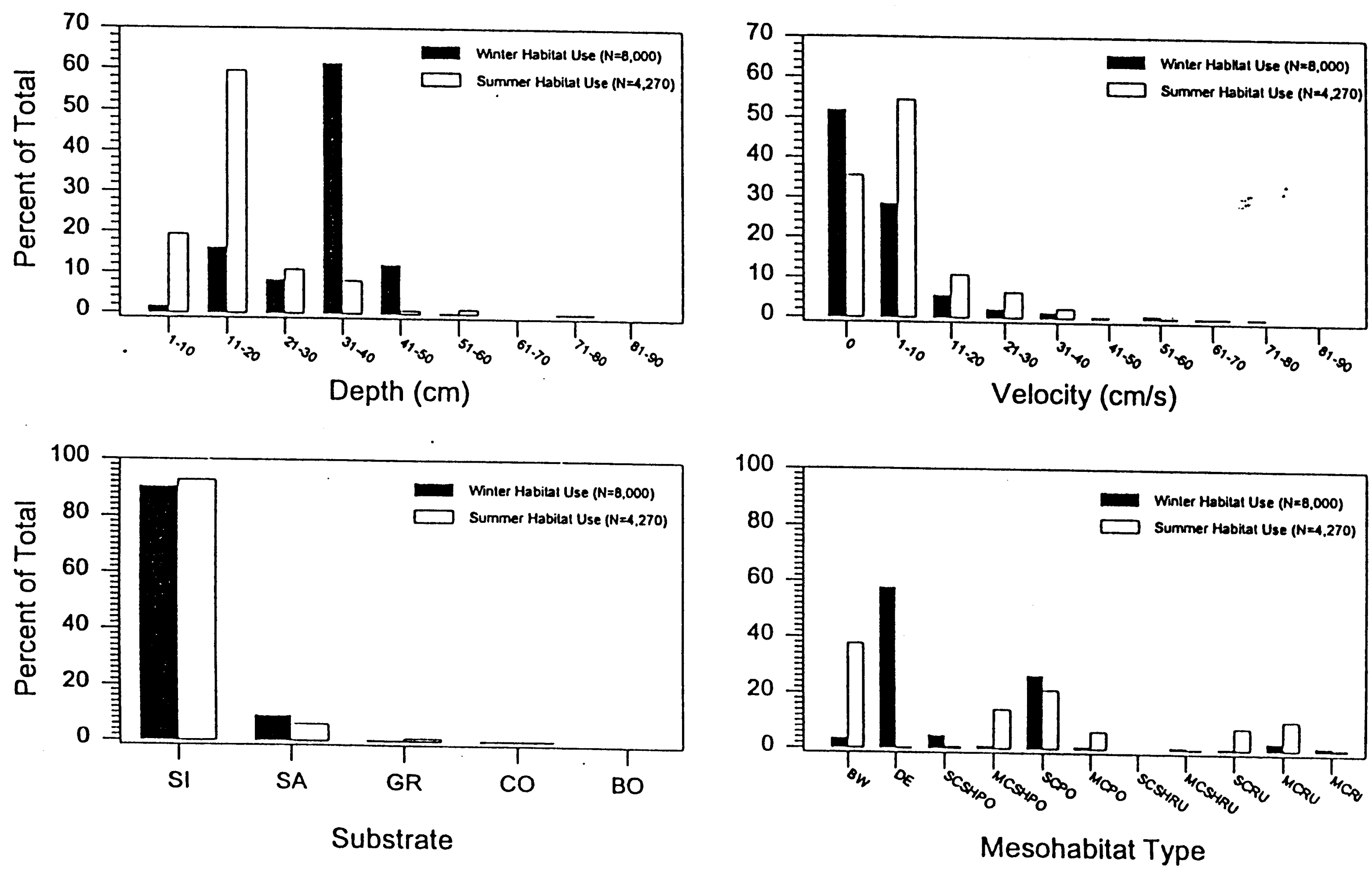

Figure 11. Comparison of mesohabitat use by Rio Grande silvery minnow broken down by season. (Substrate and habitat definitions are given on page 30).

Summary/Discussion:

The 1994-1996 fish-habitat study (Dudley and Platania, 1997) demonstrated that Rio Grande silvery minnow in the middle Rio Grande occupy only a small portion of the available aquatic habitats. This concurs with the conclusions of previous investigations of fish habitat use in this reach (Platania, 1993). The reduction of low-velocity habitats that occurs in reaches of narrow channel width and during periodic high flows have further reduced the number and extent of habitats suitable to Rio Grande silvery minnow. The primary change to the Rio Grande during periods of high flow was a decrease in availability of low-velocity habitats. In reaches of the river where the channel was relatively wide, high flows may reconnect secondary channels and pools and result in an increase in low-velocity habitats.

The loss of low-velocity habitats may most severely impact smaller size-classes of cyprinids which require low-velocity shallow areas as nursery habitats and as potential protection from predation (Copp, 1992). The smallest Rio Grande silvery minnow size-class almost exclusively selected shallow low-velocity habitats. As most low-velocity habitats are engulfed during periods of high flow, larval fish vacate the flooded habitats and move to river margins, the only available low-velocity habitats.

Information obtained from the 1994-1996 habitat-association study suggests that the absence of Rio Grande silvery minnow from upstream portions of the Angostura reach may be habitat related. Between Bernalillo and Angostura, the river is relatively entrenched, substrate consists of large-sized material and low-velocity habitats are generally very limited. These factors will differentially affect the various life-history stages of Rio Grande silvery minnow but ultimately limit its distribution and population size. The species begins to increase in abundance in reaches where the river channel widens, habitat heterogeneity increases and there are more low-velocity habitats available (e.g., Socorro).

Concerns about the effects of alterations in the historic hydrologic patterns to the ichthyofaunal community of middle Rio Grande are further supported by information on the ontogenetic shifts in fish habitat use. Ontogenetic shifts in habitat use occur in many species of fish and are often accompanied by or a result of changes in diet (Mol, 1995; Putman et al., 1995; Wainwright, 1996). Morphological changes, such as increased mouth size and larger jaw muscles, directly affect which foods are consumed most efficiently and is a cost-benefit trade-off (Mol, 1995; Wainwright, 1996). Habitats selected by fishes are a trade-off between abiotic, biotic, and behavioral constraints and continually change with their reproductive and morphological development (Leveque, 1995). Interspecific interactions can strongly influence the habitats occupied by smaller individuals.

The habitats utilized almost without exception by most young-of-year (YOY) fishes, especially Rio Grande silvery minnow, were relatively shallow areas of low or no water velocity over fine particulate substrate. These conditions were most frequently encountered in backwaters and secondary channels pools; these habitats were not directly associated with the main river channel. A potential population limiting factor for Rio Grande silvery minnow appears to be the survival of larval fish through summer and autumn into their first winter. Low-velocity nursery habitats are essential for survival of larval and juvenile Rio Grande silvery minnow.

In addition to knowledge about the shifts in habitat requirements by a species throughout its life history, it is also important to understand the effects that annual changes in the river have on its selection of habitat. Seasonal shifts in habitat use by fishes are well documented in lotic systems (Facey and Grossman, 1992; Rincon and Loboncervia, 1993; Cunjak, 1996). The habitat selection and behavior of fishes during winter is largely dictated by energetic constraints and avoidance of deleterious physicochemical conditions (Riehle and Griffith, 1993; Baras, 1995; Cunjak, 1996). There are negative bioenergetic consequences to fishes if they attempt to maintain their position in the water column during winter because of decreases in metabolic benefits and decreases in swimming ability (Facey and Grossman, 1990; Facey and Grossman, 1992; Rincon and Loboncervia, 1993). Daily activity budgets have also been significantly correlated to water temperature and may be a mechanism to maintain thermal homeostasis over the seasons (Baras, 1995). Fish often seek areas of cover during winter because of the reduced water velocities and protection afforded by these areas. This is a critical factor, especially in winter when fish are relatively inactive and rarely feed, as the costs of maintaining position in the water column are greatly reduced in lower water velocities.

Rio Grande silvery minnow exhibited changes in habitat use between summer and winter. Most of the changes in habitat use corresponded with a seasonal decrease in water temperatures. The onset of the drop in water temperatures coincided with the beginning of autumn or winter and water temperatures did not rapidly rise until late spring or summer. The most notable trend between seasonal habitat associations was the fish community selection of habitats with instream debris in the winter. The diminished or absence of water velocity within debris piles appeared a major factor influencing the habitat selection of the fishes in winter.

Elevated winter water releases can result in a decrease in low water velocity habitats and often make areas with debris one of the few available and suitable low-velocity habitats. Elevated winter releases can also mobilize instream debris and reduce its availability to fish. The abundance of fish in debris piles during winter occurs despite the extreme rarity of this habitat. In a study commissioned by the Army Corps of Engineers to examine the winter habitat of Rio Grande silvery minnow, Dudley and Platania (1996) found that over 70% of individuals selected debris piles.

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 a 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, extensive portions of the Rio Grande downstream of San Acacia diversion dam were completely de-watered. All fish remaining in those sections died. It took at least two years for those populations to return to pre-1989 levels. In April and May 1996, extensive reaches of the Rio Grande in the San Acacia reach were again dewatered resulting in the loss of thousands of gravid Rio Grande silvery minnow and other members of the fish community. Flow conditions in 1989, 1990 and 1996 can be compared to other periods of no flow by using the following summary of data from the U. S. Geological Survey:

Rio Grande
Per cent of Days of No Flow

	San Acacia	San Marcial
1896-1950[5]	2	8
1951-1980	17	42
1981-present	2	18

The Rio Grande silvery minnow has, during the last 10 years, been very abundant in selected reaches of the middle Rio Grande, indicating that environmental and habitat conditions were at times conducive to its survival. This is a species with high reproductive potential that 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).

The species extirpated from the middle Rio Grande (speckled chub *Macrhybopsis aestivalis*, Rio Grande shiner *Notropis jemezanus*, phantom shiner *Notropis orca*, bluntnose shiner *Notropis simus*) shared similar ecological attributes with Rio Grande silvery minnow. They were each short-lived cyprinids that had a common reproductive strategy and egg type. Moore (1944) recognized the advantage of this strategy suggesting that it was particularly well suited for the environments of Plains stream ecosystems. The current suite of conditions in some reaches of the middle Rio Grande may not be conducive for the survival of aquatic organisms and if continued, may lead to the extirpation of the Rio Grande silvery minnow, the last surviving endemic mainstream cyprinid. The first priority must be to address and resolve concerns about river dewatering followed closely by taking steps to optimize the preferred habitat of this species. Ensuring the survival of Rio Grande silvery minnow and the aquatic community that supports this species will require maintaining some level of flow in most of the middle Rio Grande throughout the year.

[5] Flow at San Acacia is for the 1936-1950 period.

DESCRIPTION

The Rio Grande silvery minnow, *Hybognathus amarus*, was originally described as *Algoma amara* by Girard (1856) from specimens obtained from the Rio Grande near Brownsville, Texas. Over the next 120 years, the form was variously submerged with several other members of the genus *Hybognathus*. A detailed morphomeristic study (Bestgen and Propst 1996) of *Hybognathus* species demonstrated the distinctiveness of *H. amarus*. The following description is derived largely from Bestgen and Propst (1996) but includes data from Niazi and Moore (1962), Pflieger (1971), Hlohoskyj et al. (1989), and Cook et al. (1992).

Rio Grande silvery minnow is a small, relatively heavy-bodied fish that is round to ovate in cross-section and rarely exceeds 100 mm total length (ca. 4 in.). Live specimens are light greenish-yellow dorsally and light cream to white ventrally. Fins of Rio Grande silvery minnow are moderate in length and variable in shape; dorsal and pectoral fins are rounded at tips. Scales above the lateral line are sometimes outlined by melanophores, suggesting a diamond grid pattern. The lateral band, about one scale wide, rests on but does not intersect the lateral line and barely extends anteriorally beyond the insertion of the pectoral fin and is diffuse on the posterior portion of the caudal peduncle. The head and snout are moderately pigmented dorsally by melanophores. Laterally, pigmentation extends to about and around the eye, and ventrally the head is without melanophores. Relatively few melanophores are found on the sides of the body below the lateral line, and almost none are present ventrally. The body is fully scaled with breast scales slightly embedded and smaller. The cycloid scales are round except ventral scales which are pointed posteriorly. The number of lateral line scales are usually 36-38 (mean 37, range 34-40) and body circumference scales are usually 26-30 (mean 28, range 22-33). The subterminal mouth extends horizontally to almost the anterior margin of the orbit. The snout is rounded and overhangs the upper lip when viewed ventrally. The eye is small and orbit diameter (0.0533 x standard length) is much less than gape width or snout length. Pharyngeal filtering apparatus includes a broad pharynx and short, stubby papillae on the pharynx and basibranchial. The pharyngeal dentition is usually 0, 4-4, 0 and less commonly 0, 5-4, 0 or 0, 4-5, 0. Pharyngeal teeth are relatively long with expanded or flattened grinding surfaces. The basioccipital is short and deflected ventrally with a shallow concave posterior margin. The tightly coiled (counter-clockwise from ventral aspect) intestine is relatively short (4.7 x standard length $\pm$ 0.70). Unique alleles at loci Est-1, Est-3, and Sod-2 distinguish Rio Grande silvery minnow from closely related congeners.

Rio Grande silvery minnow expresses little sexual dimorphism. The pectoral fins of males flare broadly from their base to a triangular fan shape whereas those of females are shorter, narrower, and oval-shaped. The pectoral rays of breeding males are thickened while those of females are slender. Pectoral fin length (as a proportion of standard length) is significantly greater for males than females. Both males and females are tuberculated during the spawning season. Tubercles are densely distributed over the head and snout and less densely over the body and fins.

TAXONOMY AND SYSTEMATICS

The Rio Grande silvery minnow, *Hybognathus amarus,* is a member of a broadly distributed genus of the family Cyprinidae. Members of the genus are morphologically similar and this has contributed to the confusing taxonomic history of *Hybognathus* (Bestgen and Propst 1996). Although at least 15 forms of *Hybognathus* have been proposed as species or subspecies (e.g., Girard 1856, Cope and Yarrow 1875, Hildebrand 1932), only seven species are currently recognized (Smith and Miller 1986, Robins et al. 1991, Mayden et al. 1992). Among the currently recognized *Hybognathus* species, only the cypress minnow, *H. hayi* (Jordan 1885a), and brassy minnow, *H. hankinsoni* (C. L. Hubbs *in* Jordan 1929), have remained taxonomically stable since their original description.

Girard (1856) originally described the Rio Grande silvery minnow as *Algoma amara* and based this description on specimens obtained from the Rio Grande near Brownsville, Texas. Subsequently *A. amara* and *H. placitus* (plains minnow) were placed in synonymy with *H. nuchalis* (Mississippi silvery minnow) (Jordan 1885b, Hubbs and Ortenburger 1929, Bailey 1954). This submersion of Rio Grande silvery minnow and plains minnow with Mississippi silvery minnow was based upon similarities among the three forms in body shape, eye size, fin shape, and scale structure. Jordan (1929) and Hubbs and Ortenburger (1929), however, believed the plains minnow was a valid species and separated it from Mississippi silvery minnow. Thereafter, Hubbs (1940), Koster (1957), and Trevino-Robinson (1959) treated Rio Grande *Hybognathus* as a subspecies of the plains minnow, *H. placita amara.* Bailey (1956), however, continued to treat the plains minnow (*H. placitus*) as a subspecies of Mississippi silvery minnow (*H. nuchalis),* stating that the former was merely an ecophenotype of the latter.

As a consequence of the discovery by Niazi and Moore (1962) of distinctive differences in the shape of the pharyngeal processes of the basioccipital among putative *Hybognathus* species, *H. placitus* was removed from synonymy with *H. nuchalis* (Bailey and Allum 1962, Al-Rawi and Cross 1964) and was thus recognized as a valid species. Similarities in the basioccipital process therefore allied Rio Grande *Hybognathus* with *H. nuchalis* rather than *H. placitus*. In addition to including Rio Grande *Hybognathus* within *H. nuchalis*, this species "complex" also included the nominal forms *H. regius* (eastern silvery minnow of Atlantic slope drainages) and *H. argyritis* (western silvery minnow of the Missouri River drainage).

In his comprehensive review of *Hybognathus,* Pflieger (1971) recognized *H. regius* and *H. argyritis* as species distinguishable from *H. nuchalis*. He also suggested that the nominal Rio Grande form, *H. amarus*, was separable from *H. nuchalis.* This view was supported by Hlohowskyj et al. (1989) who found that differences in pharyngeal filtering apparati among *Hybognathus* species could be used to distinguish species within the genus. In an allozymic study of Rio Grande *Hybognathus* and species with which it had been synonymized, Cook et al. (1992) found fixed allozyme differences at each of two loci that differentiated Rio Grande *Hybognathus* from *H. nuchalis* (Sod-2 and Est-3) and *H. placitus* (Est-1 and Est-3). Phylogenetic studies by Cavender and Coburn (1988), Mayden (1989), and Schmidt (1994) of *Hybognathus* further justified recognition of *H. amarus.* Bestgen and Propst (1996) detailed the morphomeristic characters that distinguish *H. amarus* from other members of the genus (Table 2). Their study also found no consistently reliable characters that could be used to recognize subspecies within *H. amarus.*

Table 2. Summary of Quantitative and Qualitative Differences Among Seven Species of *Hybognathus*.

Character	SPECIES						
	amarus	*argyritis*	*hankinsoni*	*hayi*	*nuchalis*	*placitus*	*regius*
Maximum body size[a]	small	large	small	medium	large	large	large
Orbit diameter[b]	medium	small	medium	large	med.-large	small	med.-large
Gape width[c]	wide	moderate	moderate	narrow	narrow	wide	narrow
Body width[d]	round	ovate	ovate	compressed	compressed	round	compressed
Circumferential body scales[e]	medium	medium	high	low	low	high	medium
Basioccipital process[f]	wide	moderate	narrow	moderate	wide	narrow	moderate

a. Data from specimens examined in Bestgen and Propst (1996) general literature sources: small ≤ 80 mm SL; medium = 80 - 100 mm SL; large ≥ 100 ml SL. Typical adult body sizes are usually much smaller.

b. Mean eye diameter (% SL) from specimens examined in Bestgen and Propst (1996): small = 4.5 - 4.8% SL, medium = 5.3 - 5.6% SL; large = 5.8 - 7.0% SL.

c. Mean gape width (% SL) from specimens examined in Bestgen and Propst (1996): narrow = 5.5 - 5.9% SL, moderate = 6.1 - 6.3 % SL; large = 6.5 - 6.9% SL.

d. Body shape and width (BW) measurements: round = round cross-sectional profile, BW 15 - 16% SL; ovate = oval profile slightly laterally compressed, BW 14 - 14.5% SL; compressed = laterally compressed, 11 - 13% SL.

e. Median body circumferential scales: low = 26; medium = 27 - 29; high = ≥31.

f. Width of posterior margin of basioccipital: wide = expanded and spatualte, 3.5 - 4.0% SL; moderate = slightly expanded posterior margin, 2.3 - 2.7% SL; narrow = peg or rod-shaped, 1.2 - 1.9 % SL.

SL = Standard length, the distance between the tip of the snout and the end of the vertebral column.

PART II - RECOVERY

Objective:

The goals of this recovery plan are to: 1) stabilize and enhance Rio Grande silvery minnow and its habitat in the middle Rio Grande valley and 2) reestablish Rio Grande silvery minnow in at least three other areas within its historic range.

Criteria:

Population levels of Rio Grande silvery minnow vary within and between each of the four middle Rio Grande valley reaches but collectively are not currently considered of sufficient magnitude for recovery of this species. Recovery of Rio Grande silvery minnow will require that populations in some reaches of the middle Rio Grande valley be stabilized while others will require both stabilization and enhancement. Following accomplishment of these actions, recovery of Rio Grande silvery minnow in the middle Rio Grande valley will be considered achieved when there are no biologically significant declines in distribution, abundance, or levels of reproduction in the middle valley for a period of five consecutive years and when institutional mechanisms to assure adequate deliveries of water and restoration of aquatic and riparian habitat are in place to protect the species and its habitats.

The goal for reestablishing Rio Grande silvery minnow populations outside of the middle valley will be considered met when self-sustaining populations of Rio Grande silvery minnow have become established in at least three of the reaches identified in this document for reestablishment. For these populations to be considered reestablished, there should be no biologically significant declines in reproduction, distribution, and abundance for a period of five consecutive years and institutional mechanisms must be in place that will protect the species and its habitat.

The term "biologically significant decline" as used in the Recovery Criteria will be used to quantify whether recovery is progressing or has been achieved. The method used to determine biological significance is based upon a determination of the statistical deviation from the moving five-year mean of autumn population abundance and a minimum over-winter mortality rate. A detailed description of the process used to determine biological significance is provided below.

Discussion and Basis for Determination of Biologically Significant Decline:

The current overall population level of Rio Grande silvery minnow in the middle Rio Grande valley is not considered sufficient for downlisting or delisting of the species. Recovery of Rio Grande silvery minnow will require that populations in some reaches of the middle Rio Grande valley be stabilizing while others will require both stabilization and enhancement. Prior to the selection of individual recovery protocols for middle Rio Grande valley populations, reach specific evaluation of Rio Grande silvery minnow will be performed. Biological concerns in the middle Rio Grande valley which will need to be addressed include providing sustained flow, the need to minimize entrainment of propagules and amelioration of the negative impacts of instream diversion dams on fish movement, and improvement of water quality.

The Recovery Team believes it more prudent to pursue a reestablishment protocol examining river reaches instead of attempting to designate a specific number of miles of river necessary for recovery. Upon completion of examination, specific reaches would be identified for reestablishment. Determining the total number of miles of suitable riverine habitat necessary to recover Rio Grande silvery minnow is further complicated by aspects of its life history. While little is known about the longitudinal movement and home range of adult Rio Grande silvery minnow, the distance traveled by drifting propagules (eggs and larvae) can exceed 100 miles. The morphogenetic stage at which Rio Grande silvery minnow move upstream or the distance individuals will travel is not known. The vagile nature of the early life history stages of this species and undetermined distance traveled during their life cycle precluded the designation of a specific number of river miles as required for recovery.

Rio Grande silvery minnow will be considered recovered when it has been reestablished and secured in three geographically distinct river reaches (as defined in this recovery plan). Currently, the species persists in one geographic river reach, the Rio Grande between Cochiti and Elephant Butte Reservoir. Six other geographic river reaches are identified as potential recovery reaches. Secure reestablishment (defined below) in three reaches was deemed by the Recovery Team to be the minimum necessary to ensure survival and recovery of the species (i.e., achieve delisting requirements). The logic for determining that three geographic reaches were necessary involved: 1) consideration of the biology of the species, 2) the factors in each reach that may inhibit or enhance reestablishment and security of the species, and 3) the probability that any single factor or combination of factors (abiotic and biotic) would eliminate the species from a specific reach. The following is a synopsis of the key points considered in the process of determining that secure establishment of Rio Grande silvery minnow in three additional river reaches is necessary to justify a determination of species recovery.

Few, if any, Rio Grande silvery minnow live more than 12 to 14 months. For this reason, Age 1 fish are almost entirely responsible for perpetuation of the species. Therefore, spawning must occur every year. Spawning must result in a sufficient number of Age 0 fish such that mean autumn density or abundance throughout a reach is not less than one standard deviation of the moving five-year mean density for the immediately preceding years.

The initial baseline autumn density is based upon the mean abundance of Rio Grande silvery minnow during 1993, 1994, 1995, and 1997 in the San Acacia segment of the Cochiti to Elephant Butte reach of the Rio Grande. Subsequently, the annual evaluation of abundance will be based upon a moving five-year mean. However, in any autumn that density or abundance is one standard deviation less than the moving five-year mean, the minimum density standard is violated and that year cannot be used in the calculation of subsequent moving five-year means. The San Acacia segment mean density or abundance will apply to all other Cochiti to Elephant Butte segments and will be the initial baseline value for the species in other geographic reaches. During winter, habitat must be sufficient to ensure that winter mortality does not result in a spring density or abundance less than 70% of the preceding year's autumn density. If densities decrease by more than 70% from autumn to spring, conditions must be provided in the subsequent year to ensure that population standards are restored the subsequent year.

The initial standards for reaches other than the Cochiti to Elephant Butte reach will be a moving five-year mean autumn density of not less than one standard deviation of the comparable time-frame moving autumn mean of the Cochiti to Elephant Butte reach (i.e., biologically significant). The value for reestablished reaches may be, based upon data from that reach, modified to reflect environmental conditions of the reestablished reach. For example, the minimum effective population size in the Cochiti to Elephant Butte reach may be several million individuals, but in another reach with different factors limiting or enhancing the well-being of the species the minimum effective population size may be only several hundred thousands. This information will be accumulated as recovery efforts are monitored.

The abiotic and biotic factors that affect actual or potential security of Rio Grande silvery minnow vary among reaches. For example, in the Cochiti to Elephant Butte reach, channel desiccation during critical life stages is a primary reason for the tenuous status of the species there. However, in the Sumner to Brantley reach of the Pecos River, nonnative plains minnow may be the primary factor limiting or precluding successful reestablishment of Rio Grande silvery minnow. To the extent possible, with existing data, such issues and the likelihood that they can be resolved were weighed in the process of determining that secure reestablishment in three reaches was necessary to achieve recovery of the species. Each of these issues was considered in relation to the life history and ecology of Rio Grande silvery minnow.

Given the uncertainty of successful reestablishment of Rio Grande silvery minnow in any reach, coupled with the need to have at least three secure reestablished populations, efforts to reestablish the species should not be limited to three reaches. To some extent, recovery will be trial and error. It is likely that secure reestablishment of the species will not be successful in all reaches in which it is attempted, but it is impossible to predict with confidence where it will fail or succeed. For these reasons, recovery efforts should simultaneously proceed in several reaches.

It is unlikely that any single factor or combination of factors will simultaneously eliminate the species from three reestablished reaches, but the probability of simultaneous elimination increases if there are only two reestablished populations. The probability of survival of the species is enhanced by the extent to which the populations are allopatric.

Although more than three secure reestablished populations would further reduce the extinction probability of the species, the number of reaches available for reestablishment is limited and chances of success are variable and not quantifiable. To secure at least three reestablished populations, efforts must be expended in more than three reaches.

The subset of years chosen (1993-1995,1997) were from the period of greatest collecting activity in the middle Rio Grande. The 1992-1997 data set provide the most complete and comprehensive information available on the middle Rio Grande fish community and can be used to make comparisons between fish community assemblage and density and flow conditions. Because of the random nature (spatial and temporal) of historic fish collections made in the historic range of Rio Grande silvery minnow, there are little data available on long-term changes in population levels.

An examination of the most comprehensive data set (1992-1997) on the abundance of Rio Grande silvery minnow over time revealed great fluctuations in the spatial and temporal density of this species. Current population levels of Rio Grande silvery minnow (1993-1995,1997) were chosen as a baseline to which future years could be compared. The Recovery Team chose current population levels as a baseline because those were the only data available from which informed estimates of the number of Rio Grande silvery minnow could be made. A notable drop below current populations levels was determined to be unacceptable for the recovery process to proceed successfully. Recent drops in population levels of Rio Grande silvery minnow have been directly attributable to river dewatering. This is the single most important factor in determining the recent population fluctuations for Rio Grande silvery minnow. When determining the current population levels of Rio Grande silvery minnow, some years (1992 and 1996) were excluded since significant portions of the Middle Rio Grande were dewatered and large portions of the Rio Grande silvery minnow population were eliminated.

Institutional Mechanisms

Institutional Mechanisms, as used in the Recovery Criteria, is defined as the operating or administrative practices of the various natural resource agencies and end users which are implementable and which ensure habitat enhancement and maintenance.

The processes and techniques of an institutional mechanism will be employed consistent with existing law and in such a manner that will result in the protection and enhancement of the habitat of endangered species in the middle Rio Grande valley and Rio Grande silvery minnow reestablishment sites. It is assumed that the year-long needs of Rio Grande silvery minnow will accommodate and benefit other native terrestrial and aquatic biota of the middle Rio Grande valley.

The institutional mechanisms that address water supply of the middle Rio Grande were generally categorized in the "Water Management Strategy for the Middle Rio Grande" (Whitney, et al., 1996). These categories include a suite of general activities which are being addressed by agencies represented on the Recovery Team. The list of Implementation Tasks contained in the Recovery Plan itemize some administrative mechanisms and contain anticipated time lines, costs and responsible and participating agencies.

Institutional Mechanisms that would help ensure habitat enhancement and maintenance and that encompass operating practices include:

- Stabilization and enhancement of streamflow through certain reaches of the Rio Grande and Pecos River by the use of forbearance agreements with water users, conjunctive ground water and surface water use and operation of diversion structures and reservoir storage capacity for environmental purposes;
- Restoration of the diversity of the aquatic and riparian habitat in the Rio Grande and Pecos River through the operation of reservoirs to encourage the dynamic fluvial processes of the Rio Grande and Pecos River (flow regime and sediment transport), innovative river channel maintenance techniques, and control and management of invasive non-native phreatophytes.

Institutional Mechanisms that would help ensure habitat enhancement and maintenance and that encompass administrative practices include:

- Collection of data (discharge measurements and habitat mapping) and monitoring of water use and habitat conditions;
- Development of Habitat Conservation Plans (with states, municipalities, Soil and Water Conservation Districts and Irrigation Districts) and Reasonable and Prudent Alternatives (Section 7 consultations) that could implement some of the operating practices described above;
- Adoption of rules and regulations for the operation of water banks and the conjunctive use of ground water and surface water;
- Development and use of hydrologic and biological computer models;
- Adoption of water quality standards adequate to protect Rio Grande silvery minnow habitat and enforcement of those standards through the implementation of Total Maximum Daily Loads (TMDLs) and enforcement of NPDES permit effluent limitations;
- Administration of water right permits and court decrees.

<u>Actions taken to date to stabilize and enhance the Rio Grande silvery minnow:</u>

The purpose of the Recovery Plan is to outline the research, data collection and recovery actions that may be required to ensure the conservation of the Rio Grande silvery minnow in the wild and to provide and protect habitat essential to its recovery. At this time, it does not appear that de-listing the species can be achieved in the very near future.

Significant effort has been contributed by members of the Recovery Team in the development of the recovery steps identified in this Recovery Plan. Much has been learned about the biology of the species and their habitats, and steps have been taken to stabilize and enhance the Rio Grande silvery minnow. These efforts are described in the following paragraphs.

Research and Monitoring:

- Since 1991, the New Mexico Department of Game and Fish, the U. S. Fish and Wildlife Service, the Bureau of Reclamation, the Corps of Engineers, and the University of New Mexico have cooperated to conduct research on and monitor the status of the Rio Grande silvery minnow and the associated fish community and aquatic habitat condition in the middle Rio Grande valley. Studies have focused on the distribution and abundance, life history, and habitat use of the Rio Grande silvery minnow. Ongoing studies are addressing entrainment, reproduction and effects of habitat fragmentation.

Endangered Species Act Section 7 Consultations:

- In the fall of 1995, the Corps of Engineers entered into Section 7 consultation with the Service over the evacuation of approximately 98,000 acre-feet of flood control storage in Abiquiu Reservoir. This water was stored for flood control purposes during the 1995 snow-melt runoff and retained in storage in Abiquiu in accordance with the operating rules prescribed by Public Law 86-645. The Rio Grande Compact Commission consented to operate Abiquiu Reservoir to evacuate the flood control storage over the period November 1, 1995, though March 31, 1996, which resulted in a lesser discharge rate through the middle valley than would have occurred had the storage been released to ensure all of the flood water was delivered to Elephant Butte Reservoir by January 1, 1996, the manner in which flood control storage has historically been evacuated. This operation reduced the impacts of the flood storage evacuation on the Rio Grande silvery minnow.
- The Bureau of Reclamation and the Corps of Engineers have jointly entered into a Section 7 process to programmatically consult with the Service on federal water operations and river maintenance actions on the middle Rio Grande in New Mexico over a multi-year, approximately 5 year, period. This biological assessment considers the effects of these activities on federally protected species occurring in or near the Rio Chama or Rio Grande from Heron Reservoir and Velarde, NM, respectively, to the headwaters of Elephant Butte Reservoir. The assessment will focus on Rio Grande silvery minnow, the willow flycatcher, and the bald eagle.

Water Resource Planning and Management

- In the fall of 1996, representatives from selected state, federal and local agencies initiated discussions about water management strategies for the middle Rio Grande valley that would address the long-term water needs of the Rio Grande silvery minnow and water users in the middle Rio Grande valley. The water management and administration actions identified for study and the recommendations of the group outlined in the November 14, 1996, document entitled "Water Management Strategy for the Middle Rio Grande Valley" are incorporated in the recovery activities of this Recovery Plan. The recommendations of the group were concurred with by the leadership of the agencies involved. A copy of the "Water Management Strategy for the Middle Rio Grande Valley" is attached as Appendix D.
- Representatives of local, state and federal agencies conduct regular telephone conferences to discuss the water supply and the daily operation of the reservoirs in the middle Rio Grande. During summer months, the group will confer at least daily to anticipate water supply and demands to ensure that sufficient water remains in the Rio Grande to stabilize and enhance the habitat of Rio Grande silvery minnow. This daily conference results in decisions made about the operation of the system and represents a nascent adaptive management process.
- In 1996, six Federal Agencies signed the *Memorandum of Understanding for the Development of an Upper Rio Grande Water Operations Model for Enhanced Systems Management.* These agencies are the Bureau of Reclamation, the Corps of Engineers, the Fish and Wildlife Service, the U. S. Geological Survey, the Bureau of Indian Affairs, and the International Boundary and Water Commission, U. S. Section.

In February 1997, these six federal agencies issued a report entitled "Upper Rio Grande Water Operations Model - Plan for Development". The scope and intent of this effort is to develop a numerical computer model capable of simulating water storage and delivery operations in the upper Rio Grande basin, which is described in the plan as being the Rio Grande from its headwaters to Ft. Quitman, Texas. The primary purpose of the model is to facilitate more efficient and effective management of the basin's water supply. The federal agencies conduct monthly meetings to guide development of the modeling efforts.

Acquisition of Water

- During the drought conditions that existed in the middle Rio Grande valley during the 1996 irrigation season, the MRGCD operated its system to allow native Rio Grande water to remain in the river undiverted for the Rio Grande silvery minnow and the City of Albuquerque and other entities made some of their San Juan-Chama Project water available to the MRGCD for use by the irrigators at no cost to the MRGCD irrigators. It is expected, however, that the San Juan-Chama Project water will not be available in future years to supplement surface water supplies in the middle Rio Grande valley.
- In 1997 the Bureau of Reclamation entered into an agreement with the City of Albuquerque to purchase up to 30,000 acre-feet of the City's San Juan-Chama Project water annually for three years. This water is provided as needed to water users in the middle Rio Grande valley who have been bypassing native Rio Grande water to provide a minimal flow in the river for the Rio Grande silvery minnow. Other, uncontracted San Juan-Chama Project water has been used in a similar manner.
- In 1998, the Bureau of Reclamation, in cooperation with other water management entities in the middle Rio Grande basin, has secured a total of 54,000 acre-feet of supplemental water which has been made available to water users in the middle Rio Grande valley in order that native Rio Grande water may be bypassed to provide a minimal flow in the river for the Rio Grande silvery minnow.

The water supply of the Rio Grande has been fully appropriated for over 100 years. Works have been authorized and constructed to conserve the limited water supply and to control floods and sediment. Rules were adopted to ensure these works are operated and deliveries made in compliance with the Rio Grande Compact. Programs to conserve water and help ensure Compact deliveries include projects to reduce the consumptive use of water (evapotranspiration) through management of riparian vegetation, construction of floodways and construction of drains to recover groundwater and return flows. During periods of low flow, the MRGCD's irrigation delivery system is most efficiently operated by delivering water to users on the lower end of the system via canals, thereby resulting in a dry riverbed. Any changes to these historic operations needed to achieve the recovery goal must be made with a minimum of social and economic impact and in compliance with applicable laws, including the Rio Grande Compact.

Narrative Outline:

The following narrative outline briefly describes the activities that, if implemented, will result in achieving the Recovery Plan's objective. The number format used in this outline does not necessarily indicate the relative priority or chronological sequence of the recovery task, although some of the efforts described under item 1., below are underway. Recovery task priorities are given in Part III.

The conduct of research and data collection under this recovery plan should identify the measures that if funded and implemented should achieve the Plan's objective. The Plan will be evaluated, and updated if necessary, at the end of each five year period. Revision will be part of the recovery process until the Rio Grande silvery minnow is delisted. The performance of activities described herein will be reviewed at least annually by the Recovery Team. The methodologies and results of research activities conducted under this Recovery Plan may be the subject of additional peer review.

Not all measures identified hereunder necessarily would need to be implemented in order to satisfy the objectives and criteria of the Recovery Plan. Recovery of the Rio Grande silvery minnow may not be dependent upon completion of all the activities described hereunder.

1. Restore and protect habitats within the middle Rio Grande valley necessary for the stabilization and enhancement of the Rio Grande silvery minnow.

The Rio Grande silvery minnow survives only in the middle Rio Grande valley from just below Cochiti Dam downstream to the head of Elephant Butte Reservoir. Perpetuation of the species in the wild depends upon a thorough knowledge of the Rio Grande silvery minnow's life history, ecology and habitat needs, and application of that knowledge.

1.1. Investigate and determine biological requirements.

1.1.1. Determine relationship between streamflow and fecundity, spawning and egg and larval migration.

Rio Grande silvery minnow eggs and larvae drift downstream with the streamflow. Knowledge of the nature, extent and distance traveled by the Rio Grande silvery minnow immediately following reproductive effort is necessary to develop and implement an effective plan for the management of the species.

1.1.2. Determine habitats occupied by early life history stages of larval Rio Grande silvery minnow.

This information was not part of the Dudley and Platania [1997] study. The habitat requirements of very early life stages need further study in order to effectively manage for populations of Rio Grande silvery minnow.

1.1.3. Determine relationship between streamflow and habitat availability and recommend stream flows designed to provide suitable habitats for all life stages of Rio Grande silvery minnow.

Ways to reverse the effects of the change in flow and its effects on channel geomorphology and habitat availability in various reaches through the middle Rio Grande valley are not fully understood. An understanding of the relationship between stream flow and habitat availability will help determine the amount, location and duration of flows necessary to provide suitable habitat for the Rio Grande silvery minnow.

Based solely upon the hydrologic and meteorologic conditions that existed in the middle Rio Grande valley during the 1998 irrigation season, it is estimated that a continuous bypass of up to 200 cfs of supplemental water into the floodway at San Acacia is required to maintain flowing water in the channel downstream to San Marcial. Depending upon the magnitude and duration of runoff from the summer "monsoons" and the availability of suitable habitat, the actual amount of bypass required in future years could be less.

1.2. Develop and implement a water management strategy for the middle Rio Grande valley to provide suitable habitat for all life stages of the Rio Grande silvery minnow.

The elements of the recovery activities in Section 1.2. were adopted from the November 14, 1996 document entitled "Water Management Strategies for the Middle Rio Grande Valley" authored by selected representatives of state, federal and local entities.

1.2.1. Identify and acquire funding for acquisition of valid water rights or water from willing sellers in middle Rio Grande valley.

The acquisition of water is necessary to improve water management for the habitat needs of the Rio Grande silvery minnow. Water may be made available from existing water users, and the Middle Rio Grande Conservancy District would need to be a party to any agreements to allow for non-use or forbearance of surface water in the middle valley. A water acquisition program may require sustained funding from federal, state and local sources. The total cost of water for this purpose cannot be determined at this time, and only estimates of annual costs are included in Part III - Task Schedule.

1.2.1.1. <u>Determine institutional and physical requirements necessary for delivering acquired water at appropriate locations and at appropriate times.</u>

Existing laws and contracts may be reviewed and amended, if necessary, to implement programs such as the forbearance of use of water by water users or the development of water banks. The cooperation of the Middle Rio Grande Conservancy District may be required to manage their irrigation works to deliver water at needed locations and at needed times.

1.2.2. <u>Investigate legal, institutional and technical feasibility of implementing a program of conjunctive use of surface water and ground water in middle Rio Grande valley.</u>

Investigate a management program that would allow water users to use a higher proportion of surface water in wet years for direct use or for groundwater recharge. In dry years, more groundwater would be pumped to allow additional surface water to be available. Direct diversion of groundwater into the river may provide a supplemental source to surface water in times of drought. Statutes may have to be enacted to provide for the administration of any groundwater recharge and recovery program.

1.2.3. <u>Evaluate and implement, if appropriate, changes in river and reservoir operations to enhance habitat for Rio Grande silvery minnow in the middle Rio Grande valley.</u>

Reservoirs can be operated, in accordance with existing operating rules, to enhance habitat in the middle Rio Grande valley by providing storage capacity for drought reserve and by making releases to provide flow regimes more like those found in natural flow conditions.

1.2.3.1. <u>Provide for storage of water to augment streamflow.</u>

Inactive, conservation and flood storage capacity may be available in reservoirs upstream of the middle Rio Grande valley. Changes in the operation of these reservoirs, if done in accordance with the Rio Grande Compact, may provide for temporary or long-term reallocation of portions of the capacity of Jemez Canyon, Cochiti and Abiquiu Reservoirs for carryover storage of water stored during very wet years for use in dry years.

1.2.3.2. Operate reservoirs to improve habitat diversity.

A study of the change in the operation of Abiquiu, Cochiti and Jemez Canyon Dams would be made to determine if habitat diversity could be improved by more closely mimicking the flow regimes found under natural conditions. Habitat conditions may be improved by releasing water to encourage the fluvial processes necessary for a more dynamic river channel, to provide for occasional over-bank flooding of the bosque and to by-pass sediment through the reservoirs to feed the sediment-starved reaches.

1.2.4. Implement all reasonable measures to increase water use efficiencies in middle Rio Grande valley.

Local Soil and Water Conservation Districts, in cooperation with the USDA-Natural Resources Conservation Service and the State Engineer, plan and implement programs to improve off-farm distributions systems and on-farm irrigation management. Work under this on-going program has been impeded by decreased funding. Because of future demands on surface water, responsible municipal water conservation plans must be funded and implemented. Legal and institutional issues associated with "saved" water and the impact of various plans and measures on the hydrology and the environment should be considered.

1.2.5. Design and implement a program of data collection on water supply and use for improvement of water right administration and habitat management.

Water rights in the middle Rio Grande valley have not been adjudicated, and most of the water uses in the valley are not metered. A program of metering surface water and groundwater diversions and return flows should be implemented to allow for the improved management of the water supply. A funding source for a metering program would be required. Data from additional water measurement stations might also help improve computer model capabilities for simulating the Rio Grande system hydrology. Qualification of the rights of water users in the middle Rio Grande valley, either through the adjudication process or the filing of Proof of Application of Water to Beneficial Use, in conjunction with a metering program, would allow for improved administration of water rights and improved water management. All data collected would be incorporated into the adaptive management data base system.

1.3. Determine the nature, extent and role of water quality degradation in the decline of the Rio Grande silvery minnow.

The impact of point and non-point sources of discharges into the middle Rio Grande and resulting water quality degradation on Rio Grande silvery minnow survival in unknown. Historic water quality data collection has focused on anthropocentric needs and uses, and few data are available on the impact of water quality on aquatic biota.

1.3.1. Design and undertake toxicity tests on various life stages of Rio Grande silvery minnow to identify effects of contaminants.

Determine if the concentrations of several common inorganic contaminants found in the middle Rio Grande affect the survival of the Rio Grande silvery minnow and assess the suitability of the fathead minnow as a surrogate for Rio Grande silvery minnow. Recommendations for protective water quality criteria can then be developed form the results of this investigation. An investigation simulating average water quality conditions is underway.

1.3.2. Collect and evaluate existing water and sediment quality data and identify impaired habitat and the source of the impairment.

The Recovery Team has worked on identifying areas of the Rio Grande that have water and sediment quality impairments that can correlate to the absence or low abundance of the Rio Grande silvery minnow. No conclusions have been reached and additional work needs to be done. Data collection and monitoring efforts should be coordinated with ongoing studies such as the US Geological Survey's Rio Grande Valley National Water-Quality Assessment Program (NAWQA), and the three-phase investigation of the water quality of the limitrope section of the Rio Grande undertaken by the United States and Mexico. This latter investigation could provide insight into the suitability of selected Texas streams for reestablishment. Recommendations for additional water quality data collection should be formulated, and all data should be included in the adaptive management database.

1.3.3. Determine the effects on water quality from various flow regimes in preferred Rio Grande silvery minnow habitat.

There is little information available on the correlation between water quantity and quality of the preferred habitat of the species. Water quality issues specifically associated with extreme low flow conditions such as temperature, dissolved oxygen and pH variations, can lower the toxicity thresholds of some parameters. It is important to determine this information for effective management of existing populations as well as for determining the feasibility of reestablishment sites.

1.3.4. Determine water quality impacts on the Rio Grande silvery minnow from discharge by point and non-point sources.

The various land use activities within the Rio Grande drainage basin impact Rio Grande silvery minnow habitat. Water quality degradation results from runoff from disturbed sites with improperly planned or managed runoff control plans. Much of the Rio Grande silvery minnow habitat is impacted by the wastewater treatment plant and flood channel discharge of municipalities, and runoff from feedlots and grazing land and return flows from irrigated agriculture. Population growth has resulted in rapid development of urban infrastructure. However, the precise nature of water quality degradation impact on the various life stages of Rio Grande silvery minnow is not well understood. It is important to determine the water quality impacts of this development for effective management of existing populations as well as for determining the feasibility of reestablishment sites.

1.3.5. Inventory and assess sources of sediment and habitat quality impacts.

Sediment production and transport is affected by numerous land use activities and the operation of dams. Increased sediment discharge into the sediment deficient reach from Cochiti to Angostura would diversify habitat. Sediment deposition in the channel of Rio Grande below the Rio Puerco has elevated the river bed, resulting in increased channel seepage and extensive dewatering. Because of the importance of sediments as the preferred habitat of the Rio Grande silvery minnow, it is important to identify the sources of sediment and impact on habitat quality.

1.3.6. Support adoption of state water quality standards suitable for the protection and enhancement of Rio Grande silvery minnow and its habitat.

Section 303 of the Clean Water Act requires that water quality standards be reviewed from time to time, but at least once during each three-year period. Existing and proposed State water quality standards should be reviewed to ensure that water quality standards are adequate to protect Rio Grande silvery minnow and its habitat in the middle Rio Grande valley and in those reaches determined to be most suitable for reestablishment of Rio Grande silvery minnow.

1.4. Determine nature and extent of interaction between native and nonnative fish species and Rio Grande silvery minnow and the role of these fish species in the decline of Rio Grande silvery minnow.

The introduction and spread of exotic and nonnative game fish species has been identified as a threat to the continued existence of the Rio Grande silvery minnow. Once established, these species compete with the Rio Grande silvery minnow for space and food or prey upon them. Hybridization with other species is likely a greater threat.

1.4.1. Determine distribution and extent of nonnative fish species.

Data collection should focus on nonnative seasonality of occurrence with respect to channel intermittency an the movement of reservoir species. Control measures should be undertaken if the study of the distribution of nonnative fishes through various reaches indicates that such actions should be taken.

1.4.2. Determine predation pressure, competition impacts and hybridization potential on Rio Grande silvery minnow.

Laboratory and controlled field studies that are focused on the impacts of nonnative fishes on the Rio Grande silvery minnow's life stages could provide a portion of these data. Studies would have to be designed to incorporate data on the distribution, abundance and mesohabitat use by nonnative fishes to provide information on the nature and extent of the impacts of nonnative species.

1.4.3. Determine relationship between flow regimes and non-native fish species population viability.

Some of these data could be assembled through the re-analysis of information on the distribution and abundance of nonnative fishes that was collected over a period of several years at various flows by Platania. However, only a controlled study that focuses specifically on the relationship between flow regimes and nonnative fish abundance would adequately gather information to develop management strategies.

1.4.4. Review existing policies on nonnative stocking and bait fishing.

To achieve success in controlling nonnative fish species would require a variety of methods. Management efforts may include close scrutiny of sport and bait fishing activities. The states of New Mexico and Texas should review and revise baitfish regulations in a manner that would reduce the threat from collection or use of baitfish.

1.5. Physical modification of habitat and irrigation works.

Channel construction and banks stabilization activities have discouraged the lateral channel migration reducing the extent of natural habitat creation. Side channels and backwaters may be the last refuge of Rio Grande silvery minnow during periods of low flow and habitat fragmentation.

1.5.1. Evaluate the feasibility of mechanical enhancement of required but unavailable habitat.

Certain reaches of river might be more susceptible to successful renovation than others. Areas suitable for construction of side channels and backwater should be identified. Planning for river maintenance and levee and river protection works should carefully project impacts on habitat. The limitrophe section of the Rio Grande is administered by international agreement and physical modification of habitat in this reach will require an agreement with Mexico.

1.5.2. Evaluate the feasibility of installation of main channel fish passage structures at irrigation diversion structures.

Rio Grande silvery minnow eggs and larvae are moved downstream of barriers (diversion structures) in potentially large numbers. These displaced fish must be able to return upstream to repopulate areas above the diversion structures. The successful design and implementation of fish passage structures, or other diversion facility that does not block upstream migration, could allow Rio Grande silvery minnow to repopulate areas where they were spawned. Until suitable fish passage structures are constructed, Rio Grande silvery minnow could be captured and transported to repopulate areas upstream, if adequate stock of Rio Grande silvery minnow are available.

1.5.3. Investigate the feasibility of modification of existing structures to prevent entrainment of Rio Grande silvery minnow into irrigation canals and the Low Flow Conveyance Channel.

Successful recovery of the Rio Grande silvery minnow depends upon free and unimpeded downstream transport of eggs and larvae within the Rio Grande. Entrainment of eggs, larvae and YOY Rio Grande silvery minnow into irrigation canals reduces the chances of a successful recovery. The extent of entrainment should be investigated and quantified under a range of flows and diversion structures modified to minimize entrainment, or provide for an outfall to the river.

2. Reestablish Rio Grande silvery minnow into suitable habitat within its historic range.

To ensure survival of the Rio Grande silvery minnow and maximize the probability of its successful recovery, it is necessary to reestablish populations from available fish. This can be done by transplant of wild stock from the middle Rio Grande directly to areas designated for reintroduction or removal to a fish culture facility for development of a broodstock. The first priority should be transplant of fish from peripheral habitat to enhance populations in the Angostura and Albuquerque reaches and into other historically occupied areas. The development of a captive broodstock and propagation techniques will allow for the maintenance of species genetic integrity and survival, the provision of material for various studies, and for the reestablishment of Rio Grande silvery minnow into areas historically occupied. National Environmental Policy Act and Endangered Species Act compliance will be completed for all reestablishment efforts.

2.1. Conduct baseline genetic studies (DNA) on Rio Grande silvery minnow populations.

Nothing is known about the population genetics of Rio Grande silvery minnow through its current range. This information should be obtained to determine the most effective way to sample and propagate from various gene pools for the ultimate purpose of reestablishment.

2.2. Determine spawning periodicity of Rio Grande silvery minnow under multiple flow regimes.

While Rio Grande silvery minnow are known to spawn with increases in stream flow, it is not known how the precise timing or magnitude of spawning is affected by various flow scenarios. It is also critical to understand how the seasonal timing of flows ultimately affects the spawning periodicity of Rio Grande silvery minnow.

2.2.1. Determine environmental factors that cue spawning in Rio Grande silvery minnow.

More information is needed on what factors [e.g., increases in flow, water temperature and chemical composition of water] trigger spawning. These various factors should be analyzed individually so that the most important cues can be identified.

2.2.2. Examine distances and rates of dispersal of Rio Grande silvery minnow eggs and larvae at various flows.

This work involves experimentally determining the downstream displacement of particles that mimic the physical properties and movements of Rio Grande silvery minnow reproductive products. Determination of the rates of travel and magnitude of dispersion of eggs and larvae at various flows and reaches will allow for the construction of predictive models.

2.3. Determine physiological responses and reproductive, life history, and behavioral aspects of Rio Grande silvery minnow.

2.3.1. Examine possibility of environmental sex determination of Rio Grande silvery minnow.

Temperature has been demonstrated to be a factor responsible for determining sex during embryonic development of several species. If this is true with Rio Grande silvery minnow eggs, there may be a need to reassess some of the conservation strategies.

2.3.2. Determine rate of development and hatching success under various temperature regimes for Rio Grande silvery minnow.

Previous studies have demonstrated a positive correlation between decreased hatching time and increased water temperatures. Additional investigations should be conducted to investigate rates of development and survival of larval fishes under various thermal regimes and also to determine lethal water temperatures for various sizes of Rio Grande silvery minnow.

2.3.3. Investigate upstream migration and recruitment rates of larval Rio Grande silvery minnow.

The eggs and larvae of Rio Grande silvery minnow drift significant distances downstream. Individuals must travel upstream to maintain population levels in upstream reaches. It is not understood which life stage, the seasonal timing and how far upstream Rio Grande silvery minnow move.

2.4. Determine threats to Rio Grande silvery minnow from congener competition and hybridization.

2.4.1. Determine the level and rate of hybridization between Rio Grande silvery minnow and plains minnow (*Hybognathus placitus*).

The Pecos River has been identified as a site for reestablishment of Rio Grande silvery minnow. However, prior to any reestablishment a full understanding of the mechanisms responsible for the extirpation of this species must be achieved. Hybridization between Rio Grande silvery minnow and plains minnow has been suggested as one of the factors responsible for the extirpation of Rio Grande silvery minnow. Data compilation and integration will be used to assess the ability of plains minnow to invade and become established in the Rio Grande and Pecos River.

2.4.2. Investigate interactions (competition) of various life stages between congeners.

An investigation designed to address competition between Rio Grande silvery minnow and plains minnow would be necessary prior to any effort to reestablish the silvery minnow in the Pecos River.

2.5. Identify and evaluate potential reestablishment sites.

Those stream reaches or segments of reaches which best meet the criteria for reestablishment, including requisite habitat or the ability to restore habitats, should be considered for reestablishment. The principal criteria used in determination of reestablishment potential are: an understanding of reasons for the species extirpation from the selected reach, the presence of other members of the reproductive guild (pelagic spawner; non-adhesive, semibuoyant eggs), habitat conditions (including susceptibility to river drying and presence of diversion structures), presence of congeners (i.e., other species of *Hybognathus*).
An investigation should be made into the role that water quality degradation, the impact of nonnative species and the impact that channel modification on habitat may have had on the loss of Rio Grande silvery minnow in the reaches selected for reestablishment. (See recovery items 1.3, 1.4, and 1.5, above). The relative costs of improving habitat in reaches selected for reestablishment will also be considered.

2.6. Reestablish Rio Grande silvery minnow at appropriate locations within its historic range.

Develop a Rio Grande silvery minnow reestablishment plan which would describe the purposes, implementation schedule and costs based upon the specific site selected for recovery, identify the source of fish used for reestablishment and establish target levels of both fish and habitat necessary for recovery. Reestablishment of Rio Grande silvery minnow in areas of its historic range is subject to compliance with the provisions of the National Environmental Policy Act and the Endangered Species Act.

2.7. Conduct annual monitoring of reestablished populations of Rio Grande silvery minnow and their habitat.

Develop a plan for the long-term monitoring of reestablished populations and their habitat in coordination with a basin-wide data collection and monitoring program. Monitoring should continue for at least the duration of the five year review period and data will be used to refine population goals for Rio Grande silvery minnow. The monitoring plan should describe the procedures, protocol, frequency and subject of monitoring and ensure that monitoring efforts at all reestablishment sites are integrated.

2.8. Refine captive rearing methods, establish captive populations and produce Rio Grande silvery minnow populations for experimental purposes.

2.8.1. Rear developmental voucher series of Rio Grande silvery minnow and produce description of different developmental stages.

All current descriptive studies of Rio Grande silvery minnow pertain to the adult life stage. Much of the assessment of the status of this species will be determined based on information provided by collection of larval Rio Grande silvery minnow. To aid researchers in this endeavor, it will be necessary to provide a diagnostic work that includes morphometric, meristic, and verbal description of the different stages of larval Rio Grande silvery minnow.

2.8.2. Determine the efficacy of various methods for marking larval Rio Grande silvery minnow.

Many of the proposed studies require the ability to track and identify specific sub-populations of Rio Grande silvery minnow. This laboratory study would examine and test different mechanisms of marking larval Rio Grande silvery minnow.

2.8.3. Develop and follow master plan for long-term reestablishment strategy.

2.8.3.1. Ensure that hatchery production of fish is based on the need of researchers (i.e., do not let the production of fish drive the process of reestablishment).

2.8.3.2. Prioritize and coordinate all aspects of production, stocking, and reestablishment efforts.

2.8.3.3. Determine effects of stocking conditions and release sites on survival of stocked Rio Grande silvery minnow.

2.8.3.4. Determine effects of hatchery-to-release-site transport conditions on field survival of stocked Rio Grande silvery minnow.

2.8.3.5. Monitor biologic responses of stocked Rio Grande silvery minnow.

2.8.3.6. Determine if behavioral modifications may be produced in hatchery Rio Grande silvery minnow, which could improve or reduce fitness.

2.8.3.7. Establish and maintain standardized monitoring efforts to detect establishment of stocked populations.

2.8.3.8. Collect and maintain specimens in a research museum.

2.8.3.9. Maintain single, centralized, standardized database for both stockings and captures of target species.

2.8.4. Hire a full-time coordinator responsible for oversight of captive broodstock and restocking efforts.

3. Design and implement a public awareness and education program.

Public awareness of the recovery effort for the Rio Grande silvery minnow and related water resource issues should be encouraged. A good way to achieve this is through an information and education program.

3.1. Issue notice regarding status of Rio Grande silvery minnow recovery effort.

Information distribution should attempt to make extensive use of world wide web sites and e-mail to ensure timely and convenient accessibility to information and data about and developed by the program. Establishment of the program database should also consider the distribution of data to the public.

3.2. Develop visual aids to promote better understanding of the Rio Grande silvery minnow and its habitat.

3.2.1. Develop instructional videos, slides and illustrations.

Produce a brief video or slide program concerning Rio Grande silvery minnow and its habitat and make it available to various groups, including elementary schools. Prepare professional quality color illustrations of various life stages and sexes of Rio Grande silvery minnow and sympatric cyprinids.

3.2.2. Establish an aquarium display of captive Rio Grande silvery minnow at appropriate facilities within the area of current and historic distribution of this species.

4. Implement and maintain an adaptive management program and ensure appropriate research and management activities are carried out in order to attain recovery of the Rio Grande silvery minnow.

This recovery program will only be as effective as the method of self-evaluation. This Recovery Plan may require adjustment in order to recover the Rio Grande silvery minnow while minimizing economic and social impacts. It is necessary for the Recovery Team to continually analyze the influx of new or additional information regarding the biological, physical, and chemical conditions of the Rio Grande and Pecos River.

4.1. Develop and implement a long-term monitoring program to identify changes in the endangered and other native fish species populations, status, distributions and habitat conditions.

A long-term monitoring program should be developed and implemented during the recovery program. Emphasis should be placed upon monitoring the status and trends of the resident fish community, geomorphology of the stream channel, flow and habitat relationships, changes in water quality, and hydrologic changes within the Rio Grande basin.

4.2. Establish and maintain a database for storage and retrieval of hydrologic, biologic, economic and social data.

A standardized and centralized database should be developed and maintained to incorporate the accurate compilation and storage of all relevant data, including data on population and land use activities. This database should be made available to all resource agencies, institutions and individuals conducting or evaluating research and management activities. Access to data in the database should be made available to the public through the Internet.

4.3. Review and revise research and management activities to further define the needs and threats to the Rio Grande silvery minnow.

As research projects are completed or relevant findings verified, new information may identify additional research needs or identify habitat protection actions which may be needed. Program management will allow for the conduct of new and approved research and implementation of necessary and feasible management activities. As necessary, recovery actions and goals will be refined to reflect new information and the understanding of activities taken in management of the fish community of the Rio Grande basin.

4.4. Identify recovery tasks necessary to achieve an ultimate goal of de-listing of the Rio Grande silvery minnow.

De-listing of the species is dependent upon successful stabilization of the existing populations of the Rio Grande silvery minnow and reestablishment of the species in other areas of their historic range. Based upon the knowledge gained from the research and management actions and the response of the Rio Grande silvery minnow, quantifiable goals for de-listing of the Rio Grande silvery minnow will be developed.

Interagency Cooperation

The implementation of recovery tasks identified in this Recovery Plan is not the sole responsibility of the Service. Although the Service provides leadership in the recovery of listed species, other federal, states and local agencies, Indian Pueblos and private citizens, also play a vital role. It is the responsibility of every federal agency to recover listed species. The Service will involve all affected interests in the recovery plan implementation process through the development of the Implementation Tasks, a mutually developed strategy to implement one or more specifically designated recovery actions. The following is a brief description of the authorities and missions of some of the entities participating in the recovery of the Rio Grande silvery minnow.

U. S. Fish and Wildlife Service. Protecting endangered and threatened species and restoring them to a secure status in the wild is the primary objective of the endangered species program of the U.S. Fish and Wildlife Service, an agency of the Department of the Interior. Responsibilities of the endangered species program include the following: listing, reclassifying, and delisting species under the Endangered Species Act; providing biological opinions to federal agencies on their activities that may affect listed species; overseeing recovery activities for listed species; providing for the protection of important habitat; providing grants to States to assist with their endangered species conservation efforts.

Bureau of Reclamation. The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public. The Bureau of Reclamation operates and maintains all or part of the works associated with the following major water supply projects affecting the water resources within the historic habitat of the Rio Grande silvery minnow: the San Luis Valley Project - Colorado, the San Juan-Chama Project - Colorado and New Mexico, the Middle Rio Grande Project, the Rio Grande Project - New Mexico and Texas, the Carlsbad Project, and the Brantley Project.

U. S. Army Corps of Engineers. The Corps of Engineers is authorized to operate and maintain the following Projects affecting the water resources within the historic habitat of the Rio Grande silvery minnow: Platoro Dam (flood control pool only), Middle Rio Grande Project (Abiquiu, Cochiti, Jemez Canyon and Galisteo Dams) and Santa Rosa, Sumner, Brantley (flood control pools only) and Two Rivers Dam in the Pecos River Basin. The Corps of Engineers is also responsible for the issuance of permits for the discharge of dredged or fill material into the navigable waters of the United States under Section 404 of the Clean Water Act (Federal Water Pollution Control Act).

U. S. Environmental Protection Agency. The mission of the Environmental Protection Agency (EPA) is to protect human health and to safeguard the natural environment — air, water, and land — upon which life depends. EPA's purpose is to ensure that: all Americans are protected from significant risks to human health and the environment where they live, learn and work; national efforts to reduce environmental risk are based on the best available scientific information; federal laws protecting human health and the environment are enforced fairly and effectively; environmental protection is an integral consideration in U.S. policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade, and these factors are similarly considered in establishing environmental policy. The EPA is also responsible for the administration of certain provisions of the Clean Water Act, including the issuance of permits for the discharge of pollutants under the National Pollution Discharge Elimination System (NPDES Permits, Section 402 of the Clean Water Act).

New Mexico Interstate Stream Commission and Office of the State Engineer. The Office of the State Engineer and the Interstate Stream Commission are separate but companion agencies charged with administering the state's water resources. The agencies have authority over the supervision, measurement, appropriation and distribution of almost all surface and ground water in New Mexico, including streams and rivers that cross state boundaries. The State Engineer is also secretary to the Interstate Stream Commission and oversees the staff of both agencies.

New Mexico Environment Department - Surface Water Quality Bureau. The mission of the Surface Water Quality Bureau is to preserve, protect and improve New Mexico's surface water quality for present and future users of these resources. Emphasis is placed on the maintenance of water quality adequate to guarantee the continuation, in perpetuity, of the potential and existing uses of the water through evaluation, education and outreach activities, point and nonpoint source controls and wastewater operator training and certification. The Surface Water Quality Bureau utilizes the authorities described in the federal Clean Water Act and Safe Drinking Water Act as well as the New Mexico Water Quality Act and Utility Operators Act, their attendant regulations and standards.

New Mexico Department of Game and Fish. Under the authority of the New Mexico Wildlife Conservation Act (NMSA 17-2-37 through 17-2-46, 1978), the New Mexico Department of Game and Fish is responsible for identifying and listing the threatened and endangered species in New Mexico. A total of 117 species and subspecies are on the 1998 list of threatened and endangered New Mexico wildlife, including 2 crustaceans, 25 mollusks, 23 fishes, 6 amphibians, 14 reptiles, 32 birds and 15 mammals. Only species native to New Mexico are listed. The distribution, current status, threats, and a listing recommendation are presented for each species or subspecies on the state list. The Department's data base on these species consists of over 2000 pages. The Department emphasizes the need for identifying and protecting endangered wildlife in New Mexico.

Texas Parks and Wildlife Department. In 1973 the Texas legislature authorized the Texas Parks and Wildlife Department (TPWD) to establish a list of endangered animals in the state. Endangered species are those species which the Executive Director of the Texas Parks and Wildlife Department has named as being "threatened with statewide extinction". Threatened species are those species which the TPW Commission has determined are likely to become endangered in the future. Laws and regulations pertaining to endangered or threatened animal species are contained in Chapters 67 and 68 of the Texas Parks and Wildlife (TPW) Code and Sections 65.171 - 65.184 of Title 31 of the Texas Administrative Code (T.A.C.). TPWD regulations prohibit the taking, possession, transportation, or sale of any of the animal species designated by state law as endangered or threatened without the issuance of a permit. State laws and regulations prohibit commerce in threatened and endangered plants and the collection of listed plant species from public land without a permit issued by TPWD. In addition, some species listed as threatened or endangered under state law are also listed under federal regulations.

Texas Natural Resource Conservation Commission. The mission of the Texas Natural Resource Conservation Commission is to protect the State's human and natural resources consistent with sustainable economic development. The Commission's goal is clean air, clean water and safe management of waste with an emphasis on pollution prevention. The Commission is committed to providing efficient, prompt and courteous service to the people of Texas, with decisions that are based on common sense, good science and fiscal responsibility.

Texas-New Mexico Water Commission. The Texas New Mexico Water Commission, which is comprised of representatives of water user groups from the lower Rio Grande in New Mexico and Texas, was formed after a negotiated settlement of disputes surrounding the use of groundwater resources and the effect of surface water uses on aquifer levels in the Mesilla Basin. A goal of the settlement agreement entered into between the parties in 1991 was to work together to study, identify and address common concerns, especially the interaction between the surface water and the groundwater in the Mesilla Basin of New Mexico and Texas.

Middle Rio Grande Conservancy District. The Middle Rio Grande Conservancy District (District), a political subdivision of the State of New Mexico, was organized under the 1927 New Mexico Conservancy Act. The District prepared the Official Plan of the Middle Rio Grande Conservancy District, which was filed with the District Court of the Second Judicial District of the State of New Mexico. The District Court approved the Plan on August 15, 1928. The Plan proposed the construction of El Vado Dam on Rio Chama, the construction of levees on both sides of the Rio Grande, a system of interior and riverside drains, four diversion dams, 168.6 miles of main canals, and 378.2 miles of laterals.

On November 25, 1930, the District filed with the State Engineer an Application for Permit to Change the Points of Diversion of 71 old acequias diverting water from the Rio Grande to four new permanent diversion structures. A statement of rights claimed by the District accompanied the Application, which stated that the District proposed to irrigate a total of 123,267 acres of land, of which a total of 80,785 acres of land had perfected prior water rights, and the balance, 42,482 acres of land not then in cultivation, to be irrigated by water salvaged through the drainage of water-logged lands, all with a duty of water of 3 acre-feet per acre. No protests having been received, Herbert W. Yeo, State Engineer, granted the permit on January 26, 1931, allowing each change in point of diversion as requested in the application.

The District currently operates and maintains about 200 miles of riverside levees and about 1,100 miles of canals, laterals, wasteways and drains. Between 55,000 and 60,000 acres of land are currently irrigated. Since beneficial use is the measure and limit of the right to use water, no license may be granted for the irrigation of more land than has actually been put to beneficial use during the development period. After making full use of the water as contemplated by its permit, or as much thereof as is deemed feasible the District shall file Proof of Application of Water to Beneficial Use. The State Engineer and the District are currently discussing the process and procedures that the District would use to file Proof of Application of Water to Beneficial Use.

Middle Rio Grande Pueblos: The middle Rio Grande is home to the six Native American Indian Pueblos of Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia and Isleta, and they range in size from 205,000 acres (Isleta) to 19,000 acres (Santa Ana). These Pueblos, which are, in part, located within the exterior boundaries of the Middle Rio Grande Conservancy District, were diverting water from the Rio Grande and cultivating irrigated lands long before the advent of the Spanish in 1540. The waters of the Rio Grande also play an important role in the spiritual and ceremonial aspects of the lives of the native Americans who reside along the river.

By the Act of March 13, 1928, Congress authorized the Secretary of the Interior to enter into contract with the Middle Rio Grande Conservancy District that would provide for the conservation, irrigation, drainage and flood control for the Pueblo lands in the middle Rio Grande Valley. The Legislation required the MRGCD to recognize a first and immemorial priority for 8,847 acres of irrigated lands and required that the MRGCD recognize the water rights for reclaimed new lands as equal to those of like MRGCD lands and are to be protected from discrimination in the division and the use of water. The water rights associated with the old lands, as well as the newly reclaimed lands, are not subject to loss by nonuse or abandonment.

On June 5, 1997, the Secretaries of Interior and Commerce issued a Secretarial Order entitled "American Indian Tribal Rights, Federal-Tribal Trust Responsibilities and the Endangered Species Act," which clarifies the responsibilities of the agencies of the Departments of Interior and Commerce, when actions taken under the authority of the Endangered Species Act may affect Indian lands, tribal trust resources, or the exercise of American Indian tribal rights. The Order acknowledges the trust responsibility and treaty obligations of the United States toward Indian tribes and tribal members and its government-to-government relationship in dealing with tribes. The Order provides that the Departments will carry out their responsibilities under the Endangered Species Act in a manner that harmonizes the Federal trust responsibility to tribes, tribal sovereignty, and statutory missions of the Departments, and that strives to ensure that Indian tribes do not bear a disproportionate burden for the conservation of listed species, so as to avoid or minimize the potential for conflict and confrontation.

PART III - IMPLEMENTATION TASKS

The Implementation Tasks that follows is a guide for meeting the objectives discussed in Part II of this Plan. This schedule indicates task priorities, task numbers, task descriptions, duration of tasks, the responsible agencies, and lastly, estimated costs. Implementation of actions identified as a result of research and data collection should bring about the recovery of the species and protect its habitat. It should be noted that not all the estimated monetary needs (e.g., the cost of water acquisition) for all parties involved in recovery are known and, therefore, Part III reflects the total estimated financial requirements for the research and data collection that will identify appropriate actions to be implemented for the recovery of the species. The recovery actions identified in this plan are recommendations; they can also be included through the Endangered Species Act section 7 consultation process or the development of a Habitat Conservation Plan.

Definition of Priorities:

1 = An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.

2 = An action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.

3 = All other actions necessary to provide for full recovery of the species.

Abbreviations and acronyms used in Implementation Task Table:

AB - Amigos Bravos
ALB - City of Albuquerque
CO - Colorado Division of Water Resources
COE - Corps of Engineers
FWS - Fish and Wildlife Service
IBWC - International Boundary and Water Commission, U. S. Section
MRGCD - Middle Rio Grande Conservancy District
NM - Agencies of the State of New Mexico, i. e, Office of the State Engineer, Interstate Stream Commission, Department of Game and Fish, Environment Department
NPS - National Park Service
RT - Recovery Team
TX - Agencies of the State of Texas, i. e, Texas Parks and Wildlife Department and Texas Natural Resource Conservation Commission.
UNM - University of New Mexico
USBR - Bureau of Reclamation
USGS - U. S. Geological Survey
WRRI - New Mexico Water Resource Research Institute

PART III - IMPLEMENTATION TASKS

Task Priority	Task No.	Task Description	Task Duration	Lead Agency	Responsible Entities	Estimated Costs ($'s x1000)					
						Total	FY(1)	FY (2)	FY (3)	FY(4)	FY(5)
1	1.2.1	Acquire funding for acquisition of water	Ongoing	USBR	FWS, ALB, MRGCD, NM	?	100	100	100	100	100
1	1.2.3	Change in river and reservoir operation to enhance habitat.	5 yrs.	COE, USBR	NM, TX, MRGCD	375	75	75	75	75	75
1	1.5.1	Evaluate mechanical enhancement of habitat.	Ongoing	FWS	USBR, NM, TX, IBWC	?	100	100	100	100	100
1	1.5.2	Evaluate installation of fish passage structures.	2 yrs.	FWS	USBR, MRGCD	50	25	25	-	-	-
1	2.5	Identify and evaluate potential reestablishment sites.	4 yrs.	FWS	NM, TX, UNM, NPS,	300	100	100	50	50	-
1	2.6	Reestablish Rio Grande silvery minnow.	Ongoing	FWS	NM, TX, UNM	?	50	50	50	50	50
2	1.1.1	Determine relationship between streamflow and life stage transport.	3 yrs.	NM	FWS, USBR, UNM	100	40	40	20	-	-
2	1.1.2	Determine habitats occupied by larval Rio Grande silvery minnow.	3 yrs.	UNM	FWS, NM, TX, NPS, USBR	100	40	40	20	-	-
2	1.1.3	Determine relationship between streamflow and habitat availability.	3 yrs.	USBR	FWS, NM, TX, COE, UNM	300	100	100	100	-	-
2	1.2.2	Investigate feasibility of conjunctive use.	2 yrs.	ALB	NM, USGS MRGCD, WRRI	60	30	30	-	-	-
2	1.2.4	Increase water use efficiency.	Ongoing	NM, TX	MRGCD ALB, USBR, WRRI	?	100	100	100	100	100
2	1.2.5	Develop program of data collection.	Ongoing	USBR	MRGCD, NM, TX, USGS	?	100	100	100	100	100

PART III - IMPLEMENTATION TASKS

Task Priority	Task No.	Task Description	Task Duration	Lead Agency	Responsible Entities	Estimated Costs ($'s x1000)					
						Total	FY(1)	FY (2)	FY (3)	FY(4)	FY(5)
2	1.3.1	Undertake toxicity tests.	Underway	FWS	FWS	50	50	-	-	-	-
2	1.3.2	Compile existing water quality data.	2 yrs.	RT	USGS, USBR, WRRI, FWS, NPS	50	25	25	-	-	-
2	1.3.4	Determine water quality impacts from discharges.	3 yrs.	FWS	USGS, NM, TX, IBWC	300	100	100	100	-	-
2	1.4.1	Determine distribution and extent of nonnative species.	3 yrs.	NM, TX	FWS, UNM, USBR	45	15	15	15	-	-
2	1.4.2	Determine predation pressure, competition impacts and hybridization potential.	3 yrs.	NM, TX	FWS, UNM, USBR	60	20	20	20	-	-
2	1.5.3	Evaluate modification of structures to prevent entrainment of eggs and larvae	2yrs.	USBR	MRGCD, TX, NM, WRRI IBWC	80	40	40	-	-	-
2	2.2	Determine spawning periodicity.	2 yrs.	NM	FWS, UNM, TX, USBR	100	50	50	-	-	-
2	2.3	Determine physiological and reproductive behavior.	3 yrs.	UNM	FWS, NM, TX	370	30	170	170	-	-
2	2.4	Investigate threats from congener competition and hybridization.	2 yrs.	FWS	NM, TX, UNM	50	25	25	-	-	-
2	2.7	Conduct annual monitoring of reestablished populations.	Ongoing	FWS	UNM, TX, NM, USBR	?	50	50	50	50	50
2	2.8	Produce RGSM for experimental purposes.	Ongoing	FWS	UNM, NM, TX	?	100	100	100	50	50
2	2.8.3	Develop master plan for long-term reestablishment strategy.	3 yrs.	FWS	UNM, NM, TX	90	30	30	30	-	-
2	2.8.4	Hire staff to oversee experimental populations.	Ongoing	FWS	FWS	?	50	50	50	50	50

Task Priority	Task No.	Task Description	Task Duration	Lead Agency	Responsible Entities	Estimated Costs ($'s x1000)					
						Total	FY(1)	FY (2)	FY (3)	FY(4)	FY(5)
2	3.1	Issue notice regarding status of recovery.	Ongoing	FWS	FWS	?	10	10	10	10	10
2	4.1	Implement monitoring program	Ongoing	FWS	RT	?	50	50	50	50	50
2	4.2	Establish and maintain database.	Ongoing	USBR, COE	RT	?	50	50	50	50	50
2	4.3	Review and revise research and management activities.	Ongoing	FWS	RT	?	25	25	25	25	25
2	4.4	Identify task necessary to delist Rio Grande silvery minnow	2 yrs.	FWS	RT	20	10	10	-	-	-
3	1.3.3	Determine effects on water quality from flow regimes	2 yrs.	AB	FWS, USBR, NM, TX	60	-	30	30	-	-
3	1.3.5	Assess sources of sediment and impact on habitat quality.	2 yrs.	USBR	FWS, COE	40	-	20	20	-	-
3	1.3.6	Support adequate water quality standards	Ongoing	FWS	RT	-	-	-	-	-	-
3	1.4.3	Determine relationship between flow regimes and nonnative fish viability.	2 yrs.	FWS	UNM, NM, TX, USBR, COE	40	-	20	20	-	-
3	1.4.4	Review existing policies on nonnative stocking and bait fishing.	2 yrs.	NM, TX	FWS	20	-	10	10	-	-
3	2.1	Conduct baseline genetic studies.	1 yr.	FWS	UNM, NM, TX	20	-	20	-	-	-
3	2.8.3	Determine efficacy of marking.	1 yr.	FWS	UNM, NM, TX	40	-	40	-	-	-
3	3.2	Develop visual aids.	2 yrs.	FWS	UNM	50	25	25	-	-	-

APPENDIX A

RIO GRANDE BASIN HYDROLOGY

RIO GRANDE

GEOGRAPHY AND CLIMATE

The Rio Grande headwaters lie along the Continental Divide at elevations ranging from 2,440 m (8,000 ft.) to 3,660 m (12,000 ft.) in the San Juan Mountains of southern Colorado. The entire area of the Rio Grande drainage basin is about 470,000 sq. km. (182,200 sq. mi.) of which about 230,000 sq. km. (89,000 sq. mi.) are in the United States and the remainder in Mexico (Hunt, 1974). The river flows south from Colorado through the length of New Mexico and then forms the international boundary between Texas and the Republic of Mexico. The drainage basin area above Elephant Butte Dam is about 76,275 sq. km. (29,445 mi. sq.), including 7,615 sq. km. (2,900 sq. mi.) in the Closed Basin of the San Luis Valley in Colorado. Above Velarde the drainage basin area is about 26,936 sq. km. (10,400 sq. mi.), including the Closed Basin. For the basin as a whole, the Rio Grande ranks last in a list of the world's principal rivers in the amount of water discharged per square mile of basin.

The San Luis Valley in south-central Colorado extends approximately ninety miles from north to south and fifty miles from east to west at elevations ranging between 2300 m (7,500 feet) and 2500 m (8,000 feet) above sea level. The major mountain boundaries are the San Juan Mountains to the west and the Sangre de Cristo Mountains to the east. The Rio Grande mainstem rises in the San Juan Mountains, flows south-easterly through the San Luis Valley, then into the State of New Mexico. The Conejos River rises in the southern San Juan Mountains and flows north-easterly along the southern edge of the San Luis Valley, joining the Rio Grande mainstem at Los Sauces. Despite its high altitude, short growing season, and average annual precipitation of only about 19mm (7.5 inches), the San Luis Valley sustains a productive agricultural economy dependent upon irrigation water.

A few miles north of the Colorado-New Mexico stateline, the Rio Grande enters a canyon which gradually increases in depth to more than 360 m (1200 feet) at Embudo, 112 km (70 miles) south of the state line. A short distance below Embudo the river enters the Espanola Valley, which is about 40 km (25 miles) long and 1.6 km to 4.8 km wide (1 to 3 miles). Here it is joined by the Rio Chama, an important stream draining some 8,288 sq. km. (3,200 sq. mi.). It is from this portion of the drainage basin, from the state line to the Espanola Valley, that the Rio Grande receives most of the part of the water supply which originates in New Mexico. At the lower end of the Espanola Valley, the river enters White Rock Canyon, a narrow gorge some 32 km. long (20 miles), leaving this at Cochiti, due west of Santa Fe.

The middle Rio Grande valley in New Mexico, where Rio Grande silvery minnow currently exist, extends from Cochiti Dam downstream 260 river km (160 mi.) to San Marcial. The middle Rio Grande valley constitutes 8% of the River's total length and 34% of its length in New Mexico. The valley's direct drainage accounts for 7% of the total Rio

Grande drainage and about half of New Mexico's direct tributary drainage. The middle Rio Grande valley has an arid to semiarid climate typical of the southwestern United States. The climate is characterized by abundant sunshine, low relative humidity, light precipitation, and wide diurnal temperature fluctuations. The average annual precipitation varies from 178 mm (7 in.) to 380 mm (15.25 in.) over two-thirds of the basin and may exceed 635 mm (25 in.) only in the high mountain areas. Winters are generally dry, and snow rarely remains on the ground at low elevations for more than 24 hours. Snowfall in the high mountains composes 30-75% of the total annual precipitation; in the remainder of the basin snowfall composes less than 25% of the annual precipitation. Summer precipitation supplies almost half of the annual moisture. Most of the rain falls in brief, though sometimes intense, convective thunderstorms. These summer thunderstorms have a considerable moderating effect on daytime temperatures. The periods transitional to summer and winter (March through May and September through October) are associated with some of the largest flood-generating storms. Prevailing winds are from the southwest and typically are continuous during the spring months. Evaporation rate is high throughout the lower elevations of the basin and is highest in the southern part of the basin, where arid conditions exist.

The Rio Grande, known as the Rio Bravo del Norte in Mexico, marks the 2000 km. (1,248-mile) boundary between Texas and Mexico. This stretch flows in a generally southeasterly direction through Texas from El Paso to Brownsville. The Rio Conchos rises in the Sierra Madre Occidental in Mexico and flows in a northeasterly direction to join the Rio Grande near Presidio, Texas. The Pecos River rises in the Sangre de Cristo Mountains in New Mexico and flows in a southeasterly direction to confluence with the Rio Grande near Langtry, Texas.

The Rio Grande and its tributaries drain a land area in three U. S. states (Colorado, New Mexico and Texas) and five Mexican states (Chihuahua, Coahuila, Durango, Nuevo Leon and Tamaulipas). However, only about half of this total area actually drains into surface waters that eventually flow into the Gulf of Mexico. The other half is composed of closed sub-basins, which do not discharge directly into the Rio Grande.

The northern portion of the Rio Grande in Texas is mostly desert. The climate becomes less arid and more tropical as the river flows south. In general, the region is hot and windy. The basin averages more 38 degree C (100 degree F) days than any other part of Texas for the months of May through September. Temperatures are generally higher in the southern part of the basin than in the northern part.

The upper Rio Grande (in Colorado and New Mexico) the Pecos River and the Rio Conchos (in Chihuahua) receive flow from snow melt. Springs, seasonal rains, and occasional tropical storms provide most of the flow in the lower part of the basin. In Texas, the upper part of the basin has less precipitation than the lower part. Average rainfall ranges from 19.9 cm (7.82 inches) at El Paso, 31.0 cm (12.21 inches) at Fort Stockton, and 51.2 cm (20.14 inches) at Laredo, to 64.6 cm (25.44 inches) at Brownsville.

Prior to measurable human influence on the Rio Grande, pre-14th century (Biella and Chapman 1977), it was a perennially flowing, aggrading river with shifting sand substrate. Its channel pattern was, as a rule, braided and slightly sinuous. The river would freely migrate across the floodplain, the extent being limited only by the valley terraces and bedrock outcroppings. The Rio Grande's bed would aggrade over time; then, in response to a hydrologic event or series of events, it would leave its elevated channel and establish a new course at a lower elevation in the valley, in a process called river avulsion (Leopold et al. 1964). Although an aggrading, system the Rio Grande was in a state of dynamic equilibrium, providing periods of stability that allowed riparian vegetation to become established on river bends and islands alternating with periods of instability (e.g., extreme flooding) that provided, by erosion and deposition, new locations for riparian vegetation.

HISTORY OF DEVELOPMENT

Early Years

The Rio Grande above El Paso, Texas, is one of the oldest regions of continuously irrigated agriculture in the United States. Irrigation along the river and its tributaries extends back centuries to prehistoric inhabitants of the Rio Grande valley. When the Spaniards reached the valley they found the predecessors of the present day Pueblo Indians practicing irrigated agriculture. In the 16th century the Spanish began their settlements along, and irrigated from, the river. In the middle Rio Grande valley of New Mexico, this development peaked between 1850 and 1880 with an irrigated area of about 50,600 hectares or 125,000 acres (Clark 1987). Development in the El Paso area was contemporaneous with the Spanish colonization of the New Mexico portion of the Rio Grande basin; by 1896, about 16,200 hectares (40,000 acres) was irrigated near El Paso. Development in the Mesilla and Rincon valleys of southern New Mexico did not occur until the mid 19th century (Clark 1987). All of the irrigation during this time was by ditches cut from the river, aided by temporary check dams constructed during periods of low flow.

Initial irrigation diversions in the San Luis Valley of Colorado, above which the headwaters of the Rio Grande lie, began around 1850 (with Hispanic settlement and development), but were minimal until about 1880 following the arrival of the Anglo-Americans and inception of large canal projects (Follett, 1896). The first appropriations in the San Luis Valley began in the 1850s on the Conejos River. The first appropriation on the Rio Grande mainstem was in 1866 and the most extensive development for irrigation purposes on both rivers was between 1880 and 1890. High spring runoff and low summer flows in valley streams, coupled with years of severe drought, resulted in undependable water supplies; thus, farmers turned to wells to supplement and regulate the water supply. Well construction in the San Luis Valley began during this time (1950s) and remains an integral part of the overall irrigation system in the Valley, using both artesian waters and shallow ground water derived from natural recharge as well as that caused by surface water irrigation.

Because the rapid development of the San Luis Valley was at its limits, local irrigators were developing plans for the construction of surface water storage reservoirs. The irrigation depletions in the San Luis Valley and the middle Rio Grande valley in New Mexico combined with drought resulted in the water supply shortages in the El Paso, Mesilla Valley and Juarez areas during the 1880s and 1890s. Protests from these areas, in particular on behalf of Juarez by the Mexican government, led to the era of river regulation by law and by dams.

The situation on the Rio Grande in the late nineteenth century was reported to the International Boundary Commission by Follett (1896). A summary of Follett's findings are quoted as follows:

- The fact of a decrease in the flow of the river at El Paso exists, as claimed, and dates back to 1888 or 1889. Before those years the river went dry at intervals of about 10 years. Since 1888 it has been dry every year but two.
- The use of water for irrigation has not materially increased in New Mexico since 1880, and hence is not the cause of this decreased flow.
- The use of water in the San Luis Valley of Colorado has very largely increased since 1880, and at the present stage of development it takes from the river, in excess of what was taken in 1880, an amount of water equivalent to a flow of 1,000 second-feet, running for 100 days; at least this amount is taken and possibly more.
- It is impossible to state specifically how much water was in the river prior to this increased use of water and since, as the records do not antedate this increased use, and as the flow since the records began varies within very wide limits.
- This flow of 1,000 second-feet, if allowed to remain in the river, would do much toward preventing a dry river at El Paso.
- The Mexican and American citizens of the El Paso Valley have suffered in common with their neighbors of the Mesilla Valley and those still farther up the river by this Colorado increased use of water. The suffering has been greater in the El Paso Valley than elsewhere.
- All of the summer flow of the streams in the San Luis Valley, except their flood waters, are now appropriated, and therefore the use of water therein for direct irrigation is not likely to materially increase in the future.

The Embargo of 1896 and Construction of Elephant Butte Reservoir

A governmental-imposed embargo in 1896 on the use of public land for right of way in New Mexico and Colorado for further irrigation development effectively stopped the building of dams while the embargo was in place through 1925. Following the passage of the Reclamation Act in 1902, Elephant Butte Reservoir was authorized as a Reclamation project in 1905 to accommodate irrigation demands downstream in both New Mexico and El Paso County, Texas, and in anticipation of the Mexican Treaty of 1906 that committed the United States to delivering 74 million cubic meters (60,000 acre-feet) per year to Mexico. Elephant Butte was completed in 1916, with an initial capacity of 3.27 billion cubic meters (2.65 million acre-feet).

San Luis Valley Storage Development

Practically all storage development to date in the Upper Rio Grande Basin, by reservoirs of 1.2 million cubic meters (1,000 acre-feet) capacity or more, has been for irrigation purposes.

Although the need for storage to regulate the water supply of the Rio Grande and Conejos basins for irrigation in the San Luis Valley was indicated in the early eighteen-nineties, construction on any large scale was prevented by the 1896 embargo. This was effective until 1925, and since 1929, storage development of magnitude has been limited by the terms of the Rio Grande Compact. The major storage development for San Luis Valley lands that could be accomplished notwithstanding the embargo took place in the period from about 1908 to 1914. Platoro Reservoir on the Conejos River is the only major post-Compact storage in the basin in Colorado and was constructed by the U.S. Bureau of Reclamation in 1951.

The embargo was opposed in Colorado, since even by 1896 the irrigated lands in the San Luis Valley used all the available natural flow of the Rio Grande and its tributaries in that valley. Storage appeared necessary not only for further development but even to maintain existing developments. But storage of any magnitude was impossible under the embargo. The effort of Colorado to secure permission to build reservoirs thus began early.

In the meantime, the Rio Grande system depletions in Colorado and drought, combined with the irrigation systems and practices in the middle Rio Grande valley of New Mexico, led to problems for its irrigators and those who lived there. Middle Rio Grande valley irrigation practices consisted of scores of discrete diversions and related acequias that carried water from the river to the fields. As irrigation development peaked in the middle valley, this practice gradually led to much of the land being seeped and fields being salt-laden. The naturally aggrading stream became more aggraded as it was depleted of water and had less energy to carry sediment downstream. This lead to a river perched above the surrounding fields, villages and towns, that made them vulnerable to and were frequently devastated by flooding.

Development of the Middle Rio Grande Conservancy District

After the turn of the century, the middle Rio Grande valley in New Mexico was in crisis; with cultivated land being lost to seeping and alkalinity, the total cultivated land dropped to about 16,200 hectares (40,000 acres); downtown Albuquerque was in danger of becoming a swamp; the town of San Marcial, where the river had aggraded 4 meters (12 to 14 feet) in 50 years, was destroyed in the 1929 flood. The solution to this crisis was the formation of the Middle Rio Grande Conservancy District (MRGCD), covering the Cochiti to Bosque del Apache reach of the river. The mission of the MRGCD and its accomplishments were to (1) establish, straighten and narrow the river through jetty jacks and levees, (2) construct a system of riverside and valley interior drains to draw and flush the salt from the seeped lands, (3) develop a comprehensive system of diversion dams, canals and laterals, and (4) construct El Vado Reservoir on the Rio Chama for water storage and flood control. Four permanent diversion dams, crossing the Rio Grande at

Cochiti, Angostura, Isleta and San Acacia replaced the eighty-some acequias and their temporary mud and brush dams that had been used. El Vado, with a capacity of 229 million cubic meters (186,000 acre-feet) was the second major reservoir on the Rio Grande system, being completed in 1935.

The Rio Grande Compact

Legal regulation of the river, beyond the Treaty of 1906 and the embargo of 1896, continued with the negotiation of the Rio Grande Compact among Colorado, New Mexico and Texas, to resolve the continuing interstate concerns on the sharing of Rio Grande waters. In 1923, the three states began steps toward negotiating an agreement on sharing the waters of the Rio Grande. With the lifting of the embargo in 1925 by the Secretary of the Interior, Colorado was in a position to increase its diversions of Rio Grande water through reservoir construction which gave it a more favorable bargaining position in compact negotiations and made it imperative to the downstream states that a Compact be put in place. A "status quo" compact was agreed to in 1929, pending investigations (the Rio Grande Joint Investigation completed in 1937) needed for the permanent compact. The permanent compact became effective May 31, 1939, and administration of the river under its terms began in 1940.

The compact has been the "Law of the River" since that time and allocates the water of the river between the states. The consumptive use or depletive effect to which Colorado and New Mexico are entitled is fixed by the delivery schedules, thereby determining the amount of water available at the lower terminus of their respective compact reach. The delivery schedules were determined by the inflow/outflow relationships in each portion of the basin during the study period (1928-37 for Colorado and 1909-30 for New Mexico) and sought to fix the level of depletion from the headwaters to the Colorado-New Mexico stateline and between Otowi and Elephant Butte Reservoir which existed during the study period. The flows that arrived at those points during the study period were determinate of the future delivery obligations of the two upstream states. The Rio Grande Compact therefore generally fixes the amount of water expected to flow from one compact reach to the next over the calendar year. The amount and timing of these flows is highly dependent on snowmelt runoff patterns, flood control activities, and rainstorm events throughout the year.

The Rio Grande Compact mandates water deliveries by Colorado on the Rio Grande at the New Mexico stateline amounting to a percentage of the gaged flows on the Rio Grande and Conejos River above the San Luis Valley. This percentage increases as the gaged flows above the San Luis Valley increases, ranging from about 20% in very dry years to over 60% in very wet years. The Compact also requires New Mexico to deliver into Elephant Butte Reservoir a quantity of water amounting to a percentage of the flow measured at the Rio Grande at Otowi gage located upstream of Cochiti Reservoir above the middle Rio Grande valley. This percentage also increases as the gaged native flow at Otowi increases, ranging from about 57% in dry years to about 86% in extremely wet years.

The Compact allows for under and over-delivery of water (debits and credits) from the scheduled deliveries; Colorado's and New Mexico's individual cumulative debits were not to exceed 123 million cubic meters (100,000 acre-feet) and 247 million cubic meters (200,000 acre-feet), respectively, except as either or both may be caused by holdover storage of water in post-compact reservoirs. The Compact also provides that accumulated debits or credits (to the extent that the spill exceeds accrued credit) would go to zero in any year in which actual spill occurs, and that neither state has delivery requirements in the year of a spill. The Compact also limits the use of post-1929 reservoirs, such as El Vado, when New Mexico is in a debit status and places similar limits on reservoirs constructed in Colorado after 1937. As a practical matter this has meant that El Vado was unavailable for use by the MRGCD during the many years of compact history that New Mexico has been in debit status, except for delivery to Pueblo land with prior and paramount water rights. The reader is directed to the Rio Grande Compact for details on specific provisions of the compact.

Caballo Dam and Rio Grande Canalization Project

Closure of Elephant Butte Dam had the result of cutting off annual flood flows that tended to scour the stream bed, hastening the aggrading, meandering and braided nature of the river below the dam. In 1933, the United States and Mexico entered into an agreement to straighten and stabilize the aggraded Rio Grande from El Paso to Fort Quitman, where the river is also the boundary between the two countries. In addition, the United States agreed to build Caballo Dam and Reservoir 35 km (22 miles) below Elephant Butte Dam. Caballo Reservoir, with a current capacity of 408 million cubic meters (331,000 acre-feet), was completed in 1938 for flood protection for the El Paso/Juarez area to which 123.3 million cubic meters (100,000 acre-feet) is dedicated as flood space and under the authority cf the International Boundary and Water Commission, for reregulation space to allow hydroelectric generation at Elephant Butte Dam and for water conservation purposes. In 1935, Congress authorized the Rio Grande Channelization Project, Caballo Dam to El Paso, which was undertaken to provide more efficient water delivery and alleviate the threat of flooding.

Middle Rio Grande Project (Flood Control Act of 1948)

Following the wet years of 1941 and 1942 that caused numerous failures of the MRGCD-built levees in the middle Rio Grande valley in New Mexico and extensive flooding of both urban land (the railroad tracks through downtown Albuquerque defined the river course for some weeks in 1941) and farmland in both years, a drought ensued that persisted with only minor episodes of relief into the 1980's. The drought coincided with the deterioration of MRGCD facilities, from the diversion dams to the drains and spoil-fill levees devastated by the 1941-1942 flooding. Aggradation continued raising the river higher above the developed land in the valley. Lack of maintenance on the drains and the rise in the river bed above the drain outlets to the river drastically impaired their effectiveness, leading to renewed water-logging of the valley.

A dramatic decrease in the efficiency of the delivery of water to Elephant Butte Reservoir occurred during this time due to the creation of a huge delta deposited in the upper reservoir area as a result of sediment-laden water losing its velocity above the reservoir during times when it was full or almost full. With the combination of dry succeeding years, poorly functioning mid-valley drains and the barrier to efficient flow created by the sediment delta above and within the Elephant Butte Reservoir area as it was drawn down after 1942, New Mexico was regularly unable to make its Compact deliveries and there were frequent shortages of water to the MRGCD.

Following reports by the Bureau of Reclamation and the Corps of Engineers, Congress passed the Flood Control Act of 1948 to address these problems. The essential features of this legislation were projects by the Bureau of Reclamation to rehabilitate the MRGCD's works and to construct what was to become the low flow conveyance channel to provide a route for more efficient water delivery through the sediment delta above and within Elephant Butte Reservoir. The act also authorized the Corps of Engineers to construct flood and sediment control dams on the Rio Grande, Rio Chama and Jemez River. As finally authorized and constructed, these were Abiquiu Dam on the Rio Chama and Jemez Canyon Dam on the Jemez. Finally, much of the levee system in the middle Rio Grande valley in New Mexico, particularly in the Albuquerque reach, was to be rebuilt.

With the extensive placement of jetty (Kellner) jacks along the sides of a 180 m (600 feet) cleared river channel, the previously meandering and braided river within the MRGCD levees became confined within the newly-defined and straighter water course with stabilized banks. As water was slowed by the jetty jacks, sediment would drop out providing a place for cottonwoods and other plants to colonize. This gave the river the well-defined character one can see today from the air compared to the levee to levee expanses of sand and sharp turns that formerly existed on much of the river.

Constructed between 1951 and 1959, the project that became the low flow conveyance channel (LFCC) was initially characterized as "the dredging of 20 miles of river channel above the head of Elephant Butte Reservoir." (H.D. 653, p. 10). By the time this project was initiated on the ground, Elephant Butte Reservoir had receded to below the "narrows". From at least the south boundary of the Bosque del Apache to the narrows, the river was discontinuous and largely consisted of a broad, diffuse salt cedar wetland. A contemporaneous Bureau of Reclamation estimate of the annual loss of water between San Antonio and the narrows was about 240.4 million cubic meters (195,000 acre-feet) (Initial Stage Channel Rectification, Middle Rio Grande Project, 1951).

The first phase of the project constructed a below grade channel from the narrows to the south end of San Marcial Lake. Then a channel was cut from the north end of the lake to a river heading near the south boundary of the Bosque del Apache Wildlife Refuge. Diversions at this heading began in November 1953. Sediment laden water was diverted through this heading into San Marcial Lake where sediment deposition occurred. Clearer water was decanted over the grade structure and conveyed to the reservoir. In 1958, the LFCC was connected through the silted up bed of San Marcial Lake. At the same time these channels were being built, a new "floodway" on the east side of the valley was excavated through the salt cedar delta by clearing and grubbing a 305 m (1,000 feet) wide strip essentially paralleling the conveyance channel. In 1956, the LFCC was extended from its Bosque del Apache terminus to a new heading at San Acacia, again with the creation of a parallel 180 m (600 feet) cleared "floodway." The finished LFCC was, 110 km (68 miles) long including the portion within Elephant Butte Reservoir, was designed for a capacity of 57 cms (2,000 cfs) with a heading from the river at the San Acacia Diversion Dam.

The lower portion of the LFCC beginning near San Marcial began operations in 1954. The completed LFCC was put into service near the end of 1959 and functioned continuously for essentially its full length until late summer of 1974 when discontinuities began with shunting water that had been diverted into the LFCC at San Acacia back into the river at an outfall a mile or so above the railroad bridge at San Marcial. With this operation, the upper 80 km (50 miles) remained fully functional.

Over time, the lower portions of the channel sedimented in to a point that delivery of water was impaired. Much rehabilitation work was done in the late 1970s and early 1980s, however, diversion of water to the LFCC at San Acacia was suspended in March 1985 as Elephant Butte Reservoir was filling for the first time since 1942. Water has not been diverted into the LFCC at San Acacia since that time, except for small amounts of water diverted in 1996 and 1997 which were returned to the river channel at an outfall constructed about 15km (9 mi.) downstream from San Acacia.

The LFCC continues to operate as a drain to collect water discharged from the shallow ground water and from irrigation return flows and water seeped from the Rio Grande floodway. Generally, during the irrigation season, the flow in the LFCC will gain between 5.7 cms (200 cfs) and 8.5 cms (300 cfs) from ground water and return flows between San Acacia and San Marcial.

An integral part of the middle Rio Grande project as authorized by the Flood Control Act of 1948 was the construction of flood control and sediment control dams in the Rio Grande watershed above the middle Rio Grande valley in New Mexico. The authorized purpose was to reverse the continuing aggradation through trapping sediment in the new reservoirs and using the sediment-free reservoir releases as scouring flows to degrade the riverbed. This increased channel capacity lessened flood risks and helped restore functioning of the MRGCD drains where the river bed had become higher than drain outfalls. Large amounts of sediment were carried to the river from the Rio Chama and Jemez River as well as from smaller creeks and arroyo flows up and down the river. Large sediment loads also entered the river from Rio Puerco and Rio Salado flows, a few miles upstream of San Acacia, but sediment control facilities on these stream systems have not been developed.

Jemez Canyon Dam and Reservoir, the first authorized flood control structure, was constructed on the Jemez River, two miles upstream of its confluence with the Rio Grande, north of Bernalillo and south of Cochiti Dam. The dam was completed in 1953, and has a capacity of 130.7 million cubic meters (106,000 acre-feet). No conservation storage is allowed in the reservoir, but a sediment retention pool was created with San Juan-Chama Project water in 1979.

The next structure constructed was Abiquiu Dam and Reservoir, completed in 1963 on the Rio Chama about 50 km (32 miles) upstream of its confluence with the Rio Grande at Espanola. With a physical capacity of 1.48 billion cubic meters (1.2 million acre-feet), it had an initial authorized flood and sediment control capacity of 619 million cubic meters (502,000 acre-feet) and 94.9 million cubic meters (77,000 acre-feet), respectively. There has been San Juan-Chama Project water stored in Abiquiu Reservoir since the early 1970s, first in the sediment pool space, and then, following authorization by Congress (P.L. 97-140) in 1981, up to 246 million cubic meters (200,000 acre-feet) of San Juan-Chama Project water in the sediment/flood space. In 1989, Congress authorized storage of native water in this space when it is not needed for San Juan-Chama Project water storage (P.L. 100-522).

The 1960 Flood Control Act (P.L. 86-645) authorized Galisteo and Cochiti Dams. Galisteo Dam, completed in 1970, has an 109 million cubic meters (89,000 acre-foot) capacity designed for flood and sediment control from thunderstorm events and has an uncontrolled outlet that restricts releases to about 142 cms (5,000 cfs). Galisteo Creek enters the Rio Grande below Cochiti Dam. Cochiti Dam, below the Otowi gage, was completed in 1975 as a flood and sediment control structure with a capacity of 722.5 million cubic meters (586,000 acre-feet). In 1964, Congress authorized the creation of a permanent recreation pool of 486 hectares or 1200 acres (about 61.6 million cubic meters or 50,000 acre-feet) using San Juan-Chama Project water.

Except for the storage authorized by P.L. 100-522 and imported San Juan-Chama Project water, the Corps flood control reservoirs are only authorized to store water to prevent downstream flood damage from high flows with a requirement to release the stored flood water as fast as downstream conditions permit. Thus, the effect of a flood control operation is to spread flood peaks. P.L. 86-645 provides that,

> "whenever during the months of July, August, September, and October, there is more than two hundred twelve thousand acre-feet of storage available for regulation of summer floods and the inflow to Cochiti Reservoir (exclusive of that portion of the inflow derived from upstream flood control storage) is less than one thousand five hundred cubic feet per second, no water will be withdrawn from storage in Cochiti Reservoir and the inflow derived from upstream flood-control storage will be retained in Cochiti Lake."

In practice, this provides the possibility of carryover storage in both Cochiti and Abiquiu Reservoirs. In order to minimize carryover flood storage in Cochiti, the Corps manages the system, when carryover storage is indicated, to hold as much of it as possible in Abiquiu. This provision is in place (and can be waived with consent of the Rio Grande Compact Commission) to preclude the depletion through the middle valley of released flood storage that would have otherwise reached Elephant Butte Reservoir but for the storage. All flood control storage must be evacuated by March 31 of the following year.

A purpose of the dams was to change the middle valley reach of the river from an aggrading to a degrading stream. Combined with the channel work and jetty jack placement a streambed is being incised below the banks of the surrounding flood plain. The levees acted to contain the historic meander of the river across a wide floodplain that over time deposited the sediment over its breadth. Trapping much of the sediment in the dams combined with the channelization work has changed the character of the river from a usually sediment-laden, shallow, braided stream to a more channelized, swifter flowing stream.

Elephant Butte and Cochiti Dams have effectively bracketed the middle Rio Grande valley in New Mexico. (See Table 3 for a tabulation of major reservoirs in the Rio

Grande Basin.) Within the middle Rio Grande valley, the three diversion dams at Angostura, Isleta and San Acacia can act as barriers to fish movement within the reach, particularly during periods of low flows. In periods of low flow and often when supplemental water from upstream storage is being utilized, MRGCD operations at Isleta and San Acacia diversion dams result in dewatered reaches between Isleta and Elephant Butte Reservoir. During periods of low flow, water for irrigators in the Socorro division can be diverted at Isleta and delivered all the way by the drain and canal system.

San Juan-Chama Project

In 1962, Congress authorized construction of the San Juan-Chama Project for the principal purposes of furnishing water for agricultural, municipal, domestic, and industrial uses, and for providing recreation and fish and wildlife benefits (Public Law 87-483). Project works divert San Juan River Basin water by way of tunnels, the last through the Continental Divide, to Heron Reservoir on Willow Creek, a tributary of the Rio Chama, just above El Vado Reservoir. The firm yield of the San Juan-Chama Project is 118.6 million cubic meters (96,200 acre-feet) per year, of which about 93.7 million cubic meters (75,400 acre-feet) is dedicated for use in the middle Rio Grande valley in New Mexico, including 59.4 million cubic meters (48,200 acre-feet) to the City of Albuquerque, 25.8 million cubic meters (20,900 acre-feet) to the MRGCD and 6.2 million cubic meters (5,000 acre-feet) to the Cochiti Reservoir recreation pool and smaller amounts to Los Lunas, Belen and Bernalillo. Ninety-five per cent (95%) of the firm yield of the San Juan-Chama Project has been committed to authorized purposes under fourteen contracts.

Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA)

Following several large, damaging floods east of the Rio Grande in urban Albuquerque in 1955, 1961 and 1963, AMAFCA was created in 1963 to address and alleviate the problems of urban flooding from unregulated ephemeral tributaries. A series of concrete lined drainage channels were constructed from arroyos at the foot of the Sandia Mountains and feed into the Rio Grande. Discharges from these drainage channels are collected and flow into the Rio Grande near Alameda and at Tijeras Arroyo.

The Closed Basin Project

The Closed Basin Project in Colorado was authorized by P.L. 92-514 in 1972. The project consists of 170 salvage wells that remove groundwater from the unconfined aquifer in the Closed Basin and discharge the water into the Rio Grande southeast of Alamosa. The water would otherwise be lost by evapotranspiration. The first stage of the Project became operational in 1986, with total Project completion in 1993. To date, about 246.5 million cubic meters (200,000 acre-feet) has been delivered to the Rio Grande.

Table 3. Major reservoirs in Colorado and New Mexico in the Rio Grande basin. (Source: in part, Shupe and Folk-Williams, 1988)

Reservoir	River/Location	Primary Owner	Authorization	Purpose	Year completed	Conservation Storage Capacity	Total storage capacity
Rio Grande	Rio Grande mainstem headwaters.	San Luis Valley Irrigation District	non-federally financed	Irrigation	1912	51,000 af	51,000 af
Platoro	Conejos River.	Bureau of Reclamation	1941 Interior Appropriation Act	Water supply and flood control	1951	54,000 af	60,000 af
Heron	Willow Creek, 0.2 mi. upstream of Rio Chama.	Bureau of Reclamation	1962 (PL 87-483)	Terminal storage for San Juan-Chama Project.	1971	400,000 af	400,000 af
El Vado	Rio Chama, 78 mi. above mouth.	MRGCD	non-federally financed	water supply storage, hydroelectric power.	1935	186,000 af	186,000 af
Abiquiu	Rio Chama, 32 mi. above mouth.	Corps of Engineers	1948 Flood Control Act (PL 80-858)	Flood and sediment control, water supply.	1963	200,000 af	1.2 million af
Cochiti	Rio Grande, river mile 1,588.	Corps of Engineers	1960 flood control act (PL 86-645)	Flood and sediment control, fish and wildlife enhancement.	1975	0	586,000 af
Galisteo	Galisteo Creek, 12 mi. above mouth.	Corps of Engineers	1960 flood control act (PL 86-645)	Flood and sediment control.	1970	0	89,000 af
Jemez	Jemez River 3 mi. above mouth.	Corps of Engineers	1948 Flood Control Act (PL 80-858)	Flood and sediment control.	1954	0	106,000 af
Elephant Butte	Rio Grande, at river mile 1,383.	Bureau of Reclamation	1905 Act	Water supply, hydroelectric power.	1916	2.1 million af	2.1 million af
Caballo	Rio Grande, at river mile 1,357.	Bureau of Reclamation	Acts in 1935 & 1936	Water supply, flood control.	1938	231,000 af	331,000 af
Santa Rosa	Pecos River, at river mile 757.	Corps of Engineers	1954	Water supply, flood and sediment control.	1980	(varies)	440,000 af
Sumner	Pecos River, at river mile 702.	Bureau of Reclamation	1935	Water supply, flood control.	1937	(varies)	95,000 af
Brantley	Pecos River, at river mile 479.	Bureau of Reclamation	86 Stat. (1972)	Water supply, flood and sediment control.	1988	40,000 af	1 million af

Hydrology and Hydrologic Modifications of the Rio Grande below Caballo Dam

The major tributaries of the Rio Grande below Caballo Dam are the Devils and Pecos Rivers in Texas and the Rio Conchos, Rio Salado, Rio San Juan, Rio Alamo, and Rio San Rodrigo in Mexico. Many of the river's minor tributaries are intermittent streams that cease to flow during the dry period of the year. In portions of the reach below El Paso the flow of the Rio Grande is not always continuous.

The Rio Grande waters reaching Texas are primarily provided by releases from Elephant Butte and Caballo Reservoirs. Before the waters of the Rio Grande reach the cities of El Paso and Juarez, most of the flow is diverted for irrigation and municipal uses at the American Dam (Texas) and the International Dam (Acequia Madre, Mexico). Downstream of El Paso most of the flow consists of occasional storm run-off, treated municipal wastewater from El Paso and irrigation return flows. From El Paso to Presidio, the flow is intermittent. Inflow from the Rio Conchos near Presidio provides a perennial base flow and over three-quarters of the flow to the Big Bend reach of the Rio Grande.

In the middle reach of the Texas part of the basin, the construction of International Falcon Dam in 1953 and International Amistad Dam in 1968 resulted in the most significant hydrologic modifications to the flow of the lower Rio Grande. Both of these dams were constructed by the International Boundary and Water Commission (IBWC) under the terms of the 1944 Water Treaty between the U. S. and Mexico. Also, Red Bluff Dam and Reservoir was constructed on the Pecos River just downstream of the Texas-New Mexico state line in 1936. On the Pecos River in New Mexico, Lakes McMillan and Avalon were originally constructed in the early 1890s (Brantley Reservoir replaced Lake McMillan in 1989), Sumner Lake was constructed in 1937 as Alamogordo Reservoir, and Santa Rosa Reservoir was built in 1980. Water deliveries by New Mexico in the Pecos River at the Texas stateline are subject to administration in accordance with the Pecos River Compact of 1949 and the United States Supreme Court's 1988 Amended Decree in Texas v. New Mexico.

In the Lower Rio Grande Valley (Starr, Hidalgo, Willacy and Cameron Counties) the floodplain of the Rio Grande narrows considerably and is less than a mile wide in northwestern Starr County where the river leaves the impoundment of Falcon Dam. The floodplain is about 9.7 kilometers (six miles) wide in Hidalgo County but then broadens into a wide delta fronting the Gulf of Mexico near the mouth of the river in Cameron County. The flow discharges directly into the Rio Grande, except during floods, when much of the water is diverted into flood channels and thence to the Laguna Madre.

Other hydrologic modifications include canal construction near El Paso, and river channel and levee projects on the mainstem of the Rio Grande, such as the American Canal extension project in El Paso. Anzalduas Diversion Dam and Retamal Diversion Dam in the Lower Rio Grande Valley were constructed after floods in 1958 and 1967. Anzalduas Diversion Dam diverts flood waters to the interior floodways in the Lower Rio Grande Valley. It is also used as a diversion point for irrigation by Mexico. Retamal Diversion Dam diverts floodwater into Mexico's interior floodway system.

Treaty on the Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (Water Treaty of 1944)

The Water Treaty of 1944 provides for the distribution of waters of the Rio Grande between the United States and Mexico from Fort Quitman downstream to the Gulf of Mexico. Texas is the recipient of all waters allocated to the United States under the Treaty. All measured waters originating in the United States belong to the United States. Two-thirds of the flow of certain Mexican tributaries is allotted to Mexico and one-third to the United States, provided that the one-third allotted to the United States shall not be less than 431.5 million cubic meters (350,000 acre-feet) (computed as an average in cycles of five consecutive years). All unmeasured inflows are divided equally between Mexico and the United States.

Operations of the Rio Grande - Texas/Mexico

Operations of the Rio Grande in Texas are generally divided into two regions (above Fort Quitman and below Fort Quitman) based on two treaties between the United States and Mexico. The Rio Grande in Texas is over appropriated, with demand exceeding supply.

Above Fort Quitman, the 1906 Treaty with Mexico provides for the delivery of 74 million cubic meters (60,000 acre-feet) of water to Mexico. Mexico takes its water at International Dam in El Paso. Any water which passes this point belongs to Texas until it reaches Fort Quitman where it is reapportioned in accordance with the 1944 Treaty with Mexico. Water stored in Elephant Butte and Caballo Reservoirs are used to supply water to the Elephant Butte Irrigation District and the El Paso County Water Improvement District (WID) #1. Each has the right to call for releases from Elephant Butte Reservoir. Also, the Hudspeth County Conservation and Reclamation District uses the return flows from the El Paso WID #1 as their primary source of water. This water is collected before it reaches the Rio Grande via canals and diverted from the Rio Grande. The City of El Paso continues to increase the amount of water they use from the Rio Grande. They acquire rights via contract from the El Paso County WID #1. The system is operated to minimize flows past Fort Quitman. Excess releases from Elephant Butte may reduce future years water supply and the likelihood of a "spill" pursuant to the Rio Grande Compact.

Below Fort Quitman, all water rights have been adjudicated and are administered under the Texas Natural Resource Conservation Commission's (TNRCC) Rio Grande Watermaster Program. For the reach from Fort Quitman to Amistad Reservoir, the diversions are from run of the river waters. For diversions below Amistad and Falcon Reservoirs, the watermaster tabulates the water requests and asks for water releases from Amistad and Falcon Reservoirs. The watermaster's requests for releases are made to the International Boundary and Water Commission (IBWC). In a similar manner, Mexico also requests releases from their allotment of water in Falcon and Amistad Reservoirs. Their requests are made through their section of the IBWC. The IBWC maintains an account of water for the United States and Mexico pursuant to the Treaty of 1944. The TNRCC Rio Grande Watermaster (RGWM) program is charged with allocating the water to all Texas water rights holders. Any water user who wishes to divert water must contact the watermaster for prior approval before diverting water. Each water user has an account from which water is withdrawn. The predecessor agency to the TNRCC assumed responsibility for this program in 1971, which began in the 1950s under jurisdiction of the courts. The Rio Grande Watermaster operates the system to minimize releases from Falcon and Amistad Reservoirs and strives to keep flows past the last diversion point into the Gulf of Mexico to a minimum. There is no requirement for releases from the reservoir to maintain minimum instream flows in the Rio Grande below Caballo Dam. Table 4 is an inventory of hydraulic structures in the Rio Grande Basin in Texas and Mexico.

Table 4. Structure inventory: Rio Grande, Texas and Mexico

NAME	State (if trib of RG)	Water Body	Year Const.	Constructed Capacity (acre-feet)
*American Diversion Dam		Rio Grande	1938	small div. structure
*International Diversion Dam		Rio Grande	1940	small div. structure
*Riverside Diversion Dam		Rio Grande	1940	small div. structure
Red Bluff Dam and Reservoir	Texas	Pecos River	1936	289,700
Amistad Dam and Reservoir		Rio Grande	1968	3,151,362
Falcon Dam and Reservoir		Rio Grande	1953	2,673,418
Anzalduas Dam and Reservoir		Rio Grande	1958	13,911
Retamal Dam and Reservoir		Rio Grande	1967	pass thru (flood control)
Venustiano Carranza	Coahuila			1,114,726
Piedritas	Coahuila			20,268
Nochebuena	Coahuila			32,428
San Miguel	Coahuila			19,457
La Fragua	Coahuila	Rio San Rodrigo	1992	36,482
Centenario	Coahuila			16,214
La Boquilla	Chihuahua	Rio Conchos	1916	2,224,588
Luis Leon	Chihuahua	Rio Conchos	1968	616,140
Chihuahua	Chihuahua		1960	19,457
La Rosetilla	Chihuahua			16,214
Fco Madero	Chihuahua		1949	344,552
La Colina	Chihuahua			14,593
Pico Del Aguila	Chihuahua			40,536
San Gabriel	Durango		1979	194,570
La Boca	Nuevo Leon			33,239
El Cuchillo	Nuevo Leon	Rio San Juan	1993	829,356
Cerro Prieto	Nuevo Leon			318,609
Salinillas	Nuevo Leon			15,403
Marte Gomez	Tamaulipas	Rio San Juan		755,582

* The dates associated with these structures reflect the current facilities.
On or about 1916, rock type structures were constructed and operated at these locations.

PECOS RIVER

Geography and Climate

The principle tributary of the Rio Grande in the United States, the Pecos River rises in high altitudes in the southern terminus of the Sangre de Cristo mountains in north-central New Mexico and flows southward some 1450 km. (900 miles) to join the Rio Grande in the international reach of the Rio Grande, draining some 64,750 sq. km. (25,000 square miles) in New Mexico and 49,200 sq. km. (19,000 square miles) in Texas. Watershed elevations in the basin vary from above 3900 meters (13,000 feet) at the river's source, to about 300 meters (1,000 feet) at its mouth. Most of the valley's 11.3 million hectares (28 million acres) are semiarid. About 98% of the watershed of the Pecos River is used for grazing, the remainder for cropland and municipal development. About 64% of the total area is privately owned, 18% is state owned, and 18% is federally owned or administered.

Climatic conditions vary considerably within the watershed, owing principally to variations in geographic location and topography. Generally speaking, the summers are warm in the upper part and hot in the lower part. Maximum and minimum temperatures of 116 degrees F and -35 degrees F have been recorded in Artesia, which has an elevation of 1020 meters (3,350 ft.) The average growing season at the lower elevations in Texas is about 220 days, extending from late March to mid-November. The period shortens with increasing elevation and latitude to about 100 days, from early June to mid-September, in the mountainous areas of New Mexico. The average annual precipitation varies from about 254 mm. (10 inches) in the vicinity of Pecos, Texas, to more than 762 mm. (30 inches) in the mountains at higher elevations. Snowfall follows the same general pattern, varying from 7.6 meters (300 inches) annually in the high mountains to 50 mm. (2 inches) near the river's mouth. The maximum annual precipitation record, 1.59 meters (62.45 inches), occurred in White Tail in the Sierra Blanca in New Mexico in 1941. The minimum annual precipitation of 55 mm (2.16 inches) was recorded at Lake Avalon, New Mexico, in 1917. About 75% of the mean annual precipitation occurs from July through September. This pattern of rainfall, often torrential and of brief duration, results in frequent floods. In May 1942, the National Resources Planning Board estimated that the average water production for runoff in the Pecos River drainage for the period 1905-1939 amounted to 1.35 billion cubic meters (1,095,000 acre-feet) per year, or about 4 per cent of total precipitation. Of this yield, 67 percent originated in New Mexico.

History of Development

Irrigation in the Pecos River basin was being practiced in the upper basin (above Sumner Dam) by the Indians at the time of the Spanish conquest. Beginning with the close of the eighteenth century, expansion of irrigation in the upper basin coincided with the Spanish colonization. With the exception of the development of the Storrie Project (about 1918), development in the upper basin has remained about the same as it was under early Spanish occupation.

Directly before the Civil War, the Fort Sumner Project was constructed in the middle basin (Sumner Dam to the State line). A small project was constructed in the lower basin in the late 1870's. Very little additional development took place in either basin until the late 1880's.

In the middle basin, the principal irrigation developments are in the Fort Sumner, Roswell and Carlsbad areas. The Fort Sumner Project, constructed in 1863, was rehabilitated in 1906. Development in the Roswell area by the use of surface waters commenced in the period 1889-1904. The major development, however, has been the use of artesian water, which was initiated in 1891. This was followed much later by the pumping of shallow ground water in the Roswell artesian area, which commenced about 1927, with most of the development taking place during the years 1935-37.

Development in the Carlsbad area was commenced simultaneously with the surface water development in the Roswell area. The facilities to serve the Carlsbad area, including McMillan and Avalon reservoirs and the "southern canal" were completed about 1893. Many difficulties were encountered in maintaining the system. It was severely damaged by the flood of 1904. The project was taken over in 1906 by the then United States Reclamation Service, at which time it was completely rehabilitated.

Development in the Texas portion of the basin commenced in 1876 with the construction of one small canal. No further development took place until 1888. During a period of 25 years after that date, canals were constructed to serve nine projects. Two small off-stream reservoirs were also constructed. Because most of the area was dependent upon the erratic natural flow of the stream, need arose for major reservoir development on the stream; Red Bluff Reservoir was constructed and placed in operation in September 1936.

In the meantime, the capacity of the reservoirs of the Carlsbad Project had become so depleted the need arose for replacement of such capacity. Alamogordo (Sumner) Reservoir was completed in 1937 for this purpose.

The progressive sedimentation of McMillan Reservoir was offset by two enlargements. The original capacity of 98.6 million cubic meters (80,000 acre-feet) was depleted by sediment to 46.9 million cubic meters (38,000 acre-feet) by 1947. The reservoir leaked from the time it was built. As a WPA project, dikes were constructed to shut off the flow to some of the larger sink holes. The high water of 1941 opened other holes in the reservoir. Loss of the reservoir capacity was materially retarded by the growth of salt cedars on the sediment deposit at the head of the reservoir. The salt cedars over a period of years effectively had retained the sediments, allowing the relatively clear water to pass on the reservoir. However, in performing this function, nature had taken a heavy toll in water. The salt cedars were estimated to be consuming on the average of 67.8 million cubic meters (55,000 acre-feet) per year in 1947. (Senate Document No. 109, 81st Congress, 1st Session. 1949)

By 1925, the artesian water development in the Roswell basin was threatened by overdraft. Prior to the commencement of the artesian development, it has been estimated that the contribution to the surface water of the river from the artesian area averaged 9.2 cms. (325 cubic feet per second). It is estimated that by 1925, this flow had been depleted to 2.55 cms (90 cubic feet per second)(Senate Document No. 109. 81st Congress, 1st Session. 1949). The state legislature of New Mexico enacted a ground water statute in

1931 which enabled the State Engineer to control development in the artesian basin by preventing expansion and eliminating waste. The shallow ground water development has also had a significant effect on the base flow of the stream. The pumping of groundwater in the Carlsbad area commenced in the late 1930's for the purpose of supplementing the surface flow when it is inadequate to satisfy current requirements. The State Engineer recognized the possibility of adverse effects of uncontrolled development on the groundwater supply in the Carlsbad area, and the basin was "declared" and development brought under his jurisdiction.

In the Malaga Bend area near the state line, the geologic formation which retains under artesian pressure a virtual sea of brine has been fractured. This permits leakage of about 0.01 cms. (one-half cubic foot per second) of brine into the river. The brine is a salt solution having concentrations of some 150,000 parts per million. The brine contributes 120,000 tons of salt per year to the supply of water which Texas receives from the river.

The Pecos River Compact

The Pecos River Compact, signed December 3, 1948, apportioned the waters of the Pecos River between the states of Texas and New Mexico. Under the Compact, New Mexico agreed not to deplete by man's activities, the flow of the Pecos River at the New Mexico-Texas state line below an amount which would give to Texas a quantity of water equivalent to that available to Texas under the 1947 condition. The Compact also apportioned 57% to New Mexico and 43% to Texas the consumptive use of water salvaged by federal projects which reduce non-beneficial consumptive uses on the river. The Compact also evenly apportioned between the states the consumptive use of unappropriated floodwaters. Both states also agreed to support Federal projects that would reduce the loss of water to salt cedars and to support a Federal project that effectuates a means of alleviating the salinity problems on the river. The Compact also allowed each state to construct additional storage to replace capacity of reservoirs lost due to sedimentation or other causes and allowed for the construction of flood control projects.

In March 1988, the U. S. Supreme Court entered its Amended Decree in the lawsuit styled Texas v. New Mexico, which enjoined the state of New Mexico to comply with Article III(a) of the Compact by delivering water at the State line each year in accordance with a formula adopted by the Court. The Court also appointed a River Master to perform the calculations using the adopted formula to determine annual delivery requirements and any shortfall or overages in deliveries. The Amended Decree further requires that if the River Master determines that a net shortfall has occurred in any accounting year, he must approve a plan by which New Mexico will increase the amount of water at the state line by the amount of the net shortfall prior to March 31 of the following year. Since entry of the Amended Decree, New Mexico has maintained an accumulated overage.

Pecos River and Reservoir Operations

In 1954, Congress authorized the construction of Los Esteros (Santa Rosa) Reservoir on the Pecos River 11.2 km. (seven miles) north of Santa Rosa. The Reservoir, with a total capacity of about 555 million cubic meters (450,000 acre-feet) allocated for flood and sediment control, began storage in 1980. In 1971, the Carlsbad Irrigation District filed an application to transfer to Santa Rosa Reservoir both a portion its storage rights in Alamogordo Reservoir (Sumner Reservoir) and that capacity of Alamogordo Reservoir lost to sedimentation since construction of Alamogordo Dam. Following a public hearing, the State Engineer issued an order which was conditioned as follows:

1. The amount of water stored in Santa Rosa Reservoir at any time for use by the Carlsbad Irrigation District shall not exceed 176,500 acre-feet less the total reservoir capacity available for storage by the District in Avalon, Brantley and Alamogordo Reservoirs. The total capacity in all reservoirs may exceed 176,500 acre-feet only if permission is granted by the State Engineer and provided that there is "unappropriated flood water" available, as defined by the Pecos River Compact.
2. The inflow to Santa Rosa Reservoir shall be released from the reservoir at the maximum rate consistent with existing downstream conditions when the Reservoir capacity available for the storage of water for the District is filled.
3. No water shall be released from Alamogordo Reservoir when the water content of that Reservoir is 2,500 acre-feet or less.
4. Water released from Santa Rosa Reservoir for use by the District shall not be passed through Alamogordo Reservoir until the water content of the latter is at least 5,000 acre-feet, the water content in Alamogordo Reservoir in excess of 2,500 acre-feet may be released upon the termination of the release from Santa Rosa Reservoir

In 1988, the Bureau of Reclamation completed construction of Brantley Dam and Reservoir on the Pecos River 19.3 km. (12 miles) north of Carlsbad. The Reservoir, with a total capacity of about 1.23 billion cubic meters (1,000,000 acre-feet), was constructed for flood and sediment control and for irrigation purposes. The Carlsbad irrigation District has the right to store about 49.3 million cubic meters (40,000 acre-feet) of water in Brantley Reservoir for irrigation purposes. McMillan Dam was breached subsequent to the completion of Brantley Dam.

APPENDIX B

REACH-BY-REACH ANALYSIS

and

REESTABLISHMENT SITE SELECTION PROCESS

The Recovery Team undertook a reach-by-reach analysis of the Rio Grande and the Pecos River Basins to identify the salient hydrological, chemical and biological features of each reach, to address the threats to the Rio Grande silvery minnow and to consider the suitability of each reach for the potential for reestablishment. The analysis of each reach is not based upon detailed investigations made by the Recovery Team, but is based upon the combined experience and observations of the team members and evaluation and consideration of the research that has been completed.

The identification of the of river reaches proposed for recovery was based upon the presence of dams (upstream) and reservoirs (downstream), with the intervening sections being conterminous. In such reaches, the potential for unimpeded movement by the various life stages of Rio Grande silvery minnow appeared to exist. The Recovery Team recognizes that, if reestablishment in a selected reach were to occur, not all sections within the reach would be suitable macrohabitat for this taxon (i.e., dam outfalls and river-reservoir confluence). The extent and impact of these unfavorable macrohabitats on Rio Grande silvery minnow would probably vary annually and be dependent on antecedent and current hydrologic condition. The extent of unfavorable habitats was deemed minimal compared with cumulative length of the potential suitable habitat within a reach.

Habitat within a particular reach is also an important factor in selecting reestablishment sites. The drifting early life history stages of Rio Grande silvery minnow are subject to downstream displacement and the extent of this movement is, in part, dictated by the stream habitats available in a particular reach. Areas were the river channel has been greatly reduced in width and river meandering has been largely eliminated are generally typified by deeper and faster velocity waters. There is also an associated reduction in the relative frequency of lower velocity mesohabitats (i.e., pools and backwaters) that are favored by Rio Grande silvery minnow. The loss of lower velocity habitats could result in increased downstream displacement of Rio Grande silvery minnow (especially drifting eggs and larvae). River reaches that were typified by these degraded habitats were not favored as highly by the recovery team as were reaches where the river channel was wider and allowed more freedom of movement.

Based upon the following reach-by-reach analysis and the consideration of; 1) the understanding of reasons for the species extirpation from the selected reach, 2) the presence of other members of the reproductive guild (pelagic spawner; non-adhesive, semibuoyant eggs), 3) habitat conditions (including susceptibility to river drying and presence of diversion structures), 4) presence of congeners (i.e., other species of

Hybognathus), the following preliminary list of reaches or portions of reaches were selected to be most suitable for reestablishment and prioritized as follows:

1. Pecos River, Sumner Dam to Brantley Reservoir
2. Pecos River, Girvin, Texas to Amistad Reservoir
3. Rio Grande, Presidio to Amistad Reservoir
4. Rio Grande, Amistad Reservoir to Falcon Reservoir
5. Rio Grande, Caballo Dam to Presidio
6. Pecos River, Brantley Dam to Red Bluff Reservoir

The conservation measures identified in the reach-by-reach analysis are to be studied and not all the measures are required to be implemented to satisfy the objectives and criteria of the Recovery Plan. Conservation measures will be investigated and implemented if the results of the investigation show that they are needed and feasible.

Reach-by-Reach Analysis:

1. Rio Grande - Rio Grande Above Cochiti Lake

Hydrology: This reach has perennial flow. The hydrograph has a relatively natural shape with a spring peak that follows snowmelt runoff. On the Rio Chama below Abiquiu Dam, the summer and fall flows are higher than natural due to increased reservoir releases, including releases from the San Juan -Chama Project. This reach is likely not subject to a large increased diversion demand from future growth. There will be average increases in population growth and increased use of ground water but this will require transfer of existing water rights to offset these uses.

The majority of this reach is canyon bound with the remainder in open flood plain. From Otowi bridge upstream to the Velarde-Embudo reach it is non-canyon bound. The canyon bound reach has a high gradient, with a lower gradient in the open reaches. The substrate is dominated by gravel, cobble, and boulder with little fine material. There is low sinuosity and little segmentation with the exception of several concrete instream diversion structures near Velarde.

Sections of the Rio Chama have levees and the Espanola valley has a history of channel maintenance activities. This area on the Rio Chama also contains instream diversions. This reach has a stable bed with little aggradation or degradation.
Water quality: This is a cold water reach with low conductivity and turbidity. Some tributary streams that enter this section can introduce high sediment loads during storm events. There are point discharges from wastewater effluent from the communities upstream but the water quality of the reach is most influenced by non-point sources. There are historic and current sources from mining and heavy metals in the Red River drainage that then enter the Rio Grande. The Rio Grande in this reach does not always

fully support the designated fishery use due to turbidity, siltation, reduction of riparian vegetation, streambank destabilization and metals.
Fish community: This reach is dominated by cool or cold water species including longnose dace. There has been a replacement of most native species by introduced nonnatives. Predation in this reach is from trout and northern pike. The Rio Grande silvery minnow was historically present but has not been collected since 1949 in the Rio Chama and the 1970s in the Rio Grande. There is no niche competition from other fish in this reach.
Last collection of Rio Grande silvery minnow: 1962-1963
Further Study: Contaminants from Red River and Los Alamos, additional fish studies.
Reestablishment potential: Yes (50-60 miles, marginal), perennial flows.
Cause of extirpation: Loss of habitat, dam construction, cold water temperatures, loss of suitable substrate, change in hydrology, chronic/acute contaminants exposure, competition with introduced nonnative fish species.

2. Rio Grande - Cochiti to Angostura

Hydrology: This reach has perennial flow. The hydrograph is modified to reduce the peak in some years with extended release in years of high inflow. Under flood control operations, Cochiti Dam passes flows ranging between about 5000 cfs and 8500 cfs, depending upon downstream channel conditions. There is a spring peak that coincides with snowmelt runoff. Storm runoff can enter from Galisteo and Tonque arroyos.

This reach has levees on the east side and is incised in the upper sections. The width to depth ratio is lower in the incised section than in the downstream section. This is due to sediment capture by Cochiti Dam and a lack of upstream sources of sediment. The substrate is armored cobble in the upper section. The arroyos introduce sediment to the lower sections of this reach and higher percentage of finer sediments are found on the surface of the armored cobble. This finer sediment moves downstream with higher flows. The streambed gradient is moderate and lower than the reach above Cochiti.

This reach has low sinuosity and routine channel maintenance activities are performed, mainly bank stabilization activities. The segmentation in this reach is limited to the Angostura diversion structure on the downstream end and Cochiti Dam on the upstream end. There is low habitat variability in this reach.
Water Quality: The water temperature is cold due to release from Cochiti reservoir. The water temperature warms during summer in the downstream reaches. This reach has low conductivity and turbidity except for when sediments are introduced during storm events. The water quality is most influenced by non-point sources throughout the reach. This reach of the river does not always fully support its designated fishery uses due to metals, reduction of riparian vegetation and streambank destabilization.
Fish Community: The fish community in this reach is almost exclusively nonnative fish dominated by white suckers, and bass and perch escapement from Cochiti Lake. There is no niche competition and this reach has the lowest density of Rio Grande silvery minnow of the areas currently containing populations of Rio Grande silvery minnow.

Further Study: Habitat quality (temperature and substrate), return flows, flow management, institutional constraints (e.g., Cochiti re-regulation, Rio Grande Compact), channel management studies, monitoring fish populations.
Conservation Measures: Monitoring of return flows, channel rehabilitation, nonnative fish management, monitoring fish populations, spring peak flows.
Reasons for Decline: Physical alterations in the channel (width/depth ratios, temperatures, substrate), fragmentation, flow regime changes, Cochiti Dam provides a physical barrier with colder clean tailwater, loss of low water/high water refugia, channelization, contaminants (past acute exposures resulting from mine waste spills); establishment of a permanent recreation pool at Cochiti Lake generated colder temperatures and clearer water, Galisteo sediment and flood control structure, nonnative fish introductions.

3. Rio Grande - Albuquerque Reach (Angostura diversion to Isleta diversion)

Hydrology: This reach has perennial flow. The city of Albuquerque has agreed to maintain a minimum flow of 250 cfs at Albuquerque to the year 2000. The hydrograph follows the seasonal peaks released from Cochiti Dam reduced by the water diverted for irrigation at Angostura diversion. Downstream demands for irrigation augment flows in this reach during the summer season. Flows in this reach are highly managed. There are significant storm events that add to the runoff in this reach.

A higher than average population growth is anticipated in this reach. This could result in added surface water diversion for use by the city of Albuquerque from the San Juan-Chama Project.

This reach has a low gradient and is highly braided within the channel margins. The river channel is leveed and jetty jacks occur at various locations. There is a high level of channel maintenance activities in a channel with sand substrate. This reach has high habitat variability due to the channel braiding and there is no habitat segmentation from instream barriers within the reach. There are a number of return flows from riverside drains and inflows from the Jemez River.
Water Quality: This is a warm water reach. Conductivity is low and turbidity is low to moderate except during storm runoff events. There are major urban point source inflows in this reach and non-point sources from both urban and agricultural areas.

This reach does not fully support the fishery, irrigation and recreation designated uses due to metals, un-ionized ammonia, chlorine, pathogens, siltation and habitat alteration. During the past few years there have been several sewage spills and the reach is highly vulnerable to acute toxicity due to treatment of these and other spill events.
Fish community: This reach is dominated by a warm-water fish community. There is a low predator population, mostly dominated by channel catfish. The Rio Grande silvery minnow is present and in greater numbers compared to the upstream reach. There is no niche competition in this reach for the Rio Grande silvery minnow.
Further Study: Water quality impacts and sources, diversion structure modification, river and canal transmission losses and conjunctive use of municipal supply.
Conservation Measures: Measure diversions, maintain habitat quality, fish passage/ladders, fish transplant/augmentation, hatchery rearing for transplant.

Threats: Full use of all water in the system leading to dry reaches of river. Contaminants (both acute and chronic).
Reasons for Decline: Channel maintenance activities, Jemez flood and sediment control dam, contaminants (storm drains and municipal water treatment effluent discharge), dewatering.

4. Rio Grande - Belen Reach (Isleta diversion to San Acacia diversion)

Hydrology: This reach is not perennial. The river has a spring peak that reflects the Cochiti releases and also storm peaks. The flow in this reach is highly managed for human uses. There are several riverside drains that can maintain flows in some sections of the reach. These drains are near Bernardo and San Acacia. More urbanization is anticipated in this reach but may not result in a change in river flows.

The river is leveed on both banks, especially through Belen. There are channel maintenance activities and jetty jacks in the reach. This is a low gradient reach dominated by sand substrate, with significant sediment inflows from Rio Puerco and Rio Salado. The river bed within the reach aggrades due to sediment load principally due to discharge from the Rio Puerco and Rio Salado. There is increased channel mobility downstream of the Rio Puerco. Habitat variability is high within the reach. There are no constructed barriers within the reach but the reach becomes fragmented due to ephemeral flows.
Water Quality: Water temperature, conductivity and turbidity are higher than the upstream reach. Water quality is dominated by the non-point source discharges. Portions of this reach do not fully support the fishery designated use due to metals, siltation and habitat alteration.
Fish community: This reach is predominantly a warm water native fish community. There may be predation by channel catfish. The Rio Grande silvery minnow is present in the reach with no niche competition. The silvery minnow populations are higher than in the upstream reach.
Further Study: Water quality and sediment quality impacts from the Rio Puerco, Rio Salado and return flows, channel loss studies, phreatophyte evapotranspiration water use budgets, channel conveyance efficiencies, efficient application of irrigation water and conjunctive use of municipal supply.
Conservation Measures: Acquire water for conservation program, instream flow legislation, incentives to encourage water conservation, forbearance agreements, well pumping for river augmentation, adjudication, efficient use of diverted water, basin-wide annual planning of demand versus water availability.
Threats: Full use of all water in the system leading to dry reaches of river; contaminants.
Reasons for Decline: Dewatering and water quality.

5. Rio Grande - Socorro Reach (San Acacia to Elephant Butte)

Hydrology: This reach is not perennial although the spring runoff peaks and summer storm peaks often maintain surface flow. There is a high degree of flow manipulation outside of storm events. There is a stable human population base and the demand should be relatively stable.

The river is leveed on the west bank and open on the east. The LFCC begins in this reach. There is a high level of channel maintenance to maintain stream gradient. A levee project is planned to rebuild the existing levee with a more stable material. The channel is dominated by sand/silt substrate and is aggrading in this reach. Excavation within the river channel is used to open pilot channels to maintain flows into the lake. The stream has a higher sinuosity than the upper river and is highly braided within the channel margins. Habitat variability is moderate due to channelization within the reach.

The river channel in the section near San Marcial has been reconstructed after inundation from the previous times when Elephant Butte reservoir was full.

Water Quality: This is a warm water reach with higher levels of conductivity and turbidity than upstream areas. The water quality is dominated by non-point source discharges .

Portions of this reach do not fully support its fishery designated use due to pesticides, siltation, reduction of riparian vegetation and streambank destabilization.

Fish Community: The fish community is dominated by warmwater native species. There is a predatory channel catfish population in this reach. There is no niche competition in this reach. When Elephant Butte reservoir is low there is increased riverine habitat in the lower sections of the reach.

Further Study: Water quality and sediment quality impacts, channel loss studies, phreatophyte evapotranspiration water use budgets, channel conveyance efficiencies, efficient application of irrigation water and conjunctive use.

Conservation Measures: Acquire water for conservation program, instream flow legislation, incentives to encourage water conservation, forbearance agreements, well pumping for river augmentation, adjudication, efficient use of diverted water, basin-wide annual planning of demand versus water availability.

Threats: Full use of all water in the system leading to dry reaches of river; contaminants.

Reasons for Decline: Dewatering and water quality.

6. Rio Grande - Elephant Butte to Presidio

Hydrology: The river is not perennial in this reach. There is no spring runoff peak and a highly regulated flow regime. There is an anticipated above average change in demand with an increased possibility for perennial flow in this reach due to change in water use from agricultural to urban uses. Releases in this reach are constrained by the Rio Grande Compact and downstream water demands.

There are many barriers in this reach with the major structure being Caballo Dam. Portions of the river in this reach are completely channelized with sand substrate, straight channel, high channel maintenance activity and levees in most areas.

Water Quality: This is a warmwater reach with higher levels of conductivity than upstream areas. The water quality is dominated by significant point and non-point source discharges. Within this reach, the El Paso area is heavily industrialized compared to the upstream reaches. This reach also receives both point and non-point source discharges from the Mexican side of the river which are subject to different water quality regulations than the United States.

Portions of this reach do not fully support its fishery and irrigation designated uses due to metals, siltation, un-ionized ammonia, chlorine, pH, reduction of riparian vegetation and streambank destabilization.

Fish Community: This reach has a mixed coldwater and warmwater fishery between Elephant Butte release and Caballo Reservoirs. The river from Caballo Dam to Fort Quitman is a warmwater nonnative fish community. The Rio Grande silvery minnow was historically present, but no longer is found in the reach. There are predators present, such as bass and catfish, but no niche competitors.

Last Collection: 1944-Caballo to State Line.

Further Study: None at this time.

Reestablishment potential: Poor, short distance from Elephant Butte Dam to Caballo Reservoir, low temperatures downstream of dams, and low dissolved oxygen levels are all problems. The reach below Caballo Dam is canalized.

Cause of extirpation: water quality degradation, canalization, change in hydrology, diversion (physical barriers and de-watering).

7. Rio Grande - Presidio to Amistad Reservoir

Hydrology: The river in this reach is perennial and is dominated by the Rio Conchos entering from the Mexican side of the river. There is a seasonal peak modified by upstream dams on the Conchos. The peak is short due to water diversions and upstream dams in the Conchos. There are large storm event peaks in October and November. There are increases in depletion anticipated due to increased irrigation on the Mexican side of the river. The Treaty of 1944 sets the upper limit for the amount of diversion.

This reach is not leveed and has small rock dam weirs, all but one of which (Foster's weir) are not a barrier. The substrate ranges from silt to cobble and boulder depending on local conditions. There are no channel maintenance activities in this reach. Almost half of this reach is in canyons, including the Big Bend National Park. The lower canyons reach is outside the park, but land use is managed by the National Park Service.

The channel is not mobile in the canyon sections. Outside the canyon reaches, the river is braided in some sections with a moderate gradient on average but higher gradient relative to the immediate upstream reach. Base flow in this reach is approximately 400 cfs.

Water Quality: The river in this reach has high salinity and turbidity. This reach has both point and non-point source discharges with the water quality dominated by contributions from the Rio Conchos.

Fish Community: This reach has a warm water native fish community with some nonnatives. The reach has a high number of large river species such as gar and smallmouth buffalo. The main predators are gar and channel catfish. The Rio Grande silvery minnow was historically present in this reach, but is no longer present. There is no niche competition in this reach for the silvery minnow.

Last Collection: 1960.

Further Study: Existing fish community, water quality data from Rio Conchos gage.

Reestablishment potential: Good.
Cause of extirpation: Poor water quality-Rio Conchos, canalization, dam construction, loss of spring peak flow, diversion (de-watering).

8. Rio Grande - Amistad to Falcon Reservoir

Hydrology: This reach is perennial with a small seasonal peak due to delivery schedules. Flow in this reach is highly regulated due to water releases to satisfy demands for irrigation in both Texas and Mexico. This reach is administered by a watermaster. The base flow in the reach is approximately 1000 - 3000 cfs. The demand in this reach is relatively stable but there is a conversion from agricultural to municipal uses. This reach is also subject to daily fluctuations to meet the downstream demands and for hydroelectric generation. Fluctuations can be as much as four to six feet in river level.

This section of the river is not leveed and there is no channel maintenance. The river is nearly straight with no braiding. The channel's gradient is lower than compared to the immediate upstream reach and its substrate is variable from coarse material downstream of Amistad to predominately sand substrate in the lower section of the reach. There are several barriers in this reach at Maverick, Eagle Pass and Indio.
Water Quality: This section of the river has warm water with relatively high salinity and low turbidity. There are both point and non-point source discharges in this reach.
Fish Community: The fish in the reach are dominated by warm water nonnatives with high predator populations, including several basses, catfishes and gar. There are several native minnow species but Rio Grande silvery minnow is absent. The Rio Grande silvery minnow was historically present up to the Pecos, but not found in the Rio Conchos.
Last Collection: Inferred prior to 1960.
Further Study: Water quality, fish collection data, reestablishment potential.
Reestablishment Potential: Some
Cause of extirpation: Poor water quality (agriculture discharge, saline intrusion), Change in hydrology (regulated flows).

9. Rio Grande - Falcon Dam to Gulf of Mexico

Hydrology: This reach is perennial and highly regulated by releases from Falcon dam. Base flow is approximately 500 to 1000 cfs. There is a high level of urbanization. The peak flows are caused by spills from the reservoir due to storm peaks or reservoir releases for irrigation. The river channel is stable with a low gradient and levees along some sections. There are barriers in the form of flood control structures. The substrate is dominated by sand with other particle size-classes present.
Water Quality: Water quality in this reach is brackish due to influences from the Gulf of Mexico. Turbidity is low near Falcon Dam and increases in the downstream direction. There are both point and non-point source discharges from the increased urbanization and agriculture.
Fish Community: The fish community is dominated by warm water nonnatives including estuarian species in the lower river near Brownsville. There is a high predator population and no niche competitors.

Last Collection: 1961
Further Study: Evaluate reestablishment potential.
Reestablishment potential: Some
Cause of extirpation: Esturaine conditions, predation, water quality, change in hydrology, diversion (physical barriers).

10. Pecos River - Santa Rosa to Carlsbad

Hydrology: This reach is not perennial. The flows are regulated by dams near Santa Rosa and Ft. Sumner. The reach from Santa Rosa Dam to Sumner Dam is short relative to the reach needed by the Rio Grande silvery minnow.

There are storm peaks during rain events, but significant spring peaks do not occur every year. There is no change in demand anticipated. The reach of river from Santa Rosa to Roswell loses flow but that from Roswell downstream to Carlsbad gains flow. The channel from Sumner Dam to Roswell has a moderate gradient with braiding within the stream margins as well as small sections of multiple channels. Substrate in this reach is variable with gradations from small to large substrate sizes. The upper section of this reach is similar in characteristics to the upper Rio Grande near Velarde.

The section from Roswell to Carlsbad is perennial. The gradient is moderate to low from Roswell to Carlsbad. The channel from Santa Rosa Dam to Sumner Dam is single with in-channel braiding. There is a single channel with channel braiding from Sumner Dam to Roswell. The lowest section of the reach has no braiding. Substrate in the river is cobble from Santa Rosa Dam to Sumner Dam, sand from Sumner Dam to Roswell and sand/silt from Roswell to Brantley Reservoir. There is low channel mobility in the entire reach.

Water Quality: The upper portion of this reach has cool water downstream of Santa Rosa Dam and warm water downstream of Sumner Dam. The conductivity and turbidity are low in the upper sections. The reach from Sumner Dam to Roswell has high turbidity and is highly variable in the downstream section. Salinity is high in the lower section of the reach.

Portions of this reach do not fully support the fishery designated uses due to metals, siltation, pathogens, reduction of riparian vegetation, streambank destabilization, dissolved oxygen, un-ionized ammonia and total dissolved solids.

Fish Community: The fish community is dominated by warm water native species. The Rio Grande silvery minnow was historically present, but is not currently found in the river in this reach. There is a low predator population in the upper sections with a low to moderate predator population in the section from Roswell to Brantley Reservoir. There are no niche competitors in the reach from Santa Rosa Dam to Sumner Dam, but there is potential niche competition by nonnative plains minnow from Sumner Dam downstream.
Last Collection: 1968 (Roswell).
Further Study: Pecos hydrology (Sumner Dam to Acme), additional fish recovery areas.
Reestablishment potential: None above Sumner Dam (short reach), good potential below Sumner Dam. Prior to any attempt to reestablish Rio Grande silvery minnow in the Pecos River, the plains minnow must be extirpated.

Cause of extirpation: Santa Rosa Dam to Sumner Dam: Short reach (reproductive strategy requires more river channel). Below Sumner Dam: salinity, plains minnow, dams, loss of suitable substrate, intermittent flow in river channel, change in flow regime, loss of spring peak flows, diversion (de-watering).

11. Pecos River - Red Bluff to International Amistad Reservoir

Hydrology: This reach is not perennial. The reach does have storm events evident in the hydrograph in the lower sections of the river. The flows in the upper portion of this reach are dominated by releases from Red Bluff Dam. The lower section has significant spring sources and groundwater inflows that contribute to the discharge. There are no anticipated changes to flow regimes from increased demands for human uses.

This reach is a single channel, braided within the channel margins but without levees. The river gradient is high in the lower half of this reach with variable substrate types. There are some barriers in the upper section of this reach.

Water Quality: This reach is typified by warm water with high conductivity, low turbidity, and is dominated by non-point source contaminants. This reach is subject to algal blooms from unknown causes, which have caused massive fish die-offs.

Portions of this reach do not fully support the fishery, irrigation, and livestock and wildlife watering designated uses due to metals, un-ionized ammonia, siltation, salinity, reduction of riparian vegetation, and streambank destabilization.

Fish Community: The fish community in this reach is dominated by warm water nonnatives with moderate predation from catfish and basses. The Rio Grande silvery minnow was historically present but no longer inhabits the reach. There are no niche competitors present in this reach.

Last Collection: 1954 (low numbers in collection).

Further Study: Study hydrology below Ft. Stockton, evaluate reestablishment potential.

Reestablishment potential: Unknown.

Cause of extirpation: Salinity, limited habitat, change in hydrology due to wells, diversions (physical obstructions & dewatering).

APPENDIX C

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APPENDIX D

WATER MANAGEMENT STRATEGY FOR THE MIDDLE RIO GRANDE VALLEY

prepared by

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INTRODUCTION

The listing in 1994 of the Rio Grande silvery minnow as endangered under the Endangered Species Act and the drought conditions experienced in the middle Rio Grande valley during the first half of 1996 combined to underscore the need to address long-term water management options to meet water needs in the valley. The purpose of this paper is to outline alternative courses of action to satisfy these water needs that merit further investigation by agencies and entities which have a stake in water management for the valley.

The middle Rio Grande valley is hydrologically very complex and is home to substantial agricultural activity, urban development and the silvery minnow. Uncertainties exist in our understanding of the hydrologic connections between surface-water and ground-water systems in the valley principally due to a lack of data. There are also uncertainties regarding water needs over time for various purposes. Additionally, there are numerous incompatibilities between existing institutions as well as federal and state laws which affect water management in the valley and upstream reservoir operations for the valley.

Still, during the 1996 irrigation season, agencies and entities directly involved in water operations for the middle valley largely succeeded in satisfying the water needs of the silvery minnow and water users, including Middle Rio Grande Conservancy District (District) irrigators. This success was due to the District operating its system to allow native Rio Grande water to remain in the river undiverted for the minnow and the city of Albuquerque (City) and other entities making some of their San Juan-Chama Project water available to the District for use by irrigators at no cost to the water users in the valley. It is expected, however, that San Juan-Chama Project water owned by the City and these other entities may not be available in future years to augment surface-water supplies in the valley.

Without proactive water planning and related commitments to action, water management decisions may be made through litigation. Environmental organizations have sent Notices of Intent to Sue, and others have contemplated legal action, regarding operation of the river system through the middle valley and related impacts to the silvery minnow. Government agencies with a stake in water management in the middle valley are now in the process of developing a plan for 1997 river operations for the silvery minnow and the District. Agencies and entities directly involved in water operations for the middle valley also share responsibilities in equitably meeting future water needs with the goal to satisfy water uses and the needs of the silvery minnow beyond 1997.

ACTIONS

To meet the needs of the silvery minnow, it is most desirable to take actions which will secure long-term, dependable amounts of water for the middle Rio Grande. In doing so, water users need to be accommodated. No single action will by itself accomplish these goals.

However, the preparers of this paper believe that some combination of the following actions will be instrumental in meeting these goals. These alternative actions require further investigation and refinement to ensure that actions ultimately taken are responsive to these goals and to changing needs. Actions to be taken must be legal, economically feasible, politically acceptable, and implementable in a timely manner. Successful implementation of any of these actions will require improved water measurement, monitoring and accountability. The following alternative actions are non-exclusive and no order of priority has been assigned to them.

1. <u>Acquisition of Water</u>: Acquisition of water from willing sellers to facilitate water supply management in the middle Rio Grande is an action that could be taken within existing laws. Modifications to existing laws and contracts might further facilitate various ways of implementing a water acquisition program which may involve elements of water-use forbearance agreements or water banking. While water could be acquired from water users, the District may need to be a party to agreements to allow such a program to be effective in satisfying needs of the water users and the silvery minnow. A water acquisition program may require sustained funding from federal and other sources, and it would require development of institutional and physical criteria for obtaining water in a timely manner.

2. <u>Conjunctive Ground-Water and Surface-Water Use</u>: The use of ground-water and surface-water supplies could be co-managed to contribute to meeting the needs of water users and the silvery minnow. During wet years, ground-water users such as the City might use a higher proportion of surface water for direct use or artificial ground-water recharge. During dry years, more ground water might be pumped in lieu of using surface

water so that additional surface water may augment the total surface-water supply available for the silvery minnow and surface-water users such as the District.

Another option is to strategically place shallow ground-water wells in the middle Rio Grande valley for use in times of severe surface-water shortages, thereby providing a supplemental source to the total water supply in years of low streamflow. This option could be expensive, but would provide a means to respond to emergency low-flow situations. These options would provide for a more comprehensive water use; however, institutional and water rights constraints need to be addressed to implement them.

3. Upstream Water Management: Changes to Rio Grande system water operations could increase the capability of storing native Rio Grande water upstream from the middle valley. Some reservoir and river operation options could require new authorizations, while other options could be accomplished under current authorities through changes to federal water control manuals. Possible options for consideration, in no order of priority, are: (1) storing Rio Grande water in vacant storage space in Heron Reservoir when space is available, as well as utilizing San Juan-Chama Project water; (2) transferring water from El Vado Reservoir to Abiquiu Reservoir; (3) increasing the storage capability in Abiquiu and Jemez Canyon Reservoirs; and (4) using Cochiti Lake for a re-regulation reservoir during the irrigation season. Aspects related to these options which would need to be addressed include: water supply, Native American water rights, effects on water management outside the middle valley, recreation, compliance with laws related to the environment, the Rio Grande Compact, and specific agency and project authorizations. There is also a need to annually prepare an operating plan for reservoirs and diversions of

the Middle Rio Grande Project in consultation with stakeholders to specifically evaluate water management needs and opportunities for the middle valley.

4. Water-Use Efficiency Increases: Increased water-use efficiencies in the middle Rio Grande valley should contribute to an increase in the flexibility to manage the water supply. Options for action by which water-use efficiencies could be increased include improving off-stream water-delivery systems by such means as lining canals, improving on-farm irrigation practices, or improving water delivery scheduling. Prior to taking action to increase efficiencies, the impacts of various options on the hydrology and the environment of the middle valley need to be assessed. Further, the disposition of water "saved" by these measures would need to be resolved in accordance with state and Federal water law and possibly by agreement with the District to allow water saving measures to effectively aid water managers in meeting the needs of the water users and the silvery minnow.

5. Water Rights Administration: Water rights in the middle Rio Grande valley are not adjudicated and much of the water uses in the valley are not metered. Metering surface-water and ground-water irrigation deliveries and drain flows would help clarify existing water uses and needs, quantify the available water supply, and identify water management options. Adjudicating water rights in the middle valley would, in conjunction with a metering program, allow for improved administration of water rights and improved water management. However, an adjudication may not be completed for the middle valley in the foreseeable future unless alternative dispute resolution procedures can be adopted by the state, water users and the court to carry the adjudication

forward. Still, sustained funding from federal and other sources to meter and monitor flows throughout the valley is needed.

RECOMMENDATIONS

Agencies and entities directly involved in water operations for the middle Rio Grande valley should diligently and cooperatively investigate with the broader community of interests, the feasibility of implementing the actions described herein and develop a plan of action to serve as the basis for future river and reservoir operations to meet the needs of water users and the silvery minnow in the middle valley. Such a plan of action might include any combination of the alternative actions described herein which would lead to maximum improvements in water management for water users and the silvery minnow as a whole.

Attention should first be directed towards more immediately attainable actions such as upstream water management options which can be accomplished within existing authorities and the acquisition of water. Concurrently, existing institutional constraints to implementing potential actions should be examined and efforts should be initiated to make institutional changes as may be deemed appropriate to help accommodate both water users and the silvery minnow in the long term. Where additional studies are deemed required to fully evaluate a potential action, the agencies and entities represented in the preparation of this paper should cooperate in securing the necessary resources to complete such studies promptly. These agencies and entities should also continue to dedicate staff to working on issues related to development and implementation of a plan of action to address future needs of both water users and the silvery minnow in the middle valley. To this end, the preparers of this paper seek confirmation from the leadership of their respective agencies or entities that the actions described herein should be pursued.

ALB-400
RES-3.10

DEC 24 1996

LTC Lloyd S. Wagner
District Engineer
U.S. Army Corps of Engineers
4101 Jefferson Plaza NE
Albuquerque NM 87109

Subject: *White Paper* Addressing Water Management Strategy for the Middle Rio Grande

Dear Mr. Wagner:

The purpose of this letter is to inform you of the Bureau of Reclamation's position regarding the subject paper, which was prepared by members of our staffs. The paper addresses water management strategies for the middle Rio Grande valley that should be explored to assure that the future water needs of water users and the Rio Grande silvery minnow can be satisfied.

Our Commissioner, Regional Director, and myself discussed the document at length. We understand that the *white paper* is only a single step in the continuum of activities that all of us need to pursue, but an important step. The Bureau of Reclamation endorses the paper, and is committed to work with your agency and others to develop workable solutions to the water management challenges.

Sincerely,

Garry M. Rowe
Area Manager

cc: Mr. Eluid Martinez
Commissioner
Bureau of Reclamation
1849 C Street, NW
Main Interior, Room 7060-MIB
Washington DC 20240-0001

Mr. Charles Calhoun
Regional Director
Bureau of Reclamation
Upper Colorado Regional Office
125 South State Street, Room 6103
Salt Lake City UT 84138-1102

WBR:RLeutheuser:tjp:12/23/96:248-5380:11paper.let

CITY OF
Albuquerque
Public Works Department

Robert E. Gurulé, Director

Martin J. Chávez, Mayor

January 3, 1997

Mr. Garry Rowe
Area Officer Manager
Bureau of Reclamation
505 Marquette Ave. NW, Suite 1313
Albuquerque, NM 87102

Dear Mr. Rowe:

I have reviewed the White Paper prepared by representatives from the Corps of Engineers, Interstate Stream Commission, Middle Rio Grande Conservancy District, Fish and Wildlife Service and our respective staffs. It was prepared in the context of the fresh memory of the crisis-driven and difficult but successful management of Rio Grande flows during this drought year for the protection of the endangered Rio Grande Silvery Minnow while ensuring adequate deliveries for mid-Valley farmers. This crisis year served to drive home the need for developing a long term strategy for water management to meet the full range of water uses in the Middle Valley. The White Paper is a helpful initial step to accomplish this. The City stands ready to continue cooperative efforts with your agency and others to pursue the recommendations to determine the feasibility of implementing the actions proposed for consideration in the Paper while assuring that the needs of the City's water ratepayers continue to be met.

One of the proposed actions proposed for consideration in the White Paper is the conjunctive use of ground and surface water supplies. As you know, pursuant to Mayor Chavez's directive, my Department is actively formulating a strategy to transition as quickly as possible to full use of its renewable water supplies and away from reliance upon non-replenished ground-water. Contemplated in this planning effort is an ultimate ability for the City to conjunctively use surface and ground water in a manner reflecting their hydrologic interconnection and with flexibility to accommodate periods of limited surface water availability while at the same time ensuring the continued viability of the ground water resource. While consideration of this course of action is being driven by imperatives facing the City, we understand it can only be accomplished in the context of all water uses and needs in the Middle Valley being met as is the premise of the White Paper. Accordingly, this City effort amounts to a significant undertaking towards realization of the water management goals of the White Paper.

The City will not be as directly involved in the consideration and implementation of some of the other proposed alternative actions, but understands their vital importance to success of the goal of meeting overall Middle Valley water needs for the future and the City's needs in particular. In that light, we would hope that all the proposed alternatives and any others that emerge are actively pursued by the appropriate parties.

Finally, the City views the White Paper as a useful guide to continued efforts to meet the middle Rio Grande Valley communities' individual and shared water management goals and needs.

Sincerely,

Robert E. Gurule, Director
Public Works Department

c: Mayor Martin Chavez
Lawrence Rael, CAO

ORIGINAL

DEPARTMENT OF THE ARMY
ALBUQUERQUE DISTRICT, CORPS OF ENGINEERS
4101 JEFFERSON PLAZA, NE
ALBUQUERQUE, NEW MEXICO 87109-3435
FAX (505) 342-3199

Reply to
Attention of:

Engineering and Planning Division
Planning Branch

Mr. Garry M. Rowe
Area Manager
Albuquerque Area Office
U.S. Bureau of Reclamation
505 Marquette, Northwest
Suite 1313
Albuquerque, New Mexico 87102-2162

Dear Mr. Rowe:

The purpose of this letter is to provide you my position on the "white paper" titled *Water Management Strategy for the Middle Rio Grande* and dated November 14, 1996. This paper, which was prepared by members of our staffs, is primarily focused on the long-term needs of the Rio Grande Silvery Minnow. I certainly support the concepts embodied in the paper. However, I recommend that we re-title it *Water Management Strategy for the Silvery Minnow in the Middle Rio Grande*.

While it is imperative to address the needs of the silvery minnow, we need to place yet greater emphasis on the development of a broader comprehensive water management strategy that all interests in the Middle Rio Grande can support. The U.S. Army Corps of Engineers, Albuquerque District, is committed to working with your agency, and all interests, toward these objectives.

Sincerely,

Lloyd S. Wagner

Lloyd S. Wagner
Lieutenant Colonel, EN
District Engineer

ORIGINAL

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Mexico Ecological Services Field Office
2105 Osuna NE
Albuquerque, New Mexico 87113
Phone: (505) 761-4525 Fax: (505) 761-4542

January 24, 1997

Memorandum

To: Area Manager, Bureau of Reclamation, Albuquerque Area Office, Albuquerque, New Mexico (Attn: Garry M. Rowe)

From: Field Supervisor, New Mexico Ecological Services Field Office, U.S. Fish and Wildlife Service, Albuquerque, New Mexico

Subject: White Paper entitled Water Management Strategy for the Middle Rio Grande

I wanted to acknowledge receipt of your letter dated December 24, 1996, voicing endorsement of the subject paper which members of our respective staffs have developed.

The Regional Director, Regional Office staff, and I all endorse and support the concepts identified by the entities represented. The Service agrees that this document is a first step toward broader suite of activities to assure that the future water needs of all water users and uses are considered and can be satisfied to the fullest extent possible. I look forward to continued cooperation with your Agency and the other participants in furthering the development of solutions related to the issues identified in the white paper.

Jennifer Fowler-Propst

cc:
District Engineer, U.S. Army Corps of Engineers, Albuquerque, New Mexico
Secretary, New Mexico Interstate Stream Commission, Santa Fe, New Mexico (Attn: Thomas Turney)
Chief Engineer, Middle Rio Grande Conservancy District, Albuquerque, New Mexico (Attn: Subhas Shah)
Director, Public Works Department, City of Albuquerque, Albuquerque, New Mexico (Attn: Robert E. Gurule)
Regional Director, U.S. Fish and Wildlife Service, Albuquerque, New Mexico

ORIGINAL NEW MEXICO INTERSTATE STREAM COMMISSION

COMMISSION MEMBERS
J. PHELPS WHITE, III, Chairman, Roswell
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THOMAS C. TURNEY, PE, Secretary, Santa Fe
PALEMON A. MARTINEZ, Valdez
PAULINA SALOPEK, Las Cruces
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February 3, 1997

Garry M. Rowe, Area Manager
Bureau of Reclamation
Albuquerque Area Office
505 Marquette, N.W., Suite 1313
Albuquerque, New Mexico 87102-2162

Dear Mr. Rowe:

This letter is in response to your request for comments on a white paper entitled: "Water Management Strategy for the Middle Rio Grande Valley (MRGV)." The document is dated November 14, 1996, and was prepared by an ad hoc work group representing several organizations.

I support the study of alternative water management actions for the MRGV outlined in the paper. However, the paper presents a study strategy which may not be fully comprehensive in dealing with all water issues in the MRGV. I suggest that other issues be addressed during the course of further studies by the ad hoc work group.

Please continue to coordinate activities related to water management for the MRGV and development of a recovery plan for the Rio Grande Silvery Minnow with Mr. John Whipple of my staff, (505) 827-6160.

Sincerely,

Thomas C. Turney

Thomas C. Turney
Secretary

TCT:rav

cc: Nancy Kaufman
Colonel Wagner
Robert Gurule
Subhas Shah

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United States Department of the Interior

BUREAU OF RECLAMATION
Albuquerque Area Office
505 Marquette NW, Suite 1313
Albuquerque, New Mexico 87102-2162

IN REPLY REFER TO:
ALB-400
RES-3.10

FEB 18 1997

LTC Lloyd S. Wagner
District Engineer
U. S. Army Corps of Engineers
4101 Jefferson Plaza NE
Albuquerque NM 871089

Subject: *White Paper* Addressing Water Management Strategies for the Middle Rio Grande

Dear Mr. Wagner:

Enclosed is the subject *white paper* with the letters of endorsement written by you, me, and our counterparts in the other agencies who collaborated on the document. For future distributions of the *white paper*, we believe that the letters should be attached to it so every agency's viewpoints are fully represented.

The value of the *white paper* cannot be underestimated. It is the first such document, endorsed by this group representing diverse institutional interests, that begins to address the wide spectrum of middle Rio Grande water management challenges that we collectively must resolve. As we are all aware, this is but another step in a long process. Among the tasks that lie ahead are: the initiation of tasks; assuring that other members of the water management community and concerned public continue to have meaningful input to resultant activities; and, to coordinate these activities with the other programs in the Rio Grande Basin. I understand that members of our staffs are meeting in the near future to address these issues.

If you wish to discuss the *white paper* and associated activities, please do not hesitate to contact me, or Rob Leutheuser of my staff. We can be reached at 248-5357.

Sincerely,

Garry M. Rowe

Garry M. Rowe
Area Manager

Enclosure

cc: Mr. Eluid Martinez
Commissioner
Bureau of Reclamation
1849 C Street NW
Main Interior Building, Room 7060-MIB
Washington DC 20240-0001

cc: Mr. Charles Calhoun
Regional Director
Bureau of Reclamation
Upper Colorado Regional Office
125 South State Street. Room 6103
Salt Lake City UT 84138-1102

Identical letters sent to:

Mr. Thomas Turney
Secretary
New Mexico Interstate Stream Commission
P. O. Box 25102
Santa Fe NM 87504-5102

Mr. Subhas Shah
Chief Engineer
Middle Rio Grande Conservancy District
P. O. Box 581
Albuquerque NM 87103

Mr. Robert Gurule
Director
Public Works Department
City of Albuquerque
P. O. Box 1293
Albuquerque NM 87103

Ms. Jennifer Fowler-Propst
Field Supervisor
U. S. Fish and Wildlife Service
2105 Osuna Road NE
Albuquerque NM 87113

MIDDLE
RIO GRANDE
CONSERVANCY
DISTRICT

January 29, 1997

To: John Whipple, NM Interstate Stream Commission
Jeff Whitney, US Fish & Wildlife Service
Dick Kreiner, NM State Engineer's Office
Rob Leutheuser, US Bureau of Reclamation
Richard Barrios, US Bureau of Reclamation
Gary Daves, City of Albuquerque

Re: WATER MANAGEMENT STRATEGY FOR THE MIDDLE RIO GRANDE VALLEY (WHITE PAPER)

Gentlemen:

On January 13, 1997, the MRGCD staff presented the "Water Management Strategy for the Middle Rio Grande Valley" (White Paper) created by staff of the NMISC, USCOE, COA, USBOR, USFWS and the District to meet the water needs of the Rio Grande Silvery Minnow and the water users.

The MRGCD Board of Directors unanimously supported the "white paper" in concept with the consideration of comments submitted by District staff to the committee. This is a first step in water management in order to protect the diverse interests of water users along the Middle Rio Grande.

We look forward to more detailed discussion on this issue in the near future.

Sincerely,

Lawrence C. Troncosa
Chairman

xc: Subhas K. Shah, CEO
Board Members

P.O. Box 581
87103-0581
1931 Second St. SW
Albuquerque, NM
87102-4515
505-247-0234
Fax # 505-243-7308

APPENDIX E

RESPONSES TO PUBLIC COMMENTS

Pursuant to the provisions of the Section 4 (f)(4) of the Endangered Species Act, a notice was published by the U. S. Fish and Wildlife Service (Service) in the Federal Register on January 2, 1998, announcing the availability of the draft Rio Grande silvery minnow Recovery Plan for public review. The notice provided that comments of the draft Recovery Plan were to be received on or before April 2, 1998. In response to the Federal Register notice, the Service received a total of 47 written comments on the draft Recovery Plan. Written comments were received from five federal agencies, 11 State Agencies or Universities, nine local government entities, an 22 private organizations, companies or individuals. Many of the comments were addressed by incorporating them directly by revisions made to the Recovery Plan. Written comments addressing substantial issues that were received during the comment period are discussed in the following summary. Comments of a similar nature or point are grouped into a number of general issues. Additional discussion of some of these issues may be found in the Recovery Plan. These issues, and the response to each, are presented below, along with references to locations in the Recovery Plan where a discussion of the issue may be found. Comments regarding editorial changes to the text were incorporated into the Recovery Plan as appropriate.

Issue 1. The Service did not provide adequate notice of the availability of the draft Recovery Plan for public review, and the opportunity for public input to the process was inadequate.

Response. The Service has provided extensive opportunity for the public to provide input in the conservation of the Rio Grande silvery minnow, extending back to February, 1991. The Final Rule to list the Rio Grande silvery minnow as an endangered species, contained in the July 20, 1994 Federal Register, summarizes the extent of the public notice and some of the opportunities for public input into the conservation process up to that time. Also, the Rio Grande silvery minnow Recovery Team appointed by the Regional Director in March, 1995, pursuant to the cooperative policy statement of July 1, 1994, was intended to provide an opportunity to involve stakeholders in the development of this Recovery Plan. In addition to representatives of federal and state agencies, Recovery Team members represent municipal and agricultural water users, native American Indian pueblos and environmental interests. Over 525 copies of the draft Recovery Plan were mailed to interested individuals and entities in response to requests for the opportunity to comment.

Issue 2. The Endangered Species Act requires the Service to incorporate into the Recovery Plan objective, measurable recovery criteria. The recovery criteria contained in the draft Recovery Plan are subjective, and the use of the undefined terms "institutional mechanisms" and "biologically significant decline" do not allow the reader to know or determine when recovery can occur or when it has occurred.

Response: Recovery criteria must not be open to interpretation by the various individuals reading the Recovery Plan. Concise and measurable recovery criteria are necessary and required. The Recovery Plan has been modified to include measurable criteria which are based upon a moving five-year mean of Rio Grande silvery minnow population densities as determined from samples taken each fall. The criteria also include a requirement to maintain adequate winter habitat to ensure that winter mortality rates do not significantly impact spring spawning densities. The initial criteria are based upon population densities obtained from sampling in the San Acacia reach of the middle Rio Grande which will be applicable to all upstream reaches in the middle Rio Grande. Criteria for reaches determined to be suitable for reestablishment initially will be based on data from the Cochiti to Elephant Butte reach, modified to reflect environmental conditions of each reestablishment reach, and subject to reevaluation upon review of data collected during monitoring of reestablished populations. (See pages 42-44 of the Recovery Plan for a discussion of measurable recovery criteria.) The Recovery Plan was also revised to include a discussion of "institutional mechanisms" (page 45). The Recovery Plan provides a list of examples of operating and administrative practices that would help ensure habitat enhancement and maintenance, although this list does not preclude the addition of other practices that might be determined to be necessary through the adaptive management process.

Issue 3. The Recovery Criteria must include the establishment of Total Maximum Daily Loads for contaminants in all stream reaches with existing minnow populations and those proposed for reestablishment

Response. Total Maximum Daily Loads (TMDLs) involves a process whereby allowable pollution loads are allocated among different sources so that the appropriate point and non-point source control actions can be taken to reduce pollution loads and achieve water quality standards. The Clean Water Act requires the states to identify the waters within its boundaries for which effluent limitations are not stringent enough to implement any water quality standard applicable to such waters. The responsible New Mexico state agency is the Water Quality Control Commission. Neither the Service nor the Recovery Team have the authority to require the development and implementation of TMDLs, although the development and implementation of TMDLs has been added in the list of administrative institutional mechanisms that would enhance and maintain habitat (see page 46).

Issue 4. The five-year moving mean used in the Recovery Criteria must include two years of below normal precipitation in order to provide for stable populations during drought years.

Response. The initial baseline autumn Rio Grande silvery minnow density used in the Recovery Criteria is based upon the mean abundance of Rio Grande silvery minnow during the above average flow years of 1993, 1994, 1995, and 1997 in the San Acacia segment of the Cochiti to Elephant Butte reach of the Rio Grande. Subsequently, the annual evaluation of abundance will be based upon a moving five-year mean (see page 43). Population densities from the below average flow year of 1996 were not included in the baseline which provides the Recovery Criteria with a "bias" that requires the population densities in any year, included a dry year or a series of consecutive dry years, to maintain population levels comparable to population levels of the wet years used in the baseline. Successful implementation of recovery activities 1.2.1. (page 50) and 1.2.3.1. (page 51) would augment flows during low flow period and mitigate against the effects of drought. These factors make the inclusion of years of below average precipitation in the Recovery Criteria unnecessary.

Issue 5. The Recovery Plan provides no basis for the use of current levels of Rio Grande silvery minnow populations in the Recovery Criteria.

Response. The Recovery Plan was revised to provide a basis for the use of current population levels in the recovery criteria (see page 44). Current population levels used in the recovery criteria are based upon the years 1993-1995 and 1997, which is the period of most systematic collections on the middle Rio Grande valley, and provides the most complete and comprehensive information available on the Rio Grande silvery minnow populations in the middle Rio Grande valley. Because of the random nature (both spatial and temporal) of historic fish collections made in the historic range of Rio Grande silvery minnow, there are little reliable data available on long-term population levels to provide a basis for judging recovery.

Issue 6. The estimated costs for recovery contained in the draft Recovery Plan are unreasonable and would fund research of questionable need. The Recovery Plan should address the expected sources of funding and should include only those costs that are directly related to recovery activities.

Response. The Endangered Species Act requires that the Secretary include estimates of the costs to carry out recommended, not mandatory, recovery activities. The responsibility for each agency to request funding for and carry out the recovery activities identified in Part III - Implementation Tasks, is based upon the collaborative decisions of the Recovery Team members. Agencies identified in Part III will be able to justify their budget submittals because their funding requests are identified in an approved Recovery Plan and are therefore part of the overall coordinated recovery effort for Rio Grande silvery minnow. Not all costs associated with recovery are known at this time, but the Recovery Plan has been modified and the estimate of the known costs have been revised to eliminate those costs that are not directly related to recovery of the Rio Grande silvery minnow (see page 68).

At this time, it is not possible to precisely quantify the amount of water (and related costs) necessary to recover Rio Grande silvery minnow in areas currently occupied and in areas that may be selected for reestablishment. See recovery activity 1.1.3., page 50, for a discussion of an estimate of the amount of water required to maintain habitat in a portion of the middle Rio Grande valley under current habitat and hydrologic conditions. The Recovery Plan calls for the enhancement and protection of Rio Grande silvery minnow habitat. The amount of water required to recover the Rio Grande silvery minnow is dependent upon the condition of its habitat. When the relationship between the condition of the habitat and the streamflow required to maintain that habitat are better understood, it may become possible to more precisely quantify the amount of necessary water. It is also not possible to identify those individuals or entities who will provide the water, and how it will be provided. Therefore, it is difficult to quantify the total cost of this recovery activity. The process of acquiring water and the mechanism for delivering the water to locations where it is required may be addressed through the adaptive management process or in a habitat conservation plan.

Issue 7. The process and criteria contained in the draft Recovery Plan that are used to select the reaches most suitable for reestablishment are unclear and incomplete.

Also, it is not necessary to reestablish the Rio Grande silvery minnow to areas outside of the middle Rio Grande valley in order to recover the species.

Response. That section of the Recovery Plan that addresses the reintroduction site selection process was expanded to include a more thorough discussion of the various factors of habitat that led to the identification of the sites most suitable for reestablishment (see Appendix B, page B-1). The principal selection criteria include the level of understanding of the reasons that Rio Grande silvery minnow was extirpated in each reach, the presence of other members of the same reproductive guild, habitat conditions and the presence or absence of congeners. The Recovery Plan calls for a more complete evaluation of potential reestablishment sites prior to reestablishment (see recovery item 2.5., page 59). A complete inquiry into the factors that led to the loss of Rio Grande silvery minnow in the reaches identified for reestablishment must be undertaken and these factors addressed prior to reestablishment.

Secure establishment in three reaches outside of the middle Rio Grande valley was deemed by the Recovery Team to be the minimum necessary to ensure survival and recovery of the species (i.e., achieve delisting requirements). The logic for determining that three additional geographic reaches were necessary involved 1) consideration of the biology (particularly reproductive and drift) of the species, 2) the factors in each reach that may inhibit or enhance establishment and security of the species, and 3) the probability that any single factor or combination of factors (abiotic and biotic) would eliminated the species from a specific reach. Reaches or portions of reaches not included in the list of most suitable sites for reintroduction are not excluded from further consideration. Monitoring of habitat and of reestablished populations may reveal that those reaches listed in the Recovery Plan may not be capable of supporting Rio Grande silvery minnow. In that event, other reaches currently not on the list would be reconsidered. See pages 43- 44 for additional discussion about this issue.

Issue 8. Portions of the reach of the Rio Grande between Elephant Butte Dam and Presidio, Texas, should be identified as a site suitable for reintroduction.

Response. Based upon observations and data collected by the Fish and Wildlife Service New Mexico Fishery Resources Office, as well as the input received from other comments, portions of the reach of the Rio Grande from Caballo Dam downstream to Presidio, Texas, were added to the list of river reaches to be more fully evaluated for possible reestablishment of Rio Grande silvery minnow. Actual reestablishment in portions of this reach, and all other reaches, is subject to a thorough review of habitat conditions and completion of a site specific reestablishment plan (see recovery task 2.6., page 59).

Issue 9. Too much emphasis is placed upon continuing research of Rio Grande silvery minnow and its habitat, with an insufficient attention given to activities or actions that would directly lead to recovery of Rio Grande silvery minnow. The precarious position of Rio Grande silvery minnow should result in the identification of steps that can be immediately taken to recover Rio Grande silvery minnow.

Response. The Recovery Team has reviewed the Recovery Plan and has revised the recovery activities to reflect the concerns of the many individuals and entities who expressed this concern. The necessity of conducting some of the research proposed in the draft Recovery Plan has been reconsidered, and many of those research activities have been postponed. The adaptive management process may identify additional research that may lead to the identification of recovery tasks. A number of recovery activities identified in the Recovery Plan have already been initiated. For example, the Bureau of Reclamation has provided funds for acquisition of water to maintain habitat in the middle Rio Grande valley (see page 48) and the Service has initiated investigations into the potential lethality of the water quality of the middle Rio Grande on Rio Grande silvery minnow (see recovery task 1.3.1, page 53).

Physical removal and relocation of Rio Grande silvery minnow has been identified as a step to be taken to enhance populations in the upper reaches of the middle Rio Grande valley until the evaluation of alternatives to the existing diversion structures or the feasibility of installing fish by-pass structures are completed (see recovery task 1.5.2., page 56). Physical removal and relocation could also be used to reestablish Rio Grande silvery minnow in other suitable areas of its historic range, provided that it does not adversely impact existing populations. The Recovery Plan will be reviewed and reevaluated on a regular basis and revised whenever there is a significant change identified as a result of new data on the biology or life history of Rio Grande silvery minnow. New recovery activities may be identified and included in the recovery process as they are identified.

Issue 10. The Rio Grande silvery minnow Recovery Plan is clearly a "major federal action" and an Environmental Impact Statement must be prepared in accordance with the National Environmental Policy Act.

Response. It is important to note that pursuant to the Endangered Species Act, recovery plans provide guidance only as to what actions are necessary to achieve objectives which are critical to the conservation of endangered species. The plans themselves do not require persons or agencies to implement the specific actions suggested within. See Fund for Animals v. Rice, 85 F.3d 535 (11th Cir. 1996); Defenders of Wildlife v. Lujan, 792 F. Supp. 834 (D.D.C. 1992). Accordingly, due to the discretion that exists in implementing a recovery plan, the development of a recovery plan under the ESA is not considered to be a major federal action under NEPA. In fact, because proposed recovery actions (such as actual reestablishment of Rio Grande silvery minnow, see page 57) will be subjected to NEPA analysis at the time they are actually "proposed" with the meaning of NEPA, the Service considers recovery plans to fall within a categorical exclusion set forth in the DOI Departmental Manual, 516 DM Appendix 1, § 1.10:

> 1.10 Policies, directives, regulations and guidelines of an administrative, financial, legal, technical or procedural nature; or the environmental effects of which are too broad, speculative or conjectural to lend themselves to meaningful analysis and will be subject later to the NEPA process, either collectively or case-by-case.

Issue 11. The Recovery Plan does not address social or economic issues, and individuals with expertise in social or economic issues were not named to the Recovery Team.

Response. Service policy on Recovery Plan participation and implementation requires that the social and economic impacts of implementing recovery actions be minimized. The Recovery Plan states that all recovery activities will be undertaken in accordance with applicable statutes and rules and regulations, including an assessment of the impact of reestablishment of Rio Grande silvery minnow on existing water supplies and uses. The acquisition of water required to maintain suitable Rio Grande silvery minnow habitat would be acquired from willing sellers, and it is assumed that the willing sellers would be compensated at going market rates. Water should be acquired from those uses and transferred from those locations that would avoid a significant disruption of existing social conditions which are dependent upon the continued use of water at those locations. Diversion structures have been identified as a threat to the species, because of their ability to de-water the river and to prevent upstream migration of Rio Grande silvery minnow and because of the possibility of entrainment of Rio Grande silvery minnow into irrigation canals. If the diversion structures are to be removed, alternative measures of supplying water in the same location, in the same amount, and at the same time, would have to be provided. It is the responsibility of the Recovery Team to ensure that recovery activities are undertaken while minimizing social and economic costs. It should be pointed out that it is not likely, and it is not required, that recovery take place with no social and economic impact. For example, although an agricultural water user who sells or leases water to improve Rio Grande silvery minnow habitat would be fairly compensated, indirect impacts to seed, fertilizer or farm implement dealers or the reduction of property values (property taxes), may not be avoided.

Notwithstanding the non-applicability of NEPA, the Service does have a policy to involve potentially affected parties in the development of recovery plans in order to minimize social and economic impacts consistent with timely recovery of the species. The Service has sought to fulfill this policy through creation of a Recovery Team which includes representatives of several state and local agencies as well as private interest groups (see page iii). In addition, the direct notice and request for comments to a diverse array of interested parties were intended to further the purposes of the Service's cooperative policy. The Service will involve representative interests in implementation of the recovery plan through the list of implementation tasks. The implementation tasks involve the appropriate agencies and affected interests in the mutual development of a strategy to implement specifically designated recovery actions. Finally, an economic consultant (Dr. Robert G. Cummings) was appointed to the Recovery Team by the Regional Director, who is available to assist the Recovery Team in developing strategies to minimize social and economic impacts of implementing recovery activities.

Issue 12. The Recovery Plan should include the designation of critical habitat as a recovery action, or, the Recovery Plan implicitly designates critical habitat.

Response. The Recovery Team is not empowered to propose or designate critical habitat, although it may, as it has in this instance, identify habitat areas that may be essential to the species recovery. The Endangered Species Act requires that the Service designate critical habitat for Rio Grande silvery minnow within one year of listing the species as endangered. On March 1, 1993, the Service proposed to list the Rio Grande silvery minnow as an endangered species with critical habitat on Rio Grande from the downstream side of NM State Highway 22 bridge crossing Rio Grande immediately downstream of Cochiti Dam, extending south downstream approximately 262 km (163 mi.) to where the Burlington Northern and Santa Fe Railroad crosses the river near San Marcial, Socorro County. The effective date of the final rule listing the Rio Grande silvery minnow as an endangered species was August 19, 1994, although the Service found that critical habitat was not determinable at that time. The Service did not designate critical habitat within the time frame established by the Endangered Species Act, and a lawsuit was filed in the U. S. District Court under the citizen suit provision of the Endangered Species Act and the Administrative Procedures Act. On October 23, 1997, the U. S. District Court found that due to budgetary constraints and biological priorities, the Service was justified in deferring designation of critical habitat for Rio Grande silvery minnow. The Court also ordered the Service to provide periodic updates on the status of critical habitat designation for the Rio Grande silvery minnow.

Issue 13. Acquisition of water or water rights to provide instream flow for the protection of fish and wildlife is not allowed by New Mexico law.

Response. Since the release of the draft Rio Grande silvery minnow Recovery Plan on January 2, 1998, the New Mexico Attorney General has issued an opinion that addressed the question of whether New Mexico law affords legal protection to instream flows for fish and wildlife purposes. The Attorney General's Opinion, dated March 27, 1998, addressed the limited instance of an application before the New Mexico State Engineer requesting a change in place and purpose of use from some historic use to a use for instream flow for recreational, fish, wildlife or ecological purposes. The opinion concluded that there is nothing in the New Mexico constitution, statutes, or case law that should preclude the State Engineer from approving an application to change the purpose or place of use of an existing water right to an instream purpose.

Issue 14. The acquisition of water to conserve Rio Grande silvery minnow and its habitat must be done consistent with state and federal law and without impairment to existing uses.

Response. The Endangered Species Act requires that the Secretary of the Interior cooperate to the maximum extent practicable with the states, including consultation with the states before acquiring water required to conserve Rio Grande silvery minnow. Any entity that purchases or leases water from private individuals and which requires the transfer of these water rights is required to follow the state laws which are designed to ensure that existing water rights will not be impaired. The state administrative process involved in reviewing the proposed transfer may also consider the impacts of the proposed water rights transfer on each states ability to comply with the requirements of interstate stream compacts. The numerous regional water planning efforts that have addressed issues such as the protection of critical habitats and aquatic life and its impact on water supplies would also be of assistance in devising strategies to address matters related to the public welfare and conservation of water.

The ongoing practice in which the federal government acquires San Juan-Chama Project water for the purpose of providing it to irrigators in the middle Rio Grande in exchange for the irrigators forbearing a diversion of the natural flow is consistent with state and federal law. All options for the acquisition of water will be evaluated consistent with applicable laws.

Issue 15. The Recovery Plan concludes that low water velocity habitat is essential to the propagation of the Rio Grande silvery minnow. Thus, any action that causes an increase of water velocity, such as a reservoir release, will likely cause "significant habitat modification or degradation". Changes in reservoir operations to ensure low velocity flows will have an impact on existing water supply and demands.

Response. The construction of river channel protective works and flood control levees has resulted in deeper and narrower river channel cross sections which has improved the water transport efficiency. This has resulted in the loss of side channels and backwater areas which provide low velocity habitat areas which provide food and protection for larval Rio Grande silvery minnow. The recovery of the Rio Grande silvery minnow will require the modification of river channel areas to provide more low velocity habitat (see recovery activity 1.5., page 56). This does not mean or imply that the velocity of the entire river channel cross section area will have to be reduced at all times and cause major disruption of historical reservoir operating procedures. It is believed that operation of reservoirs in a manner that would mimic flow regimes found under natural conditions would improve habitat diversity and benefit Rio Grande silvery minnow (see recover task 1.2.3.2., page 52). Modification and improvement of Rio Grande silvery minnow habitat could increase stream channel losses resulting in decreased downstream water deliveries which may have to be offset in some fashion to ensure no net increase in stream depletion.

Issue 16. The Service should provide strict liability for damages caused to persons and property from listing and recovering an endangered species.

Response. Only the Congress can provide a waiver of the United States sovereign immunity and determine the terms under which the government may be liable for damages.

Issue 17. The Recovery Plan does not adequately describe how required research and recovery activity will be prioritized and scheduled.

Response. The Recovery Team, or some other entity designated by the Regional Director, will be responsible for implementing the Adaptive Management process to ensure that research is prioritized, funded and conducted in a logical and sequential manner once the plan has been approved. Funding of individual participation of Recovery Team members in the adaptive management process will be the responsibility of the agency represented by the Recovery Team member. Funding, implementation and administration of the recovery activities identified in the Recovery Plan could also be a component of a habitat conservation plan (Endangered Species Act - Section 10), but there has been little, if any, interest expressed by stakeholders in the development of a habitat conservation plan. Some steps to protect and enhance Rio Grande silvery minnow have been undertaken in the middle Rio Grande valley during the 1996-98 period without the benefit of an approved Rio Grande silvery minnow Recovery Plan. These steps were the result of a collaborative effort of an ad-hoc group of federal, state and local agencies who communicate on a regular basis to address urgent management issues in the middle Rio Grande valley. The activities of this ad-hoc group will continue and should evolve into a group to adaptively manage this Recovery Plan with periodic participation of researchers, representatives of Indian Pueblos and representatives of water users from areas of Rio Grande silvery minnow historic range.

Issue 18. Collections of what were presumed to be the Rio Grande silvery minnow from 1963 to 1965 in the Pecos River indicated the Rio Grande silvery minnow was widespread and common between Sumner Reservoir and Lake McMillan (now Brantley Reservoir). The last known collections of the Rio Grande silvery minnow occurred in 1968, and these include the first verified collections of the plains minnow. According to statements made in the Recovery Plan, gel electrophoretic data to distinguish between species of Hybognathus were not available until 1998 and 1992. Therefore, what data are available to indicate that collections prior to these dates were actual Rio Grande silvery minnow and not plains minnow?

Response. Preserved specimens were available to document that collections prior to 1988 and 1992 were actually Rio Grande silvery minnow and not plains minnow. (Cook et al. 1992) Also, the use of gel electrophhoretic data to distinguish the difference between the two species is not necessary, as the species were distinguished morphologically in the review of historic distribution of Rio Grande silvery minnow and elsewhere (see Bestgen and Platania 1991).