DISTRIBUTION AND STATUS OF

RIO GRANDE CHUB IN COLORADO

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Executive Summary

The few early records available described Rio Grande chub in the Rio Grande Basin, Colorado, as widespread and abundant but the present status of the species has not been assessed. We used museum records, literature, and sampling at sites throughout its historical range to describe changes in status of Rio Grande chub in Colorado. Distribution and abundance of Rio Grande chub in the Rio Grande drainage, Colorado, has declined rather dramatically. Formerly abundant populations in the main stem Rio Grande may be extirpated. Rio Grande chubs remain in just a few smaller streams and populations can be considered relatively large and stable only in Hot Creek and Saguache Creek. Sampling showed that chubs in La Jara Creek and Rio San Antonio were more restricted and threatened by water diversion or drought. Several populations, including formerly large ones in McIntyre Spring and San Luis Creek, have declined since sampling in the early 1980's. Rio Grande chubs occurred most often in cool water streams up to about 2500 m in elevation at sites that had permanent flow, sand and gravel substrate, deep water, and cover. Although chubs were often found in streams that supported salmonids, chubs were most abundant at sites where brown trout were rare or absent. Possible reasons for decline of Rio Grande chubs varied by stream system and included habitat loss via drought and water diversion, negative interactions with introduced species including brown trout, acute and chronic effects of heavy metal pollutants, and high water temperatures induced by low flows. We discuss research and management actions that may enhance the status of Rio Grande chub in Colorado.

INTRODUCTION

Distribution, biology, and status of Rio Grande chub *Gila pandora* in the Rio Grande Basin, Colorado, New Mexico, and Texas, is poorly understood (Koster 1957, Minckley 1980, Woodling 1985, Sublette et al. 1990, Calamusso 1993, Rinne 1995). Although the species is relatively widespread in New Mexico in the Rio Grande and Pecos River drainages, only a single population of Rio Grande chub persists in the Davis Mountains of Texas (Koster 1957, Miller and Hubbs 1962), and nearly nothing is known range-wide of it's life history (Minckley 1980). Status and ecology of Rio Grande chub in Colorado is especially poorly known, given the scattered historical collection records. The few early records documented relatively widespread occurrence of Rio Grande chub in Colorado and accounts noted their abundance at several localities (Jordan 1891, Ellis 1914). Based on apparent declines in historical distribution and abundance (Zuckerman and Langlois 1990), extensive modification of streamflow patterns and habitat, and historic declines of Rio Grande cutthroat trout *Salmo clarki virginalis* and Rio Grande sucker *Catostomus plebeius* in Colorado (Behnke 1992, Swift-Miller et al. 1999), Rio Grande chub was listed as a Species of Special Concern by the Colorado Division of Wildlife.

Early ichthyologists provided the first glimpses of the fish fauna of Colorado, but apparently only after extensive modifications to habitat were already underway (Jordan 1891). More recently, Zuckerman (1983, 1984, 1985, see also Zuckerman and Langlois 1990) completed a relatively comprehensive survey of the Rio Grande Basin, Colorado, from 1981 to 1985, and the Colorado Division of Wildlife has continued sporadic sampling since, re-sampling many of Zuckerman's original sites. However, a summary of available information and a recent survey of Rio Grande chub distribution and abundance across the basin have not been completed.

The primary goal of this study was to describe the distribution, abundance, and status of Rio Grande chub in the Rio Grande Basin, Colorado. Three main tasks guided research efforts.

First, we attempted to gather all historical collection data to describe past distribution and abundance of Rio Grande chub. Second, we sampled historical and new localities in the Rio Grande Basin, Colorado, to determine current distribution of this species. Third, we compared historical and recent sampling information to determine if distribution and abundance of Rio Grande chub has changed in Colorado, and we report notes on its ecology. We also provide recommendations for research and management, which should enhance efforts aimed at conservation of Rio Grande chub in Colorado.

Life history of Rio Grande chub.--Rio Grande chub are commonly found in pools of small to moderate-sized perennial streams at higher elevations, where substrate particles are sand, gravel, or cobble (Koster 1957, Bestgen and Platania 1990, Sublette et al. 1990, Platania 1991, Bestgen and Platania 1991, Calamusso 1993, Swift-Miller et al. 1999). They are usually associated with undercut banks, overhanging vegetation or brush, aquatic plants, and deep water in stream reaches cool enough to support trout (Platania 1991, Rinne 1988, Rinne 1995, Swift-Miller et al. 1999). A common inhabitant of cool or cold lakes and ponds, particularly in the San Luis Valley, Colorado, Rio Grande chub survived in Kerr Lake at an elevation of 3,468 m in southern Colorado (reported in Zuckerman 1984). Rio Grande chub is a mid-water carnivore that includes zooplankton, aquatic and terrestrial insects, crustaceans, juvenile fish, as well as a limited amount of detritus in its diet (Sublette et al. 1990).

Rio Grande chub exhibit orange-red coloration along the mouth, lower fins, and the lower sides of the head and body during the reproductive season (Koster 1957). Rio Grande chubs reproduce mostly in spring and early summer, but autumn spawning has been documented in Hot Creek, Colorado, in the Native Species Recovery Facility, Alamosa, Colorado (J. Alves, pers. obs.), and was likely in one year in the Rio de las Vacas, NM, suggesting that autumn spawning may occasionally occur when environmental conditions are suitable (Rinne 1995). Spawning

occurs in riffles and embryos develop without parental care (Koster 1957). Hybridization with longnose dace *Rhinichthys cataractae* has been documented (Cross and Minckley 1960, Suttkus and Cashner 1981). One hybrid specimen was collected in 1968 in the Rio Grande north of Monte Vista (Suttkus and Cashner 1981). Hybridization may have been associated with fish crowding in limited habitat which was enhanced by drought and irrigation diversions (Cross and Minckley 1960, Suttkus and Cashner 1981).

STUDY AREA

The Rio Grande Basin in south-central Colorado drains approximately 19,712 km^2 including high elevation mountains to the east, west, and north (Fig. 1, unpublished U. S. Geological Survey Water Resource data 2002). The Rio Grande headwaters in the San Juan Mountains near Creede, Colorado, flows east to Del Norte, and then onto the San Luis Valley floor, an open, flat, relatively treeless, high-elevation valley in a cold desert region. The Rio Grande then flows south until it exits Colorado into New Mexico. Major tributaries of the Rio Grande in Colorado include the Alamosa River, Conejos River, Culebra Creek, La Jara Creek, and Trinchera Creek (Fig. 1). The valley has an elevation of 2,268 to 2,438 meters, is arid throughout the year, and cold in winter and hot in summer. Precipitation averages only about 25 cm/year (Swift-Miller et al. 1999) and system hydrology is dominated by snowmelt runoff in spring. Flows in basin streams at other times of the year are typically low, due to arid conditions and extensive use of surface water for irrigation. Much of the north end of the Basin (7,526 km^2) does not drain into the Rio Grande due to a low divide formed by the alluvial fan of the Rio Grande on the west and alluvial material from the Sangre de Cristo Mountains on the east (U. S. Department of Interior 1970). This disconnected area, which is a sump for Saguache Creek, San Luis Creek, and their tributaries, is known as the Closed Basin.

The San Luis Valley contains an extensive and complex water supply. Two separate aquifers are estimated to contain over two billion acre-feet of ground water (Pearl 1974). Thermal springs, artesian wells, spring creeks, ephemeral streams, playa lakes, cirque and oxbow lakes, and wetland marshes are also present. Water development activities have been prevalent since the valley was settled after about 1850. Jordan (1891) noted that lower elevation runoff in most streams he observed was consumed by irrigation and "In these streams thousands of trout are destroyed each year by the irrigating ditches, especially at the time of their downstream migration in the fall". As of 1993, the total basin inflow of native water was about 1,576,000 acre-feet per year, not including depletions and storage. Total basin outflow from Colorado as of 1993 was about 325,000 acre-feet per year (Ugland et al. 1994, www:/cwrii.colostate.edu). The primary consumptive use of water in the valley is agriculture (85 to 99%), with an estimated 624,219 acres (252,621 hectares) under irrigation (U. S. Bureau of the Census 1999).

Highest flows in the main stem Rio Grande occurring in June, May, and April, in that order (period of record 1931-2002, U. S. Geological Survey gage, 08251500, near Lobatos, CO, just upstream of the New Mexico border) and flows during other months are lower. Drought during 2001 and 2002 reduced flow in most streams in the Rio Grande Basin. For example, mean daily flow of the Rio Grande at the Lobatos gage in the 2002 water year was only 3.3 m^3/sec, and mean daily flow peaked at 11.1 m^3/sec on 14 March 2002. In contrast, the average flow from 1931 to 2002 was 12.6 m^3/sec, average maximum daily flow was 140 m^3/sec.

METHODS

Historical data compilation.--To describe historical distribution and abundance of Rio Grande chub in the Rio Grande Basin, Colorado, we conducted an exhaustive primary and

secondary literature search and queried all available museum databases. Scientific names used in searches for chubs in the Rio Grande Basin, Colorado, included the following:

Clinostomas gula
Clinostomas pandora
Gila pandora
Gila gula
Gila nigrescens
Leuciscus pulchellus
Leuciscus nigrescens
Richardsonius nigrescens
Squalius pulchella
Squalius gula
Squalius nigrescens
Squalius pandora
Tigoma pulcher

Gila nigrescens, the Chihuahua chub, is distinct from *G. pandora* and occurs in the Mimbres drainage of southwestern New Mexico and several drainages in northern Mexico (Miller and Hubbs 1962). Therefore, presumptive *Gila nigrescens* collected by Jordan (1891) in the Conejos River, by Beckman in Saguache County, by F.W. Worman in 1943 on the Rio Grande near Alamosa, and in 1968 in the Rio Grande north of Monte Vista are considered Rio Grand chub, *G. pandora*. Museum acronyms follow Leviton et al. (1985). We also included all Colorado Division of Wildlife (CDOW) sampling data collected since 1992 in our database.

Present sampling.--We attempted to sample all sites where Rio Grande chubs historically occurred, including those visited by Zuckerman (1983, 1984, 1985), so that we could make comparisons of chub distribution over time. We also identified locations where little or no historical sampling occurred where chubs may be present. We added additional sampling sites in some streams so that the distributional extent of chubs in the basin would be better understood.

Sample site selection was influenced by private property access and presence of water. Most landowners were agreeable to allowing access for sampling. Sites where chubs once

occurred but were now dry due to ongoing drought and extensive use of water for irrigation were noted, as were observations of other dry sites on named streams.

Sampling procedure.--If a previous sampling site locality was described in detail, we attempted to sample the same stream reach. We chose reaches that included all meso-level habitats including runs, riffles, and pools. Undercut banks, overhanging vegetation, cobble or rip-rap structure, and other habitat features within meso-habitats that likely supported chubs were sampled. Sample site length was increased if meso-habitats were lacking in shorter reaches. Natural and artificial barriers such as beaver ponds, deep pools, diversion dams, and private land boundaries sometimes also limited the extent of sampling reaches.

Fish were collected primarily with a backpack electrofisher (Smith-Root, model 12-B). The DC programmable output waveforms used were 30 Hz and 3 ms at 600-700 volts, or 60 Hz and 6 ms at 300-500 Hz. We used a second backpack electrofisher (Coffelt, model BP-4) to increase sampling effort in the larger Rio Grande and a third while sampling McIntyre Spring. Electrofishing effort was applied in all habitat types and all stunned fishes were collected and placed in a live basket until the entire reach was sampled.

Following sampling, captured fishes were identified to species. For the first seven sites completed on Saguache Creek, all Rio Grande chubs were counted and measured and presence of other species was recorded. At all other sites, Rio Grande chubs and salmonids were counted and measured, predatory fishes were counted and usually measured, and all other fish species were counted. Fish were then released. A small number of voucher specimens were preserved in 10% formalin to assure identity of potentially problematic specimens. Those specimens were deposited in the fish collection at the Larval Fish Laboratory, Colorado State University. Fin clips from Rio Grande chub were also collected from Saguache Creek (RG-06) and Rio San Antonio (RG-19) in 2001 for genetic analyses (Douglas and Douglas 2003).

Water temperature, dissolved oxygen, conductivity, salinity, and pH were recorded at every site using a handheld meter (YSI, model 85). Site locality and elevation was recorded with a hand-held GPS unit and a qualitative description of the sample site and habitat was also made.

Factors affecting chub distribution.--We were interested in understanding if Rio Grande chub presence at sites in the Rio Grande drainage was associated with physical habitat variables at sites or presence of predaceous fish. Presence/absence of Rio Grande chub at a site was treated as a binary response in a logistic regression model that predicted the probability of presence of Rio Grande chub as a function of a suite of explanatory variables. Because most streams were small, sample sites relatively long, and intensive effort was applied in the relatively simple habitat, we assumed we captured Rio Grande chub if they were present at sites. Explanatory variable data collected at each site that was considered in the regression model included elevation, stream width, estimated maximum depth, presence/absence of instream cover (undercut banks, large woody debris), presence/absence of boulders or bank rip-rap, dominant substrate particle size (boulder, cobble, gravel, sand, silt), stream flowing or not, dominant land use (agricultural, undisturbed natural, recreational), water visibility, presence of brown trout, and presence of other potentially predaceous fishes (sunfish *Lepomis* spp, largemouth bass *Micropterus salmoides*, northern pike *Esox lucius*, and yellow perch *Perca flavescens*). Akaike's Information Criterion (AIC) was used to arrive at a reduced model with a useful subset of explanatory variables (Burnham and Anderson 1998). An initial model was developed using data from all sites and streams where fish were captured. Those model results were useful to understand a broad view of factors that presently influence chub distribution in the Rio Grande, Colorado. Another model was estimated with the same explanatory variables using only sites from streams where Rio Grande chubs were collected. This analysis attempted to more closely define factors important to chub presence when chubs were known from the system.

RESULTS

Distribution and chronology of sampling effort.--We located a total of 26 Colorado records for *G. pandora* prior to 1981 (Table 1). Locality data, particularly for some older records, was sometimes incomplete which frustrated efforts to map records or duplicate sampling at those sites. Early records, collected mostly by ichthyologists passing through the region, were scattered with most sampling in the main stem Rio Grande upstream of Alamosa.

Zuckerman (1983, 1984, 1985) completed the first systematic survey of native fishes in the Rio Grande drainage from 1981 to 1985, reporting over 250 collections at different sites throughout the basin. Although a complete reporting of all sampling records and sites visited was never generated, his Rio Grande chub sampling records were acquired from a collection housed by the U. S. Geological Survey at the Museum of Southwestern Biology (USGS-MSB, Table 2).

From 1992 to 2000, Colorado Division of Wildlife (CDOW) collected 73 fish samples at 59 sites (Table 3). From 2001-2002, we visited a total of 86 sites (Table 4). Twenty-nine of those sites were dry; sampling occurred at the remaining 57. The goal of much of the recent sampling has been to monitor distribution and status of rare Rio Grande fishes over time, so many samples taken since 1992 were at sites visited by Zuckerman. Additional miscellaneous samples, including some of questionable taxonomic identity, are also reported (Appendix I).

Rio Grande chub distribution.--The first Rio Grande chub reported was collected in 1871 at Sangre de Cristo Pass (Cope and Yarrow 1875, Jordan 1896, Ellis 1914), from a tributary to the Rio Grande (Table 1, Fig. 2). That sample, likely from nearby Sangre de Cristo Creek, provided the type specimens for description of the species. The types were not designated clearly (Cope and Yarrow 1875, Jordan 1896) and some were supposedly collected in the Rio San Juan, near Pagosa Springs, CO, which is a Colorado River Basin stream. With the exception

of single samples from the Conejos River (Jordan 1891), Sangre de Cristo Creek, an unknown Watrita Creek, and Closed Basin locations San Luis Lakes (1909) and Russell Spring (1950), all other Rio Grande chubs captured prior to Zuckerman were from the main stem Rio Grande. Jordan (1891) found chubs in the Rio Grande at Del Norte and Alamosa, and three other sites with incomplete descriptions in the Rio Grande in 1889. *Gila pandora* was further documented from the Rio Grande in 1912 (Ellis 1914), 1927, 1934, 1944, and 1968 (Table 1). Chubs were also reported from the Alamosa River in 1978 (N = 2) and Terrace Reservoir (N = 17) in 1975 (Woodling 1995).

Cope and Yarrow (1875) also reported chubs from the Rio San Juan, near Pagosa Springs, CO, which they attributed to *G. pandora*. Those specimens were likely native roundtail chub, *Gila robusta*, because the San Juan River is in the Colorado River Basin where *G. pandora* is not native. We reported those records as well for completeness.

The USGS-MSB records we obtained suggested Zuckerman collected Rio Grande chubs from 29 locations on 36 different sampling occasions (Table 2, Fig. 2). This included four samples from the Rio Grande from upstream near Del Norte downstream nearly to the New Mexico border near Antonito, two from the Conejos River, three from Rio San Antonio, two in Rock Creek (Alamosa County, near Alamosa), five in Hot Creek, five in McIntyre Spring, and one in the stream exiting McIntyre Spring. Closed Basin captures of Rio Grande chub from 1981-1985 included two sites in San Luis Creek, six in Saguache Creek, one in Hot Springs Creek, and one at Trite Lakes (Russell Lakes SWA). Chubs were also found at two sites in Rio Chamita and one in Sexto Creek, both of the Chama River drainage, which is tributary to the Rio Grande near Espanola, New Mexico. Rio Grande chubs were also collected from Dome Lakes, Gunnison River drainage, Colorado River Basin.

The CDOW records from 1992-2000 suggested Rio Grande chub were detected on 45 sampling occasions at 32 sites throughout the basin (Table 3, Fig. 3). Chubs were found once in the Rio Grande (near Del Norte), three times in La Jara Creek, four in Rio San Antonio, and 12 times in Hot Creek. Closed Basin Rio Grande chub records included five samples from Saguache Creek, nine from San Luis Creek, and one from Rock Creek. Lentic sampling sites where chubs were found included one each at Swale, Chico, and Teal Lakes, two at Roaring Fork Pond, and three at Silver Lakes. Gunnison River Basin records of introduced Rio Grande chub were also verified for Upper Dome Lake (N = 3 specimens) and upstream Archuleta Creek (N = 33, D. Brauch, CDOW, pers. comm.).

During sampling from 2001-2002, we detected chubs on 15 of 57 sample sites (chubs found on 18 sampling occasions, Table 4, Fig. 4). We sampled the main stem Rio Grande at 17 locations from approximately 8.9 km upstream of Del Norte downstream to CR G, east of Antonito, Colorado near the New Mexico border. We also sampled 21 sites (three sampled twice) in Rio Grande tributaries Alamosa River, La Jara Creek, Hot Creek, Conejos River, Rio de los Pinos, and Rio San Antonio. Other sites visited included tributaries in the eastern portion of the basin. The confluences of Trinchera and Culebra creeks with the Rio Grande were observed dry in October of 2001. Those creeks were barely discernable, presumably due to long-term irrigation withdrawals and they rarely flow to the Rio Grande. In September 2002, additional dry river reaches included tributaries of Ventero Creek along CR 21 (Cuates Creek, Jaroso Creek and Torcido Creek), Rito Seco northeast of San Luis, and Sangre de Cristo Creek, 8.5 kilometers northeast of Fort Garland along Highway 160. There may be isolated stream reaches that support chub populations in other foothills stream reaches in that area, but additional sites were not sampled because of access issues or drought.

We also sampled Closed Basin sites including seven in Saguache Creek, two in San Luis Creek, one in Rock Creek (Saguache County) and two at Big Spring Creek. One site each was sampled in Wild Cherry Creek, Cotton Creek, Kerber Creek, Slaughterhouse Creek, and Russell Spring below Russell Lakes State Wildlife Area, also in the Closed Basin.

We did not find Rio Grande chubs in the main stem Rio Grande. In tributaries of the Rio Grande, chubs were collected at nine sites: one in La Jara Creek, three in Hot Creek, two in McIntyre Spring, two in Rio San Antonio, and one in Rio de los Pinos. In the Closed Basin, we found chubs at four sites in Saguache Creek, one site in San Luis Creek, and one site in Rock Creek.

Chronological abundance at selected stream sites.—In the mainstem Rio Grande, Rio Grande chubs (N=1 to 212) were found on 12 sampling occasions through 1968. Following that, Zuckerman collected one chub at each of four main stem Rio Grande sites. The Colorado Division of Wildlife collected four Rio Grande chubs at Del Norte in 1996.

Fifteen Rio Grande chubs were collected from the Conejos River in 1889. Zuckerman collected single Rio Grande chubs on two different sampling occasions in the Conejos River at CR 28, approximately one mile above the confluence with the Rio Grande.

At McIntyre Spring, Zuckerman captured Rio Grande chubs on six sampling occasions (N=6 to 98, 324 total). The CDOW did not detect Rio Grande chubs there in 1997, although we collected 12 at one site in 2002. Zuckerman sampled the outflow of McIntyre Spring and captured 18 chubs; we found three chubs near that same location.

Zuckerman twice sampled Rio San Antonio at Highway 285 south of Antonito and found five and 25 Rio Grande chubs; a downstream location at Sego Springs State Wildlife Area (SWA) produced one chub. The CDOW sampled at the Highway 285 site in 1997 and found 32 chubs. We sampled this location and found Rio Grande chubs twice (N=27 and 75). The

Colorado Natural Heritage Program sampled at the V-Heart Ranch but did not find chubs. The CDOW found Rio Grande chubs at two locations (N=3 and 7) on the T-Bone Ranch. A T-Bone Ranch site and the Sego Springs SWA site was dry in 2001, so we did not sample there. We extended the upstream range of the Rio Grande chub in Rio San Antonio by collecting six chubs at CR C in San Antonio, Colorado. Another site at CR M southeast of Manassa was sampled but no chubs were collected. Low flows in 2001 and 2002 resulted in intermittent stream conditions, and existing pools were being pumped for irrigation water. The Highway 285 site had flowing water in 2001 but was ephemeral in 2002 and remaining pools had poor water quality.

Rio de los Pinos, a tributary of Rio San Antonio, headwaters within Colorado, flows south into New Mexico, and then back into Colorado. The confluence with Rio San Antonio is approximately 0.5 km north of the Colorado/New Mexico border. Two sites were sampled in Colorado, the first documented sampling in that area. The upstream site was in the Rio Grande National Forest south of Osier; no chubs were detected. Eight chubs were captured at the downstream site upstream of CR B, south of Ortiz. Distribution and abundance of Rio Grande chub in the New Mexico section of Rio de los Pinos is unknown.

La Jara Creek was first sampled by CDOW at four locations (1993-1997) and we collected four samples at three additional locations. Sites were from La Jara State Wildlife Area downstream to CR S-112 (approximately 5 km west of the confluence with the Rio Grande). No chubs were detected at the two upstream sites within the SWA where brown trout occurred, but chubs (N=1 to 17) were detected at four of five sites from downstream of the SWA to Capulin, Colorado. No brown trout occurred at those downstream sites. In October 2001, La Jara Creek was dry downstream of Capulin to La Jara at six locations. Water returned to La Jara Creek at CR 22, but no Rio Grande chubs were collected. The creek was again dewatered downstream at

CR 24 (CRS-112). The geographically restricted population of Rio Grande chubs in La Jara Creek is isolated downstream during low water years.

Rio Grande chubs were abundant in Hot Creek, a warm, homothermal spring tributary of La Jara Creek (Zuckerman and Langlois 1990, Swift-Miller et al. 1999). Zuckerman collected Rio Grande chubs (N=3 to178, 528 total) on five occasions (five sites) within Hot Creek State Wildlife Area (SWA). Swift-Miller et al. (1999) studied the single remaining Colorado population of Rio Grande sucker in Hot Creek and recorded Rio Grande chub at several sites as well (Appendix I). The CDOW sampled five Hot Creek monitoring sites and they consistently collected high numbers (N=2 to 280) of Rio Grande chubs. Upstream sites within the SWA tended to support more chubs than the downstream sites. We sampled three localities in Hot Creek: one upstream of the SWA, one within the SWA, and one downstream of the SWA. The upstream canyon site produced 15 chubs, the SWA site produced 91 chubs and the downstream site, at FDR 240 Road, produced one chub. Cattle grazing and sedimentation degrade habitat after Hot Creek flows out of the SWA.

Zuckerman sampled Rock Creek, Alamosa County, twice in 1984 at State Highway 285 and collected chubs both times (N=1 and 5). The CDOW sampled Rock Creek at five locations in 1997 and 1999, but did not find chubs. We visited Rock Creek in 2001 at the Highway 285 crossing but found it dry there and at other locations downstream to Monte Vista National Wildlife Refuge during this study (J. Alves, pers. obs).

The Alamosa River has been sampled infrequently through time. Historic CDOW records for Terrace Reservoir showed that Rio Grande chubs were present in 1975. The Alamosa River above Terrace Reservoir was also sampled in 1978 and two Rio Grande chubs were collected (Woodling, 1995). In 1986, Galactic Resources Limited began an open pit cyanide heap leach operation at Summitville, CO. The mine is located at 3800 meters elevation

in the headwaters of the Alamosa River. Cyanide contaminated discharge was released directly into Wrightman Fork of the Alamosa River, and that and discharge high in metals was thought responsible for absence of fishes upstream and in Terrace Reservoir (Woodling 1995). The Alamosa River above and below Terrace Reservoir and Wrightman Fork were sampled in 1993 and 1994 and no fish were detected (Woodling 1995). The EPA sampled the Alamosa River near the confluence of French Creek above Terrace Reservoir in 1994 and two Rio Grande chubs were collected. The CDOW found chubs in Terrace Reservoir in 2001 (N = 4) and 2002 (N = 21). In 2002, we sampled the Alamosa River at two locations upstream of Terrace Reservoir and two locations downstream of the reservoir. Five rainbow trout and three cutthroat trout were the only fish captured above the reservoir and two rainbow trout were found below the reservoir. Silver Lakes, which flow into French Creek, an Alamosa River tributary, are owned by a private fishing club and support a large population of Rio Grande chubs. Silver Lakes have been sampled repeatedly by the CDOW (N=295 to 3,575). French Creek was dry in the fall of 2001.

Zuckerman collected Rio Grande chubs (N=12 and 13) at two sites on Rio Chamita, and one chub on Sexto Creek in 1985. These sites were resampled in 1999 by CDOW and no chubs were found; we did not resample these sites.

Zuckerman collected Rio Grande chubs (N=1 to 234) at six locations on Saguache Creek. We sampled 13 evenly spaced sites (1997-2002) from the Curtis Ranch (approximately two kilometers upstream of the western most State Highway 114 river crossing) downstream to CR 48-X southeast of Saguache. Abundance of Rio Grande chub increased downstream. Two of five sites at or upstream of Hodding Creek contained Rio Grande chubs (N=3 and 5). Conversely, seven out of eight sites downstream of Hodding Creek supported Rio Grande chubs (N=1 to 516). Saguache Creek flowed intermittently downstream of CR 48-X and was dry there in August of 2002. Our seven samples in Saguache Creek in 2001-2002 provided evidence of

complementary relative abundance of Rio Grande chub and brown trout (Fig. 5). Three upstream samples contained only brown trout, the most downstream sample only chubs, and a mix of both occurred at three intermediate sites.

San Luis Creek is a marshy, productive spring fed creek with abundant aquatic vegetation. In 1983, Zuckerman collected six chubs at the upstream Hayden Pass Road site and 668 were collected about one km downstream on the Freel Ranch, directly east of Villa Grove. On July 23, 1997 an intense rainstorm flushed heavy metal runoff into Kerber Creek, a tributary of San Luis Creek, and caused a fish kill. Sampling in San Luis Creek suggested that about 43 percent of the fish died in the four km contamination area downstream of the Kerber Creek confluence on the Freel Ranch. All fish in Kerber Creek died (Alves 1997). Four sites were sampled five days after the fish kill and six chubs were found at the most downstream site on the Freel Ranch. Two sites on the Freel Ranch were sampled in 1999; a single chub was collected at the upstream site and 70 chubs were collected at the downstream site. We sampled two localities on the Freel Ranch in 2002 and collected three chubs at the downstream site. We also sampled Kerber Creek and tributary Slaughterhouse Creek and no Rio Grande chubs were observed. A constructed spring fed drainage ditch supports a stable chub population on the Fullenwider Ranch near the confluence of Peterson Creek and upstream of Kerber Creek. This ditch may connect with San Luis Creek only during periods of high flow. The CDOW captured Rio Grande chubs (N=15 and 48) at two sites within that ditch system in 1997 and 1999. Restricted access on private property and drought conditions limited our ability to sample many portions of San Luis Creek other than on the Freel Ranch. San Luis Creek was dry in September 2002 at CR GG west of Valley View Hot Springs, this being our most downstream observation. Rock Creek of the Closed Basin was sampled twice by the CDOW from the confluence of San Luis Creek

upstream. Two chubs were collected on one occasion. We found one chub in Rock Creek in 2002.

Distribution and abundance in lentic localities.-- Wetlands, spring fed ponds, human-made impoundments, and oxbow and playa lakes present in the San Luis Valley have supported Rio Grande chub populations since at least 1909 when E.R. Warren sampled San Luis Lakes and found three chubs (Table 5). No other chub sampling records for San Luis Lakes have been located since then. Beckman detected one chub at Russell Spring on Russell Lakes SWA in 1950. The spring was sampled again in 2002 and no chubs were found. Zuckerman collected one chub at Trites Lake, Russell Lakes SWA, in 1983. Trites Lake was dry in 2002 (J. Alves, pers. obs.). Chico and Teal Ponds, Blanca Wildlife Habitat Area (BWHA) were sampled in 1996 and 1999 by the CDOW and Rio Grande chubs were collected (N=5 and 55). Roaring Fork Pond in the Goose Creek drainage southeast of Creede was sampled by the CDOW in 1992 and 1998, and Rio Grande chubs were numerous (N=156 and 270). Schutte rearing ponds on Rio Grande SWA were sampled in 1998 and no Rio Grande chubs were detected. No Rio Grande chubs were observed at the Higel SWA ponds in 1999, and one chub was collected at Swale Lake in 1997. The Silver Lakes population has already been discussed. Rio Grande chubs from some of these waters have been translocated (Table 6).

Habitat use.--Rio Grande chubs were found in small to moderate-sized streams that were 2.5 to 10 m wide on average and at a fairly restricted elevation band of 2310 to 2560 m. All lower elevation sampling sites which did not support chubs were from the larger main stem Rio Grande. Higher elevation sites in the Conejos and Alamosa rivers, the upper portions of Rio de los Pinos and Saguache Creek, and several other smaller tributaries were sampled but did not support chubs. Land use at most sites was mixed but was mostly agricultural or relatively undisturbed (State Wildlife Areas). Flow in nearly all streams sampled was affected to some

extent by diversions, but flowing water existed at all sites occupied by Rio Grande chubs except one in the Rio San Antonio in August 2002. Water temperature measured at all sampling sites varied by season and time of day but never exceeded 20.5 C even during low flow conditions in August 2002 (minimum was 7.5 C). Specific conductance was relatively low at most sites (89 to 237 microsiemens) and pH ranged from 8.5 to 9.4. Rio Grande chubs were generally found in stream reaches with a mix of cobble, gravel, and sand substrate, although sand generally predominated. Some type of instream cover (undercut bank, large woody debris, boulders, bank rip-rap) was nearly always present and maximum water depth at occupied sites averaged about 1 meter (0.3 to 1.75 m). Captured chubs were nearly always associated with deeper pools over sand-gravel substrate, and were adjacent to or in cover.

A logistic regression model using all site data where fish and sufficient habitat data were collected (N = 49 observations) suggested that substrate particle size, stream width, and presence of brown trout were important variables to explain presence of Rio Grande chubs at sites in the Rio Grande Basin, Colorado (Table 7). Chubs were found at sites where cobble, gravel, sand, and silt were the most common substrate type. However, chubs were found most often at sites with predominantly sand substrate and least often where cobble was the most common particle size. Stream width was negatively associated with chub presence. This was likely due to the relatively large number of sites (N = 17, about 1/3 of observations) that were from the relatively large main stem Rio Grande. Because no chubs were found there, this positively weighted the importance of relatively small habitats in predicting presence of chubs in this analysis. Finally, presence of potentially predatory brown trout was associated with chubs, but perhaps not in the manner one might expect. This analysis with all sites suggested that chub presence and brown trout presence were positively related. We interpreted this to suggest that chubs and brown trout both preferred cool, relatively small, and higher elevation streams. Inspection of the data (e.g.,

Saguache Creek) suggested chubs were present only when brown trout were relatively rare. Presence of brown trout in low numbers may in fact be a surrogate measure of the thermal regime of streams occupied by Rio Grande chubs.

Instream cover was present at most sites and was likely an important component of suitable habitat, but it was not included as an explanatory variable in logistic regression models. Four sites that had no cover contained a small number of chubs caused chub presence and cover to be negatively associated in the regression model; that was a spurious result considering our observations. We also found that presence of other predators and chub presence was negatively associated, not an unreasonable result. However, we did not include that variable in this analysis because only two sites supported other predators in streams that actually contained Rio Grande chubs. Thus, presence of other predator fishes seemed a variable inappropriate to include in this model. Other explanatory variables investigated had limited or no association with presence of Rio Grande chubs.

The logistic regression analysis with the dataset containing only sites from streams that contained Rio Grande chubs (N = 28 observations, 18 with chubs) suggested a similar pattern for substrate particle size importance; chubs occurred much more often at sites where sand was dominant and were negatively associated with cobble substrate. Stream width was unimportant in this analysis, likely because the relatively larger main stem Rio Grande sites were not included in this analysis. Contrary to the previous analysis, presence of Rio Grande chubs at sites in streams known to contain chubs was negatively associated with presence of brown trout. This suggested that within a stream, the suite of thermal regimes available were adequate to support both species, but that chubs and trout did not co-occur in high abundance at the level of sites.

Chub size structure.—Rio Grande chubs captured in 2001-2002 ranged in size from 21 to 186 mm TL; most fish captured were 31 to 50 mm TL (Fig. 6A). We presumed that those

smaller size classes were age-0 fish, since most samples were collected in late summer or autumn and smaller fish were absent. Samples from Saguache Creek (Fig. 6B), Rio San Antonio (Fig. 6C), and Hot Creek (Fig. 6D) contained a mix of fish sizes but demarcation of older age-classes was difficult. One exception may be age-1 fish in Saguache Creek in 2001, likely represented by a mode from 101-110 mm TL. Another may be Hot Creek, where chubs appeared represented by age-0 (27–54 mm TL), age-1 (63-115 mm TL), age-2 (140-153 mm TL), and age-3 or older (180-186 mm TL) fish. Samples with few chubs were usually composed of relatively small individuals, likely age-0 fish. An exception was the McIntyre Spring population, where only larger adult chubs 139 to 164 mm TL were found.

Fish associations.—A total of 19 fish species were collected in this study, six were native and 13 were introduced (Table 8, Appendix II). We also collected hybrids of Rio Grande and white sucker from Hot Creek. White sucker was the most widespread species in the study area, occurring in 72% of all samples, followed by fathead minnow, longnose dace, brown trout, red shiner, common carp, Rio Grande chub, and green sunfish. Rio Grande chub was present in a relatively large proportion of samples because several sites where we knew chubs occurred were sampled multiple times, and because sampling targeted streams where chubs were known to occur historically. Remaining species were detected at seven (11%) or fewer sites. Seven species occurred at two or fewer sites. Rio Grande sucker was rare, occurring only in one Hot Creek sample. The cutthroat trout collected from the Conejos River was not a native form.

Rio Grande chubs, which were detected on 18 sampling occasions, were found with only nine other species and commonly with only white suckers (15 occasions), longnose dace (15), fathead minnows (14), and brown trout (11). Chubs were found with brook trout three times, and brook stickleback, rainbow trout, red shiners, and Rio Grande suckers once each.

We detected widespread occurrence (N = 7 sites, N = 170 specimens) of flathead chubs in the main stem Rio Grande and lower Conejos River. Their absence in historical samples (Ellis 1914, Zuckerman 1984, Zuckerman and Langlois 1990) suggested a recent invasion by that species into Colorado from downstream. We also discovered introduced plains topminnow *Fundulus sciadicus* (N = 20) in the Rio Grande at the Highway 285 crossing, in August 2002.

Drought effects.--We sampled single sites on Saguache and La Jara creeks, and two Rio San Antonio sites where chubs were found in 2001 to determine if extended drought conditions affected chubs in 2002. Chubs were recaptured at all four sites but one site on Rio San Antonio was stagnant and water quality was poor. Drought also eliminated historical populations from Rock Creek near Alamosa, Hot Springs Creek, and the lower reaches of Saguache Creek because those sites were dry when we visited them in 2001-2002.

DISCUSSION

Rio Grande chub were historically widespread and abundant in the Rio Grande drainage, Colorado, but have declined rather dramatically. Rio Grande chubs remain in just a few streams and populations can be considered relatively large and stable only in Hot Creek and Saguache Creek. Sampling showed that chubs in La Jara Creek and Rio San Antonio were more restricted and threatened by water diversion or drought. Several populations, including formerly large ones in McIntyre Spring and San Luis Creek, have declined since sampling in the early 1980's, a time when Zuckerman and Langlois (1990) considered Rio Grande chub as declining in Colorado. Chubs in some lentic systems have prospered but may represent introductions from unknown sources or are of unknown genetic provenance and should be managed with caution (Douglas and Douglas 2003). Below, we further discuss historic and present distribution and

status and reasons for decline of the species. We also make recommendations for research and management activities that may enhance conservation status of Rio Grande chub in Colorado.

Distribution and status of Rio Grande chub.--Rio Grande chub have been sampled sporadically for over 130 years, but the extent of its historical range in Colorado has not been reported. Because Rio Grande chub historically occurred in a variety of small to large cool streams and historical and present populations were widespread, we determined that Rio Grande chub once occupied most montane and lower elevation streams of the Rio Grande Basin, Colorado. This generally corresponded to streams up to about 2560 m in elevation where brown trout now occur. Zuckerman (1990) reported Rio Grande chubs in Kerr Lake (3,470 m, population since removed), and speculated that may be the highest elevation reported for a member of Cyprinidae in North America. Historical habitat for Rio Grande chub in Colorado included the main stem Rio Grande from about Del Norte downstream to near the Colorado-New Mexico border. Many historical collections documented upstream presence of Rio Grande chub in the main stem Rio Grande and Zuckerman (1990) documented their downstream presence east of Antonito, Colorado. Historical accounts also suggested that Rio Grande chub was very abundant. For example, Aiken described *G. pandora* as "the common chub or pescadito of the Rio Grande and its tributaries, and is the most abundant fish in New Mexico." (Cope and Yarrow 1875). Later, Jordan (1891) described the Rio Grande chub as "everywhere abundant", and Ellis (1914) called it "very abundant".

Comparison of samples collected in lotic systems by Zuckerman from 1981 to 1985 and other investigators prior to then, to those collected by CDOW personnel and us from 1992 to present, suggest a marked decline in Rio Grande chub distribution and abundance in some localities (Table 9). Rio Grande chub were not detected throughout the main stem Rio Grande, the Conejos River, Rock Creek near Alamosa, CO, the Alamosa River, Rio Chamita, Sexto

Creek, and Hot Springs Creek (Closed Basin) and may be extirpated. Small populations persist in short reaches of the Rio San Antonio, Rio de los Pinos, La Jara Creek, and in the Closed Basin, Rock and San Luis creeks. The population in Saguache Creek is relatively widespread and abundant, and the Hot Creek population remains abundant in a relatively short reach of stream.

Timing and reasons for decline in distribution and abundance of Rio Grande chub varied by system. In the main stem Rio Grande, chubs have not been collected in large numbers since the early part of the 20th century, but persisted in low numbers throughout the system until at least 1985 (Zuckerman 1985). Our recent sampling was relatively widespread (17 localities) and intensive and should have revealed presence of chubs if they existed in reasonable numbers. Introduced predaceous fishes such as northern pike were found in the main stem Rio Grande and have the potential to reduce numbers of chubs there, but they were rare (2 sites, six individuals) during our sampling.

Low flows in the main stem Rio Grande, due to irrigation withdrawals and drought, may have reduced habitat quality and quantity and likely also allowed water temperatures to increase. Water temperatures at the main stem Rio Grande sampling sites typically exceeded 20°C (26°C maximum) during August 2002 when flow was low. The highest water temperature in occupied chub habitat recorded during this study was 20.5°C in McIntyre Spring, where only a few large fish resided. Higher water temperatures in the years we sampled may have limited Rio Grande chubs from year-round residence in most of the main stem Rio Grande.

Evidence for possible temperature limitations for chubs in the main stem Rio Grande in Colorado also comes from analysis of chub records in large rivers in New Mexico. Historical records from 1987 showed that a short distance downstream from the Colorado border, Rio Grande chubs re-appeared in reasonable numbers (10 or more) in the main stem Rio Grande at

four of five locations in the Rio Grande Gorge downstream to near Taos (K. Bestgen, unpublished data). Chubs were also abundant downstream of there at Velarde, New Mexico (Platania 1984, USGS-BRD # 3657, N = 253, 1984). Presence of deep pools with sand substrate, and relatively cool water may be the reason chubs re-appear in the Gorge reach. Presence of cooler water in that reach was indicated by presence of cool- or coldwater fishes such as longnose dace, white suckers, northern pike, and brown and rainbow trout, and absence of red shiners, which were common upstream in the main stem. Northern pike and trout were relatively rare in that area and temperature conditions may be marginal for salmonids there, conditions which may promote survival of chubs. The few observations of summer water temperature (about mid-June-September, N = 19, USGS gage # 08263500, Rio Grande near Cerro, NM) suggested it rarely exceeded 20°C (N = 2, max 22°C) in the Rio Grande Gorge area. The Rio Grande there likely cools downstream from the valley reach in Colorado because of cooler tributary inflows, cool groundwater seeps in that deep canyon, and because it is shaded for a longer portion of the day. Platania (1991) also stated that Rio Grande chub was locally abundant in the Rio Chama and Rio Grande downstream of dams, because of release of relatively cool water, but was uncommon in warmer reaches up and downstream of those areas.

Drought in 2001 and 2002 may have limited occurrence of chubs at several localities where they were previously found including portions of the Rio San Antonio, and Rock Creek near Alamosa, CO. Rio Grande chub were newly documented in the Rio de los Pinos and La Jara Creek, but the few fish present were restricted to small reaches, often because up- or downstream areas had little or no water. Chub populations in those marginal areas should be monitored through the drought period and beyond to determine if populations need immediate conservation action. Chubs in La Jara Creek downstream of Capulin, CO, may also be affected by diversion introduction of metals-laden water from the Alamosa River (Woodling 1995).

Distributional extent of Rio Grande chubs in some populations (Rio de los Pinos, La Jara Creek) needs further assessment if access issues can be resolved. Even the large Hot Creek population of Rio Grande chubs may be limited by grazing and resulting sedimentation downstream of the State Wildlife area.

In Saguache Creek, brown trout abundance and water temperature patterns may explain a pattern of decreasing upstream abundance of Rio Grande chub. Upstream, relatively large and numerous brown trout occur where water is cooler. As water temperatures warm downstream, brown trout decline and Rio Grande chub abundance increases. Upstream chub abundance may be limited by trout predation, even though water temperatures may be suitable to meet their life history requirements. Removing brown trout from an upstream reach of Saguache Creek and monitoring response of Rio Grande chub could test this hypothesis experimentally.

Comparison of San Luis Creek and Hot Creek, both productive, spring-fed systems also suggested that salmonid predation may be limiting chubs. In Hot Creek, water temperatures are sufficiently warm to limit salmonids to a few brown trout, and native fishes, including Rio Grande sucker and Rio Grande chub, persist in relatively large numbers. In the cooler San Luis Creek, both brown and brook trout thrive, and only a few Rio Grande chubs persist. Reduced distribution and abundance of salmonids in such systems may benefit Rio Grande chubs.

McIntyre Spring, which flows into the Conejos River, is a large spring that produces about 26,500 liters of water/minute (J. Lucero, Bureau of Land Management (BLM), Saguache Field Office). McIntyre Spring is a biologically significant area because it supports habitat for the endangered southwestern willow flycatcher. Zuckerman also found hundreds of Rio Grande chubs in McIntyre Spring and remnants of a population of Rio Grande suckers as recently as 1981-1985. Reasons for dramatic reductions in Rio Grande chubs there, and extirpation of Rio Grande suckers (Swift-Miller et al. 1999), are unknown. Restoration of the McIntyre Spring

population of Rio Grande chub is important because it is a possible source for downstream emigration and colonization into the Conejos River and Rio Grande.

Rio Grande chubs, and other fishes in the Alamosa River, remain limited by high levels of pollutants, mostly heavy metals. Galactic Resources declared bankruptcy in December 1992, and the Environmental Protection Agency (EPA) took over the site under the EPA Superfund Emergency Authority. Improved water quality in the Alamosa River would be necessary to facilitate Rio Grande chub recolonization from fish in Silver Lakes, which may be occurring given recent records of Rio Grande chub in Terrace Reservoir. The once very abundant population of Rio Grande chubs in San Luis Creek also appears to have declined, perhaps a result of toxic mine waste located in the upstream Kerber Creek drainage in 1997. Persistent releases of toxic material from that site are possible during rainstorms. Stabilizing or removing toxic mine wastes may enhance the population of Rio Grande chubs in San Luis Creek.

A Rio Grande chub population that seems persistent and perhaps even abundant and expanding is the introduced one in the Gunnison River drainage. Although remote from downstream warmwater reaches where native Colorado River Basin *Gila* reside, the possibility remains that these fish could move into the Gunnison River or be introduced (Zuckerman 1985).

Habitat use.—Predictions from logistic regression models partially supported field observations of Rio Grande chub habitat use. Although model predictions are congruent with field observations and the literature, model parameter estimates sometimes had large standard errors. This suggested caution when attempting to make predictions about chubs presence in other areas or years from model output based on this limited data set.

Chubs were typically found in relatively small, higher elevation streams that often supported brown trout. Although cobble, gravel, sand, and silt all dominated in chub-occupied habitat, sand substrate was the most common type. This may be because it is the primary

substrate in depositional areas such as pools, a favored chub meso-habitat. It may also be more common in lower river reaches where trout are less abundant and chubs more common.

The finding that chubs preferred smaller streams in Colorado is likely an artifact of their present limited distribution and extirpation from the larger main stem Rio Grande. Rio Grande chubs were still relatively common in cool water portions of the Rio Grande and Rio Chama in New Mexico, both relatively large streams (Platania 1991).

Instream cover was likely an important component of suitable Rio Grande chub habitat based on our observations and the literature (Rinne 1995) but was not included as an explanatory variable in logistic regression models because the limited dataset produced a counter-intuitive result. Most sites where Rio Grande chubs occurred contained cover, and chubs were most often captured in or near cover. Importance of cover to chubs was also supported by an observation from a site in San Luis Creek where there was no cover but chubs were present. The only three chubs found were inside a small, partially submerged cardboard box.

Positive association of chubs and trout at the stream level in Colorado was also supported by observations in the literature, which suggested that brown trout and chubs often co-occur in cool water habitat (Kostèr 1957, Platania 1991, Rinne 1995). A better understanding of thermal preference of chubs would allow managers to understand whether upstream distribution of chubs in streams where brown trout occur is limited by predation or other negative interactions, or if chub distribution is limited by temperature and trout simply fill that upstream habitat void. Understanding such information would be useful to target areas for restoration of chub habitat if such is deemed necessary. Understanding thermal requirements may also give clues to understanding disappearance of chubs in the main stem Rio Grande, Colorado.

Although seemingly contrary to the previous analysis that used all sites and found chubs and trout positively related, results of the reduced model logistic regression analysis using only

streams where chubs were known supported the idea of a negative interaction of chubs and brown trout in streams where chubs occurred. The data and model results suggested that chubs and trout could be present in different places in the same cool water stream, but that chubs tended not to occur at a site unless trout were relatively rare. This negative interaction, perhaps a result of predation, produced complementary patterns of chubs and brown trout in Saguache Creek. La Jara Creek showed a similar pattern, where only trout were found upstream and only chubs were found downstream. In the Rio Chama, New Mexico, a pattern of chub abundance similar to that in Saguache Creek was observed. An upstream reach just below Abiqui Reservoir supported large brown trout and just a few large chubs or none at all. A short distance downstream where water temperatures were warmer, trout abundance declined and multiple size classes of Rio Grande chubs were present (Platania 1991, KRB, pers. obs.). A rainbow trout 35 cm TL captured in the Rio Grande, New Mexico regurgitated an 8 cm TL chub during sampling there in 1987 (KRB pers. obs.), which indicated salmonids may be important predators on chubs in some systems (Koster 1957, Rinne 1988). Experimental removals of trout in habitat where both species occur may be instructive to determine what set of factors are limiting chub abundance in the upper reaches of streams such as Saguache Creek.

Size structure.--Because little is known about the natural history of Rio Grande chubs, few comparisons can be made between Colorado populations and others regarding size-structure or other aspects of its ecology. Presence of multiple size-classes at a site, such as occurred in Saguache and Hot creeks and Rio San Antonio, may represent relatively stable populations. The Hot Creek population may be represented by at least 4 year-classes. Populations with few fish or of only smaller life stages may indicate reproduction occurs elsewhere, that habitat is inadequate to support a full spectrum of sizes, or that populations may be unstable and at risk of extirpation. Presence of only large individuals, such as in McIntyre Spring, suggested recruitment was

inadequate to replace the population and thus, the population there is likely unstable. The few large individuals collected by us in McIntyre Spring on 28 August 2002 may, in fact, be survivors from a June 2002 CDOW stocking of 295 Rio Grande chub from Silver Lakes.

Species associations.—Rio Grande chub historically co-occurred with several other fishes, including Rio Grande cutthroat trout and Rio Grande sucker (Koster 1957, Swift-Miller et al. 1999), species which were rare in our sampling. Rio Grande chubs occurred commonly with only four other fishes, and two of the most abundant ones were introduced brown trout and white sucker. Both potentially could have deleterious effects on chubs via predation or competition.

Rio Grande sucker continues to be a rare species in the Rio Grande Basin, Colorado. Similar to Swift-Miller et al. (1999), we captured Rio Grande sucker only in Hot Creek. The CDOW has an active annual sampling program designed to deplete white suckers in Hot Creek, which may be helping maintain that Rio Grande sucker population. Widespread occurrence of white suckers in the basin may limit success of Rio Grande suckers reintroduced into other areas, unless white suckers are depleted or removed first.

Occurrence of flathead chubs in the main stem Rio Grande, Colorado, was somewhat surprising given declines in this species elsewhere (Cross and Collins 1995). We are confident that this invasion is not the result of an introduction because flathead chubs were found in proximal downstream reaches of the Rio Grande in the Rio Grande Gorge, New Mexico, as recently as 1987 (KRB, pers. obs.). Relatively warm and low flows in recent years may have allowed that species to disperse upstream.

Detection of plains topminnow at one main stem Rio Grande site was also surprising. Nearest known native populations of this species are in the South Platte River Basin in northeast Colorado, where they are sporadically common in some off-channel ponds and riverine backwaters. We have no explanation to offer for the origin of the population in the Rio Grande

unless they were captured and introduced with western mosquitofish *Gambusia affinis* for control of dipteran pests. We did not collect western mosquitofish in this survey; any that are introduced may be susceptible to cold winter temperatures.

Drought effects.--Positive stream flow was recorded at most sites where chubs were found in 2001-2002. An exception was in Rio San Antonio, where stream flow was very low (< 0.0283 m^3/sec) in October 2001 or non-existent in August 2002. Chubs were captured on both occasions but water quality at the single site where water had ceased flowing was very poor. In August 2002, the CDOW removed 55 Rio Grande chubs from the Rio San Antonio at the Highway 285 crossing and placed them in the Native Species Recovery Facility in Alamosa, Colorado. Fate of chubs in that system is unknown, because low flows continued for some time after August 2002. Reduced flows may affect chubs directly because such streams are more likely to desiccate. Indirect negative effects of reduced stream flows may be via reduced water quality, reduced habitat size, increased stress due to crowding, increased vulnerability to terrestrial predators, or higher water temperatures.

Increased stream flow would likely enhance habitat for Rio Grande chubs in drought-prone streams such as Rio San Antonio. This may be accomplished by reductions in diversions or increased releases from upstream reservoirs. The amount of water needed to benefit chubs is not precisely known but some general suggestions can be made. Any amount of flowing water would likely benefit chubs. This would provide some water oxygenation over a stagnant pool situation and would also serve to exchange water within pools. Maintaining wetted riffles would also be beneficial, given that most food production for this insectivorous species likely occurs there. Higher baseflows would likely also increase the downstream extent of habitat available for chubs. Summer may be the most stressful time for chubs because stream flow is lowest and

water temperatures are warmest. Therefore, summer may be an optimal time to release additional flow if such is available.

RECOMMENDATIONS

We offer the following research recommendations that may lead to increased understanding of factors limiting populations of Rio Grande chub in Colorado. Increasing understanding of limiting factors may illuminate additional management activities that may enhance the conservation status of Rio Grande chub.

1). Obtain a better understanding of thermal tolerances.

This information could be used to explain gaps in distribution of Rio Grande chubs and focus the geographic scope of areas where chubs might be introduced. Field studies may be particularly useful to furthering this understanding, particularly in streams where predators do not confound distribution patterns.

2). Obtain a better understanding of predation effects.

Understanding effects of brown trout and other potential predators on distribution and abundance of Rio Grande chubs, combined with thermal tolerance data, would also focus the geographic scope of areas where chubs might be introduced. Such research would also illuminate the efficacy of restoring stream reaches by removing predators.

3). Better define habitat needs at the site and stream level.

Such an understanding would focus efforts to enhance habitat for existing populations and would also allow for informed selection of additional sites that may be suitable for enhancement.

4). Better understand the life history and ecology of Rio Grande chub.

Nearly nothing is known about the life history or ecology of this species. Such information would be particularly useful for spring stream populations, because those habitat types presently

support large populations (e.g. Hot Creek) or formerly did (McIntyre Spring, San Luis Creek). A better understanding of effects of stream flow level on persistence, distribution, and abundance of Rio Grande chubs would provide information to justify flow management as a conservation tool.

The following management recommendations are offered that may assist with conservation of existing populations.

1). Prevent spread of additional predaceous fishes in the system.

This may be particularly important for species adapted to cool or cold-water environments that may be suitable for Rio Grande chubs.

2). Investigate flow enhancement in streams with marginal habitat.

Reducing effects of drought or irrigation diversions by enhancing stream flow may enhance existing populations and also promote their expansion. It is also important to ensure secure flows in habitat where large populations presently exist to prevent further decline of Rio Grande chub in Colorado. Most of the largest Rio Grande chub populations that have been documented in the basin since the early 1980's (McIntyre Spring, Hot Creek, San Luis Creek, Saguache Creek) have all had relatively strong stream flows to support them. The level of flow enhancement needed to restore or enhance populations is unknown, but eliminating flow intermittency would be a useful first step. Population response to flow enhancement should be monitored carefully to determine optimal use of scarce resources.

3). Identify potential chemical contamination threats to present populations.

Spills of toxic chemicals have reduced populations of Rio Grande chub in the Alamosa River and San Luis Creek. Measures should be taken to ensure that the threat of additional spills is minimized and that efforts continue to restore degraded habitat.

4). Ensure that Rio Grande chub in the Gunnison River drainage do not disperse further.

Preventing further spread of this non-indigenous population would reduce the threat to other *Gila* populations in the Colorado River Basin, many of which are rare or endangered (Carlson and Muth 1989, Bezzerides and Bestgen 2002).

5). Enhance habitat in occupied streams.

Managers should embrace management practices that maintain processes associated with relatively natural flow regimes. Creation and maintenance of mixes of habitat types, including deep pools with associated cover, should especially be promoted.

6). Continue regular monitoring.

Continued sampling will ensure early detection of declines and may identify potential threats to remaining populations. Sampling in post-drought periods at sites where chubs once existed will be useful to verify status of populations presumed extirpated from dry sites. Efforts should also be made to identify streams that may support additional populations of Rio Grande chubs. Continued monitoring would also be useful to document distribution and survival of previously stocked Rio Grande chubs.

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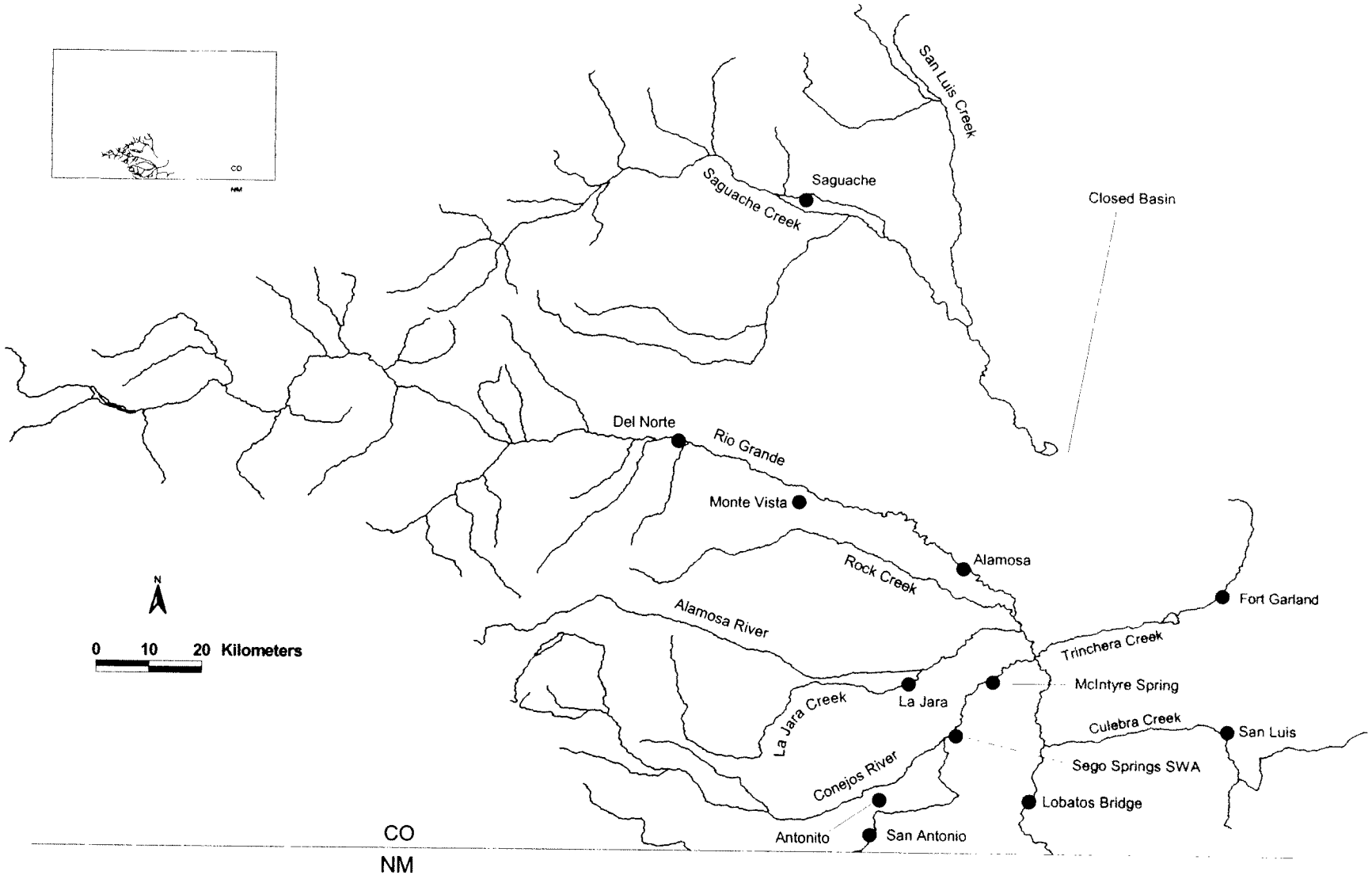

Figure 1. – Map of study area, Rio Grande Basin, Colorado. Solid dots indicate place names.

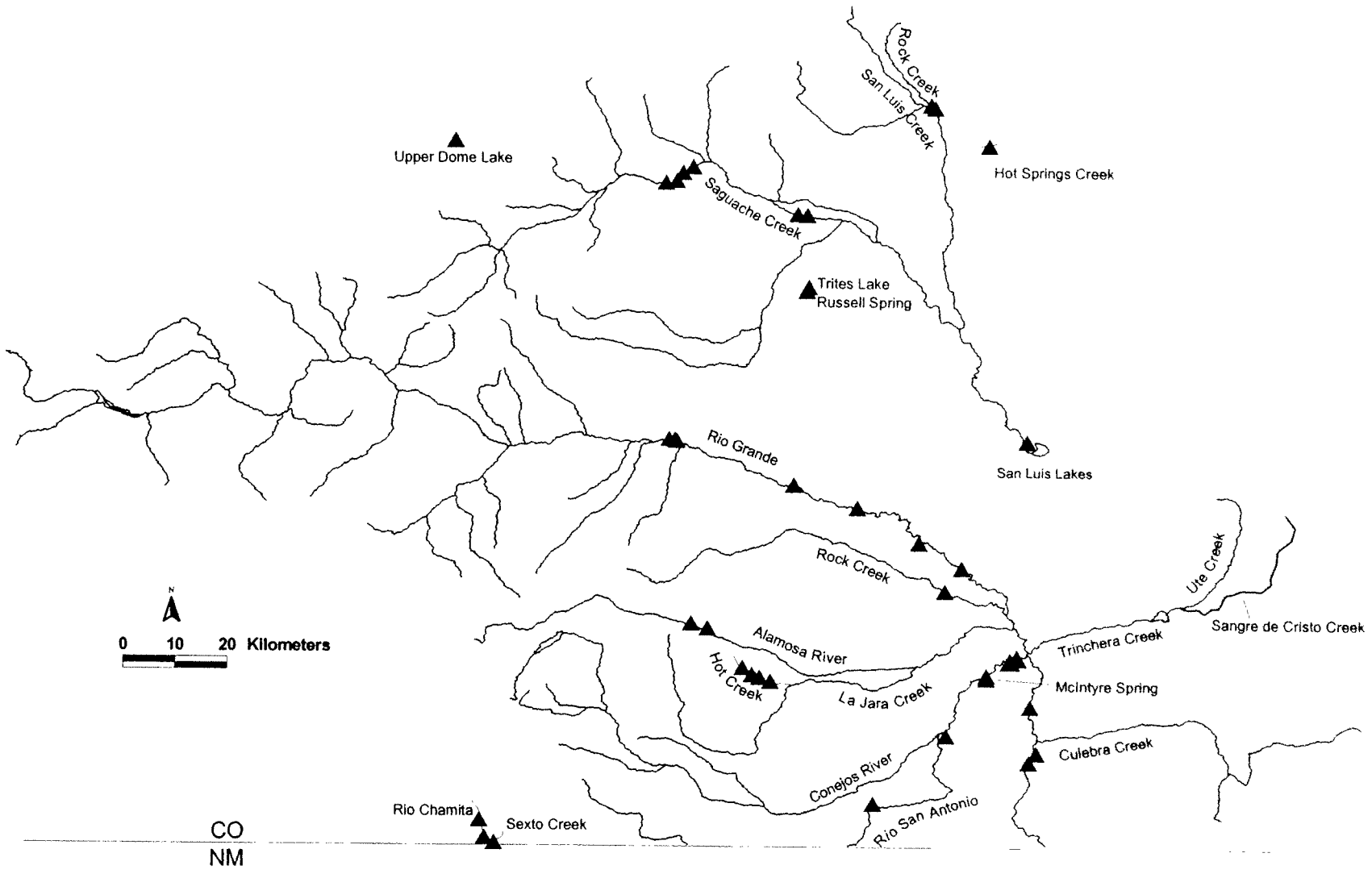

Figure 2. – Distribution of Rio Grande chub sampling localities, Rio Grande Basin, Colorado, 1871-1985.

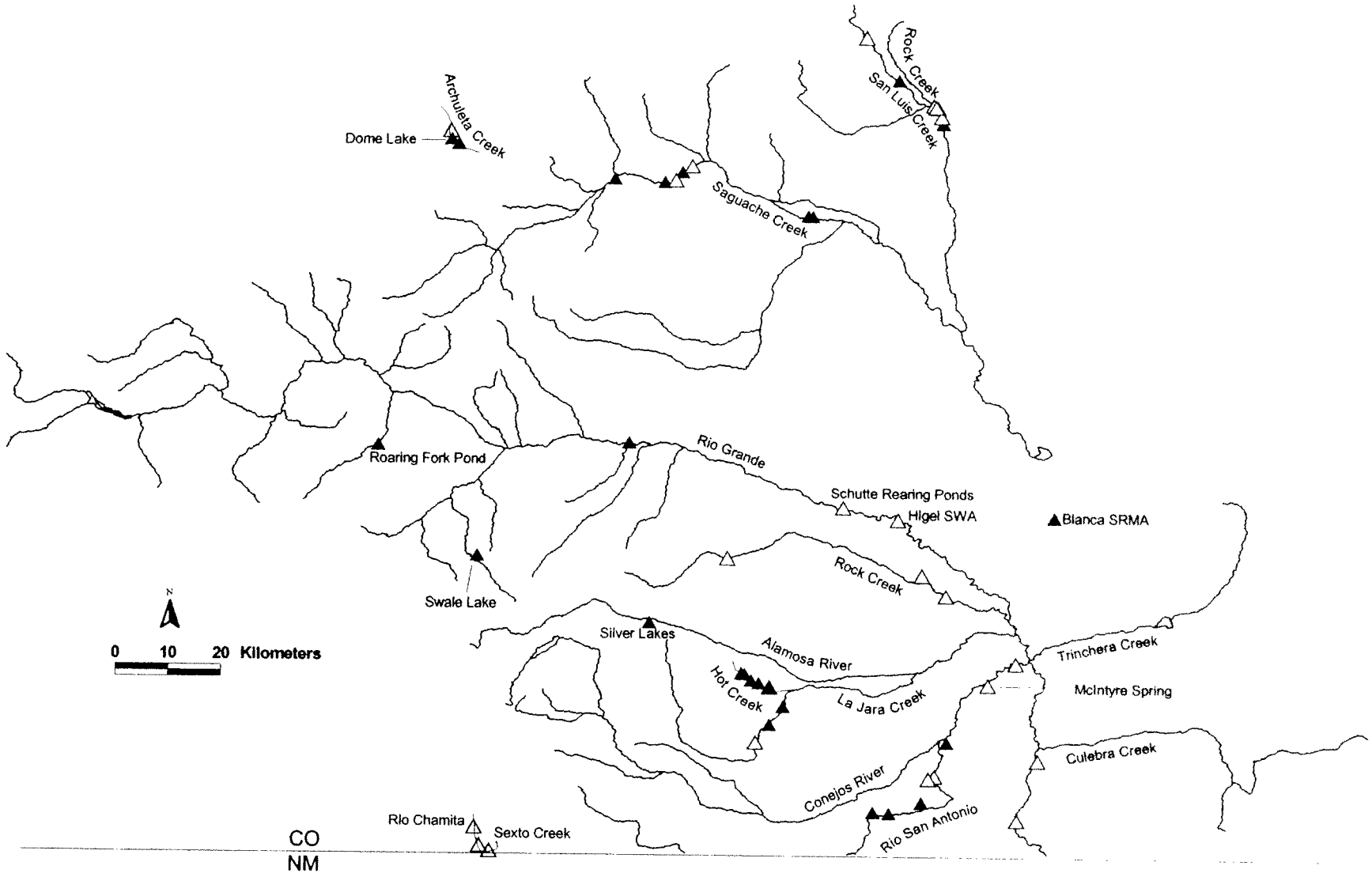

Figure 3. – Distribution of sample sites (open triangles) and Rio Grande chub sampling localities (filled triangles), Rio Grande Basin, Colorado, 1992-2000.

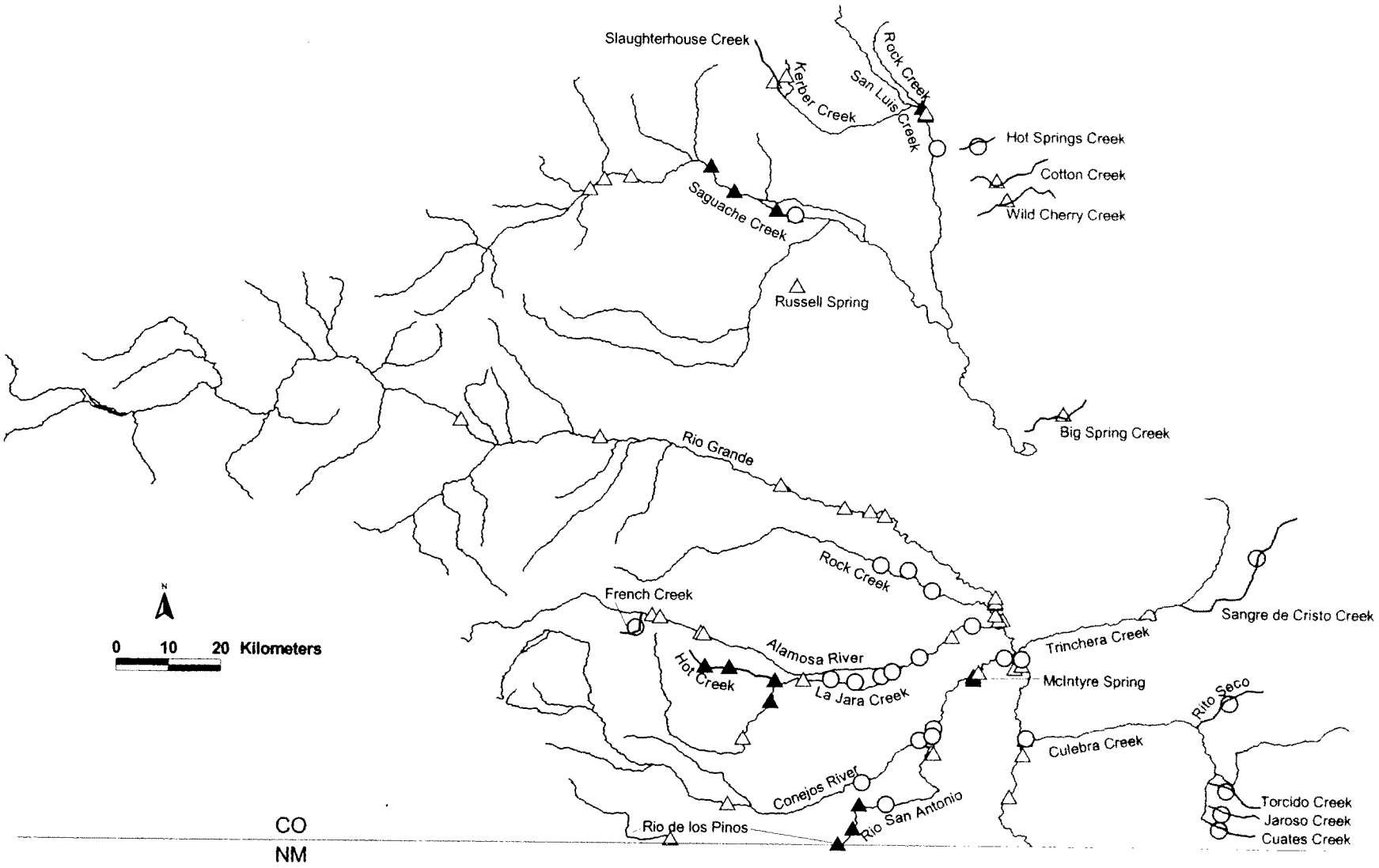

Figure 4. – Distribution of sample sites (open triangles), Rio Grande chub sampling localities (filled triangles), and sites visited that were dry (open circles), Rio Grande Basin, Colorado, 2001-2002.

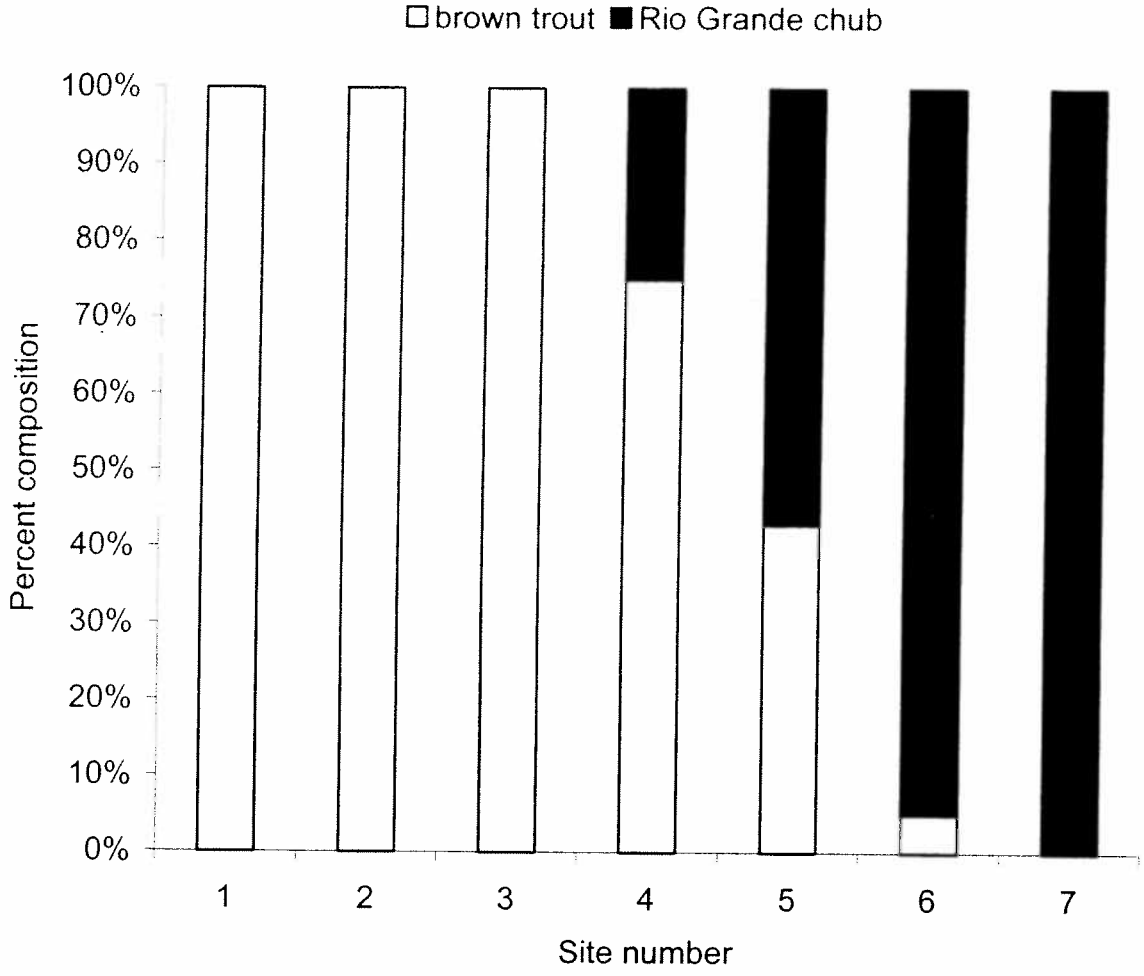

Figure 5.—Proportion of brown trout and Rio Grande chubs, up to downstream (sites 1 to 7), at seven sites in Saguache Creek, Colorado, 2001-2002.

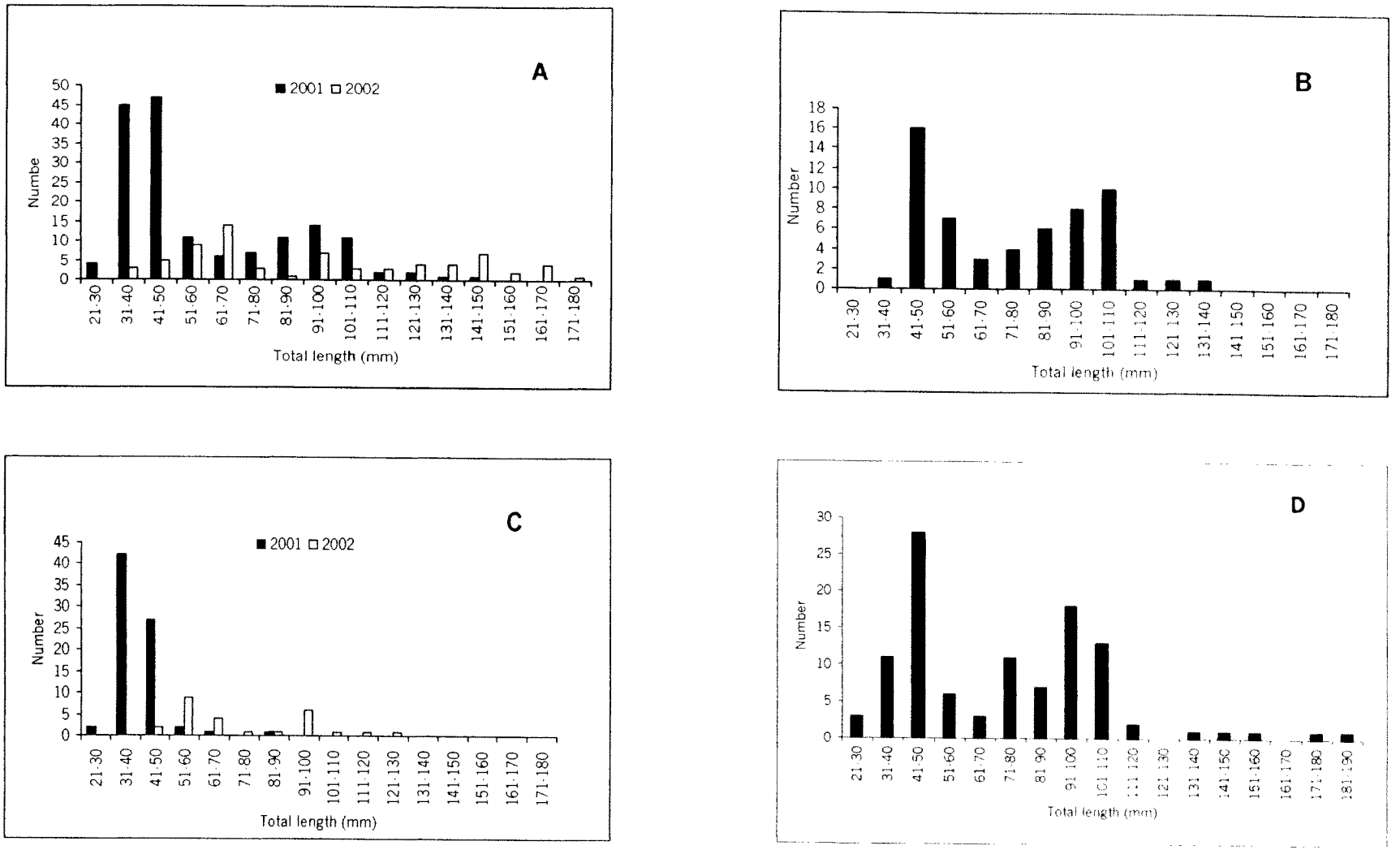

Figure 6.—Length frequency histogram of all Rio Grande chubs collected (A), Saguache Creek, 2001 (B), Rio San Antonio (C), and Hot Creek, 2001-2002 (D), Rio Grande Basin, Colorado.

Table 1.--Historical (1871-1980) Rio Grande chub (RGC) localities, Rio Grande Basin, CO. The UTM zone is 13, museum acronyms follow Leviton et al. (1985), Hybrid = *Gila nigrescens* X *Rhinichthys cataractae*. Identity of Rio San Juan specimens questionable.

River	UTM X	UTM Y	Specific Location	Date	Collector	RGC	N =	Catalog #
Alamosa River			Upstream of Terrace Reservoir	1978	CDOW	Y	2	none
Conejos River			Alamosa ?	1889	Jordan	Y	15	CAS 100781
Rio Grande	380999	4171432	Del Norte, Rio Grande County	1889	Jordan	Y	>10	USNM 41628
Rio Grande			Loma	10/--/1873	Unknown	Y	8	USNM 15798
Rio Grande	398622	4162883	Hwy 285, 2 mi N of Monte Vista, gauging station	10/09/1944	Hubbs, Kampa	Y	44	UMMZ 142523
Rio Grande	398622	4162883	Hwy 285, 2 mi N of Monte Vista, gauging station	08/22/1968	Unknown	Y	42	TU 54481
Rio Grande	398622	4162883	Hwy 285, 2 mi N of Monte Vista, gauging station	08/22/1968	Unknown	Hybrid	1	TU 54482
Rio Grande	423874	4147007	Alamosa	07/27/1912	Unknown	Y	8	UMMZ 66157
Rio Grande	423874	4147007	Alamosa	1889	Jordan	Y	>30	USNM 41638
Rio Grande	423874	4147007	Alamosa	08/--/1889	Jordan	Y	1	UCM 350
Rio Grande	423874	4147007	Alamosa	07/27/1912	Ellis	Y	212	UCM 352
Rio Grande	423874	4147007	Alamosa	No date	Jordan, Evermann	Y	41	UMMZ 219048
Rio Grande	423874	4147007	Alamosa	07/01/1927	Unknown	Y	4	UCM 6347
Rio Grande			Almora (Alamosa?)	1889	Jordan, Evermann	Y	>10	USNM 73690
Rio Grande			4.5 mi W and 1.5 mi N of Alamosa	06/02/1934	Rodeheffer	Y	1	UMMZ 117812
Rio San Juan			Pagosa Springs	No date	Aiken ?	Y?	1	ANSP 165411
Rio San Juan			Pagosa Springs	09/--/1874	Unknown	Y?	1	USNM 15761
Rio San Juan			Pagosa Springs	09/--/1874	Aiken	Y?	1	USNM 15987
Russell Spring	401136	4200368	Artesian spring stream near Russell Lakes	04/21/1950	Beckman	Y	1	UMMZ 160746
San Luis Lakes	436284	4169708	San Luis Lakes SWA, Alamosa County	06/05/1909	Warren	Y	3	UCM 351
San Luis Lakes	436284	4169708	San Luis Lakes SWA, Alamosa County	06/20/1909	Warren	Y		UCM 47
Sangre de Cristo Creek?			Sangre de Cristo Pass (Jordan and Evermann 1896)	1871	Cope, Aiken, Yarrow	Y		USNM 15984, 15985, 18000
Terrace Reservoir	385307	4135801		1975	CDOW	Y	17	none
Watrita Creek			Unable to locate; E. D. Cope collection		Wheeler Survey	Y	4	ANSP 19549
No river			Saguache County	No date	Beckman	Y	2	JFBM 17235
No river			5 mi above Alamosa, Alamosa County	07/01/1943	Worman	Y		MSB 1759
No river			Alamosa	No date	Jordan	Y	>40	USNM 63219

Table 2.--Rio Grande chub (RGC) sampling localities, 1981-1985, from Zuckerman (LDZ, 1983, 1984, 1985), Rio Grande Basin, Colorado. The UTM zone is 13. All records are from the Museum of Southwest Biology, University of New Mexico.

River	UTM X	UTM Y	Specific Location	Date	Collector	N =	Catalog #
Conejos River	433750	4128130	Main channel, upstream of CR 28, Willette Cattle Company	09/24/84	LDZ (119)	1	4154
Conejos River	433750	4128130	"	03/24/83	LDZ (36)	1	3904
Hot Creek			Gauging station, Hot Creek SWA	11/30/82	LDZ (19)	105	3854
Hot Creek	390549	4128292	Downstream of Ojito Creek confluence, Station 5	11/28/84	LDZ (142)	142	4221
Hot Creek	391996	4126907	Upstream of Parshall flume, Station 3	09/23/83	LDZ (68)	178	4008
Hot Creek	393130	4126403	Station 2	10/30/84	LDZ (133)	100	4194
Hot Creek	394756	4125631	East end (1st entrance) of Hot Creek SWA, Station 1	03/30/83	LDZ (42)	3	3933
Hot Springs Creek	428345	4227068	Valley View Hot Springs	11/29/84	LDZ (144)	10	4229
McIntyre Spring	427511	4125976	Pools at Governor's mansion	11/28/84	LDZ (143)	6	4224
McIntyre Spring	427511	4125976	"	10/29/84	LDZ (132)	62	4189
McIntyre Spring	427511	4125976	"	04/29/84	LDZ (154)	98	4253
McIntyre Spring	427511	4125976	"	11/27/83	LDZ (87)	55	4072
McIntyre Spring	427511	4125976	"	11/03/83	LDZ (86)	85	4065
McIntyre Spring	427502	4126602	From confluence with Conejos River to constriction	11/28/83	LDZ (88)	18	4078
Rio Chamita	350072	4099621	Upper road crossing near Binkley ranch	10/04/85	LDZ (162)	12	4273
Rio Chamita	350763	4096248	Road crossing near CO-NM state line	10/06/85	LDZ (161)	13	4269
Rio Grande	408235	4158439	6E RD/ N-100 RD crossing on Rio Grande SWA, E of Monte Vista	08/13/81	LDZ (24)	1	3862
Rio Grande	434095	4120652	BLM road between La Sauses and Hwy 142	03/27/83	LDZ (38)	1	3915
Rio Grande	434971	4111726	Old rock dam site downstream of Hwy 142 bridge crossing	11/24/82	LDZ (4)	1	3816
Rio Grande	433790	4110045	Between old rock dam site and G RD bridge (Lobatos bridge)		LDZ (123)	1	4287
Rio San Antonio	410158	4102181	Upstream and downstream of Hwy 285 bridge, S of Antonito	10/22/84	LDZ (127)	25	4169
Rio San Antonio	410158	4102181	"	04/27/84	LDZ (153)	5	4249
Rio San Antonio	421300	4115139	SW corner of Sego Springs SWA	03/28/83	LDZ (39)	1	3920
Rock Creek	421314	4142720	At Hwy 285 (Alamosa County)	10/24/84	LDZ (130)	5	4183
Rock Creek	421314	4142720	"	08/23/84	LDZ (99)	1	4095
Saguache Creek	379817	4220296	East end of Dabney Ranch, (old DOW access?)	08/24/83	LDZ (54)	24	3975
Saguache Creek	381456	4220627	Confluence with Hodding Creek		LDZ (23)	1	3861
Saguache Creek	382411	4222181	Hwy 114 bridge, Hill Ranch	08/26/83	LDZ (80)	10	4046

Table 2.--continued

River	UTM X	UTM Y	Specific Location	Date	Collector	N =	Catalog #
Saguache Creek	383925	4223268	Old concrete bridge, Hill Ranch	08/26/83	LDZ (75)	2	4028
Saguache Creek	399612	4214104	500 ft upstream of Hwy 285	08/26/83	LDZ (82)	106	4053
Saguache Creek	401035	4213921	Above CR 48X bridge, Coleman Ranch	08/24/83	LDZ (70)	234	4015
San Luis Creek	419709	4234769	Hayden Pass Road crossing, Station 1	08/25/83	LDZ (73)	6	4023
San Luis Creek	420318	4234221	Freel Ranch	08/25/83	LDZ (45)	668	3945
Sexto Creek	352267	4095252	Diamond S Ranch near CO-NM state line	10/05/85	LDZ (157)	1	4259
Trites Lake	400872	4199677	Russell Lakes SWA	08/24/83	LDZ (81)	1	4049
Upper Dome Lake	348223	4228572	Between outhouse and dam on E shoreline	07/30/84	LDZ (126)	1	4150

Table 3.--Sampling sites and Rio Grande chub (RGC) localities (N = absent, Y = present) from Colorado Division of Wildlife (CDOW) records, Rio Grande Basin, Colorado. The UTM zone is 13.

River	UTM X	UTM Y	Specific Location	Date	Collector	RGC	N=
Archuleta Creek	349241	4227690	Above Dome Lakes	08/23/00	CDOW (38061)	Y	33
Archuleta Creek	348118	4230190	Below Dome Lakes	08/22/00	CDOW (38061)	N	
Chico Pond	437529	4157269	Blanca SRMA	1996	CDOW	Y	5
Conejos River	433750	4128130	Main channel, upstream of CR28, Willette Cattle Company	10/29/97	CDOW (39239)	N	
Higel SWA ponds	414217	4156840		11/05/99	CDOW	N	
Hot Creek	390549	4128292	Downstream of Ojito Creek confluence, Station 5	10/19/99	CDOW (40725)	Y	224
Hot Creek	390549	4128292	"	11/03/98	CDOW (40725)	Y	234
Hot Creek	390549	4128292	"	06/16/97	CDOW (40725)	Y	142
Hot Creek	390549	4128292	"	06/07/94	CDOW (40725)	Y	280
Hot Creek	391037	4128130	Station 4	06/08/94	CDOW (40725)	Y	163
Hot Creek	391996	4126907	Upstream of Parshall flume, Station 3	10/19/99	CDOW (40725)	Y	69
Hot Creek	391996	4126907	"	06/16/97	CDOW (40725)	Y	21
Hot Creek	391996	4126907	"	06/07/94	CDOW (40725)	Y	109
Hot Creek	391996	4126907	"	10/15/92	CDOW (40725)	Y	83
Hot Creek	393130	4126403	Station 2	06/08/94	CDOW (40725)	Y	13
Hot Creek	394756	4125631	East end (1st entrance) of Hot Creek SWA, Station 1	10/19/99	CDOW (40725)	N	
Hot Creek	394756	4125631	"	06/16/97	CDOW (40725)	Y	2
Hot Creek	394756	4125631	"	06/07/94	CDOW (40725)	Y	2
La Jara Creek	392597	4115279	NE end of La Jara SWA	08/12/97	CDOW (40953)	N	
La Jara Creek	394659	4118573	Above gauging station, T34N R7E S10	08/12/97	CDOW (40953)	Y	2
La Jara Creek	396717	4121963	3.5 mi SW of Capulin, T35N R7E S35	08/11/97	CDOW (40953)	Y	9
La Jara Creek			Station 1	05/15/93	CDOW (40953)	Y	1
McIntyre Springs	427511	4125976	Pools at Governor's mansion	09/29/97	CDOW (96277)	N	
Rio Chamita	350072	4099621	upper road crossing near Binkley ranch	07/12/99	CDOW (43864)	N	
Rio Chamita	350763	4096248	road crossing near CO-NM stateline	07/12/99	CDOW (43864)	N	
Rio Grande	374090	4171594	Downstream from 17RD crossing, W of Del Norte, T40 R5E S26	09/06/96	CDOW, Nehring	Y	4
Rio Grande	434971	4111726	Old rock dam site downstream of Hwy 142 bridge crossing	09/23/92	CDOW	N	
Rio Grande	431799	4100637	Lobatos bridge to state line (NM)	08/05/97	CDOW (42515)	N	

Table 3.--continued

River	UTM X	UTM Y	Specific Location	Date	Collector	RGC	N
Rio San Antonio	410158	4102181	Upstream and downstream of Hwy 285 bridge, S of Antonito	09/24/97	CDOW (47949)	Y	32
Rio San Antonio	412584	4101933	T-Bone Ranch	08/02/99	CDOW (47949)	Y	3
Rio San Antonio	417452	4103941	T-Bone Ranch	08/02/99	CDOW (47949)	Y	7
Rio San Antonio	418591	4108420	T-Bone Ranch	08/02/99	CDOW (47949)	N	
Rio San Antonio	419509	4108876	V-Heart Ranch	07/31/99	CDOW (47949)	N	
Rio San Antonio	421300	4115139	SW corner of Sego Springs SWA	09/24/99	CDOW (47949)	Y	37
Roaring Fork Pond	336579	4171472	Browns Ranch/Goose Creek; all RGC removed and translocated	06/18/98	CDOW	Y	270
Roaring Fork Pond	336579	4171472	"	09/25/92	CDOW	Y	156
Rock Creek, Saguache County	420074	4234444	Confluence with San Luis Creek upstream to CR LL57	10/14/99	CDOW (41567)	N	
Rock Creek, Saguache County	420074	4234444	"	07/14/97	CDOW (41567)	Y	2
Rock Creek, Rio Grande County	388660	4149791	#2, off FR28, above gauging station	07/29/99	CDOW (42666)	N	
Rock Creek, Rio Grande County			#2, .25 mi East of Rinebarger residence	07/29/99	CDOW (42666)	N	
Rock Creek, Rio Grande County			#2, Nofsker Ranch, above diversion structure	07/29/99	CDOW (42666)	N	
Rock Creek, Alamosa County	421340	4142648	#1, upstream of CR 105, Fernandez property	10/01/97	CDOW (48961)	N	
Rock Creek, Alamosa County	417786	4146495	#1, upstream of CR 106, Playa Blanca SWA	05/11/99	CDOW (48961)	N	
Saguache Creek	372383	4220972	Below Hwy 114, Neilson Ranch	08/25/00	CDOW (42793)	Y	3
Saguache Creek	379817	4220296	East end of Dabney Ranch, (old DOW access?)	10/22/97	CDOW (42781)	Y	5
Saguache Creek	381456	4220627	Confluence with Hodding Creek	10/22/97	CDOW (42781)	N	
Saguache Creek	382411	4222181	Hwy 114 bridge, Hill Ranch	10/22/97	CDOW (42781)	Y	1
Saguache Creek	383925	4223268	Old concrete bridge, Hill Ranch	10/29/97	CDOW (42781)	N	
Saguache Creek	401035	4213921	Above CR48X bridge, Coleman Ranch	10/21/99	CDOW (49406)	Y	180
Saguache Creek	401705	4213819	Below CRX road, Werner property	10/21/99	CDOW (49406)	Y	516
San Luis Creek	409833	4247449	Upstream of FR947 crossing, near Alder Creek confluence	10/12/99	CDOW (42945)	N	
San Luis Creek	414608	4239544	In ditch near San Luis Creek, Fullenwider Ranch	10/12/01	CDOW (42945)	Y	20
San Luis Creek	414608	4239544	"	10/21/99	CDOW (42945)	Y	48
San Luis Creek	414608	4239544	"	08/06/97	CDOW (42945)	Y	15
San Luis Creek			In spring ditch above pond on Fullenwider Ranch	10/21/99	CDOW (42945)	Y	16
San Luis Creek	419709	4234769	Hayden Pass Road crossing, Station 1	07/28/97	CDOW (42945)	N	
San Luis Creek	420156	4234282	Freel Ranch #2, .5 miles south of Hayden Pass Road	10/17/01	CDOW (42945)	Y	17

Table 3.--continued

River	UTM X	UTM Y	Specific Location	Date	Collector	RGC	N=
San Luis Creek	420156	4234282	"	07/28/97	CDOW (42945)	N	
San Luis Creek	420867	4232595	Freel Ranch #3, .5 miles south of railroad grade crossing	10/17/01	CDOW (42945)	Y	17
San Luis Creek	420867	4232595	"	07/28/97	CDOW (42945)	N	
San Luis Creek	421051	4231304	Freel Ranch #4	10/14/99	CDOW (42945)	Y	70
San Luis Creek	421141	4231191	Freel Ranch #4, near stock pond	07/28/97	CDOW (42945)	Y	6
San Luis Creek			Freel Ranch #5, below railroad grade crossing	10/14/99	CDOW (42945)	Y	1
San Luis Creek			East of /LD Ranch Homestead, T47N R9E S7	10/12/99	CDOW (42945)	N	
Schutte Rearing Ponds	406033	4159179	Center pond, Rio Grande SWA	10/18/99	CDOW (92178)	N	
Schutte Rearing Ponds	406033	4159179	"	Fall 1998	CDOW	N	
Sexto Creek	352267	4095252	Diamond S Ranch near CO-NM stateline	07/12/99	CDOW (43965)	N	
Silver Lakes	376832	4137863	Alamosa River/French Creek; all RGC removed and translocated	06/18/02	CDOW	Y	295
Silver Lakes	376832	4137863	Alamosa River/French Creek; all RGC removed and translocated	06/11/98	CDOW	Y	1518
Silver Lakes	376832	4137863	Alamosa River/French Creek; all RGC removed and translocated	06/24/97	CDOW	Y	3575
Swale Lake	351133	4150514		07/30/97	CDOW (92483)	Y	1
Teal Pond	437529	4157269	Blanca SRMA	10/26/99	CDOW (88241)	Y	55
Upper Dome Lake	348223	4228572	Between outhouse and dam on E shoreline	06/29/99	CDOW (89640)	Y	3

Table 4.--Colorado State University Larval Fish Laboratory (CSU LFL) sample sites and Rio Grande chub (RGC) localities (N = absent, Y = present, dry = dry streambed), Rio Grande Basin, Colorado, 2001-2002. The UTM zone is 13.

River	UTM X	UTM Y	Specific Location	Date	Collector	RGC	N-
Alamosa River	379036	4138452	National Forest on FR250 before private fence downstream of FR260	08/29/02	CSU LFL (40)	N	
Alamosa River	380216	4137864	200 m upstream of Alamosa campground on FR250	08/29/02	CSU LFL (41)	N	
Alamosa River	386323	4134856	Downstream of Terrace Res., upstream of gauging station & cable car	08/29/02	CSU LFL (42)	N	
Alamosa River	386770	4134653	Downstream of Terrace Res., from 200m downstream to gauging station	08/29/02	CSU LFL (43)	N	
Big Spring Creek	441163	4176457	Confluence with ditch, Modano Zapata Ranch	09/12/02	CSU LFL (51)	N	
Big Spring Creek	441163	4176457	Ditch between Big and Little Spring Creeks, Modano Zapata Ranch	09/12/02	CSU LFL (50)	N	
Conejos River	410585	4106306	Hwy 285 crossing	Fall 2001	CSU LFL	dry	
Conejos River	419302	4114333	N branch Conejos River at Hwy 142 crossing	10/04/01	CSU LFL	dry	
Conejos River	421497	4116527	Sego Springs SWA (NW corner)	10/04/01	CSU LFL	dry	
Conejos River	433831	4127398	Conejos River diversion at CR 28 crossing	10/04/01	CSU LFL	dry	
Conejos River	390143	4102425	Massey Gulch near first public campground W of Fox Creek	09/10/02	CSU LFL (45)	N	
Conejos River	420481	4114455	S branch Conejos River downstream of Hwy 142, E of Manassa	10/04/01	CSU LFL (13)	N	
Conejos River	428324	4127358	End of CR 24, NE of Sanford, Zebulon Pike's stockade	10/05/01	CSU LFL (14)	N	
Conejos River	433750	4128130	Main channel, upstream of CR 28, Willette Cattle Company	10/04/01	CSU LFL (15)	N	
Conejos River	434827	4128699	Downstream of CR Z at confluence with Rio Grande	10/09/01	CSU LFL (16)	N	
Cotton Creek	431169	4220586	E of Hwy 17 on AA RD crossing	09/11/02	CSU LFL (47)	N	
Cuates Creek	464673	4097650	CR 21 crossing	09/12/02	CSU LFL	dry	
Culebra Creek	435436	4114719	Confluence with Rio Grande	10/09/01	CSU LFL	dry	
French Creek	377413	4138513	Downstream of Silver Lakes	Fall 2001	CSU LFL	dry	
Hot Creek	386850	4128501	Upstream of Hot Creek SWA, small canyon at dead end of road	09/18/02	CSU LFL (54)	Y	15
Hot Creek	390549	4128292	Downstream of Ojito Creek confluence, Station 5	09/18/02	CSU LFL (53)	Y	91
Hot Creek	397499	4125834	Upstream and downstream of FDR240, W of Centro	10/11/01	CSU LFL (12)	Y	1
Hot Springs Creek	428345	4227068	Downstream of Valley View hot springs	Fall 2002	CSU LFL	dry	
Jaroso Creek	465044	4100698	CR 21 crossing	09/12/02	CSU LFL	dry	
Kerber Creek	399754	4240479	Upstream of confluence with Squirrel Creek, W of Villa Grove on LL56	09/11/02	CSU LFL (48)	N	
La Jara Creek	405952	4125935	CR 10.75 crossing	10/10/01	CSU LFL	dry	
La Jara Creek	409671	4125427	CR 13 crossing	10/10/01	CSU LFL	dry	
La Jara Creek	413613	4126525	Hwy 15 crossing	10/10/01	CSU LFL	dry	
La Jara Creek	415299	4127358	Hwy 285 crossing	10/10/01	CSU LFL	dry	
La Jara Creek	419444	4130060	CR 19 crossing	10/10/01	CSU LFL	dry	

Table 4.--continued

River	UTM X	UTM Y	Specific Location	Date	Collector	RGC	N=
La Jara Creek	422431	4132153	CR AA.5 crossing (not sampled)	10/10/01	CSU LFL	pools	
La Jara Creek	422614	4132539	CR 21 crossing (not sampled)	10/10/01	CSU LFL	pools	
La Jara Creek	427390	4136055	CR S-112 crossing	10/11/01	CSU LFL	dry	
La Jara Creek	392530	4114828	La Jara SWA, end of improved road, about 1.5 miles upstream of entry	09/10/02	CSU LFL (08)	N	
La Jara Creek	392530	4114828	"	10/08/01	CSU LFL (08)	N	
La Jara Creek	396747	4121810	Upstream of CR 8 to private property fence	08/29/02	CSU LFL (09)	Y	17
La Jara Creek	396747	4121810	"	10/10/01	CSU LFL (09)	Y	6
La Jara Creek	401766	4125956	Downstream of CR 8 in Capulin, Quintana property	10/11/01	CSU LFL (10)	N	
La Jara Creek	424301	4134084	Downstream of CR 22, Don Larson property	10/11/01	CSU LFL (11)	N	
McIntyre Springs	427511	4125976	Pools at Governor's mansion	08/28/02	CSU LFL (38)	Y	12
McIntyre Springs	427502	4126602	From confluence with Conejos River to constriction	08/28/02	CSU LFL (39)	Y	3
Rio de los Pinos	381464	4095735	FR103 crossing S of Osier	08/29/02	CSU LFL (44)	N	
Rio de los Pinos	406907	4094744	Upstream of confluence with Rio San Antonio, CR B, S of Ortiz	10/05/01	CSU LFL (17)	Y	8
Rio Grande	350306	4175522	Main entrance to Collier SWA	09/19/02	CSU LFL (55)	N	
Rio Grande	371336	4172074	17RD crossing W of Del Norte, N of Hanna	08/20/02	CSU LFL (23)	N	
Rio Grande	398622	4162883	Hwy 285 crossing, about 2 mi. N of Monte Vista, gauging station	08/20/02	CSU LFL (24)	N	
Rio Grande	408235	4158439	6E RD/ N-100 RD crossing on Rio Grande SWA, E of Monte Vista	08/20/02	CSU LFL (25)	N	
Rio Grande	412125	4157852	NW boundary of Higel SWA	09/19/02	CSU LFL (57)	N	
Rio Grande	414318	4156960	NE corner of Higel SWA, between Alamosa and Monte Vista	09/19/02	CSU LFL (56)	N	
Rio Grande	431952	4137305	0.4 mi. upstream from entrance road on S end of Alamosa NWR	08/21/02	CSU LFL (26)	N	
Rio Grande	431436	4137243	0.9 mi. upstream from entrance road on S end of Alamosa NWR	08/21/02	CSU LFL (27)	N	
Rio Grande	430889	4138151	1.8 mi. upstream from entrance road on S end of Alamosa NWR	08/21/02	CSU LFL (28)	N	
Rio Grande	430790	4140360	3.3 mi. upstream from entrance road on S end of Alamosa NWR	08/21/02	CSU LFL (29)	N	
Rio Grande	430918	4140578	4.0 mi. upstream from entrance road on S end of Alamosa NWR	08/21/02	CSU LFL (30)	N	
Rio Grande	430965	4141511	4.2 mi. upstream from entrance road on S end of Alamosa NWR	08/21/02	CSU LFL (31)	N	
Rio Grande	430918	4141693	4.5 mi. upstream from entrance road on S end of Alamosa NWR	08/21/02	CSU LFL (32)	N	
Rio Grande	434748	4128868	Downstream of CR Z at confluence with Conejos River	10/09/01	CSU LFL (21)	N	
Rio Grande	435253	4114576	Downstream of Hwy 142, Conejos/Costilla county line	10/09/01	CSU LFL (22)	N	
Rio Grande	434971	4111726	Old rock dam site downstream of Hwy 142 bridge crossing	08/22/02	CSU LFL (33)	N	
Rio Grande	432870	4103736	G RD bridge, gauging station	08/22/02	CSU LFL (34)	N	

Table 4.--continued

River	UTM X	UTM Y	Specific Location	Date	Collector	RGC	N=
Rio San Antonio	414213	4102181	16 RD crossing (not sampled)	10/02/01	CSU LFL	pool	
Rio San Antonio	420928	4103766	G RD crossing, T-Bone Ranch (not sampled)	10/02/01	CSU LFL	dry	
Rio San Antonio	421300	4115139	SW corner of Sego Springs SWA	10/02/01	CSU LFL	dry	
Rio San Antonio	409163	4097650	Downstream of CR C in San Antonio, Ted Sandoval property	10/05/01	CSU LFL (18)	Y	6
Rio San Antonio	410158	4102181	Upstream and downstream of Hwy 285 bridge, S of Antonito	08/28/02	CSU LFL (19)	Y	27
Rio San Antonio	410158	4102181	"	10/03/01	CSU LFL (19)	Y	75
Rio San Antonio	421436	4111894	Upstream and downstream of CR M, SE of Manassa	10/04/01	CSU LFL (20)	N	
Rito Seco	466180	4121688	3 km NE of San Luis	09/12/02	CSU LFL	dry	
Rock Creek, Alamosa County	421340	4142648	#1, upstream of CR 105, Fernandez property	Fall 2001	CSU LFL	dry	
Rock Creek, Alamosa County	417786	4146495	#1, upstream of CR 106, Playa Blanca SWA	Fall 2001	CSU LFL	dry	
Rock Creek, Alamosa County	421314	4142720	Hwy 285 crossing	Fall 2001	CSU LFL	dry	
Rock Creek, Saguache County	420074	4234444	Confluence with San Luis Creek upstream to CR LL57	08/27/02	CSU LFL (37)	Y	1
Russell Spring	401183	4200631	Downstream of Harrence Lake, Russell Lakes SWA	09/12/02	CSU LFL (52)	N	
Saguache Creek	370250	4219103	North of old Curtis Ranch house	09/26/01	CSU LFL (01)	N	
Saguache Creek	372383	4220972	Downstream of Hwy 114, Neilson Ranch	09/25/01	CSU LFL (02)	N	
Saguache Creek	376447	4221460	Downstream end of Neilson Ranch property	09/26/01	CSU LFL (03)	N	
Saguache Creek	388449	4223312	Upstream of Ward ranch house	09/27/01	CSU LFL (04)	Y	1
Saguache Creek	391901	4218554	Upstream of CR 42 to diversion	08/27/02	CSU LFL (05)	Y	9
Saguache Creek	391901	4218554	"	09/27/01	CSU LFL (05)	Y	11
Saguache Creek	398251	4214978	Upstream of CR 46, Hill Ranch	09/26/01	CSU LFL (06)	Y	58
Saguache Creek	401035	4213921	Above CR 48X bridge, Coleman Ranch	08/19/02	CSU LFL (07)	dry	
Saguache Creek	401035	4213921	"	09/27/01	CSU LFL (07)	Y	3
San Luis Creek	422289	4226682	CR GG crossing	09/11/02	CSU LFL	dry	
San Luis Creek	420664	4233448	Upstream of railroad crossing	08/26/02	CSU LFL (35)	N	
San Luis Creek	420554	4232995	From stock pond to railroad grade crossing	08/27/02	CSU LFL (36)	Y	3
Sangre de Cristo Creek	470306	4149344	Various points along Hwy 160, Forbes-Trinchera Ranch	09/12/02	CSU LFL	dry	
Slaughterhouse Creek	397885	4239362	Upstream of National Forest boundary, from LL56 to 46PP	09/11/02	CSU LFL (49)	N	
Torcido Creek	465775	4105006	CR 21 crossing	09/12/02	CSU LFL	dry	
Trinchera Creek	434827	4129776	Confluence with Rio Grande	10/09/01	CSU LFL	dry	
Wild Cherry Creek	432687	4217007	E of Hwy 17 on AA RD crossing, 100m upstream of trailhead	09/11/02	CSU LFL (46)	N	

Table 5.--Lake and pond localities for Rio Grande chubs (RGC), Rio Grande Basin, Colorado. Museum acronyms follow Leviton et al. (1985). CDOW = Colorado Division of Wildlife, SRMA = Special Recreation Management Area, SWA = State Wildlife Area.

Year	Locality	# RGC	Collector	Catalog #
1909	San Luis Lakes	3	Warren	UCM 351
1950	Russell Spring (Russell Lakes SWA)	1	Beckman	UMMZ 160746
1978	Terrace Reservoir	17	CDOW	
1983	Trites Lake (Russell Lakes SWA)	1	Zuckerman	USGS-MSB 4150
1992	Roaring Fork Pond	156	CDOW	
1996	Chico Pond (Blanca SRMA)	5	CDOW	
1997	Swale Lake	1	CDOW	
1998	Roaring Fork Pond	270	CDOW	
1999	Teal Pond (Blanca SRMA)	55	CDOW	

Table 6.—Source of Rio Grande chubs (RGC) translocated to various sites, Rio Grande Basin, Colorado. Records were compiled from literature and data files of the Colorado Division of Wildlife (CDOW). SWA = State Wildlife Area, SRMA = Special Recreation Management Area.

Date	Removed from:	# of RGC	Translocated to:
09/25/84	San Luis Creek	Unknown	Russell Lakes SWA
05/29/85	Hot Creek	Unknown	Russell Lakes SWA
09/25/92	Roaring Fork Pond	156	Swale Lake
06/24/97	Silver Lakes	2100	Blanca SRMA ponds (Teal, Chico and Snipe Lakes)
06/24/97	Silver Lakes	1475	Schutte Rearing ponds, Rio Grande SWA
10/08/97	Hot Creek	115	Schutte Rearing ponds, Rio Grande SWA
06/11/98	Silver Lakes	1518	Schutte Rearing ponds, Rio Grande SWA
06/18/98	Roaring Fork Pond	270	Blanca SRMA ponds (Teal, Chico and Snipe Lakes)
06/18/02	Silver Lakes	295	McIntyre Springs
09/16/02	CDOW Alamosa native fish hatchery	500	Teal Lake (Blanca SRMA pond)
09/16/02	CDOW Alamosa native fish hatchery	13000	Chico Lake (Blanca SRMA pond)
09/16/02	CDOW Alamosa native fish hatchery	1000	Snipe Lake (Blanca SRMA pond)
09/16/02	CDOW Alamosa native fish hatchery	5000	McIntyre Springs
09/16/02	CDOW Alamosa native fish hatchery	8523	Rio Grande (old dam site)

Table 7.—Parameter coefficients, confidence limits, and significance levels for full (all sites) and reduced models (all sites in streams where chubs were known to occur) for binomial response regression models to predict presence of Rio Grande chubs at sampling sites in the Rio Grande Basin, Colorado, 2001-2002 as a function of explanatory variables. Negative parameter estimates suggest the explanatory variable and chub presence were negatively associated. The very large estimate for sand in the reduced model reflects the dominance of sand at all sites where chubs were found.

Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Full Model							
Intercept	1	1.4717	1.4759	-1.4210	4.3644	0.99	0.3187
Cobble	1	-2.4055	1.7035	-5.7444	0.9334	1.99	0.1579
Gravel	1	1.0523	1.4238	-1.7382	3.8429	0.55	0.4598
Sand	1	2.3096	1.6244	-0.8741	5.4934	2.02	0.1551
Silt	0	0.0000	0.0000	0.0000	0.0000	.	.
Width	1	-0.2781	0.1254	-0.5239	-0.0324	4.92	0.0265
Brown trout present	1	1.5346	0.8301	-3.1615	0.0923	3.42	0.0645
Brown trout absent	0	0.0000	0.0000	0.0000	0.0000	.	.
Reduced Model							
Intercept	1	-0.8778	1.8729	-4.5487	2.7931	0.22	0.6393
Cobble	1	-0.4439	1.6075	-3.5946	2.7067	0.08	0.7824
Gravel	1	3.7355	1.7888	0.2296	7.2414	4.36	0.0368
Sand	1	28.8847	251347.9	-492604	492661.6	0.00	0.9999
Silt	0	0.0000	0.0000	0.0000	0.0000	.	.
Width	1	-0.2024	0.3134	-0.8166	0.4118	0.42	0.5183
Brown trout present	1	-1.6007	1.5041	-1.3472	4.5487	1.13	0.2872
Brown trout absent	0	0.0000	0.0000	0.0000	0.0000	.	.

Table 8.—Fish community composition on 61 sampling occasions in the Rio Grande Basin, Colorado, 2001-2002. I = introduced, N = native.

Species	Common name	Status	Frequency in samples	% (N = 61)	# collected	% of total
Salvelinus fontinalis	brook trout	I	7	11.5	328	2.3
Salmo trutta	brown trout	I	27	44.3	518	3.6
Oncorhynchus clarki	cutthroat trout	I	2	3.3	2	*
Oncorhynchus mykiss	rainbow trout	I	7	11.5	14	0.1
Esox lucius	northern pike	I	2	3.3	6	*
Cyprinus carpio	common carp	I	18	29.5	153	1.1
Pimephales promelas	fathead minnow	N	40	65.6	6316	43.5
Platygobio gracilis	flathead chub	N	7	11.5	170	1.2
Rhinichthys cataractae	longnose dace	N	36	59.0	1421	9.8
Cyprinella lutrensis	red shiner	N	20	32.8	2232	15.4
Gila pandora	Rio Grande chub	N	18	29.5	347	2.4
Catostomus plebeius	Rio Grande sucker	N	1	1.6	115	0.8
Catostomus commersoni	white sucker	I	44	72.1	2725	18.8
Ictalurus punctatus	black bullhead	I	2	3.3	5	*
Fundulus sciadicus	plains topminnow	I	1	1.6	20	0.1
Culaea inconstans	brook stickleback	I	7	11.5	67	0.5
Lepomis cyanellus	green sunfish	I	14	23.0	91	0.6
Micropterus salmoides	largemouth bass	I	1	1.6	3	*
Perca flavescens	yellow perch	I	1	1.6	1	*
					Total: 14,534	

* < 0.1%

Table 9.--Occurrence (X = present, O = absent) of Rio Grande chubs documented during sampling occasions in the Rio Grande Basin streams from 1871 to 2002. Numbers in parentheses represent the number of chub collections at a site (1871-1980, 1981-1985) or the frequency of chubs in samples from sites visited (1992-2000, 2001-2002); 2001-2002 data include sites that were dry. Status determinations were from chronology of presence of chubs at sites and population size and stability of chubs at those localities. Questions marks indicate that population stability was unknown or that few samples were available to determine status.

Site	1871-1980	1981-1985	1992-2000	2001-2002	Status
Rio Grande Basin					
Rio Grande	X (12)	X (4)	X (1 of 3)	O (0 of 17)	Extirpated
Alamosa	X (1)			O (0 of 4)	Extirpated
Conejos	X (1)	X (2)	O (0 of 1)	O (0 of 9)	Extirpated
Sangre de Cristo Creek	X (1)				Extirpated?
Rio San Antonio		X (3)	X (4 of 6)	X (3 of 6)	Small, stable?
Hot Creek		X (5)	X (many)	X (3 of 3)	Large, stable
McIntyre Spring		X (6)	O (0 of 1)	X (2 of 2)	Small, declining
Rio de los Pinos				X (1 of 2)	Small, stable?
La Jara Creek			X (3 of 4)	X (2 of 12)	Small, stable?
Rock Creek		X (2)	O (0 of 5)	O (0 of 3)	Extirpated
Rio Chamita		X (2)	O (0 of 2)		Extirpated?
Sexto Creek		X (1)	O (0 of 1)		Extirpated?
Closed Basin					
Saguache Creek		X (6)	X (5 of 7)	X (5 of 9)	Large, stable
San Luis Creek		X (2)	X (9 of 14)	X (1 of 3)	Small, declining
Hot Spring Creek		X (1)		O (0 of 1)	Extirpated
Rock Creek			X (1 of 2)	X (1 of 1)	Small, stable?