Rio Grande Chub (*Gila pandora*): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

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COVER PHOTO CREDIT

Rio Grande chub (*Gila pandora*). Photo taken by John Woodling and Don Domenick (Woodling 1985).

Summary of Key Components for Conservation of the Rio Grande Chub

Status

The Rio Grande chub (*Gila pandora*) is considered a sensitive species within the USDA Forest Service (USFS), Rocky Mountain Region (Region 2). Native populations of this species in Region 2 occur on the Rio Grande National Forest within the Rio Grande Basin of Colorado. Rio Grande chub populations in Colorado have been reduced from historic levels. The species has likely been extirpated from the mainstem Rio Grande and is now only found in tributary streams.

Primary Threats

The primary threats to the Rio Grande chub generally result from anthropogenic events. Water diversion projects have resulted in flow regime changes in both tributary and mainstem rivers and streams. Construction of diversion dams and reservoirs has degraded and fragmented habitats and caused passage barriers. The introduction of non-native species has increased predation of and competition with the Rio Grande chub. Other threats to this species include land use changes and local development and excessive grazing in riparian zones, which reduce the natural stream ecosystem function.

Primary Conservation Elements, Management Implications and Considerations

Recovery of the Rio Grande chub to a less threatened status will require detailed local and regional information concerning its distribution, life history, population trends, and community ecology. Management strategies regarding this species should begin with a detailed survey of drainages on National Forest System land that could contain populations of Rio Grande chub. Biological data should be collected concurrent with such a survey. This effort should be coordinated with other agencies (i.e., state game and fish departments, Bureau of Land Management, U.S. Fish and Wildlife Service) to obtain information from stream reaches that may be influenced by USFS management activities even though they are not on National Forest System lands. Given the known threats to this species, conservation measures should concentrate on determining sensitive habitats required for each life stage and maintaining habitat diversity and natural temperature and flow regimes in stream reaches with Rio Grande chub populations. In addition, concurrent tracking of introduced species would provide information on biological threats.

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INTRODUCTION

This is one of many assessments being produced to support the Species Conservation Project for USDA Forest Service (USFS), Rocky Mountain Region (Region 2). The Rio Grande chub is the focus of an assessment because it is considered a sensitive species in Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance and/or in habitat capability that would reduce its distribution (FSM 2670.5 (19)). Due to concerns about population viability, a sensitive species requires special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of Rio Grande chub throughout its range in Region 2 (**Figure 1**). This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on existing scientific knowledge. Such information could be used by USFS managers and biologists for addressing this species' needs as well as for revising Forest plans.

The goal limits the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. Thus, this assessment does not provide specific management recommendations. Rather, it provides the ecological background upon which management can be based and focuses on the consequences of environmental change that result from management activities (i.e., management implications). This assessment also cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented elsewhere.

Scope

The Rio Grande chub assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of Region 2. Although some of the literature on the species may originate from field investigations outside the region, this document places that literature in the ecological context of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of Rio Grande chub in the context of the current environment rather than under historical or geological conditions. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on Rio Grande chub are referenced in the assessment, nor were all published materials considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were used in the assessment when information was unavailable elsewhere, but these were regarded with greater skepticism. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of this species. These data required special attention because of the diversity of persons and methods used in their collection.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to this uncertainty is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed in certain physical sciences. Ecological science, however, is more similar to geology than physics because of the difficulty in conducting critical experiments and the reliance on observation, inference, good thinking, and models to guide our understanding of the world (Hillborn and Mangel 1997). The geologist T. C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (e.g., experiments, modeling, logical inference). A problem with using the approach outlined in both Chamberlain (1897) and Platt (1964) is that

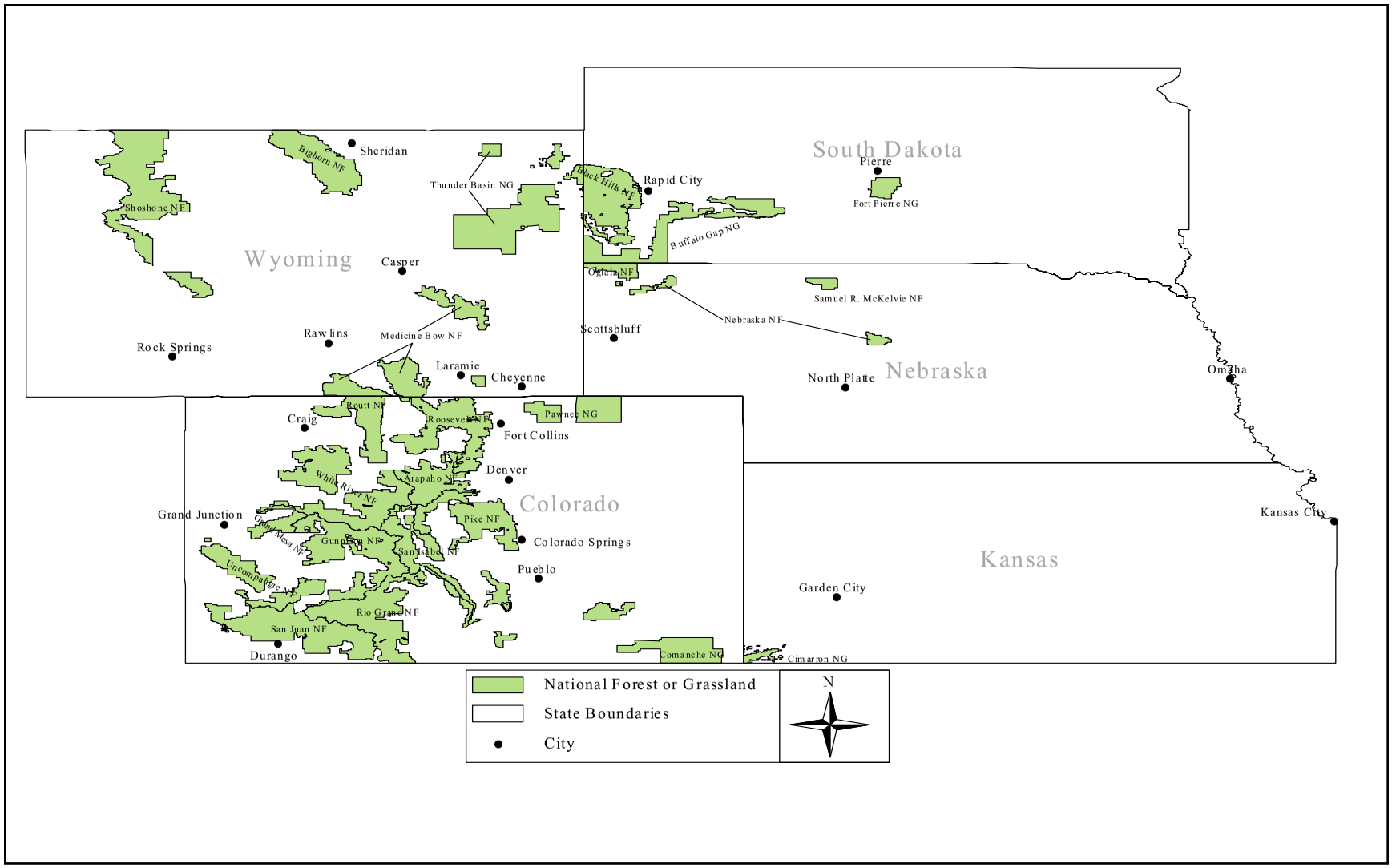

Figure 1. USDA Forest Service Region 2 national forests and grasslands.

there is a tendency among scientists to resist change from a common paradigm. Treatment of uncertainty necessitates that a wide variety of hypotheses or experiments be undertaken to test both the true or false nature of the uncertainties at hand (Vadas 1994). Confronting uncertainty, then, is not prescriptive. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding and used in synthesis for this assessment. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Like many non-game fish, the Rio Grande chub has not been studied extensively within Region 2 or rangewide. The limited knowledge regarding this species' needs creates uncertainty in the assessment for its conservation. This species assessment has synthesized the available data collected throughout the Rio Grande Basin and the San Luis Closed Basin, including historical and current distributions, conservation strategies, habitat needs, and management requirements. However, a general lack of precise information regarding the distribution of Rio Grande chub on or near National Forest System lands limited the data useful to this assessment. This required inference from available data, using a scientific approach, to enhance our understanding of the current needs of this species.

Application and Interpretation Limits of This Assessment

Information used in this assessment was collected from life history and ecological studies made throughout the geographic range of the Rio Grande chub, but emphasis was placed on studies specific to Region 2. Although most information should apply broadly throughout the range of the species, it is likely that certain life history parameters (i.e., growth rate, longevity, spawning time) will differ along environmental gradients. Information regarding conservation strategies of the species pertains specifically to Region 2 and does not apply to other portions of the species' range.

Publication of Assessment on the World Wide Web

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site (www.fs.fed.us/r2/projects/scp/assessments/index.shtml). Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This report was reviewed through a process administered by the American Fisheries Society, which chose two recognized experts on this or related taxa to provide critical input on the manuscript. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

Management Status and Natural History

Management Status

The Rio Grande chub is not a federally listed species, but it has been given special status with other agencies. The USFS Region 2 considers the Rio Grande chub to be a sensitive species. In the National Forest System, a sensitive species is a species for which population viability is a concern due to a current or predicted downward trend in population numbers or in habitat capability that would reduce its distribution. The Bureau of Land Management considers the Rio Grande chub to be a sensitive species in Colorado.

The Rio Grande chub currently has Natural Heritage Program global rank of G3 (vulnerable) and a state rank of S1 (critically imperiled) in Colorado. The G3 ranking signifies that the species is either very rare or local throughout its range or found locally in a restricted range. The S1 ranking signifies that the species is critically imperiled because of extreme rarity or because of some factor of its biology that makes it especially vulnerable to extirpation from the state.

The Colorado Division of Wildlife (CDOW) considers the Rio Grande chub a species of concern but does not provide statutory protection (http://wildlife.state.co.us/species_cons/list.asp). Although New Mexico has relatively stable populations of Rio Grande chub, it considers this species to be sensitive. Texas lists Rio Grande chub as threatened.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

There are no existing conservation or management plans for the Rio Grande chub. Current Colorado law prohibits the taking of Rio Grande chub by any means for any purpose. Few anglers specifically target Rio Grande chub but incidental take probably does occur as fisherman attempt to catch game fish species, such as trout. Several CDOW regulations are intended to protect native fish species as a group and thus aid in the conservation of the Rio Grande chub. Specific restrictions in the Rio Grande Basin (in Colorado) prohibit the live release of non-native fish species into rivers and lakes. Another regulation indirectly assisting the conservation of Rio Grande chub is a statewide statute that prohibits the seining, netting, trapping, or dipping of Rio Grande chub in natural streams. Any future laws designed to assist in the recovery of this species should be directed toward protecting the limited habitat that the species is able to utilize.

Biology and Ecology

Systematics and general species description

The Rio Grande chub was described by Cope (1872) as *Clinostomus pandora* from specimens taken at Sangre de Cristo Pass, Rio Grande Basin, New Mexico. Cope and Yarrow (1875) transferred the species to the genus *Gila* and described it as *G. gula*. The genus *Gila* is part of the Family Cyprinidae within the order Cypriniformes.

In the past, several workers have mistakenly identified *Gila pandora* with other similar species, especially Chihuahua chub (*G. nigrescens*). Evermann and Kendall (1894), collecting in the Rio Grande Basin, treated the species as *Leucisus nigrescens*. Robins et al. (1980) officially transferred the common name Rio Grande chub from *L. nigrescens* (Chihuahua chub) to *G. pandora*.

Gila pandora is easily confused with *Leucisus nigrescens* from Mexico and has often been treated as this species, as noted by Miller and Hubbs (1962), Sublette et al. (1990), Zuckerman and Langlois (1990). We presume that any treatment of *L. nigrescens* in the Rio Grande Basin and San Luis Closed Basin in Colorado was in fact *G. pandora*. In cases where *G. pandora* was found outside these two drainages, it is presumed that the species was actually *L. nigrescens* if the source was published before 1975, unless it was an area where *G. pandora* is known to have been introduced.

The Rio Grande chub reaches up to 250 mm (9.8 inches) total length (TL) in lacustrine habitats but averages 130 to 150 mm (5.1 to 5.9 inches) TL in most streams (Zuckerman and Langlois 1990). The following description is taken from Sublette et al. (1990): *"Coloration dark dorsally and laterally, with two darker stripes laterally, silver ventrally, perinotum tan with occasional black spots, insertions of anal, pelvic, and pectoral fins yellowish orange. Mouth reaching posteriorly even with anterior edge of pupil of eye. Total head pores 43-58. HL/Caud Ped D (2.1-2.8), SL/HL 3.5(3.0-3.8), SL/OrL 16.0(14.5-17.5), HL/OrL 4.6(4.0-5.3), SL/Caud Ped D 8.7(7.7-9.5). Dentition 2,5-4,2 (1,5-4,2; 2,5-4,1). Gill rakers on first arch 6-10. Maximum standard length 167 mm. Lateral line with 51-68 scales, decurved. Scales above lateral line 14-18, below lateral line 8-14, predorsal scales 31-48, scales around caudal peduncle 13-19. Vertebrae 40-44. Dorsal fins triangular, rays 8(8-9). Pectoral fins rounded, rays 16(12-20). Anal fins triangular, rays 8(7-9). Caudal fin deeply forked with lobes broadly pointed, rays 18-19. The populations in the Rio Grande basin usually have 9-9 pelvic rays while those of the Pecos River drainage usually number 8-8."*

Distribution and abundance

The native range of the Rio Grande chub is thought to have included most streams in the Rio Grande and Pecos River basins (Sublette et al. 1990) and the San Luis Closed Basin (Zuckerman and Bergersen 1986, Zuckerman and Langlois 1990). This species is likely extirpated from the mainstem Rio Grande and now is found only in tributary streams (Bestgen et al. 2003). Although present in all sample sites collected between 1981 and 1985, the Rio Grande chub was only present in only 25 percent of the locations sampled in the Rio Grande Basin from 2001-2002 (Bestgen et al. 2003). Medano Creek, Mosca Creek, and Sand Creek, small streams that terminate in Great Sand Dunes National Monument, Colorado, historically contained the native fish community that evolved in the Rio Grande Basin (Zuckerman and Bergersen 1986). It is not possible to identify every stream from which the Rio Grande chub has been extirpated due to the absence of complete records on historical distribution.

Prior to 1990, the Rio Grande chub was reported in south-central Colorado from the following streams and lakes: Rio Grande, Rio San Antonio, Conejos River, Rock Creek; Russell Lakes, Saguache Creek,

and San Luis Creek (San Luis Closed Basin); Hot Creek and McIntyre Springs, Hot Springs Creek below Valley View Hot Springs; Humphries Lake (Goose Creek drainage); Silver Lakes, Kerr Lake, and Terrace Reservoir (Alamosa River drainage); Continental Reservoir (North Clear Creek drainage); Platoro Reservoir (Conejos River drainage) (Zuckerman and Langlois 1990). Much of this range exists within the Rio Grande National Forest boundary. A map of USFS lands (**Figure 1**) can be compared to a map that identifies watershed units from which Rio Grande chub have been collected in Region 2 (**Figure 2**).

An isolated, introduced population of Rio Grande chub does occur in Dome Lake on the Gunnison National Forest. Rio Grande chub is capable of sustaining viable populations in many places where it has been introduced. There is some concern that these introduced fish may cause problems by hybridizing with native cyprinid species.

Outside of Region 2, the Rio Grande chub is widespread in New Mexico in suitable habitat throughout the Rio Grande drainage. Calamusso and Rinne (1996) found this species in the following streams in the Sante Fe and Carson national forests in New Mexico: Rio de los Pinos, Rio San Antonio, Rio Nutrias, Rio Grande, Rio Tusas, Rio Vallecitos, El Rito, Canjilon Creek, Rio Grande del Rancho, Jemez River, East Fork Jemez River, San Antonio Creek, Rio Guadalupe, Rio de las Vacas, Rio Cebolla, Rito de las Palomas, American Creek, and Clear Creek. Populations were only present in reaches with gradients less than 2 percent and at elevations ranging 1,717 to 2,810 m (5,633.2 to 9,219.6 ft.). The Rio Grande chub has also been introduced into the headwaters of the Canadian River, New Mexico. Platania (1991) found Rio Grande chub to be most common in the reaches of the Rio Grande upstream of the confluence with the Rio Chama than downstream of the Rio Chama. A lower site where Rio Grande chub was common was downstream from Cochiti Dam where the hypolimnetic release from the dam created conditions similar to the upper reaches of the river.

Historically, the Rio Grande chub was probably the most common fish in the San Luis River and Rio Grande basins (Cope and Yarrow 1875). Within Region 2, this species has declined dramatically. This decline in abundance has paralleled the decline in abundance of two other native fish, the Rio Grande sucker (*Catostomus plebeius*) and the Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*). Together, these three species once composed the majority of the fish assemblage in the Rio Grande and San Luis River drainages.

Population trend

There are several populations of Rio Grande chub in Colorado and many populations throughout New Mexico (Zuckerman and Langlois 1990, Calamusso and Rinne 1996, Bestgen et al. 2003). While populations in New Mexico are still considered stable, this species has substantially declined from historical levels in both Colorado and New Mexico.

Rio Grande chub were once the most common fish in the Rio Grande Basin and San Luis Closed Basin, existing at high levels that were harvested as a food source by pre-Columbian residents of the San Luis Valley (Zuckerman and Langlois 1990). Although there are currently small populations in many parts of its historical range in Region 2, the overall numbers of Rio Grande chub are reduced by as much as 75 percent (Bestgen et al. 2003).

Probable factors contributing to the decline of Rio Grande chub include competition with and predation by introduced brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*), habitat fragmentation due to impoundments, destruction of habitat due to cattle grazing and other land use practices (e.g., road building, timber harvesting, mining) (Bestgen et al. 2003). Hypolimnetic releases below impoundments cause a change in the thermal regime in the river downstream. The modified thermal regime is usually colder in the summer and warmer in the winter than historic conditions.

Activity pattern

Little information has been obtained regarding activity or movement patterns for the Rio Grande chub. While Rio Grande chubs are usually found in pools with overhanging banks and brush, they apparently move into riffles to spawn in the spring and early summer (Zuckerman and Langlois 1990, Rinne 1995). Further research that focuses on migration patterns and those factors (environmental or anthropogenic) that influence various movement behavior is warranted.

Habitat

Some general information on habitat associations for the Rio Grande chub is available, but specific seasonal and life history information is relatively limited. This versatile species is able to inhabit

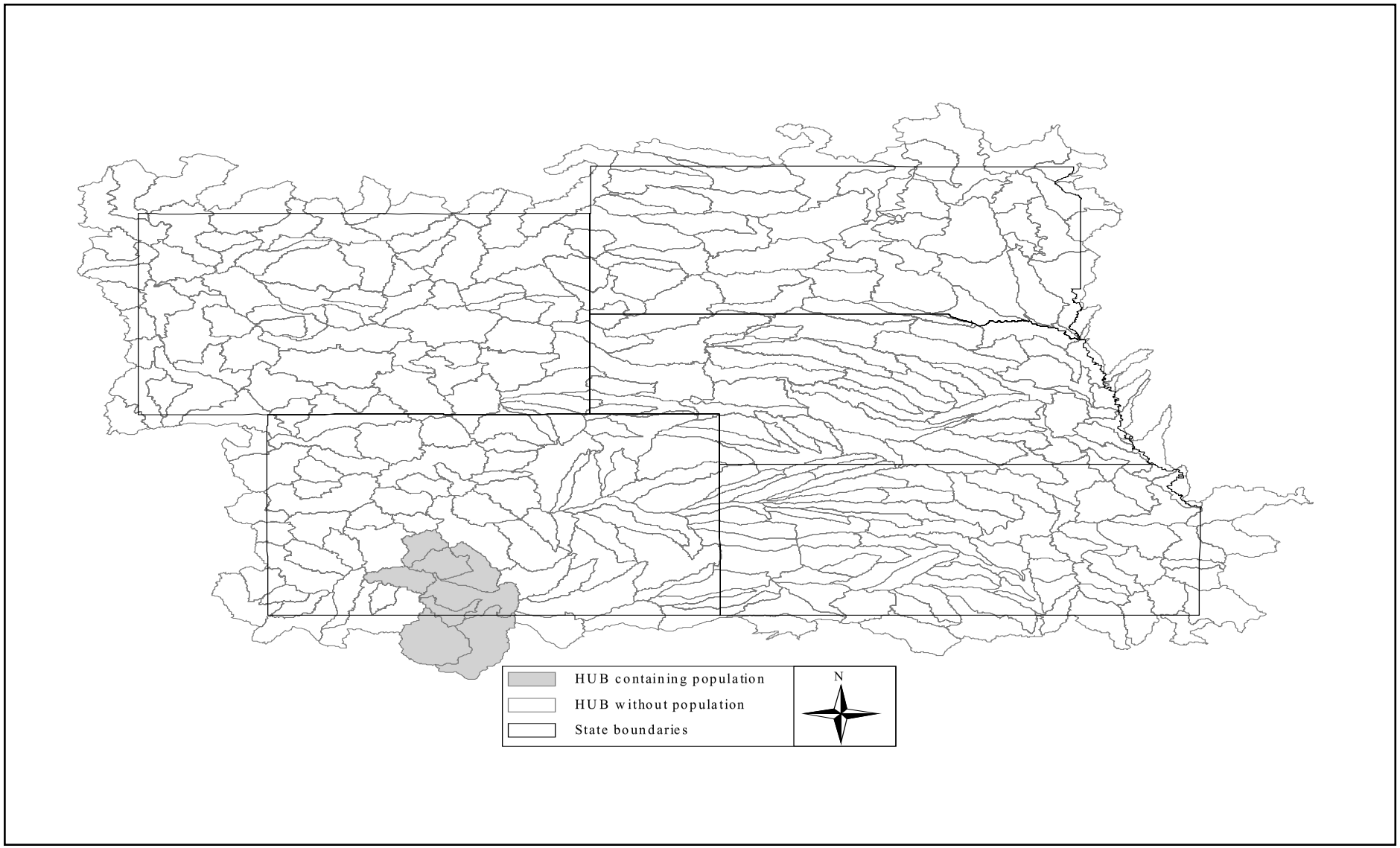

Figure 2. USDA Forest Service Region 2 hydrological unit boundaries (HUB) containing Rio Grande chub populations.

both riverine and lacustrine habitats (Zuckerman and Langlois 1990). It has been known to thrive at elevations up to 3,470 m (11,370 ft.; Kerr Lake) (Zuckerman and Langlois 1990). It is usually found in pools with overhanging banks and brush (Rinne 1995). Platania (1991) found the Rio Grande chub to be part of a guild preferring cool, fast-flowing reaches with gravel or cobble substrate. Bestgen et al. (2003) found that substrate particle size, stream width, and presence of brown trout were important variables that explained the presence of Rio Grande chub in the Rio Grande Basin, Colorado. They found chubs at sites where cobble, gravel, sand and silt were the most common substrate types. Chubs were most often found at sites where sand was the dominant substrate and least often found at sites with cobble substrate (Bestgen et al. 2003). Rio Grande chub often utilize undercut banks in association with aquatic macrophytes, (i.e., *Potamogeton* sp.) (Jordan 1891). Larger specimens can be found in pools and runs, and below instream structures (Zuckerman and Langlois 1990). Young chubs can be found in beds of aquatic macrophytes (i.e. *Nasturtium officinale*), and utilizing the cover provided by overhanging banks (Zuckerman and Langlois 1990). However, the relative importance of these habitats to each life stage of the Rio Grande chub is unknown.

Habitats in the mainstem and tributaries of the Rio Grande are being degraded by reduced flows and other land and water use practices (Bestgen et al. 2003). Cattle grazing can have a particularly large impact due to the destruction of stream banks and associated undercut habitat. Stream bank degradation can result in increased sedimentation. Additional sediment loads can fill pool and run habitats, cover benthic substrate, and smother benthic organisms. The change in sediment load also can result in streams becoming wider and shallower and result in higher than normal water temperatures. The aquatic habitats of both the Rio Grande drainage and San Luis Closed Basin have been degraded by dewatering, sedimentation, fish culture and stocking, fishing, transbasin diversions, irrigation, input of domestic sewage effluent, stream channelization, and input of fertilizers and pesticides (Zuckerman and Langlois 1990).

Food habits

Very little information exists on the feeding habits of the Rio Grande chub. This species is an omnivore that is known to feed on aquatic and terrestrial insects, crustaceans, other small invertebrates, small fish, plankton, and some vegetation (Koster 1957). Information is not available on the specific taxa of food ingested. No information exists regarding feeding preferences, temporal shifts in feeding, developmental shifts in feeding, shifts due to migration, competition, or differences in diet in lotic and lentic habitats. In laboratory experiments, the Rio Grande chub was shown to prey more successfully on caddisfly larvae (*Limnophilus frijole*) with smaller cases than larger cases (Nislow and Molles 1991, Nislow and Molles 1993), and larger fish were significantly more successful than smaller fish (Nislow and Molles 1991). The larvae were sucked into the buccal chamber, manipulated with the pharyngeal mill, and expelled. This procedure was repeated until the larva was separated from its case or was lost. Larvae with larger cases were more likely to survive this treatment and were sometimes found clinging to the remnants of their case (Nislow and Molles 1991, Nislow and Molles 1993).

Breeding biology

Stream populations of Rio Grande chub spawn in riffle habitat without building nests and provide no parental care after egg laying (Koster 1957). No information is available on the behavior of this species during spawning. The Rio Grande chub is also reported to reproduce in lakes, but this spawning has never been observed (Zuckerman and Langlois 1990).

Rinne (1995) provides a description of breeding age Rio Grande chub in the Rio de las Vacas, a third order stream above 2,500 m (8,202.1 ft.) elevation in New Mexico. The description was compiled from dissections and measurements of preserved specimens. Adult females were larger and more robust than males. The caudal peduncle, anal fins, and caudal fins of adult males possess more pronounced tubercules than those of females. Females were assumed to be mature if the gonadal index (calculated as gonadal weight divided by body weight multiplied by 100) was above 5.0. Mature females were >90 mm (3.5 inches) and had brighter, more intense colors. Each mature female contained 1000 to 4000 ova. Based on the condition of the females, breeding could take place from March through June. Another spawning period was hypothesized for autumn, but the apparent breeding condition of the females could have been caused by early maturation of gametes in preparation for the spring breeding season. Zuckerman and Langlois (1990) speculated that the population in Hot Creek, in the Rio Grande drainage, might have an additional autumnal spawning period, due to the presence of female specimens at this time that appeared to be gravid.

Demography

There are many data gaps regarding the demography of Rio Grande chub: population differences in altered and unaltered streams, specific effects of fragmenting populations, specific effects of hybridization, survival rate, fecundity, sex ratio, age structure, and factors affecting population size. Rio Grande chub is known to hybridize with the longnose dace (*Rhinichthys cataractae*) in the Rio Grande, Jemez River, Rio Hondo, and Rio Penasco (Cross and Minckley 1960, Suttkus and Cashner 1981). These supposed hybrids were recognized solely on the basis of morphological characteristics, the most useful of which were intermediate characteristics of the head and mouth. Some of the hybrids were hypothesized to be caused by overcrowding due to low flows and damming (Suttkus and Cashner 1981).

The development of a meaningful life cycle diagram for Rio Grande chub requires life stage-specific data regarding survival rates, fecundity, and sex ratio. Existing data on Rio Grande chub survival rates and other components necessary to construct a valid life cycle diagram are sparse (especially data specific to Rio Grande chub populations occurring in Colorado). The following life cycle description is presented as a tool to recognize the existing data and to identify the data needed to refine the model (**Figure 3**).

Input data needed for a population projection matrix model consists of sex ratios, age-specific survival and fecundity rates. Research on other native western species has determined that these characteristics often depend on location (e.g., stream size, habitat) and can be highly variable (Bezzerides and Bestgen 2002). Data specific to Rio Grande chub are incomplete and restricted to a few site-specific studies. No information on sex ratios is available, so a ratio of 1:1 was used in the life cycle diagram (**Figure 3**). Typical of many fish species, the Rio Grande chub is assumed to have a high mortality rate from egg through age 1, and a high mortality rate following the first year of spawning. Other life stages have lower mortality rates. Age-specific survival rates for the life cycle diagram were estimated from population age structure data provided by Bestgen et al. (2003). Estimates were used for portions of the population age structure that were inconclusive or incomplete. Fecundity values used in the model were based on Rinne (1995), who reported an average of 3,362 ova produced by females >100 mm (3.9 inches) TL. This was a mean value obtained from 20 females with individual ova production ranging from 1,366 to 6,322. This study did not report a relationship between fecundity and age. Rinne (1995) provided information on size at sexual maturity for Rio Grande chub populations in Rio de las Vacas, New Mexico. This study determined that females become sexually mature at 90 mm TL. Based on size and information provided by Bestgen et al. (2003) and fecundity data provided by Rinne (1995), the life cycle diagram was constructed using an average fecundity of 3,362 ova (with sexual maturity beginning at age 3) for all adult ages (**Table 1**, **Figure 3**). Spawning and recruitment

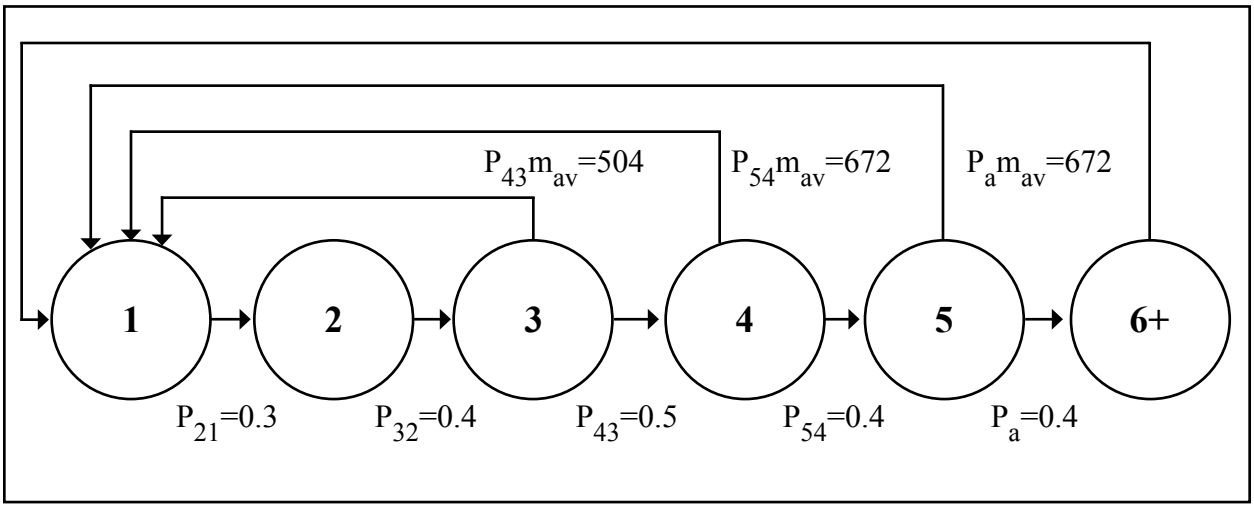

Figure 3. Life cycle graph for the Rio Grande chub. The number of circles (nodes) represent the five age-classes. The arrows connecting the nodes represent survival rates. Fertility is represented by the arrows that point back to the first node. Fertilities involve offspring production, mi, number of female eggs per female as well as survival of the female spawners. Note that reproduction begins in the third year.

Table 1. Parameter values for the component terms (P_i and m_i) that make up the vital rates in the projection matrix for the Rio Grande chub. Survival rates were estimated from age structure data estimated from Bestgen et al (2003). Rinne (1995) provided data from which fecundity was estimated. The model assumes a 1:1 sex ratio so the egg number used is equal to half the total fecundity.

Parameter	Numeric value	Interpretation
P_{21}	0.3	First year survival rate
P_{32}	0.4	Survival from 2nd to 3rd year
P_{43}	0.5	Survival from 3rd to 4th year
P_{54}	0.4	Survival from 4th to 5th year
P_a	0.4	Survival rate for oldest adults
m_{av}	1681	Average fecundity for mature females

likely takes place each year but with a high rate of variability. Overall success depends on location and fluctuating environmental conditions.

Community ecology

Rio Grande chub evolved as part of a unique community of fish in the Rio Grande Basin that also included Rio Grande cutthroat trout and Rio Grande sucker. Rio Grande cutthroat trout, a piscivore/insectivore, evolved as the top predator in this system. Rio Grande sucker, an algivore/insectivore, evolved as a benthic feeder. The Rio Grande chub evolved as an insectivore/omnivore. This algivore-piscivore-insectivore assemblage is thought to provide a balance to allow the survival of the entire fish community (Zuckerman and Bergersen 1986).

The extent to which parasitism, disease, hybridization, interactions with invasive species, and anthropogenic disturbance affect the population dynamics of the Rio Grande chub is not yet understood. Many species have been introduced to the Rio Grande drainage, including common carp (*Cyprinus carpio*), white sucker (*Catostomus commersoni*), northern pike (*Esox lucius*), and over 25 other species. Interactions between many of these species and the Rio Grande chub have yet to be characterized, but sympatric piscivores presumably feed on various lifestages. For example, introduced brown trout and brook trout prey extensively on Rio Grande chub (Zuckerman and Bergerson 1986).

An envirogram for Rio Grande chub was developed to help illustrate the relationships between land use practices/management and Rio Grande chub characteristics (**Figure 4**). In general, the usefulness of an envirogram is the visual representation of linkages between Rio Grande chub life history parameters and the environmental and biological factors that affect those parameters. Those elements that directly affect Rio Grande chub are depicted in the envirogram by the centrum, which is further separated into resources, predators, and malentities. Resources elicit a positive response in Rio Grande chub populations whereas predators and malentities produce negative and neutral responses, respectively. Web levels illustrate factors that modify elements within the centrum or within the next lower web level. Andrewartha and Birch (1984) provide further detail into the specific description of all envirogram components. The relative importance of the linkages is poorly understood and warrants further study to validate.

CONSERVATION

Threats

The abundance and distribution of the native fish community (including Rio Grande cutthroat trout and Rio Grande sucker) that evolved in the Rio Grande Basin have been greatly reduced as a result of human activities during the last 100 years (Bestgen et al. 2003). These mechanisms can be separated into two general categories: 1) habitat degradation that includes habitat loss, modification, and/or fragmentation and 2) interactions with non-native species. Each major threat may work independently of or in conjunction with the other to create an environment where Rio Grande chub populations may be reduced or eliminated. The relative importance of each threat and the specific cause-effect relationship can depend on a number of biotic and abiotic factors. The complexity of interactions of specific threats with Rio Grande chub populations requires further explanation.

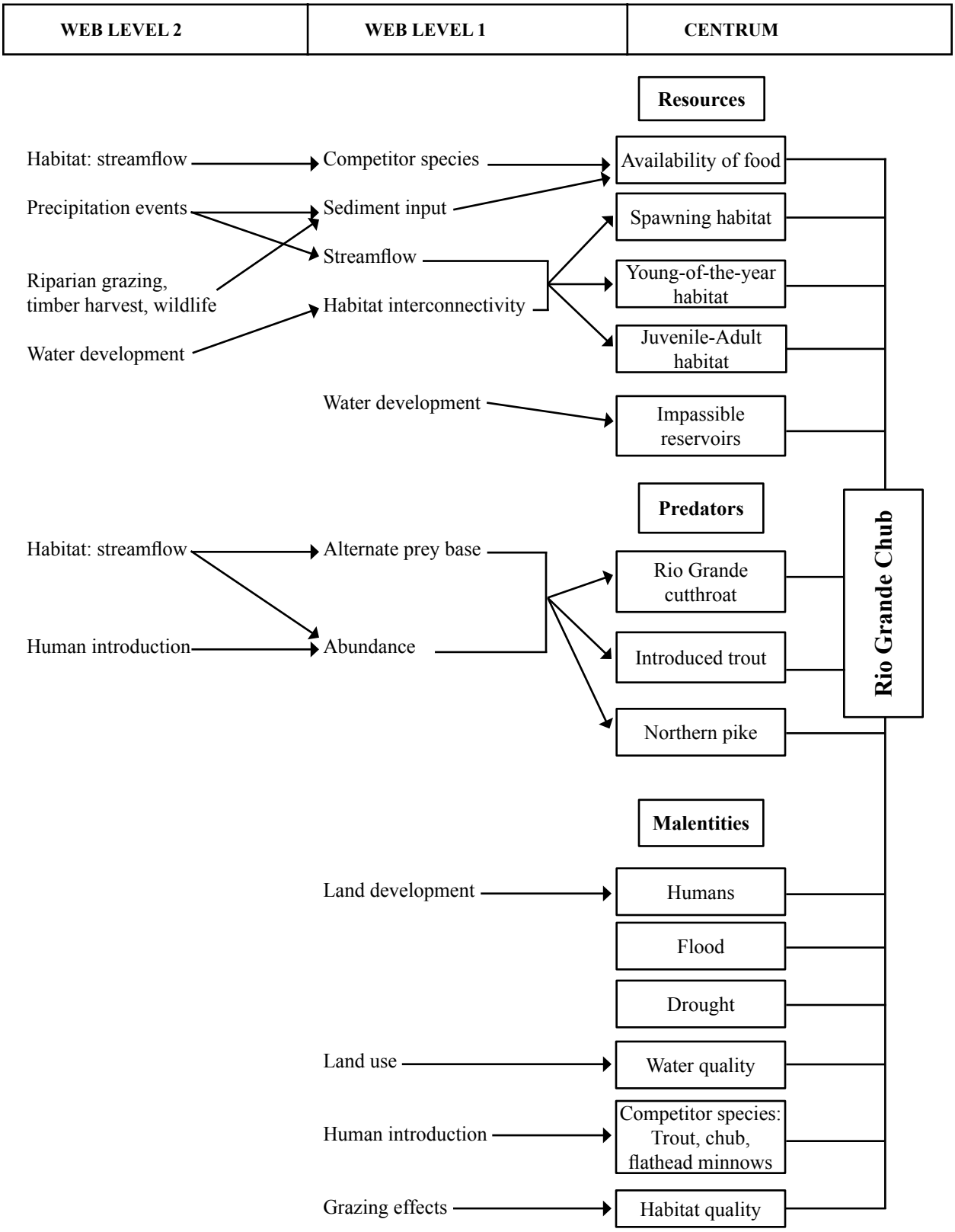

Figure 4. Envirogram for the Rio Grande chub.

Habitat degradation includes three extensive areas of concern: habitat loss, habitat fragmentation, and habitat modification. Habitat loss typically occurs when streams are dewatered due to water use practices.

Habitat fragmentation is often a result of dewatering, but it can also be caused by the creation of barriers to fish passage such as dams and diversions. Large and small scale water development projects can profoundly impact the persistence of Rio Grande chub. Even undersized (or improperly designed) culverts at road or trail crossings can act as barriers, especially at low flows. Irrigation diversions and small capacity irrigation reservoirs reduce streamflow, alter the natural hydrograph, and provide barriers to migration and normal population exchange. Barriers that preclude fish passage can cause population fragmentation and completely prevent or significantly reduce genetic exchange between populations. The fragmented populations in some areas remain viable and maintain population levels at the same density as they were before fragmentation occurred. This currently occurs in tributaries to the Rio Grande that have become isolated from the mainstem river due to water diversions. In instances where habitat is fragmented and populations are isolated, the probability that genetic "bottlenecks" will occur becomes more pronounced and single catastrophic events may extirpate populations from entire drainages.

Habitat modification includes not only aspects discussed under fragmentation and loss, but also includes modification of stream channels due to channelization, scouring, or sedimentation; changes in temperature and flow regimes; and alterations to water chemistry related to pollution. Land use practices that can impact stream channels include construction of roads through highly erodible soils, improper timber harvest practices, irrigation, and overgrazing in riparian areas. These can all lead to increased sediment load in the system and a subsequent change in stream channel geometry (e.g., widening, incision). These modifications alter width: depth ratios, pool:riffle ratios, and other aspects such as pool depth that affect the quality of habitat occupied by Rio Grande chub. While fire has little direct impact on the quality of habitat, post-fire conditions can also result in increased sediment loads. Inputs of large quantities of sediment into streams frequently occur during storm events on recently burned areas. Once in the watershed, the increased sediment load can cover substrate, decrease pool depth, diminish suitable spawning habitat, and reduce fitness by decreasing the nutritional value of the food base. Severely reduced stream flows may lead to increased water temperatures, changes in the algal community, and reduced dissolved oxygen levels especially in smaller tributary systems. Although specific tolerances to water quality parameters (i.e., temperature, dissolved oxygen, toxicants) are undefined for this species, it is likely that as water quality is reduced, Rio Grande chub fitness will also decline.

Competition with and predation by non-native species are two more extensive threats to Rio Grande chub population health and viability. The Rio Grande chub is a desirable prey item for native and non-native predator species. Non-native predators such as northern pike and brown trout occur in many of the drainages that currently or historically contained Rio Grande chub. Introduced species, such as common carp and white sucker compete with Rio Grande chub for food resources.

The current distribution of Rio Grande chub on or near USFS lands in Colorado (Bestgen et al. 2003) creates a situation where forest management strategies may cause substantial negative impacts on populations occurring many kilometers downstream of USFS boundaries. The introduction of non-native fish into stream reaches that do not contain Rio Grande chub often results in the uncontrollable dispersal of these fish into other stream reaches. Water development, road construction and maintenance, timber harvest, and grazing of riparian and upland areas are likely to continue to impact Rio Grande chub habitat in the future. Stream flow (or lack thereof) was one of the major issues identified by Bestgen et al. (2003) affecting Rio Grande chub populations. Land use practices can result in an increase in soil erosion in the Rio Grande Basin. Modification of land use management techniques to decrease the impact to Rio Grande chub habitat may lessen the anthropogenic threats to this species; however, it is unlikely that all impacts or threats could be eliminated or halted.

Conservation Status of the Rio Grande Chub in Region 2

Rio Grande chub is a species of concern in Colorado due to combined impacts of habitat loss, habitat modification, habitat fragmentation and interactions with non-native species, and the status of remaining populations is a concern throughout its range (Bestgen et al. 2003). Although specific mechanisms of impacts to this species are still poorly understood, it is likely that instream flows, sediment loading in streams, and interactions with non-native species are important considerations for conservation of Rio Grande chub in Region 2.

The potential is high for future declines in Rio Grande chub distribution and abundance. Isolated populations are more susceptible to catastrophic events because of the impediment to recolonization from nearby populations. Translocations into suitable unoccupied habitat should proceed with caution due to potential unknown genetic variability among existing populations. Educated fish management strategies and land use practices could determine the fate of these remaining populations.

Potential Management of the Rio Grande Chub in Region 2

Implications and potential conservation elements

Management of Rio Grande chub should be based on an understanding of specific threats to the species. This species is vulnerable due to reduction of stream flows, increased sediment loads, and predation from non-native fishes. Considerations for conservation elements should include:

- protection of riparian areas
- minimization of sediment input due to anthropogenic causes (e.g., road building, timber harvest)
- maintenance of channel stability and natural fluvial dynamics
- removal of non-native fish species.

Construction associated with road improvements or development, timber harvesting, grazing, and/or fire activity can result in a) increased sediment loads and b) loss of riparian vegetation along and adjacent to streams. While, increased sediment loads or sediment deposition could negatively impact Rio Grande chub populations, specific thresholds and mechanisms associated with this impact have not been studied well enough to make precise predictions. Impacts to riparian vegetation may result in channel in-stability (widening or incision), degraded water quality conditions (i.e. stream temperature), and loss of complex fish habitat.

Preservation of stream flows that are adequate to maintain habitat complexity (quality of instream cover) and interconnectivity (contiguous aquatic networks free from migration barriers) should be a focal point of management objectives. Conservation of Rio Grande chub will require a better understanding of the entire aquatic and riparian ecosystem, with particular attention to downstream populations. Future plans for Rio Grande chub conservation should take into account the entire native fish assemblage, which includes Rio Grande cutthroat trout and Rio Grande sucker. These fish would benefit from management to restore historical flow regimes and associated channel maintenance.

Conservation of Rio Grande chub populations will require carefully considered management regulations regarding non-native fish species. Predation by large non-native species (i.e., brown trout and brook trout) is already reducing chub populations. Implementation of management strategies should be designed to remove or restrain further expansion of non-native fish distribution on USFS lands. These strategies should include strict enforcement of existing prohibitions regarding the release of fish. Additionally, programs for the eradication of non-native fish in streams within the historical range of Rio Grande chub should be considered in conjunction with the reintroduction of the other native fish species. The best candidate streams would be those without a viable native fish community and where there is the high potential for re-establishment of native fish species.

Tools and practices

The absence of habitat and life history data for Rio Grande chub in Region 2 is a concern. This section will discuss techniques intended to gather the missing or needed information outlined in the Information Needs section that follows.

Habitat selection and preference can be determined by a variety of techniques. The simplest involves correlating capture locations during distribution surveys to specific habitat types. Construction of habitat suitability use is time intensive, but it could be used in conjunction with hydraulic modeling methodologies to estimate how habitat changes in relation to stream flow. Winters and Gallagher (1997) developed a basinwide habitat inventory protocol that would be a cost-effective (i.e., relatively inexpensive and obtains quantitative data) tool to collect general habitat data.

The implementation of a recurring survey to determine Rio Grande chub distribution and abundance can also provide insight into movement of the species through the use of PIT (passive integrated transponder) tags for smaller fish or radio telemetry for larger fish. Both of these techniques would require surgically implanting a small device. PIT tags are long-lasting (indefinitely), uniquely coded tags that allow the

determination of movement. These tools may provide a useful means of monitoring movement of natural or transplanted populations.

Population estimates would provide baseline information on recruitment with which the effectiveness of future management strategies could be evaluated. Focus should be on areas where future management strategies may include activities (e.g., timber harvest, grazing, water diversion) that impact Rio Grande chub populations. However, the long-term monitoring goal should be population estimates and population trend data on all streams containing Rio Grande chub populations that may be influenced by activities on USFS lands. Several electrofishing techniques exist that could provide population estimates. These include mark/recapture and multiple pass removal estimates. Each has its advantages. However, due to the smaller size of many streams on USFS lands, estimating populations using depletion/removal technique should be a cost-effective method to produce high quality data. Riley and Fausch (1992) recommend that a minimum of three passes be conducted when using the removal method. Use of a single pass method to develop a catch per unit of effort index is cost-effective on a time basis, but precision may be sacrificed and the introduction of bias is more likely, especially over long-term monitoring with significant researcher/technician turnover. With removal estimates, researchers are able to calculate confidence intervals, allowing insight into sampling quality.

Defining the relationship between habitat alteration and Rio Grande chub population characteristics is a relatively difficult task. This process requires significant amounts of data including quantitative analysis of differences in food resources over time, changes in habitat quality/function, and some form of abundance estimates. This type of data could be obtained by repeated sampling over time at multiple locations in streams with known populations.

To efficiently gather data for species conservation, managers should coordinate with private landowners and agencies that manage portions of streams downstream of USFS boundaries. This would help to determine potential effects of USFS management policies and strategies.

Information Needs

Basic knowledge of Rio Grande chub life history is inadequate for its conservation. To attain the level of understanding necessary to properly manage this species at a local level, specific studies must be conducted for each drainage. These studies should provide information about the species' distribution, habitat requirements and associations, general life history attributes, ecology, and movement patterns; the influence of non-native fish; and the effects of human-induced habitat modification. Population distributions in Region 2 were recently inventoried (Bestgen et al. 2003). Additional distribution data on USFS lands should be regularly monitored.

The highest priority is to obtain a better knowledge of the Rio Grande chub's habitat requirements (for local and basin-scale populations), life history attributes, and ecology, and the effects of predation on population viability. Further, information on response of habitat and populations with change in streamflows would provide data for management decisions on flow regimes required for species conservation.

Habitat requirements and preferences are poorly understood for most life-stages and life history events. More information is needed that describes the mechanisms that link habitat degradation (e.g., sedimentation, reduced flows, pollution) to Rio Grande chub population attributes. The development of a process-response model would further identify Rio Grande chub life history components that are not adequately understood. In addition to general distribution and abundance information, a temporal component should be added to data collection to provide seasonal information. Abundance, distribution, and age structure should be documented prior to implementation of conservation strategies to enable evaluation of conservation efforts. Given the small number of isolated populations representing this species in Region 2, future management practices (e.g. timber harvest, grazing) should proceed cautiously but include frequent population monitoring.

During population surveys, information regarding the physical and chemical characteristics of the habitat should be obtained. Data collected should include elevation, water temperature, dissolved oxygen, dissolved solids (pollutants), discharge, depth, turbidity, substrate, and habitat type. This information will provide baseline data regarding habitat requirements and preferences for each physical parameter. Fish collected should be tagged with PIT tags to allow studies of movement, migration, and growth rates during continued monitoring.

Specific studies need to be designed to provide information on spawning behavior and habitat,

and larval biology and drift. Habitat requirements and feeding habits at each life stage should also be addressed. Monitoring of tagged fish will also provide an estimate of survival rate that is a necessary component for the creation of a life cycle diagram. Sex ratio and fecundity data should be collected to provide the other components missing from the life cycle diagram. It may be important to collect data from several populations because much of the specific life history information may vary by drainage.

To better understand the community ecology of Rio Grande chub, future studies should include inventory and monitoring of all populations of fish (adult, juvenile and larvae), macroinvertebrates, and periphyton taxa in streams where Rio Grande chub occur. Stomach content analysis at various life stages will allow for a better understanding of Rio Grande chub feeding habits. Feeding studies on sympatric fish populations need to be conducted to determine potential competition and to understand the impact of introduced and native predators on Rio Grande chub populations.

Genetic testing during future studies on Rio Grande chub populations could be important to determining and maintaining the genetic diversity. Tissue samples should be taken from fish for analysis of genetic structure from mainstem and isolated populations. Genetic characterization would allow studies of population diversity, viability of isolated populations, and the extent and effects of hybridization.

DEFINITIONS

Centrum – any component that directly affects the central organism

Hybridization – the production of offspring by crossing two individuals of unlike genetic constitution.

Malentities – all components other than predators that directly affect the central organism and cause a negative response.

Web Level 1 – any component that affects the centrum.

Web Level 2 – any component that affects Web Level 1.

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