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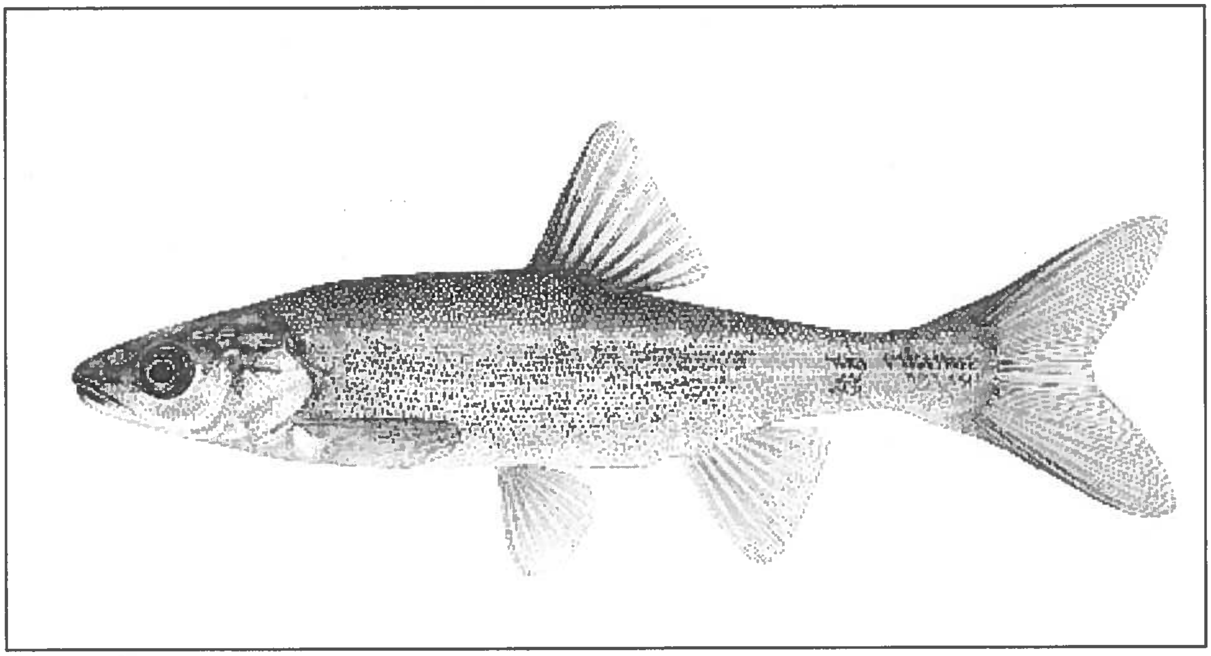
Roundtail Chub (*Gila robusta robusta*): A Technical Conservation Assessment



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

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AUTHORS' BIOGRAPHIES

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Dr. William J. Miller has over 23 years experience in fisheries, instream flow, and aquatic ecology studies. He has worked extensively throughout the western U.S. and is a recognized expert in the areas of Colorado River basin endangered fish species, instream flow, water temperature modeling and habitat assessments. Dr. Miller's experience includes research and evaluations for several threatened, endangered, and candidate aquatic species in the Colorado River and Platte River basins. He has extensive experience in designing and conducting studies using the Instream Flow Incremental Methodology (IFIM), instream water temperature modeling and developing and implementing ecological models for aquatic systems. He has developed habitat suitability criteria for both anadromous and resident salmonids as well as warm-water game and forage species. Dr. Miller is a Certified Fisheries Scientist (No. 2008).

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Roundtail Chub (*Gila robusta robusta*). © Joseph Tomelleri.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF THE ROUNDTAIL CHUB

Status

The roundtail chub (*Gila robusta*) is considered a sensitive species within the USDA Forest Service (USFS) Rocky Mountain Region (Region 2). It has been estimated that this species, which is endemic to the Colorado River Basin, has been extirpated from 45 percent of its historical range, which includes medium to large tributaries of the Colorado River. Populations currently exist in western Colorado and south-central Wyoming. Distribution of this species on National Forest System lands is limited or unknown.

Primary Threats

Primary threats to the roundtail chub generally result from anthropogenic activities. Diversion of water has changed flow regimes in both mainstem rivers and tributary stream systems. Construction of diversion dams and reservoirs has degraded and fragmented habitats. Introduction of non-native fish species has increased the abundance of roundtail chub predators and competitors. Other threats to the species include modification of streambeds through channelization, landscape scale changes resulting from land misuse, and local disturbance of riparian zones that reduces the natural function of stream ecosystems.

Primary Conservation Elements, Management Implications and Considerations

Detailed information concerning the distribution, life history, population trends, and community ecology of roundtail chub is relatively limited. Specific local and regional information must be obtained to facilitate the development of management actions for this species. Initial research should include detailed surveys of every drainage on USFS land that could potentially hold populations of roundtail chub. Such efforts 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 are off USFS land yet may be influenced by forest management activities. Like other fish species endemic to the Colorado River Basin, roundtail chub have not been well-studied until recent years. Most of the recent fishery studies in this basin have been directed toward the recovery of federally listed species. Consequently the information obtained for roundtail chub is often incidental to the primary study, but it could still be useful to USFS managers. Given the known threats to this and other native Colorado River fishes, conservation measures should concentrate on controlling non-native fishes, maintaining habitat diversity, and providing natural temperature and flow regimes in stream reaches with roundtail chub populations. These measures should contribute to the maintenance of current populations.

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INTRODUCTION

This assessment of the roundtail chub (*Gila robusta*) is one of many being produced to support the Species Conservation Project for the USDA Forest Service (USFS) Rocky Mountain Region (Region 2), which considers the roundtail chub a sensitive species. 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 quality that would reduce its distribution (FSM 2670.5 (19)). Due to concerns with population viability and abundance, a sensitive species requires special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology, ecology, conservation, and management of roundtail chub throughout its range, which is entirely within Region 2.

Goal

The purpose of this species assessment is to provide forest managers, research biologists, and the public with a thorough discussion of the current understanding of the biology, ecology, conservation status, and management of the roundtail chub. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, this assessment cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope

This conservation assessment examines the biology, ecology, conservation status, and management of the roundtail chub with specific reference to the geographic and ecological characteristics in Region 2 and in the context of the current environment rather than under historical conditions. In producing this assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on the roundtail chub are referenced in the assessment, nor were all published materials considered equally reliable. This assessment emphasizes refereed literature because this is the accepted standard in science. We did use non-refereed literature in the assessments when other information was unavailable, but these sources were regarded with greater skepticism. Unpublished data (e.g., Natural Heritage Program records) were important in determining the species' status and in estimating its geographic distribution. 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 science 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. 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). In some ways, ecology is similar to geology 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). A problem with using the approach outlined in both Chamberlain (1897) and Platt (1964) is that 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 by undertaken to test both the true or false nature of the uncertainties at hand (Vadas 1994). Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

The synthesis of material for the roundtail chub included the use of the limited data sets that are available concerning the distribution, abundance, movements, habitat requirements, and life history requisites of the roundtail chub. This species, like many non-game native fish, has not been extensively studied throughout it's range. The limited data on key characteristics of the species and the lack of understanding concerning its resource needs create a great deal of uncertainty pertaining to the assessment for conservation of roundtail chub. For the purpose of this assessment, we have synthesized a wide range of available data throughout the Colorado River Basin including historical and current distribution, conservation strategies, habitat needs, and management requirements. The general lack of precise information regarding species distribution on National Forest land or near forest boundaries limits the actual data that can be used for this assessment. We have used a sound scientific approach to infer from available data an understanding of the current needs of this species.

Application and Interpretation Limits of This Assessment

Information used in this assessment was collected from studies that occurred throughout the geographical range of this species. The greatest emphasis for information regarding life histories and ecology was placed on studies and reports that were specific to Region 2. Although most information should apply broadly throughout the range of the species, it is likely that certain life history parameters (growth rate, longevity, spawning time, etc.) 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 and general management relevance of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

The roundtail chub is not a federally listed species (i.e., threatened or endangered) (U.S. Fish and Wildlife Service; http://endangered.fws.gov/). In 1989, it was placed into Category 2 (a candidate species for federal listing), but this designation was discontinued in 1995 when the candidate list was re-evaluated. Its range is restricted to the Colorado River Basin, and populations currently exist in Wyoming, Colorado, Utah, New Mexico, and Arizona. The USFS considers the roundtail chub to be a sensitive species, as do the Bureau of Land Management (BLM) offices in Colorado and Wyoming. Criteria that apply to BLM sensitive species include the following: 1) species under status review by the U.S. Fish and Wildlife Service; or 2) species with numbers declining so rapidly that federal listing may become necessary; or 3) species with typically small and widely dispersed populations; or 4) species inhabiting ecological refugia or other specialized or unique habits.

The Colorado Division of Wildlife (CDOW) considers the roundtail chub a species of concern. The Wyoming Game and Fish Department (WGFD) has assigned a rank of NSS1 for the roundtail chub, defined as vulnerable with isolated populations. This species currently holds a Natural Heritage Program global rank of G3 (vulnerable) and a state rank of S2 (imperiled) in both Colorado and Wyoming (http://natureserve.org/explorer). In states outside of Region 2, the roundtail chub has the following designations: "imperiled" in Arizona, "endangered" in New Mexico, "threatened" in Utah, and extirpated from California (http://natureserve.org/explorer). These designations suggest that the roundtail chub is rare or restricted throughout its range and is vulnerable to extirpation.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Ongoing recovery programs for federally listed fish in the Upper Colorado River Basin and the San Juan River drainage should provide benefits for all native fish species. Recovery efforts include flow recommendations, removal of migration barriers, removal of non-native species, and restoration of habitat. A conservation agreement specifically for roundtail chub, flannelmouth sucker (*Castostomus latipinnis*), and bluehead sucker (*C. discobulus*) has been prepared with the goal to ensure the persistence of these populations throughout their range (Utah Department of Natural Resources 2004). This agreement will incorporate cooperative efforts from states within the current and historic ranges of the roundtail chub (including Colorado and Wyoming from Region 2). Each state will develop an individual management plan for the conservation of these species. The CDOW intends to develop a conservation/management plan for roundtail chub by the year 2005. This plan will provide direction for research and management goals.

Currently, the CDOW has no regulations specifically designed to protect roundtail chub. However, several regulations are intended to protect native fish species and thus aid in the conservation of roundtail chub. Restrictions are in place in the Upper Colorado River Basin (in Colorado) regarding the live release of non-native fish species into rivers and lakes. Another regulation indirectly assisting the conservation of roundtail chub is a statewide statute prohibiting the seining, netting, trapping, or dipping of fish for bait in natural streams. The WGFD has mitigation objectives that permit projects in a manner that avoids alteration and degradation of roundtail chub habitat (Weitzel 2002).

The roundtail chub is not considered a gamefish in Region 2. However, it is probably incidentally caught by fishermen. There have been no studies that have determined mortality to roundtail chub by fishermen.

Biology and Ecology

Systematics and general species description

The Colorado River roundtail chub (*Gila robusta robusta*) is a medium-size fish (usually 200 to 300 mm [7.9 to 11.8 inches] total length [TL]) and one of several chubs native to the Colorado River Basin. In large rivers, adult roundtail chub may reach 500 to 600 mm (19.8 to 23.7 inches) in TL; adult size in the smaller tributaries can be less than 200 mm (7.9 inches) (Joseph et al. 1977). It is a member of the minnow family (Cyprinidae). Cyprinids are characterized by one to three rows of pharyngeal teeth, thin lips, large eyes, abdominal pelvic fins, and usually soft fin rays. Members of the genus *Gila* have soft fin rays and a fusiform body, but they vary considerably in other morphological characteristics. The roundtail chub is distinguished from other members of the genus *Gila* using the following characteristics described by Bezzerides and Bestgen (2002).

> *"Roundtail chub may have a somewhat flattened head, but are lacking the nuchal hump found in humpback chub (G. cypha) and, to some extent, bonytail (G. elegans). The mouth is large, sub-terminal, and associated with an acute snout. Eyes are small, low, and anteriorly placed on the head. Fins are generally large. Pectorals are pointed (fin rays[1] 14-15[12-17]); dorsal fin weakly falcate (rays 9[8-10]), originating slightly posterior to the pelvic fins (rays 8-9[7-9]); anal fin strongly falcate with fin rays 9[7-10]; caudal peduncle slender, but not approaching the pencil-thin narrowness of G. elegans; and caudal fin (rays 19[19-20]) deeply forked with somewhat rounded lobes.*
>
> *Other physical characteristics include a strongly decurved lateral line (scales 75-85[70-96]); a robust pharyngeal arch with teeth usually 2, 5-4,2; gill rakes 11-14 and 12-15 in the 1st and 2nd arches, respectively; and vertebrae 46[43-48]. Adults are usually dusky green to bluish gray dorsally and silver to white below, and may grow to 500 mm total length (TL). More commonly, adult roundtail chubs are 200-300 mm TL."*

The taxonomy of the genus *Gila* continues to evolve with recent changes in the status for several subspecies. In addition to *G. elegans* and *G. cypha*, other closely related chubs known only to exist in tributaries of the Lower Colorado River Basin include *G. seminuda* (Virgin River roundtail chub; previously *G. robusta seminuda*) in the Virgin River of Arizona, Nevada, and Utah; *G. nigra* (headwater chub) from tributaries of the Gila River in Arizona and New Mexico; and *G. r. jordani* (Pahranagat roundtail chub) from the White River in Nevada (Joseph et al. 1977, Minckley and DeMarais 2000, Bezzerides and Bestgen 2002).

[1]Counts (fin ray, vertebrae, dentition, etc.) are presented with the most commonly reported count outside the brackets and the range of values encountered in the literature inside the brackets.

Distribution and abundance

The roundtail chub is an endemic species to the Colorado River Basin in Colorado and Wyoming (Sublette et al. 1990). A map of USFS lands (**Figure 1**) can be compared to a map of watershed units that identifies where roundtail chub have been collected in Region 2 (**Figure 2**). Distribution of roundtail chub populations have been determined based on accounts by various researchers and distribution information provided by NatureServe (2003) at www.natureserve.org.

Historically, roundtail chub were known to commonly occur in most medium to large tributaries of the Upper Colorado River Basin (Vanicek 1967, Holden and Stalnaker 1975, Joseph et al. 1977). Roundtail chub historically occurred in lower elevation (below 2,300 m [7,546 ft.]) streams, including the Colorado, Dolores, Duchesne, Escalante, Green, Gunnison, Price, San Juan, San Rafael, White, and Yampa rivers (Bezzerides and Bestgen 2002). This distribution includes much of Region 2, but little is actually on USFS land.

Jordan (1891) described accounts of roundtail chub in several tributaries of the Upper Colorado River Basin and determined it was most common in transitional areas of streams between the mountains and low gradient reaches. Holden and Stalnaker (1975) reported that roundtail chub were abundant or common at all sites sampled on the Yampa River (including locations near Juniper Springs and Craig, Colorado), and at most sites in the Dolores River, Colorado. McNatt and Skates (1985) found roundtail chub to be common at most sites in the Green River and Yampa River in Dinosaur National Monument. Olson (1967) reported that roundtail chub were common in collections from Navajo Reservoir during 1965.

Roundtail chub are not restricted to large rivers within the Colorado River Basin. Miller and Rees (2000) described historical and recent accounts of roundtail chub in the mainstem of the San Juan River and various tributaries in the southwestern portion of Colorado and in New Mexico. These tributaries include the Animas, Florida, La Plata, and Mancos rivers as well as Navajo Wash (tributary to the Mancos River). Records of roundtail chub in these tributaries approach the boundary of the San Juan National Forest, but there is no evidence to suggest that this species ever commonly occurred within the boundary of that national forest.

Roundtail chub were once abundant in Wyoming in the Green River and the Blacks Fork River and were reportedly abundant in the Little Snake River drainage (Simon 1946, Baxter and Simon 1970). Currently, roundtail chub are found in the Blacks Fork River and the Green River drainage as well as the Big Sandy River, the Hams Fork River, Fontenelle Creek and Reservoir, and Halfmoon, Burnt, Boulder, Little Halfmoon, Willow and Fremont lakes. Roundtail chub were "widely distributed" in the Little Snake River from the lower stateline crossing upstream to the Highway 70 bridge at Dixon, Wyoming (Oberholtzer 1987). They were absent in collections from Dixon upstream. Fish surveys conducted on 131 streams in the Little Snake River drainage indicated the presence of roundtail chub in only one other stream, Muddy Creek (Oberholtzer 1987). Historically, roundtail chubs may have been found in parts of Savery Creek, a tributary to the Little Snake River, but records are not conclusive (Wyoming Game and Fish Department 1998). Recent investigations failed to find roundtail chub in the Savery Creek drainage (Wheeler 1997, Wyoming Game and Fish Department 1998). Roundtail chub continue to persist in the Region 2 portion of Wyoming in the Little Snake River and its tributary, Muddy Creek (Wheeler 1997, Weitzel 2002), but none of these accounts are within national forest boundaries.

The current distribution of roundtail chub on Region 2 USFS land appears to be very limited. However, comprehensive annual and seasonal distribution information is lacking for streams within Region 2. At the present time, only the San Juan National Forest contains a documented population of roundtail chubs (Gerhardt 2003 personal communication); this population occurs in the Dolores River, downstream from McPhee Reservoir, Colorado. Several roundtail chub populations exist in tributary streams immediately downstream of National Forest System lands. These tributary streams include Divide Creek and Rifle Creek (tributaries to the Colorado River), Elkhead Creek (tributary to the Yampa River), and Florida River, La Plata River, and Los Pinos River (San Juan River drainage).

Population trend

Roundtail chub have been extirpated from 45 percent of their total historical habitat, especially portions of the Price, San Juan, Gunnison, and Green rivers (Bezzerides and Bestgen 2002). A decline in populations has been observed in the Animas, Green,

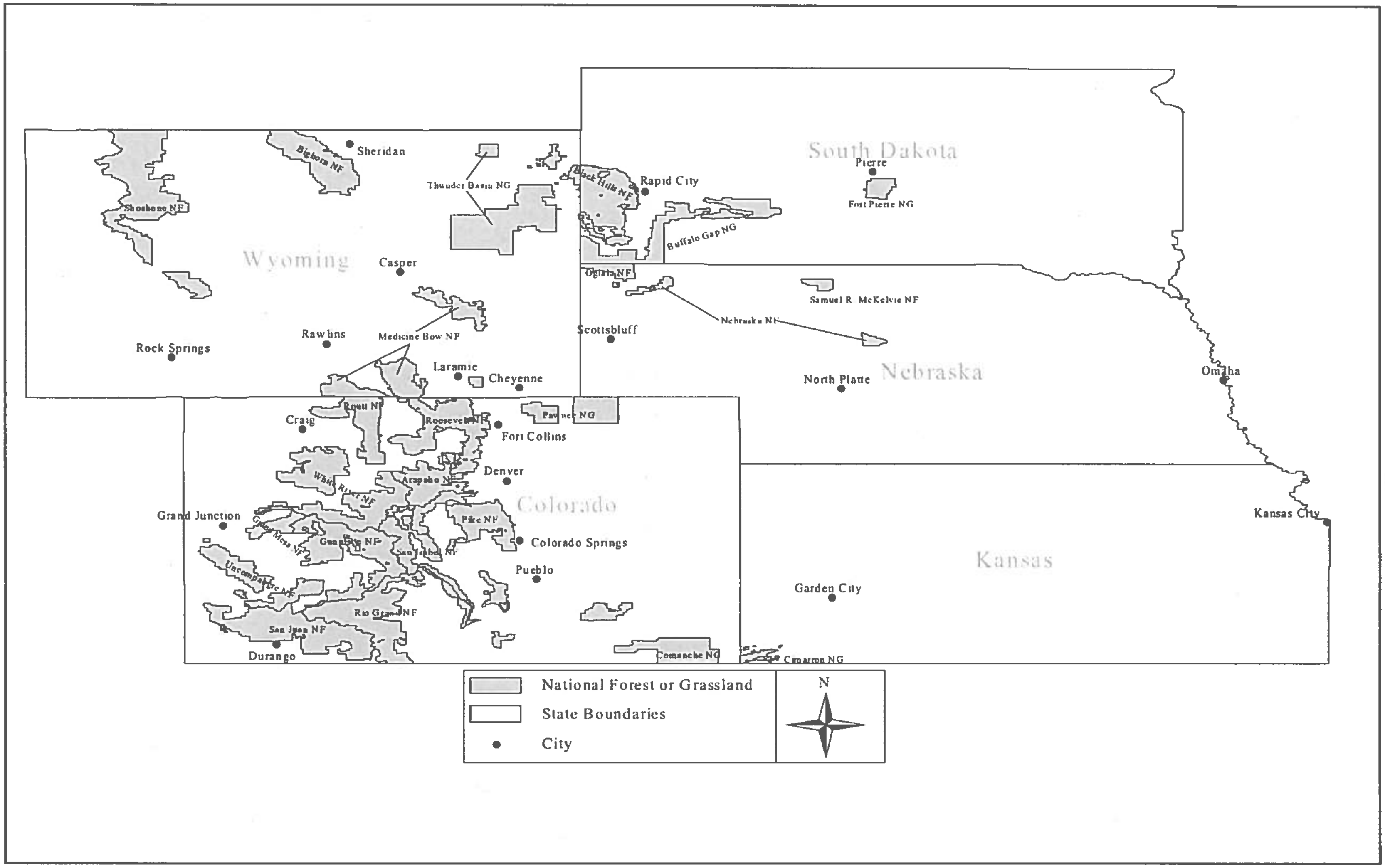

Figure 1. USDA Forest Service Region 2 national forests and grasslands.

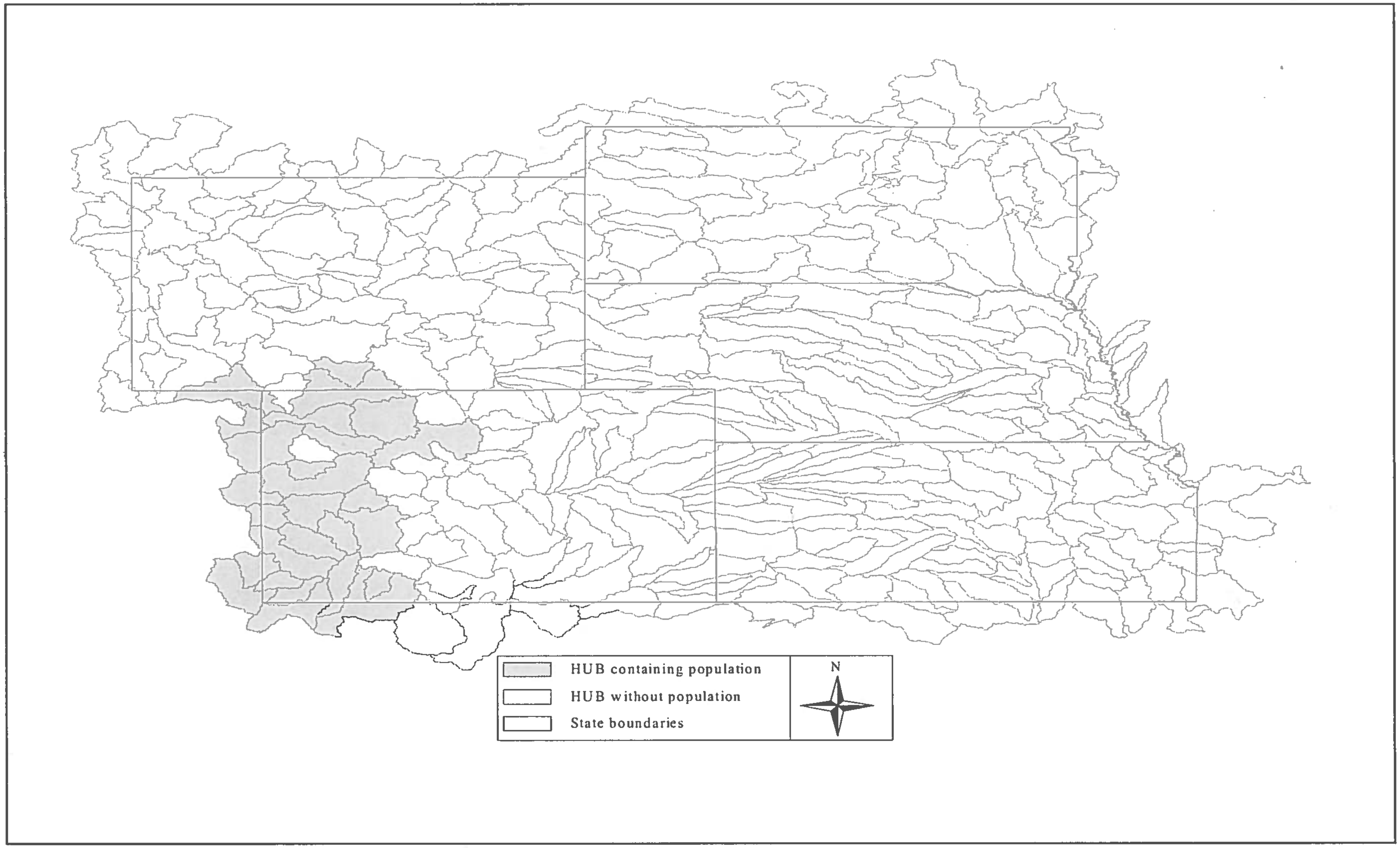

Figure 2. USDA Forest Service Region 2 hydrological unit boundaries (HUB) containing roundtail chub populations.

Gunnison, Salt, San Juan, White, and Yampa rivers (Minckley 1973, Platania 1990, Wheeler 1997, Lentsch et al. 1998, Propst and Hobbes 1999, Bestgen and Crist 2000, Miller and Rees 2000). The population trend for roundtail chub in Wyoming is unknown but thought to be declining (Wheeler 1997). Fish surveys in southwestern Wyoming in 1995 and 1996 indicated that this species no longer occurred in several drainages from which it was collected in 1965 (Wheeler 1997).

Roundtail chub populations have declined due to impacts of water development projects, land use management, and interactions with non-native species. Reductions of roundtail chub have been documented in the San Juan River downstream from Navajo Dam (Joseph et al. 1977) and in the Green River downstream from Flaming Gorge Dam (Vanicek and Kramer 1969, Karp and Tyus 1990). Hypolimnetic releases below impoundments cause changes in the thermal regime within the river downstream; temperatures are usually colder in the summer and warmer in the winter than historic conditions. Low numbers of roundtail chub in the San Juan River may also be attributed to the use of rotenone (fish toxicant) to eliminate all species from approximately 112 km (69.6 miles) of the river during 1961 (Olson 1962).

In 1962, 116 kilometers (72.1 miles) of the Green River and many of its tributaries upstream from the Colorado-Utah state line were treated with fish toxicant in an attempt to eliminate "coarse" fish prior to the construction of Flaming Gorge and Fontenelle Dams (Binns 1967). Pre-treatment surveys indicated that roundtail chub were common in the treatment area; however, populations post-treatment were completely eliminated. After the construction of Flaming Gorge Dam, the altered temperature and flow regimes downstream precluded effective recolonization of roundtail chub populations upstream in the Green River (Karp and Tyus 1990). Vanicek and Kramer (1969) provide evidence to suggest that the growth rate of roundtail chub has decreased in the Green River for approximately 74 km (46 miles) downstream of Flaming Gorge Dam due to the change in seasonal stream temperature. Absence of certain year classes suggests that successful spawning did not occur during some years in the Green River between Flaming Gorge Dam and the confluence of the Yampa River (Vanicek and Kramer 1969). Vanicek et al. (1970) also reported that roundtail chub were nearly absent in the Green River within 32 km (19.9 miles) of Flaming Gorge Dam.

Karp and Tyus (1990) acknowledge that the change in temperature and flow regime caused by Flaming Gorge Dam may be responsible for a decline in roundtail populations in the Green River upstream from its confluence with the Yampa River, but they additionally suggest that a negative interaction between roundtail chub and the non-native channel catfish (*Ictalurus punctatus*) is present in this reach. Competition for food and predation by channel catfish on young roundtail chub were cited as partial explanations for the decline of this species. It is likely that a combination of impacts from impoundments and competition with non-native fish has been responsible for reductions in roundtail chub populations. The cause of roundtail chub population declines in smaller tributaries has been poorly studied. However, Weitzel (2002) suggested that habitat degradation (e.g., bank erosion, sediment deposition, and poor riparian quality) from heavy grazing may contribute to population declines in Wyoming.

Activity pattern

Few studies have been specifically designed to describe the movements of roundtail chub. Available research indicates that, when movement occurs, it mostly depends on life-stage and location. Life-stage related movements include larval drift and spawning migrations. Carter et al. (1986) and Haines and Tyus (1990) reported capturing roundtail chub larvae in the drift after they emerged from spawning substrate in the upper Colorado and Yampa rivers.

Migration associated with spawning has not been studied throughout most of the range occupied by roundtail chub in Region 2. The limited information suggests that spawning related movement may depend on location and population, and may range from minimal localized movements to movement of more than 30 km (18.6 miles). In the Colorado River near Black Rocks, Kaeding et al. (1990) found roundtail chub moving in excess of 30 km during the reproductive season.

Miller et al. (1995) found roundtail chub in the La Plata River in Colorado and New Mexico to be relatively sedentary, with a maximum movement of 1.4 km (0.9 miles). Average movement (four sampling events in 11 months) was 0.42 km (0.3 miles) for 17 recaptures in this smaller tributary of the San Juan River. Bryan and Robinson (2000) reported sedentary behavior of roundtail chub in two Colorado River tributaries in the lower basin, as did Beyers et al. (2001) in a 3.2 km (2.0 miles) study area in the Colorado River during a fall survey. Beyers et al. (2001) did, however, document a significant difference in localized diel movement patterns for roundtail chub. Adults moved from shallow habitat at night to deeper habitat during the day.

Habitat

Roundtail chub evolved in the Colorado River Basin below an elevation of approximately 2,300 m (7,546 ft.). Most reaches of this system receive heavy sediment loads and high annual peak flows that contrast with low base flows. Little is known about the specific influence of these annual events, but healthy roundtail chub populations have persisted in habitats with a wide range of annual flows, sediment transport, and even sediment deposition, providing that these physical events are associated with a natural flow regime.

Studies documenting habitat use related to diel or seasonal changes are rare; however, several researchers have made general observations regarding habitat associations. Roundtail chub are often found in stream reaches that have a complexity of pool and riffle habitats (Bezzerides and Bestgen 2002). Juveniles and adults are typically found in relatively deep, low-velocity habitats that are often associated with woody debris or other types of cover (Vanicek and Kramer 1969, McAda et al. 1980, Miller et al. 1995, Beyers et al. 2001, Bezzerides and Bestgen 2002). Sigler and Sigler (1996) reported that substrate in roundtail chub habitat may range from rock and gravel to silt and sand. Seasonal or life stage associations with specific substrates were not identified. Beyers et al. (2001) determined that the mean depth of habitat used by roundtail chub was less at night than during the day in the Colorado River near Grand Junction, Colorado, suggesting that there may be a diel habitat preference. Larvae have been reported in low velocity areas associated with backwater habitats (Haines and Tyus 1990, Ruppert et al. 1993); however, there was no specific study to determine the importance or necessity of this habitat to larvae.

Temperature tolerance of roundtail chub has been reported up to 39 °C (102.2 °F), but temperature preference ranges between 22 °C (71.6 °F) and 24 °C (75.2 °F) (Weitzel 2002).

Food habits

The roundtail chub is an omnivorous species with "opportunistic" and "sporadic" feeding habits. The diet of juvenile roundtail chub (<200 mm TL) consists predominately of aquatic macroinvertebrates (Vanicek 1967, Vanicek and Kramer 1969, Joseph et al. 1977). Young roundtail chub in the Green River consumed primarily Chironomidae larvae and Ephemeroptera nymphs (Vanicek 1967, Vanicek and Kramer 1969).

Adult roundtail chub (>200 mm TL) have been documented feeding on filamentous algae, aquatic invertebrates, terrestrial invertebrates (especially grasshoppers and ants), fish, and plant debris (Vanicek and Kramer 1969, Joseph et al. 1977). The presence of crayfish in the diet of adult roundtail chub has been observed in the Colorado River near Grand Junction, Colorado (authors personal observations). Minckley (1973) indicates that adult roundtail chub may consume their own eggs as well as the eggs of other fish species. Olson (1967) reported that the diet of roundtail chub in Navajo Reservoir was similar to that of rainbow trout (*Onchorhynchus mykiss*), which was primarily composed of plankton and some aquatic insects.

Breeding biology

Roundtail chub in the Upper Colorado River Basin begin spawning when water temperatures reach about 18.3 °C (64.9 °C) (Vanicek and Kramer 1969, Joseph et al. 1977). In most Colorado River tributaries this increase in temperature coincides with a decrease in discharge after peak runoff (Bezzerides and Bestgen 2002). Karp and Tyus (1990) indicate that spawning of roundtail chub in the Yampa River at Dinosaur National Monument occurs between mid-May and early July. The time of spawning in other drainages and locations is probably similar but is influenced by water temperature and the hydrograph. Females typically produce 39,500 to 41,350 adhesive demersal eggs per kg of body weight (Muth et al. 1985). A review of fecundity by Bezzerides and Bestgen (2002) indicated that the number of eggs produced by a roundtail chub varies with female size, age, and location. Depending on water temperature, eggs usually hatch within four to 15 days after spawning. Young roundtail chub begin feeding approximately 10 days after they hatch (Minckley 1973). During the first 54 days after hatching, mean daily growth rate was 0.3 mm (0.01 inches) for cultured fish (Muth et al. 1985). Carter et al. (1986) suggested that roundtail chub actively drift during the mesolarval stage of development. Drifting occurs primarily after mid-July and appears to become more frequent as water temperatures initially increase. It was not determined whether the increase in drift was related to an increase in activity or an actual increase in larval abundance.

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The drifting process provides a means of dispersal for roundtail chub and other members of the genus *Gila* in the Colorado River Basin.

Karp and Tyus (1990) collected ripe males ranging from 292 to 419 mm (11.6 to 16.5 inches) TL, and ripe females from 343 to 380 mm (13.5 to 15 inches) TL. Vanicek (1967) reports that most roundtail chub become sexually mature by age six. Muth et al. (1985) collected spawning females that ranged in age from five to seven years, and spawning males that ranged in age from five to eight years. Prior to spawning, male and female roundtail chub typically develop breeding tubercles. These tubercles are usually uniformly scattered over the surface of the male (although mostly restricted to the head) and caudal peduncle of the female. Both sexes develop an orange-red coloration on the ventral surface and ventral fins (Muth et al. 1985).

Little information is available concerning the specific spawning behaviors of roundtail chub. Due to the high turbidity commonly associated with the Colorado River and its tributaries, the exact spawning behaviors and habitat used by roundtail chub has not been observed. Vanicek and Kramer (1969) reported that while exact spawning sites or deposited eggs were never observed, all ripe fish were collected in eddies or shallow pools with boulder or cobble substrate. Although they had no direct observations indicating that eddy habitat was used for spawning, Karp and Tyus (1990) stressed the importance of this habitat during spawning whether it is used for spawning, feeding, or as a staging area.

Demography

The construction of impoundments in the Colorado River Basin has effectively separated roundtail chub populations. At this time there is no flow of genetic material between populations that are separated by impoundments. The potential loss of genetic heterogeneity and diversity is unknown at this time. It is logical that, as populations become more isolated, the impacts from catastrophic events become more severe.

There is some speculation that human-induced changes (e.g., regulated flows, altered temperature regimes) to the Colorado River Basin may be contributing to the breakdown of reproductive isolation mechanisms that have evolved between roundtail chub and other chub species (Kaeding et al. 1990). Reported hybrids between roundtail chub and other *Gila* species have been collected in the wild (Holden and Stalnaker 1970, Karp and Tyus 1990), and they have been cultured (Hamman 1981). Spawning of roundtail chub and bonytail chub is concurrent in time but thought to be spatially separated (Vanicek 1967). Kaeding et al. (1990) additionally suggests that the difference between roundtail chub and humpback chub micro-habitat selection is an important mechanism contributing to the reproductive isolation of each species. Because so little is known about specific spawning requirements of roundtail chub (and other chubs) in the Colorado River Basin, further research must be conducted to develop or confirm theories regarding spawning success of roundtail chub.

The development of a meaningful life cycle diagram for roundtail chub requires life stage-specific data regarding survival rates, fecundity, and sex ratio. Existing data on roundtail chub survival rates and other components necessary to construct a valid life cycle diagram are sparse (especially data specific to roundtail chub populations occurring in smaller tributary streams). We include the following life cycle description as an illustration of the data needed to refine the model (Figure 3).

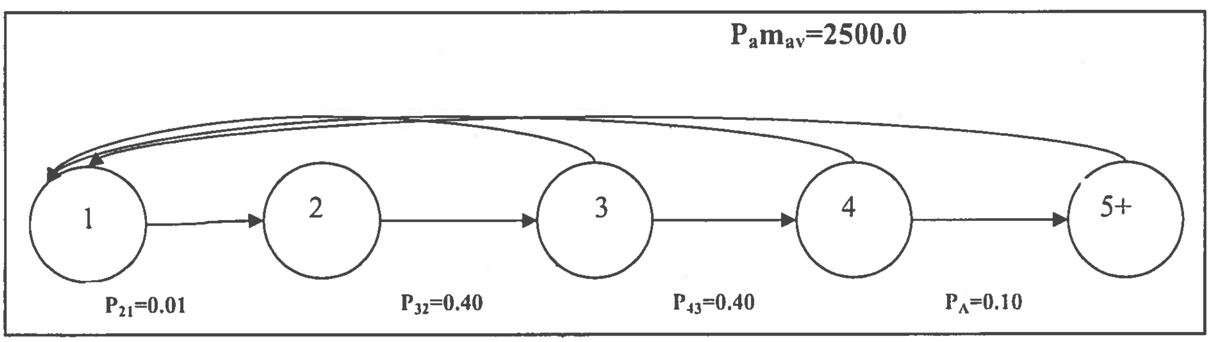

Figure 3. Life cycle graph for roundtail chub showing both the symbolic and numeric values for the vital rates. The circles denote the 5+ age classes in the life cycle, first year through adult females. Arrows denote survival rates. Survival and fertility rates provide the transition between age classes. Fertilities involve offspring production, mi, number of female eggs per female as well as survival of the female spawners.

Input data needed for a population projection matrix model consists of age-specific survival and fecundity rates. Very little data of this type is available for roundtail chub. Age at sexual maturity, length/age relationships, and fecundity depend on location (e.g., stream size, habitat) and can be highly variable (Bezzerides and Bestgen 2002). Therefore, we chose to use an average fecundity for all adult ages with sexual maturity beginning at age 3. The value for eggs per mature female (25,000) is an estimate for an approximately 250 mm (9.8 inches) TL female. We used roundtail chub data from Bezzerides and Bestgen (2002) and Muth et al. (1985) to provide average adult fecundity estimates. Information on survival rates, gender specific survival rates, or fertility rates of roundtail chub has not been reported. To provide some information on survival and population dynamics, we have used a general survival rate for both males and females. The annual survival rates (**Table 1**, **Figure 3**) provide longevity of the species to over age 10. Survival rates of roundtail chub populations likely depend on the flow regime and water quality characteristics at the time of spawning. Long-lived species such as roundtail chub would not require high recruitment success of individuals each year. Typical of many long-lived fish species, the roundtail chub likely has a high mortality rate from egg through age 1, followed by decreasing mortality rate with age and probably a fairly constant mortality rate for adult fish. This life history trait would provide large cohorts to infuse the population in years when conditions were optimal for spawning. This pulse of young roundtail chub would provide a strong cohort that would replenish or augment the adult population until the next period of favorable spawning conditions. Spawning and recruitment likely take place each year but with a very high rate of variability and overall success dependent on fluctuating environmental conditions.

Community ecology

Historically, roundtail chub may have been the most abundant carnivore in the Upper Colorado River Basin (Holden and Stalnaker 1975). Recently, a decrease in range and abundance has been documented at several locations (Vanicek et al. 1970, Joseph et al. 1977, Kaeding et al. 1990). Joseph et al. (1977) suggested that declines in roundtail chub populations are often correlated with the introduction and establishment of predatory non-native fish. They also suggested that prior to the introduction of non-native fish, roundtail chub were probably a major prey item for Colorado pikeminnow (*Ptychocheilus lucius*). Osmundson (1998) documented Colorado pikeminnow predation on roundtail chub in the Colorado River. It is very likely that roundtail chub are preyed upon by both native and non-native sympatric predators. Nesler (1995) documented northern pike (*Esox lucius*) utilization of roundtail chub as a significant prey item in the Yampa River, Colorado. Roundtail chub were the second most common prey item for northern pike in that system. Other introduced predators include rainbow trout, brown trout (*Salmo trutta*), smallmouth bass (*Micropterus dolomieui*), and channel catfish (Weitzel 2002). The red shiner (*Cyprinella lutrensis*), when present, may act as a predator on larvae as well as a competitor with juvenile roundtail chub (Ruppert et al. 1993).

Little is known about the influence of parasites on roundtail chub community ecology. A list of the known parasitic protozoan, trematodes, and nematodes can be found in the comprehensive report on roundtail chubs at www.natureserve.org. There is also concern that the introduction of non-native fish has resulted in the introduction of the Asian tapeworm (*Bothriocephalus acheilognathi*). This parasite can reduce growth and suppress swimming ability, especially in young roundtail chub (Weitzel 2002). The Asian tapeworm and anchor worm (*Lernia*) have been found in the system, but there is little evidence that roundtail chub are commonly used as hosts, despite their apparent susceptibility (Landye et al. 1999).

An envirogram for roundtail chub was developed to help elucidate the relationships between

Table 1. Parameter values for the component terms (P_i and m_i) that make up the vital rates in the projection matrix for roundtail chub. Available parameters were estimated from Muth et al. (1985) and Bezzerides and Bestgen (2002).

Parameter	Numeric value	Interpretation
P_{21}	0.001	First year survival rate
P_{32}	0.40	Survival from 2nd to 3rd year
P_{43}	0.40	Survival from 3rd to 4th year
P_a	0.10	Survival for adults
m_{av}	25000	Average fecundity for mature females

land use practices/management and roundtail chub population characteristics (**Figure 4**). Those elements that directly affect the roundtail chub are depicted in the envirogram by the centrum, which is further separated into resources, predators, and malentities. Resources elicit positive response in roundtail chub whereas predators and malentities produce either negative or neutral responses. 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. Relative importance of the linkages is poorly understood and warrants further study.

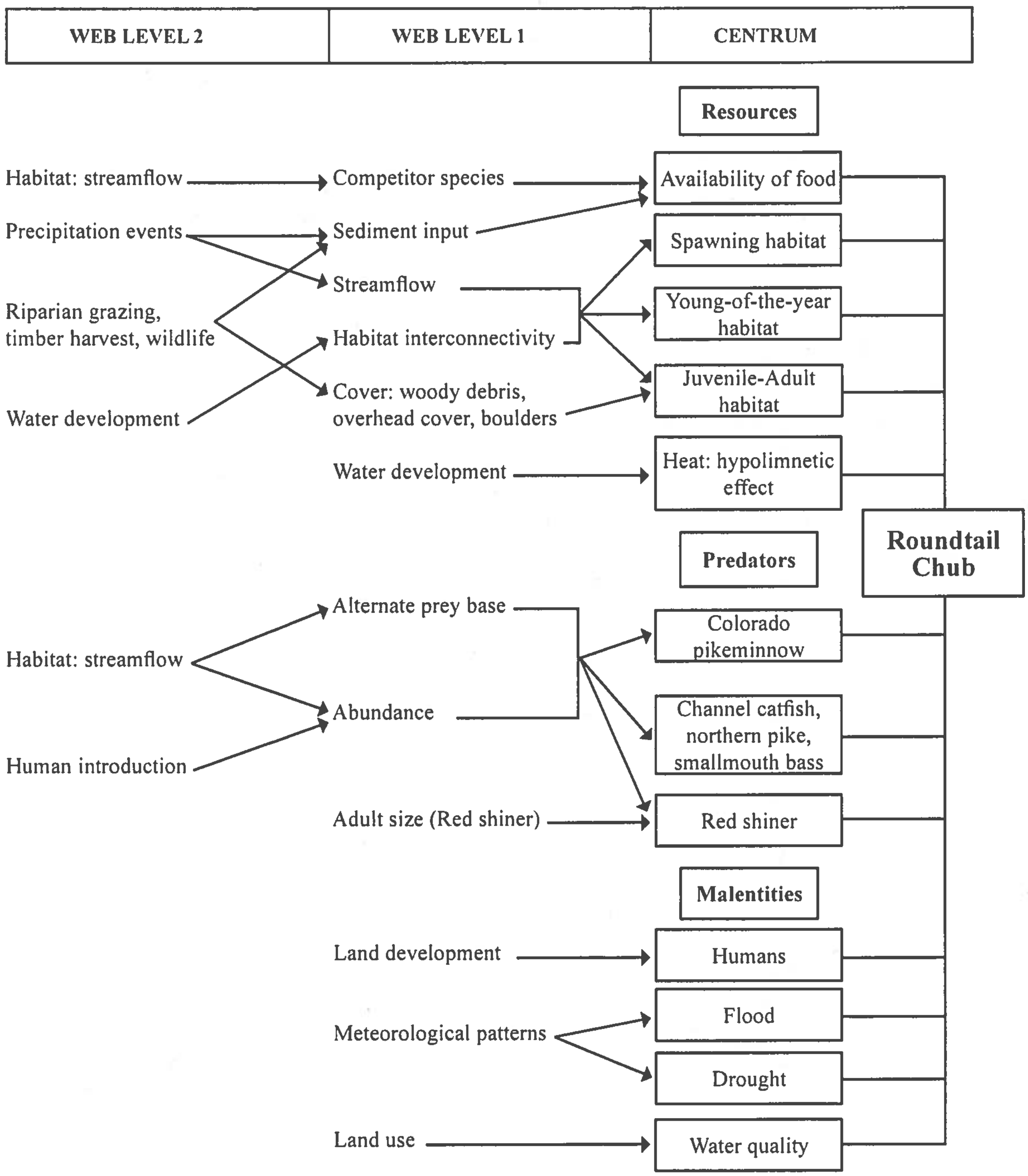

Figure 4. Envirogram for the roundtail chub.

Conservation

Threats

The native fish community that evolved in the warm-water reaches of the Upper Colorado River Basin has been greatly reduced as a result of human activities during the last 100 years. Roundtail chub populations have suffered reductions in abundance and distribution from the same mechanisms that have caused the near extinction of other endemic fish species in this drainage. These mechanisms can be separated into two general categories that encompass the majority of the threats to the current and future survival of roundtail chub: 1) habitat degradation through loss, modification, and/or fragmentation and 2) interactions with non-native species (Tyus and Saunders 2000).

Both types of threats imperil the long-term persistence of roundtail chub. Each may work independently or in conjunction with the other to create an environment where populations may be reduced or eliminated. The relative importance of each category and the specific cause-effect relationship usually depend on location. The complexity of each requires further explanation.

Effects of habitat degradation may not be limited to localized areas but may cascade through the system. Therefore, activities or events occurring on National Forest System lands may have detrimental impacts on populations of roundtail chubs existing in rivers many kilometers downstream of USFS lands.

Habitat loss typically occurs when streams are dewatered or when reservoir construction inundates suitable roundtail chub habitat. Habitat modification occurs when the natural flow regime is altered, and when stream channels are modified due to channelization, scouring, or sedimentation from land use practices. Land use practices that can impact stream channels include construction of roads through highly erodible soils, improper timber harvest practices, and overgrazing in riparian areas. These can all lead to an increased sediment load within 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 (e.g., pool depth) that affect the quality of habitat occupied by roundtail chub.

The effect of wildfire has little direct impact on habitat quality. However, post-fire conditions can affect downstream populations. Input of large quantities of sediment into streams frequently occurs during storm events at recently burned areas. The increased sediment load can diminish suitable spawning habitat, smother eggs and larvae, reduce habitat for prey, and cause direct mortality through suffocation at all life stages.

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. Even undersized (or improperly designed) culverts at road or trail crossings can act as barriers, especially at low flows. Large and small scale water development projects can have profound impacts on the persistence of roundtail chub. 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 typically occurs in the larger mainstem river sections. In smaller rivers and tributaries to the mainstem, habitat fragmentation can eventually lead to habitat loss and extirpation of populations. As 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 aspects already discussed under fragmentation and degradation but also includes changes in temperature and flow regimes, as well as alterations to water chemistry related to pollution. Severely reduced streamflows may lead to increased water temperatures 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, roundtail chub fitness will also decline.

Water development, road construction, timber harvest, and grazing of riparian areas are likely to continue to impact roundtail chub habitat. While modification of land use management techniques to decrease the impact to roundtail chub habitat may lessen anthropogenic threats to this species, it is unlikely that all impacts or threats could be minimized or halted. Modifications of land use management techniques include:

- the specification of fish passage at new or existing low head diversions to eliminate or reduce habitat loss and fragmentation;
- the specification of minimum flow regimes to promote habitat connectivity;
- maintenance of baseflow habitat during summer or irrigation seasons;
- the specification for buffer zones for both road construction and timber harvest;
- the reduction of grazing in riparian areas to promote healthy riparian growth and reduce sedimentation from upland areas.

Competition with and predation by non-native species is another extensive threat to roundtail chub population health and viability. Many introduced species tend to be well-adapted to a variety of environmental conditions, giving them a competitive advantage on a spatial or temporal scale. Non-native species such as red shiner, fathead minnow (*Pimephales promelas*), redside shiner (*Richardsonius balteatus*), and young smallmouth bass compete with juvenile roundtail chubs for available macroinvertebrate food resources. Many of these species are prolific spawners and capable of successfully producing multiple broods each year.

A fusiform shape and lack of protecting spines makes the roundtail chub a desirable prey item for predatory non-native species. Large non-native predators, including northern pike, channel catfish, and smallmouth bass, occur in many of the drainages containing roundtail chub. In addition, red shiners have been reported to feed on native larval fish within the Upper Colorado River Basin (Ruppert et al. 1993). Preferred habitat for red shiners is slack water shoreline or backwater areas, which are also used by larval roundtail chub.

Hybridization with other *Gila* species is a minor threat to roundtail chub persistence. Currently, only small populations of bonytail and humpback chubs occur sympatrically with roundtail chub, but the future stocking of bonytail in the Upper Colorado River Basin is likely. Although these species historically co-existed, the alteration of natural temperature and flow regimes in some regulated stream reaches may reduce the reproductive isolation mechanisms that have evolved between species. Further treatment of hybridization can be found in the Demography section.

Given their proximity to USFS lands and the effects of some of the threats such as increased sedimentation from grazing, timber practices, and road construction, USFS activities could impact downstream roundtail chub populations. Fragmentation of populations or habitat loss could occur due to barriers to migrations that occur on occupied USFS lands at water diversions or impassable stream crossings. Both of those threats could be eliminated with inclusion of fish passages during construction of diversions, and proper sizing and construction of culverts to allow natural passage conditions at road crossings or bridges.

Conservation Status of the Roundtail Chub in Region 2

At present, there is concern regarding the status of roundtail chub in the Colorado River Basin. A decrease in roundtail chub populations has been documented or suggested throughout most of the basin. Existing research suggests that the decline in range and populations of this species is due to the combined impacts of habitat loss, habitat degradation, habitat fragmentation, and interactions with non-native species. Although the specific mechanisms of most threats to this species are poorly understood, it is imperiled throughout its range in the Upper Colorado River Basin.

Stable populations of roundtail chub still exist in various locations in the Upper Colorado River Basin (i.e., tributaries and sections of the Green, Colorado, and San Juan rivers). These locations are usually defined by adequate habitat (as specified in the habitat section of this report), and natural temperature and flow regimes. These areas often maintain healthy populations of other native fish species.

The roundtail chub evolved in a system with a high natural disturbance regime. This disturbance regime included a large contrast between annual peak flows and base flows, and considerable sediment transport. Life history attributes and population dynamics allowed this species to persist during (or to recolonize after) a disturbance event; however, modifications (loss of channel complexity, refugia) to the physical environment (e.g., loss of channel complexity and refugia) and the biological environment (e.g., increase in non-native species, predation, and competition) have reduced the species' ability to recover after such events. Habitat fragmentation through streamflow reduction, passage barriers, and habitat degradation disconnects metapopulations of roundtail chubs. Additional pressure from competition and predation can depress or extirpate roundtail chub populations.

Based on the impacts to roundtail chub abundance and distribution that have occurred in the last century, the potential for future declines is high. Unless alleviated, habitat degradation, habitat fragmentation, and non-native species interactions could intensify and jeopardize the existence of roundtail chub. While this species is not found on USFS lands, much of the water in rivers that currently support roundtail chub originates on those lands. Activities on USFS lands that impact streamflows and water quality could affect roundtail chub populations in downstream reaches.

Potential Management of the Roundtail Chub in Region 2

Implications and potential conservation elements

A brief description of threats is provided here to form a basis for the conservation elements; however, further discussion of threats to roundtail chub can be found in the Conservation Threats section of this document.

Management of roundtail chub should be based on an understanding of specific threats to the species. Habitat loss, degradation, and fragmentation due to land and water use practices are prime threats to roundtail chub persistence in the Upper Colorado River Basin. Reduction of streamflows and creation of barriers to fish passage can severely degrade habitat to the extent that roundtail chub populations are extirpated from the area. The degree of influence that population fragmentation has on roundtail chub populations is speculative but could impact the long-term persistence of this species. Creating isolated populations disrupts the natural exchange of genetic material between populations. Isolated populations are subject to extinction due to catastrophic events because of the impediment to recolonization from other nearby populations. Loss of genetic diversity can also lead to depression of fecundity and survival rates. The genetic exchange along a metapopulation framework within the roundtail chub distribution can provide the required demographic variability and viability.

Considerations for conservation elements should include:

- ❖ preservation of instream flows
- ❖ minimization of sediment input due to anthropogenic causes (e.g., road building, timber harvest)
- ❖ management of non-native fish species
- ❖ protection of riparian areas

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. Increased sediment can result in loss of habitat (e.g., pools), siltation of riffles and subsequent loss of food production, and changes in stream geometry (e.g., width:depth ratios). It is likely that increased sediment loads or sediment deposition could negatively impact roundtail chub populations. However, 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.

The presence of non-native fish species threatens roundtail chub populations. Specifically, competition between roundtail chub and introduced species and predation by large non-native species represent the two most deleterious effects of non-native interaction. Implementation of management strategies should be designed to restrain further expansion of non-native fish distribution on USFS lands. These strategies should include strict enforcement of existing prohibitions regarding the release of non-native fish. Eradication programs for non-native fish (including game fish) in streams within the historical range of roundtail chub could also be considered.

Preservation of instream flows that are adequate to maintain complex habitat, interconnectivity of habitats, and instream cover should be a focal point of management policy or strategy. Conservation elements should address the function of the entire aquatic and riparian ecosystem, with particular attention to downstream populations. Any future plans for the conservation of roundtail chub should take into account the entire native fish assemblage in the Colorado River Basin. This assemblage of species evolved in a system with a high differential between peak spring runoff and fall base flows. Native fish species of the Colorado River all require similar management considerations related to channel maintenance and restoration of historical flow regimes.

Tools and practices

We are unaware of any management approaches implemented specifically for roundtail chub in Region 2. Because little information exists or is currently being collected regarding this species, this section will deal with techniques intended to gather information identified in the Information Needs section that follows.

The absence of distribution and abundance data for roundtail chub in Region 2 (with emphasis toward USFS land) should be a concern. The compilation of all available distribution data would provide a foundational database that further surveys could supplement. The initial priority should be a complete survey of all National Forest System streams that may contain roundtail chub. Because adult roundtail chub frequent areas with complex instream cover, the use of electrofishing as a means to determine distribution and abundance is warranted.

Once basic distribution information has been gathered, intensive population estimates would provide baseline information with which effectiveness of future management strategies could be evaluated. Focus should be on areas where future management strategies may include activities that could possibly impact roundtail chub populations. However, the long-term monitoring goal should be population estimates and population trend data on all streams containing roundtail chub populations on Region 2 lands. Consultation with agencies managing populations that are not on National Forest System lands but are affected by forest practices is imperative to allow forest managers to continually monitor the status of those populations. Several electrofishing techniques exist that would 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 National Forest System lands, estimating populations using a multiple pass removal technique should be a cost effective method to produce high quality data. Riley and Fausch (1992) recommended 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 (CPUE) 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, thereby allowing this approach to be comparable through time.

General stream reach habitat surveys should be conducted concurrently with distribution and abundance surveys. Winters and Gallagher (1997) developed a basinwide habitat inventory protocol that would be a cost-effective tool to collect general stream habitat data. This protocol includes characterization and quantities of habitat type, channel type, substrates, and bank stability. All of these parameters assist in describing habitat quality.

A large data gap exists in the knowledge of roundtail chub movement and use of streams on USFS lands. The implementation of a survey methodology to determine roundtail chub distribution and abundance can also provide insight into movement through the use of PIT (passive integrated transponder) tags. PIT tags are unobtrusive, long lasting (indefinitely), uniquely coded tags that allow for the efficient determination of movement with a minimum of disturbance. Establishment of a long-term monitoring program would be required. Even in areas considered to be strongholds for roundtail chub, the species is often rare; therefore, the time required to develop a robust data set is dependent upon sample size, recapture rates, and survey frequency.

Habitat selection and preference can be determined through the use a variety of techniques. The simplest technique involves correlating capture locations (during distribution surveys) to specific habitat types. Construction of habitat suitability curves is time intensive but could be used in conjunction with hydraulic modeling methodologies to estimate how habitat changes in relation to streamflow. This would allow land use managers to effectively compare the impacts of different altered flow regimes (due to water development projects) on roundtail chub habitat. Data obtained could also be used to justify the acquisition of adequate instream flows for roundtail chubs and other native fishes.

Defining the relationship between habitat alteration and roundtail chub population characteristics will be a difficult task. This process may require significant amounts of data including quantitative analysis of differences in prey base over time, changes in habitat quality/function, and some form of abundance estimates.

In addition to collecting data specifically related to the distribution and life history of roundtail chub, forest managers can implement techniques that will increase the quality of habitat for roundtail chub and other native fish (e.g., flannelmouth sucker, bluehead sucker). A healthy riparian corridor is important to overall aquatic ecosystem function. Forest managers can address minor riparian issues by altering the grazing rotation or by fencing riparian areas. In areas with severely degraded riparian growth, revegetation of the riparian area may also be warranted. Other tools and techniques to improve habitat condition and function could include physical habitat restoration. This technique can be costly and time intensive and may only be practical when previously mentioned techniques are unsuccessful.

Managers can also work to ensure that barriers do not fragment roundtail chub populations. In addition to properly designing future stream culverts (i.e., size and gradient to allow fish passage), managers should inventory and assess the threat of all potential barriers currently in place. Barriers located within roundtail chub range (as defined by distributional surveys) within Region 2 should receive priority and when possible, be removed.

The mechanical removal of non-native fish is currently conducted on lower mainstem rivers and pertinent stream systems occupied by roundtail chub within the Upper Colorado River Basin. The effectiveness of this technique to significantly reduce non-native fish populations is not clearly understood. Mechanical removal is likely most effective when utilized before non-native fish populations become well established and prolific.

In order to effectively gather data valuable for the conservation of this species, managers need to coordinate with federal and state agencies, academia, and private firms that are managing or studying portions of streams downstream of USFS lands. This is necessary to determine or verify the distribution and abundance of roundtail chub populations that exist off National Forest land, but that are still affected by USFS management policies and strategies.

Information Needs

Most of the available information regarding the roundtail chub has been collected as a byproduct of studies that were designed to learn more about federally listed fish in the Colorado River Basin. In order to attain the level of understanding that is necessary to properly manage this species at a localized level, specific threats must be identified by drainage. General information needs for roundtail chub include a wide range of information:

- distribution
- habitat requirements and associations
- general attributes of life history and ecology
- movement patterns
- influence of non-native fish
- genetic variation of populations
- effects of human-induced habitat modification.

The current distribution of roundtail chub on USFS lands in Region 2 is poorly understood. Specific knowledge of streams and watersheds containing roundtail chubs is essential prior to the development of any regional management strategies designed to preserve this species. The research priority should be to survey all streams with potential habitat for the presence of roundtail chub. Initial focus should be on streams with known populations downstream and adjacent to USFS lands. In addition to general distribution and abundance information, additional data on temporal and spatial changes in abundance and distribution is required. Roundtail chub may not establish resident populations in USFS-managed streams, but these tributaries may provide important spawning habitat.

During these 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 tolerances for each physical parameter. The available data on habitat use emphasizes large river systems, and few studies have been conducted on smaller tributary systems. Habitat requirements and preferences are poorly understood for most life stages and life history events. Specific studies need to be designed to provide information on spawning behavior and habitat, larval biology, and the importance of larval drift. Habitat requirements and feeding habits at each life stage should also be addressed.

Fish collected should be tagged with PIT tags to allow for studies of movement, migration, and growth rates. Continued 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 other components missing from the life cycle diagram. It may be important to collect data from several sub-basins because much of the specific life history information may vary by drainage. It is unknown whether roundtail chub life history traits are uniform between large river and small tributary systems.

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

Genetic testing during future studies on roundtail chub populations is important. Tissue samples should be taken from fish for analysis of the genetic structure of mainstem and isolated populations. Genetic characterization would allow studies of population connectivity, migration, population diversity, viability of isolated populations, and the extent and effects of hybridization with other chub species.

In order to ensure the long-term conservation of this species, research must also examine how to minimize the impacts of human activities on roundtail chub populations. Studies specifically designed to evaluate the effects of riparian grazing, road construction, passage barriers, and non-native species interactions are imperative to preserving this species. Techniques to minimize the effects of impoundments on flow regime, temperature regime, and movement of native fish are particularly important. This research should focus on modifying existing impoundments, providing guidelines for construction of future impoundments, and exploring the use of off-channel impoundments. The development of a process-response model that portrays the biological response of a species to physical factors would further identify roundtail chub life history components that are not adequately understood.

DEFINITIONS

Centrum – any component that directly affects the central organism

Endemic – confined to a particular geographic region.

Habitat quality – the physical characteristics of the environment (e.g., soil characteristics for plans or channel morphology for fish) that influence the fitness of individuals. This is distinguished from habitat quantity, which refers to the spatial extent.

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

Lithophilic – associated with stony substrates.

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

Metapopulation – one or more core populations that are fairly stable and several surrounding areas with fluctuating populations.

Process-response model – either a conceptual or mechanistic model to portray the biological response to physical factors.

Scale – the physical or temporal dimension of an object or process (e.g., size, duration, frequency). In this context, extent defines the overall area covered by a study or analysis and grain defines the size of individual units of observation (sample units).

Viability – a focus of the Species Conservation Project. Viability and persistence are used to represent the probability of continued existence rather than a binary variable (viable vs. not viable). We note this because of the difficulty in referring to 'probability of persistence' throughout the manuscript.

Web Level 1 – any component that affects the centrum.

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

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References

Andrewartha, H.G. and L.C. Birch. 1984. The ecological web: more on the distribution and abundance of animals. University of Chicago Press, Chicago, IL.

Baxter, G.T. and J.R. Simon. 1970. Wyoming fishes (revised). Bulletin No. 4, Wyoming Game and Fish Department, Cheyenne, WY.

Bestgen, K.R. and L.W. Crist. 2000. Response of the Green River fish community to construction and re-regulation of Flaming Gorge Dam, 1962-1996. Colorado River Recovery Implementation Program Project Number 40, Fort Collins, CO.

Beyers, D.W., C. Sodergren, J.M. Bundy, and K.R. Bestgen. 2001. Habitat use and movement of bluehead sucker, flannelmouth sucker, and roundtail chub in the Colorado River. Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO.

Bezzerides, N. and K. Bestgen. 2002. Status review of roundtail chub *Gila robusta*, flannelmouth sucker *Catostomus latipinnis*, and bluehead sucker *Catostomus discobolus* in the Colorado River basin. Colorado State University Larval Fish Laboratory, Fort Collins, CO.

Binns, N.A. 1967. Effects of rotenone treatment on the fauna of the Green River, Wyoming. Fisheries Technical Bulletin 1, Wyoming Game and Fish Commission, Cheyenne, WY.

Bryan, S.D. and A.T. Robinson. 2000. Population characteristics and ;movement of roundtail chub in the lower Salt and Verde rivers, Arizona. Final Report-October 2000 AGFD to U.S. Bureau of Reclamation, Phoenix, AZ.

Carter, J.G., V.A. Lamarra, and R.J. Ryel. 1986. Drift of larval fishes in the upper Colorado River. Journal of Freshwater Ecology 3:567-577.

Chamberlain, T.C. 1897. The method of multiple working hypotheses. Journal of Geology 5:837-848 (reprinted in Science 148:754-759).

Gerhardt, D. 2003. Forest Fisheries Biologist, USDA Forest Service, San Juan National Forest, Durango, CO. Personal communication.

Haines, G.B. and H.M. Tyus. 1990. Fish associations and environmental variables in age-0 Colorado squawfish habitats, Green River, Utah. Journal of Freshwater Ecology 5:427-435.

Hamman, R.L. 1981. Hybridization of three species of chub in a hatchery. Progressive Fish-Culturist. 43(3):140-141.

Hillborn, R. and M. Mangel. 1997. The ecological detective: confronting models with data. Princeton University Press, Princeton, NJ.

Holden P.B. and C.B. Stalnaker. 1975. Distribution and abundance of mainstream fishes of the middle and Upper Colorado River Basins, 1967-1973. Transactions of the American Fisheries Society 104:217-231.

Jordan, D.S. 1891. Report of explorations in Colorado and Utah during the summer of 1889 with an account of the fishes found in each river basin examined. Bulletin of the U.S. Fish Commission 9:1-40.

Joseph, T.W., J.A. Sinning, R.J. Behnke, and P.B. Holden. 1977. An evaluation of the status, life history, and habitat requirements of endangered and threatened fishes of the upper Colorado River system. FWS/OBS-77-62. U.S. Fish and Wildlife Service, Fort Collins, CO.

Kaeding L.R., Burdick B.D., Schrader P.A., and C.W. McAda. 1990. Temporal and spatial relations between the spawning of humpback chub and roundtail chub in the upper Colorado River. Transactions of the American Fisheries Society 119:135-144.

Karp, C.A. and H.M. Tyus. 1990. Humpback chub (*Gila cypha*) in the Yampa and Green rivers, Dinosaur National Monument, with observations on roundtail chub (*G. robusta*) and other sympatric fishes. Great Basin Naturalist 50:257-264.

002285

Landye, J., B. McCasland, C. Hart, and K. Hayden. 1999. San Juan River fish health surveys (1992-1999). San Juan River Basin Recovery Implemenation Program, U.S. Fish and Wildlife Service, Pinetop, AZ.

Lentsch, L.D., C.A. Toline, T.A. Crowl, and Y. Converse. 1998. Endangered fish interim management objectives for the Upper Colorado River Basin recovery and implementation program. Utah Division of Wildlife Resources, Salt Lake City, UT.

McAda, C.W., C.R. Berry, Jr., and C.E. Phillips. 1980. Distribution of fishes in the San Rafael River system of the Upper Colorado River Basin. The Southwestern Naturalist 25:41-50.

McNatt R.M. and D.L. Skates. 1985. Fishery investigation of the Yampa and Green Rivers, Dinosaur National Monument, Colorado and Utah, 1981. Pages 91-100 *in* E.P. Pister, editor. Proceedings of the Desert Fishes Council. Volume 13-15-A. Desert Fishes Council, Bishop, CA.

Miller, W.J., J. Hogle, and D.E. Rees. 1995. Final report, Animas-La Plata Project native fish studies. Miller Ecological Consultants, Inc., Fort Collins, CO.

Miller, W.J. and D.E. Rees. 2000. Ichthyofaunal surveys of tributaries of the San Juan River, New Mexico. Miller Ecological Consultants, Inc., Fort Collins, CO.

Minckley W.L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix, AZ.

Minckley, W.L. and B.D. DeMarais. 2000. Taxonomy of chubs (Teleostei, Cyprinidae, Genus *Gila*) in the American Southwest with comments on conservation. Copeia 1:251-256.

Muth R.T., C.M. Haynes, and C.A. Carlson. 1985. Culture of roundtail chub, *Gila robusta* (Cyprinidae), through the larval period. Southwestern Naturalist 30:152-154.

NatureServe. 2003. NaturServe Explorer: An online encyclopedia of life [web application]. Version 1.8. NatureServe, Arlington, VA. Available http://www.natureserve.org/explorer.

Nesler, T.P. 1995. Interaction between endangered fishes and introduced gamefishes in the Yampa River, Colorado, 1987-1991. Final Report, September 1995, Colorado Division of Wildlife, Colorado River Recovery Implementation Program Project No. 91-29, Federal Aid Project SE-3, Fort Collins, CO.

Oberholtzer, M. 1987. A fisheries survey of the Little Snake River drainage, Carbon County, Wyoming. Wyoming Game and Fish Department, Cheyenne, WY.

Olson H.F. 1962. Rehabilitation of the San Juan River. Federal Aid Project F-19-D4, Job No. C-16-4. New Mexico Game and Fish, Santa Fe, NM.

Olson H. F. 1967. A post-impoundment study of Navajo Reservoir and Navajo Reservoir tailwaters. Section 8 project, Job No. A-3(a) and A-3(b). New Mexico Department of Game and Fish, Santa Fe, NM.

Osmundson, D.B. 1999. Longitudinal variation in fish community structure and water temperature in the upper Colorado River: implications for Colorado pikeminnow habitat suitability. Final Report for Recovery Implementation Program, Project No. 48. U.S. Fish and Wildlife Service, Grand Junction, CO.

Platania, S.P. 1990. Biological summary of the 1987-I989 New Mexico-Utah ichthyofaunal study of the San Juan River. U.S. Bureau of Reclamation, editor. Salt Lake City, UT.

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Propst, D.L. and A.L. Hobbes. 1999. Seasonal abundance, distribution and population size-structure of fishes in San Juan River secondary channels: 1991-1997. New Mexico Department of Game and Fish, Santa Fe, NM.

Riley, S.C. and K.D. Fausch. 1992. Underestimation of trout population size by maximum-likelihood removal estimates in small streams. North American Journal of Fisheries Management 12:768-776.

Ruppert, J.B., R.T. Muth, and T.P. Nesler. 1993. Predation on fish larvae by adult red shiner, Yampa and Green Rivers, Colorado. The Southwestern Naturalist 38:397-399.

Sigler, W.F. and J.W. Sigler. 1996. Fishes of Utah; a natural history. University of Utah Press, Salt Lake City, UT.

Simon, J.R. 1946. Wyoming fishes. Bulletin No. 4, Wyoming Game and Fish Department, Cheyenne, WY.

Sublette, J.E., M.D. Hatch, and M. Sublette. 1990. The fishes of New Mexico. University of New Mexico Press, Albuquerque, NM.

Tyus, H.M. and J.F. Saunders, III. 2000. Nonnative fish control and endangered fish recovery: lessons from the Colorado River. Fisheries 25(9):17-24 (cf. http://ww.r6.fws.gov/crrip).

Utah Department of Natural Resources. 2004. Range-wide conservation agreement for roundtail chub (*Gila robusta*), bluehead sucker (*Castostomus discobulus*), and flannelmouth sucker (*Castostomus latipinnis*). Utah Department of Natural Resources. Division of Wildlife Resources. Salt Lake City, UT.

Vadas, R.L. Jr. 1994. The anatomy of an ecological controversy: honey bee searching behavior. Oikos 69:158-166 (http://www.beesource.com/pov/wenner/oikos94.htm).

Vanicek, C.D. 1967. Ecological studies of native Green River fishes below Flaming Gorge Dam, 1964-1966. Ph.D. thesis, Utah State University, Logan, UT.

Vanicek, C.D. and R.H. Kramer. 1969. Life history of the Colorado squawfish, *Ptychocheilus lucius*, and Colorado chub, *Gila robusta*, in the Green River in Dinosaur National Monument, 1964-1966. Transactions of the American Fisheries Society 98:193-208.

Vanicek C.D., R.H. Kramer, and D.R. Franklin. 1970. Distribution of Green River fishes in Utah and Colorado following closure of Flaming Gorge Dam. Southwestern Naturalist 14:297-315.

Weitzel, D.L. 2002. Conservation and status assessments for the bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*Catostomus latipinnis*), roundtail chub (*Gila robusta*), and leatherside chub (*Gila copei*): rare fishes west of the Continental Divide, Wyoming. Wyoming Fish and Game Department, Cheyenne, WY.

Wheeler, C.A. 1997. Current distributions and distributional changes of fish in Wyoming west of the Continental Divide. M.S. Thesis, University of Wyoming, Laramie, WY.

Winters, D.S. and J.P. Gallagher. 1997. Basin-wide stream habitat inventory, a protocol for the Pike and San Isabel National Forests and Cimarron and Comanche National Grasslands. U.S. Forest Service.

Wyoming Game and Fish Department. 1998. Little Snake River water management project: High Savery Reservoir site. Wyoming Game and Fish Department, Cheyenne, WY.