PETITION TO LIST THE ROUNDTAIL AND HEADWATER CHUBS (*Gila robusta* and *nigra*) AS ENDANGERED SPECIES IN THE LOWER COLORADO RIVER BASIN

CENTER FOR BIOLOGICAL DIVERSITY

April 2, 2003

Ms. Gayle Norton
Secretary of the Interior
Office of the Secretary
Department of the Interior
18th and "C" Street, N.W.
Washington, D.C. 20240

The Center for Biological Diversity and Noah Greenwald hereby formally petition to list a distinct population segment of the roundtail chub (*Gila robusta*) in the Colorado River basin below Glen Canyon Dam, and the headwater chub (*Gila nigra*) throughout its range as endangered (or threatened) pursuant to the Endangered Species Act, 16 U.S.C. 1531 et seq. (hereafter referred to as "ESA"). This petition is filed under 5 U.S.C. 553(e) and 50 CFR 424.14 (1990), which grants interested parties the right to petition for issue of a rule from the Assistant Secretary of the Interior.

Petitioners also request that Critical Habitat be designated concurrent with the listing, as required by 16 U.S.C. § 1533(b)(6)(C) and 50 CFR 424.12, and pursuant to the Administrative Procedures Act (5 U.S.C. 553).

Petitioners understand that this petition action sets in motion a specific process placing definite response requirements on the U.S. Fish and Wildlife Service and very specific time constraints upon those responses. See 16 U.S.C. § 1533(b).

Petitioners:

Center for Biological Diversity is a non-profit public interest organization dedicated to protecting the diverse life forms of western North America. It has offices in New Mexico, Arizona, and California.

EXECUTIVE SUMMARY

Like many southwestern native fish, roundtail and headwater chub have declined precipitously due to a combination of habitat loss and degradation related to livestock grazing, dams, diversions, groundwater pumping, mining, recreation, and human population growth, competition and predation from non-native fish, and inadequate existing laws and regulations. In the lower Colorado River basin, roundtail and headwater chub occupy only 18% and 40% of their historic ranges respectively, and their status is poor and declining. The small and isolated nature of remaining populations puts both species at a high risk of extinction. Many of the factors that lead to this significant diminution of range continue to threaten remaining populations. As a result, both the roundtail and headwater chub meet four of five factors for determination as threatened or endangered species:

Present or threatened destruction, modification, or curtailment of habitat or range:

- Livestock grazing is occurring in the watersheds of 29 of 30 remnant populations of roundtail or headwater chub. Forest Service documents determined that grazing is impacting chub populations on at least 17 allotments spread across five national forests and that livestock grazing on two allotments would eventually lead to a trend towards federal listing. The Forest Service failed to analyze impacts on 15-23 allotments, where the species is known to occur and there is active livestock grazing. Adverse effects from grazing also occur on other Federal, State, and private lands where the two chub persist.

- A growing human population threatens to dewater substantial portions of the upper Verde River and its tributaries, where there are a number of remnant populations of roundtail and headwater chub, and one of the most intact native fish communities remaining in the Southwest. Dewatering also threatens at least 11 other chub populations and precludes recovery in large portions of their historic range.

- At least 18 major dams have been constructed throughout the ranges of the roundtail and headwater chub in the lower Colorado River basin. They have destroyed substantial areas of historic range. Operations of these dams prevents or inhibits recovery in major areas and adversely affects chub populations in others. The reservoirs are stocked and managed for nonnative sport fishes, which are highly detrimental to roundtail and headwater chub.

- Ongoing urban and suburban development threatens existing chub populations and limits recovery on the Verde, East Verde, Salt, San Pedro, and Gila Rivers and Oak, West Clear, Wet Beaver, Aravaipa, and Tonto Creeks.

- Roads, mining, recreation and other factors continue to impact many roundtail and headwater chub populations.

- Stream channel alteration and channelization has destroyed extensive areas of roundtail and headwater chub habitat. Ongoing channelization and incremental channel alteration continue to alter chub habitat making it unsuitable for the two species and resulting in population losses.

Other natural or manmade factors affecting the continued existence of the roundtail and headwater chubs:

- Non-natives have been documented in 28 of the 30 streams with known populations of roundtail or headwater chub. Competition and habitat alteration by these non-natives has been highly detrimental to the two chub. New detrimental nonnative species continue to invade.

- Stochastic disturbances, such as fire and drought, threaten remaining populations of roundtail and headwater chub. Serious ongoing drought may lead to losses of already highly stressed populations of both species.

Disease or predation:

- Largemouth bass, smallmouth bass, green sunfish, flathead catfish, channel catfish, black bullhead, yellow bullhead, and crayfish are all known or suspected to prey on native fish and have been introduced into the ranges of roundtail and headwater chub. Some stocking of these species is still ongoing within, or adjacent to, populations of roundtail and headwater chub.

- Increased rates of parasitic infection, particularly anchor worm, have been observed in roundtail chub in recent decades. These observations in combination with observations of infestation occurring in habitat stressed fish suggest that declining habitat quality may be increasing disease rates for roundtail chub.

Inadequacy of existing regulations:

- No existing Federal laws, regulations, or policies provide sufficient protection to stem the ongoing decline of roundtail and headwater chub. Protections for federally listed species or habitat have not prevented the decline of these species or other native fish in the southwest and are insufficient to protect roundtail or headwater chub.

- Existing State laws, regulations, and policies are inadequate to protect roundtail and headwater chub. In addition, substantial adverse activity is ongoing under existing State provisions. Conflict of interest between income from, and mandates for, sport fish stocking and conservation of native fish result in contradictory actions by State wildlife agencies that often harm native fish.

- On private lands, little protection is available for roundtail and headwater chub.

TABLE OF CONTENTS:

INTRODUCTION

The unique and highly endemic fish fauna of the Colorado River basin has been decimated by a century of habitat degradation and non-native fish introductions (Miller 1961). Carlson and Muth (1989) report that of 54 species or subspecies in the Colorado River basin, "17 are either endangered, threatened or extinct, and most have experienced drastic abundance and range reductions." Presently, 21 Colorado River basin fish species or subspecies are Federally listed as endangered or threatened or proposed for listing, one species is extinct, and one is being managed under a conservation agreement in-lieu of listing (50 CFR §17.11). In the genus *Gila* alone, of the six species endemic to the Colorado River basin, four are listed or proposed for listing and the other two are the subject of this petition.

Non-native fish species dominate most fish communities in the Colorado River basin, and include at least 67 introduced species (Minckley 1973, Carlson and Muth 1989, USFWS 2001a). These introductions have been facilitated by drastic habitat modification, which favors non-natives over natives (Rinne et al. 1998, Minckley 1999). A majority of waters in the Colorado River basin are now regulated with associated changes in the hydrograph, channel geomorphology, water temperatures and mineral and sediment concentrations (Carlson and Muth 1989). Less than 1% of the river's historic flow reaches the Colorado River delta. These changes have been compounded by groundwater pumping and diversion that reduce flows, and habitat altering activities, such as livestock grazing, construction of roads, channelization, and mining. Together these factors constitute a massive assault on the integrity of aquatic ecosystems in the Colorado River basin.

Reversing declines in almost the entire aquatic fauna of the Colorado River system and avoiding further listings of species under the Endangered Species Act, will require a paradigm shift in the attitudes of land and river managers and government officials throughout the Colorado River basin that places the health of the river and its tributaries on an equal footing with water consumption and resource extraction. Listing of roundtail and headwater chub as endangered (or threatened) will assist in achieving that paradigm shift and help prevent the impending extinction of the two fishes and the destruction of the ecosystem on which they depend.

I. NATURAL HISTORY

A. DESCRIPTION

Roundtail chub (*Gila robusta*). Roundtail chub is a cyprinid fish with a slender, fusiform body, which is oval in cross-section (Propst 1999). It is olive-gray with silver on the sides. It possesses a moderately slender caudal peduncle and a large forked caudal fin. The mouth is terminal. Individual roundtail chubs may reach total lengths of 50.0 cm with the majority between 25 and 35 cm (Minckley 1973). Roundtail chub are quite similar in appearance to other species of the *Gila robusta* complex (see later discussion of taxonomy). Distinguishing characters between the closely related roundtail, headwater, and Gila chubs are shown in Table 1. A key to the species of the complex is provided in Minckley and DeMarais (2000).

Headwater chub (*Gila nigra*). A dark gray or brown fish, often with diffuse longitudinal stripes on the sides (Minckley and DeMarais 2000). Headwater chubs have meristic and morphometric counts intermediate between *G. robusta* and *G. intermedia* (Table 1; DeMarais 1992a and Minckley and DeMarais 2000). While quite similar in shape to roundtail chub, headwater chub are generally smaller (Voeltz 2002).

Table 1. Distinguishing characteristics of *G. robusta*, *G. intermedia* and *G. grahami* (Minckley 1973; Sublette et al. 1990; DeMarais 1995; Propst 1999; Minckley and DeMarais 2000; Voeltz 2002).

Characteristic	*G. robusta*	*G. nigra*	*G. intermedia*
Shape	Body slender, long, and fusiform; caudal peduncle thin, but not pencil-like; fins moderate in size and square, convex, or falcate.	Body slender, moderate in length, and moderately fusiform; caudal peduncle moderately thin; fins moderate in size and square, convex or falcate.	Body chunky and relatively short; caudal peduncle thick; fins small and round or square.
Total length	250-350 mm	-----------------------------	150 mm
Color	Olive-gray to silvery, belly lighter. Sometimes irregular dorso-lateral blotches.	Dark overall, silver laterally, white below. Often with diffuse longitudinal stripes.	Dark overall, belly lighter, sometimes with diffuse longitudinal stripes.
Scales	Small, thin, slightly imbricate	Small, thin, slightly imbricate	Large, thick, broadly imbricate
Basal radii	Absent to weakly developed	Absent to weakly developed	present
Lateral-line scales	75 to 90 (typically > 78, 71 and 99)	73 to 83 (Usually < 80, 71 and 90)	62-74 (usually < than 70, 51 and 83)
Dorsal fin-rays	9 (rarely 8 or 10)	8 (rarely 7 or 9)	8 (rarely 7 or 9)
Anal fin-rays	9 (rarely 8 or 10)	8 (rarely 7 or 9)	8 (rarely 7 or 9)
Pelvic fin-rays	8-9 (7-9)		8 or 9
Length of head/depth of caudal peduncle (population mean)	>3.25	<3.2	≤3.0
Nuchal hump	Rare	-----------------------------	Rare
Total # vertebrae	43-49	-----------------------------	38-45 (usually <42)
Post-Weberian vertebrae	≥39 (extremes 36 and 42)	≥39 (extremes 36 and 42)	≤38 (extremes 35 and 41)
Pharyngeal teeth	2, 5-4,2	-----------------------------	2, 5-4,2

B. TAXONOMY

Roundtail chub (*Gila robusta*) and headwater chub (*Gila nigra*) are minnows of the family Cyprinidae. They are members of what has been called the *Gila robusta* complex or species group (Minckley and DeMarais 2000). The complex is comprised of seven taxa (bonytail chub *Gila elegans*, humpback chub *Gila cypha*, Virgin chub *Gila seminuda*, Gila chub *Gila intermedia*, Pahranagat roundtail chub *Gila jordani*, roundtail chub, and headwater chub (Gerber et al. 2001)), the first four of which are Federally-listed as endangered and the fifth proposed for such listing. All seven are endemic to various areas or habitats of the Colorado River basin

The only representative of the complex outside the Colorado basin is the entity nominally known as *Gila robusta* in basins of the Rios Yaqui, Fuerte, and Sinaloa in Mexico (Hendrickson et al. 1981, Hendrickson 1983, Campoy-Favela et al. 1989, Propst 1999). Although no formal redescription has been published yet, significant genetic differences between those roundtail chub populations in Mexico and roundtail chub in the Colorado River basin indicate the Mexican populations (outside of the Colorado basin) are substantially different, at the species level (possibly more than one distinct species), from that in the Colorado basin (Desert Fishes Recovery Team 2002, Voeltz 2002, S.M. Norris, Univ. of Michigan, pers. comm. February 2003). The upcoming book *Fishes of Mexico*, by R.R. Miller (assisted by S.M. Norris) will address the distinctness of non-Colorado basin chub in Mexico. Therefore, the definition of *Gila robusta*, as used in this petition, excludes *Gila* from the Rios Yaqui, Fuerte, and Sinaloa, and *Gila robusta* is considered to include only those within the Colorado River basin, both in the United States and in Mexico.

Gila robusta was first described by Baird and Girard in 1851 from specimens collected from the Zuni River in northeastern Arizona and northwestern New Mexico (Baird and Girard 1853). In 1874, *Gila nigra* was described from Ash Creek and the San Carlos River in east-central Arizona (Cope and Yarrow 1875).

Since the 1800's, *Gila robusta* and *G. nigra* have always been recognized as distinct entities, although at varying taxonomic levels. However, each has had several different names used over the years and the relationship of the two species to each other and to other members of the complex has undergone several revisions (see Miller 1945, Holden 1968, Rinne 1969, Holden and Stalnaker 1970, Rinne 1976, Smith et al. 1977, DeMarais 1986, Douglas et al. 1988, Rosenfeld and Wilkinson 1989, DeMarais 1992b, Dowling and DeMarais 1993, DeMarais 1995, Douglas et al. 1998, Minckley and DeMarais 2000, Gerber et al. 2001). At present both are recognized as distinct species (Minckley and DeMarais 2000). A summary of the nomenclature can be found in Voeltz (2002).

In general, the most commonly used scientific name for roundtail chub has been *Gila robusta* or *Gila robusta robusta.* For headwater chub, the most commonly used scientific name has been *Gila grahami* or *Gila robusta grahami.* However, under zoological nomeclature rules, *grahami* is not available for use for headwater chub and the name becomes *Gila nigra,* as described in Minckley and DeMarais (2000).

Relationships within the *robusta* complex have been the subject of extensive study using a variety of techniques (e.g. Miller 1945, Holden 1968, Rinne 1969, Holden and Stalnaker 1970, Rinne 1976, Smith et al. 1977, DeMarais 1986, Douglas et al. 1988, Rosenfeld and Wilkinson 1989, DeMarais 1992b, Dowling and DeMarais 1993, DeMarais 1995, Douglas et al. 1998, Minckley and DeMarais 2000, Gerber et al. 2001). Although all seven taxa in the complex have been recognized as distinct (at some level) since the 1800's, their relationship to each other has been deliberated, various combinations and names proposed, and all seven have been considered at various times as subunits of an overarching species *robusta.* *Gila intermedia* (as *Gila gibbosa*) was first recognized as a species in 1854 (Baird and Girard 1854), *Gila elegans* in 1856 (Girard 1856), *Gila cypha* in 1946 (Miller 1946), *Gila seminuda* in 1875 (Cope and Yarrow 1875), and *Gila jordani* in 1950 (Tanner 1950), although acceptance of each as independent species has waxed and waned. Aided by recent advances in taxonomic techniques, most notably population genetics, all seven forms are now recognized as distinct species (Mayden et al. 1992, Minckley and DeMarais 2000, Gerber et al. 2001, Voeltz and Timmons 2001, Voeltz 2002), including recognition of both *Gila robusta* and *Gila nigra* as separate species (Minckley and DeMarais 2000) with differing distributions and habitats. Minckley and DeMarais (2000), for example, concluded:

> "persistent parapatry of morphologically distinguishable *robusta*, *intermedia*, and *nigra* has been documented, confirmed, and reconfirmed by collections since the 1920s by C.L. Hubbs, R.R. Miller, and WLM and students. In no instance was any two of the three caught at the same locality, although *intermedia* or *nigra* commonly lives upstream or in smaller tributaries and *robusta* downstream or in the mainstream of the same creeks or rivers."

Based on the all of the above information, particularly the formal taxonomic determination of Minckley and DeMarais (2000), we are petitioning endangered status for *G. robusta* and *G. nigra* as separate and distinct species. Based on the requirements for discreteness and significance that qualify populations of *G. robusta* in the upper and lower Colorado basins as distinct population segments under the February 7, 1996 joint policy of the Fish and Wildlife Service and National Oceanic and Atmospheric Administration (61 FR 4722-4725)(see below), we are petitioning endangered status only for the distinct population segment of roundtail chub in the lower basin.

C. REPRODUCTION/ONTOGENY/GROWTH

Although life history differences likely exist between roundtail and headwater chub, any such distinctions are blurred by the taxonomic history and the failure of most studies to distinguish between the two species. Generalized information given in this and the following sections on life history are believed to apply to both species, except where noted. Based on the locations of their work, researchers cited below were working with both headwater and roundtail chub. Neve (1976) may have been studying a mixed roundtail/headwater chub population and Barrett and Maughan (1995) were working with both species. Bestgen (1985), Bestgen and Propst (1989), and Propst (1999) were most likely working with headwater chub, but may also have included some roundtail chub in their studies. Vanicek and Kramer (1969), Siebert (1980), Minckley (1981), Muth et al. (1985), Schreiber and Minckley (1981), Kaeding et al. (1990), Rinne (1992), Rinne and Stefferud (1996), Rinne et al. (1998), Bryan and Robinson (2000), and Brouder et al. (2000) were working with roundtail chub.

Roundtail/headwater chub first reproduces at ages 2-5 with females at 100-180 mm total length (Neve 1976, Bestgen 1985, Brouder et al. 2000). External changes occur in both male and females during spawning with both sexes possessing breeding tubercles. In males, tubercles are usually uniformly distributed from the head to the base of the dorsal fin, and rarely to the base of the caudal fin (Vanicek and Kramer 1969). Tubercles may also occur on the fins. Females display tubercles only on the head, operculum, pectoral fin, and caudal peduncle (Neve 1976, Bestgen 1985). Both males and females may develop red or orange coloration on their opercles, posterior parts of lips, paired fin bases, and on ventral-lateral surfaces. Males also develop distinct bicolored bodies, dark above and lighter below. Females may also develop these pigment changes, although not as intense (Rinne and Minckley 1991).

Spawning takes place during spring and early summer when spring runoff is subsiding (February through June), and when water temperatures are approximately 20ºC (Neve 1976, Minckley 1981, Bestgen 1985, Propst 1999, Brouder et al. 2000). Bestgen et al. (1985) reported that temperature was the most significant environmental factor triggering spawning in the upper Gila River, but recognized that other factors may be primary in locations such as Fossil Creek, where water temperatures are relatively constant. Suitable water temperatures for spawning were reported as approximately 14 to 24ºC by Kaeding et al. (1990), as 20ºC by Bestgen (1985), and as 18ºC by Vanicek and Kramer (1969).

Spawning involves several males escorting a female, during which the males remain in close contact with the female and all remain 6 to 10 cm above the substrate (Neve 1976, Brouder et al. 2000). Spawning occurs in pool, run and riffle habitats. Eggs are scattered randomly at the same time milt is released. Eggs, which range in size from 0.48-1.69 mm in diameter, are adhesive and demersal. They are scattered over gravel substrates of pools or moderate velocity runs where they sink to the bottom and adhere to the substrate (Sigler and Miller 1963, Brouder et al. 2000). Females produce anywhere from 1,000 to 36,000 eggs (Neve 1976, Brouder et al. 2000). At water temperatures of 19-20ºC, eggs hatch after 4-7 days without parental care (Muth et al. 1985). Larval periods last up to 53 days.

Roundtail/headwater chub are believed to have an average life span of about 8 to 10 years, with fish in larger streams living longer than those in smaller streams (Bestgen 1985, Brouder et al. 2000). Growth is relatively rapid, but is dependent upon water temperature and habitat size and other characteristics. Maximum size for roundtail and headwater is about 50 cm, but may vary substantially between habitats (Minckley 1973, Brouder et al. 2000).

D. DIET

Roundtail and headwater chubs are omnivorous and consume a large variety of insects, algae, gastropods, crayfish and fish. They are opportunistic feeders showing no apparent trends in food habits, instead feeding on whatever food is available (Vanicek and Kramer 1969, Neve 1976, Schreiber and Minckley 1981, Bestgen 1985, Rinne 1992).

Roundtail chub. In the Green River principal food items of roundtail chub >200 mm TL were terrestrial insects—mostly adult beetles, grasshoppers, and ants. Smaller individuals typically consumed larvae of Chironomids and nymphs of Ephemeropterans, feeding on a greater diversity of foods as they grew, including aquatic and terrestrial insects. Chubs were often seen feeding on surface drift material consisting of terrestrial insects and plant debris, including leaves, stems, seeds, woody fragments, and stems of horsetail (*Equisetum*). No seasonal or geographic differences in diet were observed. Eight percent of the stomachs examined contained fish remains (Vanicek and Kramer 1969).

In Aravaipa Creek food items of chub included nymphs of Ephemeroptera, Odonata, Belostomatidae, Trichoptera, Chironomidae, and Simuliidae, Coleopteran adults, Hymenoptera, fish, algae, detritus, and sand. Chubs were noted to be secretive animals, inhabiting deeper water near cover, yet occurrence of terrestrial organisms such as an iguanid lizard and ants, and a variety of benthic inhabitants (e.g., Odonata naiads), other fishes, and Belostomatids, indicated active feeding from bottom to surface. Opportunism appeared a common tendency (Schreiber and Minckley 1981). Chubs are the top carnivore in this low desert ecosystem, preying on larvae and juveniles of the other fishes that happened to occupy pools through innate life history characteristics or displacement by increased flows (Rinne 1992).

Headwater chub. Ontogenetic and seasonal changes in food habits of chub in Turkey Creek showed that fish consumed a variety of foods with no particular selection or preference (Table 2). Chubs from the Gila River exhibited similar food habits but also consumed fish (*Catostomus* sp. and longfin dace) and crayfish. Seasonal changes in diet probably reflected the availability of food (Bestgen 1985).

Bestgen (1985) found that trout (rainbow and rainbow x cutthroat hybrid trout) ate a wider variety of food items (additional items primarily of terrestrial origin) than chubs. He speculated that chubs were perhaps more discriminating in their selection of food items, or that trout occupied feeding stations that allowed greater access to terrestrial foods.

Table 2. Principle food items by season in stomachs of three size ranges of chubs from Turkey Creek (Bestgen 1985) .

Total Length	May	July	September	November	January	April
≤100 mm (n = 82)	Caddisflies, algae, misc. insect parts	Diptera, mayflies, algae, ostracods	Organic debris, insect parts	Mayflies, insect parts	Stoneflies	Insect parts
101-170 mm (n = 64)	Diptera, mayflies, algae	Diptera, Coleoptera, algae	Diptera, caddisflies, organic debris	Caddisflies, organic debris	Diptera, mayflies, caddisflies, stoneflies, insect parts, ostracods	Algae
≥170 mm (n = 26)	No data	No data	Gastropods	Caddisflies, Coleoptera	Empty (n = 1)	Diptera, mayflies, Gastropods,

In Fossil Creek principal food items of adult chubs were larval insects, Ostracods and plant material, although there was seasonal variation in food habits. Chubs were opportunistic feeders and apparently had no preferred food items, instead exploiting whatever food is present. The diversity of types of organisms consumed by the chubs suggested that they exploited every habitat available in the stream for food sources. Consumption of Ostracods indicated chubs foraged in backwaters, sediments provided bloodworms, riffles produced larvae of caddis and black flies, and vegetation was a source for dragonfly and mayfly larvae. Surface drifting prey was also consumed, as were two iguanid lizards. For adults, vegetation was probably consumed to obtain the organisms living on it, as little digestion of filamentous algae and macrophytes was observed. No fish were found in any stomachs examined. Fish <50 mm consumed only diatoms and filamentous algae with no seasonal variation. Empty stomachs were found in only 8% of specimens examined (n=453) (Neve 1976).

E. ASSOCIATED FISH SPECIES

Over its broad historical range, roundtail chub was associated with a comparatively large proportion of the native warmwater fishes of the Colorado River basin. Headwater chub, being confined to the smaller streams probably interacted with fewer native species (Miller 1950, Vanicek and Kramer 1969, Holden and Stalnaker 1975, Minckley 1985, Bestgen and Propst 1989, Minckley and Rinne 1991, Platania et al. 1991, Stefferud and Rinne 1995, Sigler and Sigler 1996).

Roundtail chub. Roundtail chubs co-occurred with a large proportion of the native warm water fishes in the Colorado River basin. In the upper Colorado River, roundtail chub frequently was associated with humpback chub, Colorado squawfish (*Ptychocheilus lucius*), speckled dace (*Rhinichthys osculus*), flannelmouth sucker (*Catostomus latipinnis*), and bluehead sucker (*Catostomus discobolus*) (Vanicek and Kramer 1969, Holden and Stalnaker 1975, Platania et al. 1991, Sigler and Sigler 1996). In the lower Colorado Basin the native fish assemblage commonly included roundtail chub, longfin dace (*Agosia chrysogaster*), speckled dace, spikedace (*Meda fulgida*), loach minnow (*Tiaroga cobitis*), Sonora sucker (*Catostomus insignis*), and desert sucker (*Pantosteus clarki*), and often Gila topminnow (*Poeciliopsis occidentalis*), Colorado squawfish, flannelmouth sucker, and razorback sucker (*Xyrauchen texanus*) depending on specific habitats available (Minckley 1985, Bestgen and Propst 1989, Minckley and Rinne 1991, Stefferud and Rinne 1995).

Headwater chub. Headwater chub co-occurred with many of the same species as the roundtail chub. In New Mexico, longfin dace, speckled dace, spikedace, loach minnow, Sonora sucker, desert sucker and Gila topminnow were commonly present, and Gila trout (*Oncorhynchus gilae*) in some waters. Except for Gila topminnow, all of the above species remain extant (Miller 1950, Bestgen 1985). In addition to the above fishes, Gila chub was also present but not sympatric with roundtail chub in Tonto Creek (Abarca and Weedman 1993).

The original fish fauna of the Colorado River has been increased from a total of 32 species to more than 80 (Minckley and Rinne 1991). A large diversity of nonnative fishes is now established within the historical range of roundtail chub. Red shiner (*Cyprinella lutrensis*), common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), green sunfish (*Lepomis cyanellus*), smallmouth bass (*Microterus dolomieu*i), channel catfish (*Ictalurus punctatus*), and many others occur throughout the original range of roundtail chub (Minckley 1973, Sublette et al. 1990, Sigler and Sigler 1996).

Introduction and invasion of nonnative species has led to declines in populations of headwater and roundtail chub. In Fossil Creek roundtail chub abundance (catch per unit effort [CPUE]) decreased and mean size of individuals increased concurrently with increase in range and abundance of smallmouth bass during 1994 to 1999 (Adil et al. 1999). In Turkey Creek, chubs were common and smallmouth bass uncommon in 1978, but by 1989 the proportions were reversed (Anderson 1978, Bestgen and Propst 1989). In the Verde River, changes in river hydrograph and apparent undefined anthropogenic impacts appeared related to the observed changes from upstream to downstream in fish community structure, which is reflected in both the ratio of native to nonnative components and linear species-specific changes. Occurrence of chubs (presence/absence in samples) declined from upstream to downstream, reflecting changes in river hydrograph (unregulated to regulated) and anthropogenic impacts (undeveloped to developed) (Rinne et al. 1998).

F. HABITAT REQUIREMENTS

Roundtail and headwater chubs occupy similar habitats in that both are pool-dwellers in warm water, mid-elevation streams and rivers throughout their ranges. They spawn in spring, often in relationship to flooding. A natural hydrograph is apparently important for completion of their life cycle (Barber and Minckley 1966, Vanicek and Kramer 1969, Neve 1976, Kynard 1976, Anderson and Turner 1978, Marsh and Minckley 1982, Bestgen 1985, Ziebell and Roy 1989, Bestgen and Propst 1989, Kaeding et al. 1990, Rinne 1992, Abarca and Weedman 1993, Stefferud and Rinne 1995, Barrett and Maughan 1995, Rinne and Stefferud 1996, Rinne and Stefferud 1997, Velasco 1997, Brouder et al. 2000, Brouder 2001). In the relatively depauperate fish fauna of the Southwest, few congeneric species are sympatric. This helps to explain the extreme habitat separation, at the intrafamilial level, found in these fishes. Each of the various minnows commonly occurring in southwestern streams, for example, occupies relatively distinct habitat, with overlap occurring depending on the ontogeny of the species life histories (Barber and Minckley 1966).

Roundtail chub

Elevation, temperature, and water chemistry. In the Green River, the threshold temperature for spawning was 65 F (18C). Higher or lower water temperatures after impoundment by Flaming Gorge Dam resulted in an apparent reduction in growth rate of chub (Vanicek and Kramer 1969). In the Phoenix area, canals where chub occur, water temperatures ranged from 15 to 40 C, and dissolved oxygen was <5 to nearly 20 mg/l (Marsh and Minckley 1982).

Macro Habitat. In Green River, chubs apparently avoided turbulent, canyon areas (Kaeding et al. 1990). Adult roundtail chub in Verde River positively selected for backwater pools that were boulder formed, pocket waters, and corner pools, and avoided lateral scour pools. Adult chub avoided depths <20 cm, and used depths >20 cm. Chub selected for velocities ≤20 cm/s and used velocities >20 cm/s in proportion to their availability, and did not select for any substrate type. Chub avoided cover types associated with shallow water (i.e., shoreline and overhanging vegetation) and selected for instream boulders. In West Clear Creek, glides were the predominant macro-habitat type available, but young-of-year, juvenile, and adult chubs selected for pool habitat. Juvenile and young-of-year chubs used glides less than expected, and juveniles used riffles less than expected. Adult use of riffles and glides was similar to available proportions. Young-of-year avoided depths of 51-100 cm and were never collected in depths >100 cm. Juveniles avoided boulders and bedrock. Young-of-year avoided bedrock and cobble. All life stages were collected during the day in and around some type of cover; primarily instream boulders associated with pocket water areas (Brouder et al. 2000).

Occupation of pool-type habitats by almost 60% of Sonora sucker and roundtail chub taken in upper Verde River also suggests the importance of the lentic component. Where chubs were found, pool depths averaged 46 cm (20-90) and velocities 22 cm/s (0-70). Roundtail chub were most abundant (#/100 m2) in backwater pools and lateral scour pools (pools adjacent to swift water). Chubs were also captured in glides, runs, and riffles in low abundance (Rinne 1992, Stefferud and Rinne 1995, Rinne and Stefferud 1996).

Aravaipa Creek is a low-gradient (<1%), narrow (3-5 m), often braided, hydrologically stable stream, with a gravel-pebble substrate. Modal discharge ranges between 0.5 and 1.0 m^3/sec (18-35 cfs). Roundtail chub used habitat with depth of 33.2 cm, velocity of 15.8 cm/s, (and sand/gravel substrate). Roundtail chub were secretive and often found in pools along canyon walls, with undercuts (Rinne 1992). Collections of chubs occurred in pools behind diversion structures, in small eddies behind boulders, in pockets beneath ledges, and in occasional pools near canyon walls. In relative terms, *G. robusta* was consistently uncommon throughout the creek. Roundtail chubs require pools in which to live. Movement of sand into streams of the Southwest during and following an erosion cycle of the late 1800's (Hastings 1959, Miller 1961) probably decimated populations of chub, even in streams that maintained permanent flow (Barber and Minckley 1966).

Roundtail chub rarely used irrigation diversions from the Verde River, probably because of lack of suitable habitat (Ziebell and Roy 1989). In the Verde, most of the chubs were consistently in an area that was characterized by riffles followed by deep pools with undercut banks and logs or tree roots to offer cover. If habitat differed markedly from this type, then roundtail chubs were either few in number or absent (Ziebell and Roy 1989).

Adult and young fish used different habitat when feeding. Young fish moved from slow water areas into shallower, faster habitat at the heads of pools. Adults fed in medium velocity runs (0.3 – 0.5 m/sec [1-1.6 feet/second]) well away from streambanks. When disturbed, fish of all sizes took refuge in the deepest, most cover-filled areas available, which was usually the least abundant in the river. In Gila River valleys the amount of deep pool habitat available was related to the number of streambank trees that streamflow had undercut. Loss of large trees was probably related to reduction in number of chubs in the Gila River (Bestgen 1985).

In the Phoenix canal systems, chubs were rare. They were first collected in the canals in 1890, and continue to be present. Most modern canals are steep-sided, concrete-lined, and of uniform depths with a variety of macrophytes, including *Potomogeton pectinatus, P. crispus*, *Zannichellia palustris*, *Myriophyllum spicatum*, *M. brasiliense,* and *Typha domingensis*. Fish were concentrated, and essentially restricted to, the largest canals. Greatest numbers and diversity occurred within the first few kilometers downstream from the Granite Reef Diversion. Beyond 25 km, only a few individual red shiners or western mosquitofish (*Gambusia affinis*) were found and most collecting sites yielded no fishes (Marsh and Minckley 1982).

<u>Spawning habitat.</u> In Verde River, chub deposited eggs over clean gravel at the base of a riffle in close proximity to the transition from riffle to glide. Depth was 31.6 cm and velocity was 43.8 cm/s. Spawning (mid-May) came 3 weeks after a small spate (Brouder et al. 2000). In the Green River, ripe males were collected in shallow pools and eddies over rubble or boulder bottoms covered with silt (Vanicek and Kramer 1969).

Cover. Vegetation/pool habitat was important rearing area for young chubs in Eagle Creek (Kynard 1976).

Discharge. A natural hydrograph and spring flooding appears important in initiation of spawning and/or recruitment of roundtail chub (Vanicek and Kramer 1969, Rinne 1992, Stefferud and Rinne 1997, Velasco 1997, Brouder et al. 2000, Brouder 2001).

In the Green River, no consistent relationship between mean annual discharge and year-class strength of chubs was apparent. However, the range of chubs in Green River was reduced subsequent to initiation of Flaming Gorge Reservoir operations in late 1962, suggesting that dam operations and regulation of discharge had some influence on either spawning or recruitment (Vanicek and Kramer 1969).

A natural hydrograph and sections of streams where late-winter/early-spring floods ($\geq$40 – 50 m^3/s [1400-1800 cfs]) occurred and where an intact riparian corridor existed was beneficial for the reproduction, recruitment, and survival of chub in the Verde River. There was a strong relationship between maximum daily discharge in the late-winter/early-spring of a given year and mean CPUE of age 1 roundtail chub in the following year. Floods can restructure substrate material (Mueller 1984), which may have increased spawning success in Verde River by clearing interstitial spaces for eggs, ultimately leading to increased recruitment (Stefferud and Rinne 1997, Brouder et al. 2000, Brouder 2001).

Because roundtail chub can live 7 years (Vanicek and Kramer 1969), a decade-long drought or a regulated discharge could severely reduce populations. Additionally, in the event of reduction in flow, intermittent surface flow could result in many of the smaller streams. If that occurred, only chub and Sonora sucker would have a higher probability of surviving under such conditions than the other minnows present (Rinne 1992).

Adult chub elicit more immediate negative response to increased variance in discharge by becoming uniformly distributed among reaches in the creek. Native fishes in Aravaipa Creek depend on disturbance regime (Velasco 1997).

Headwater chub

Elevation, temperature, and water chemistry. Chubs occupied tributary and mainstream habitats in the Gila River at elevations of 1,325 m to 2,000 m (Bestgen and Propst 1989). Where headwater chubs occur, maximum water temperatures range from 20 to 27 C, and minimum water temperatures are around 7 C (Kynard 1976, Bestgen and Propst 1989, Barrett and Maughan 1994). Water temperature in Fossil Creek was a consistent 19C (Barrett and Maughan 1995). Spawning in the Verde River occurred in the spring when average water temperature was 18.3 C (Brouder et al. 2000). Temperature may limit distribution (Bestgen and Propst 1989).

In Eagle Creek, water chemistry parameters were unremarkable. pH was 7.6 to 8.5. Nitrates were usually less than 0.05 mg/l. Ortho-phosphate levels were usually below 0.05 mg/l, however ortho-phosphate was 0.5 to 1 mg/l at Dry Prong where abundant young chubs were collected. Eagle Creek had TDS levels between 150 and 190 mg/l (Kynard 1976). pH readings in Tonto Creek were circumneutral to moderately alkaline for Tonto Creek and its tributaries (Abarca and Weedman 1993). In Harden Cienega total alkalinity was 234 mg/l, hardness 88, sulfate 4.0 mg/l, nitrate 0.5 mg/l, nitrite 0.0025 mg/l, turbidity 1 NTU, conductivity 180 microS/cm^2, TDS 192 mg/l, and total soluble salt 168 mg/l (Anderson and Turner 1978).

Macro Habitat. Adult headwater chubs (to 435 mm TL) were usually in large pools in the main Gila River. Young-of-year and juvenile chub (<200 mm) usually were found in pools and areas with undercut banks and slow current. Typical adult microhabitat consisted of deep, nearshore pools adjacent to swifter riffles and runs. Chubs 40-95 mm used 0.3 m (0.2-0.6) deep, 0.1 m/s (0.0-0.2) current within 0.5 m (0.0-1.5) of bank over sand. Chubs >120 mm TL used 0.6 m deep (0.3-2.1), 0.15 m/s (0.0-0.4) velocity within 0.3 m (0.0-1.2) of bank over sand-gravel substrate (Anderson and Turner 1978, Bestgen and Propst 1989). Thirteen percent of chubs in Tonto Creek were taken in run habitats, 1.5% in riffles, 27% in pools, and 38% in backwaters (Abarca and Weedman 1993).

Lack of pool habitat has been documented to limit numbers of large adult headwater chubs and may limit the species distribution. Voeltz (2002) states:

> "In the Gila River mainstem, Bestgen (1985a) found that 90% of the chubs occurring below Mogollon Creek in New Mexico were less than 110 mm total length. Habitat in this reach consisted primarily of run and riffles, with pools rare and almost exclusively formed by undercuts beneath tree root systems. Scarcity of pool habitat was suggested as a potential reason for the lack of large adults. Lack of suitable habitat (mainly deep pools) was suggested as a limiting factor to downstream distribution of chubs in the mainstem Gila River of New Mexico."

Detailed habitat preference studies determined that in Wet Beaver Creek headwater chub consistently used the deepest (depth >1.8 m) and lowest velocity (velocities <0.086 m/s [0.28 feet/sec.]) portions of the study area. Adults did not use riffles (velocities >0.14 m/s [) or shallow areas. Values of depth preferences declined rapidly at depths above and below 2.1 m. In Fossil Creek adult chub generally used deep (depth >1.8 m), slow (velocity <0.10 m/s) waters, but they also occasionally used shallow (depth <0.9 m) and swift (velocity >0.46 m/s) waters. Juveniles used riffles more than adults did. Preference values for adult chub in Fossil Creek were highest at 0.23 m/s (0-0.96 m/s) and then declined gradually until they reached zero. Preference values for depth appeared to be bimodal, with a lesser peak between 0.9 m and 1.2 m and the highest values at depths between 2.1 and 3.1 m. Subadult chub had high preference values for velocities near 0.15 mps and avoided velocities > 0.61 mps. Preference values were high for depths between 0.9 and 1.5 m, but low for depths >2.1 m (Barrett and Maughan 1995).

<u>Spawning habitat.</u> Spawning occurred in spring in Fossil Creek and was observed in March. Males were observed in close contact with females 6-10 cm above the substrate. All spawning occurred in pool-riffle areas with sandy-rocky substrates. After emerging,

fry inhabited water along the stream banks and shallow backwaters where they fed on diatoms and filamentous algae, and utilized macrophytes for protection (Neve 1976).

Cover. The highest preference value for cover in Wet Beaver Creek was for instream cover. Adults had high preference values for any cover but areas adjacent to large instream objects had the highest value. The area most often occupied had a bedrock bottom and was adjacent to a large cliff. There was a deep crevice in the bedrock at the base of the cliff. When disturbed, the chub would swim into this crevice. They also congregated near large shadows and entered these shadows when disturbed (Barrett and Maughan 1995). Juvenile chubs displayed little preference for specific habitats with exception of the fry, which were found along the stream banks. Adult chubs preferred pool and backwater habitats. Spawning was observed in shallow water in pool-riffle habitats over gravel. Development of ova probably took place in the sediments (Neve 1976).

In the Gila River, cover was usually present and consisted of large rocks, tree rootwads, submerged organic debris, undercut cliff walls, or deep water. Adult chubs were observed feeding in moderate-velocity pools and runs but retreated to deep pools and undercut streambanks when disturbed. Smaller chubs generally occupied shallower, low-velocity water adjacent to overhead bank cover. Chubs congregated in certain pools, and were not found in similar, nearby habitats (Bestgen and Propst 1989).

Substrate. Substrate most often used by headwater chub in Wet Beaver and Fossil creeks was rubble and gravel. Preference values were high for sand but also relatively high for all substrates except bedrock and large boulders. (Anderson and Turner 1978, Barrett and Maughan 1995).

Discharge. Chub were eliminated from the San Francisco River during drought in the 1950's, aided by flow depletion, drought-reduced habitat size, and predation by flathead and channel catfishes. A similar scenario probably caused loss in the Gila River below Redrock. In habitats where smallmouth bass occurred, chub recruitment was apparently sporadic and populations were mainly composed of large adults (Bestgen and Propst 1989).

G. HISTORIC AND CURRENT DISTRIBUTION

Of the seven taxa in the *Gila robusta* complex, four (Virgin, Gila, Pahranagat roundtail, and headwater chubs) are found only in the lower (defined as below Glen Canyon Dam) Colorado River basin and their ranges never extended into the upper basin (Lee et al. 1980). The remaining three (humpback, bonytail, and roundtail chubs) had ranges that include both the upper and lower basins, although the humpback chub never historically ranged downstream of about the present location of Lake Mead (Minckley 1973). The bonytail chub and roundtail chub historically ranged throughout the upper and lower basins, including the Gila River basin. Roundtail chub, which ranged further upstream in the Gila basin than bonytail, was the most widespread of the *Gila robusta* complex species. Only the lower Colorado River basin range of roundtail chub is discussed below, in keeping with our petition for listing of a discrete population in the lower basin.

Roundtail chub. In the lower Colorado River Basin, the historic range of roundtail chub included most major river drainages with the exception of the Virgin, Moapa, and pluvial White River basins, which supported other species of *Gila*. Roundtail chub were historically found in the mainstems and many perennial tributaries of the Colorado, Little Colorado, Bill Williams, Gila, Verde, Salt, San Francisco, San Pedro and Zuni Rivers (Voeltz 2002).

Because most of the lower Colorado River system was very poorly sampled prior to the late 1900's, reconstruction of historic ranges and distributions of native fishes is subject to interpretation. Reconstructions of the historic range of roundtail chub in the lower Colorado River basin differ from Bezzarides and Bestgen (2002) to Voeltz (2002). Bezzarides and Bestgen use a human-oriented approach, generally excluding areas unless historic records exist to prove the presence of roundtail chub. As a result, they exclude significant portions of the mainstem Colorado, Gila and Little Colorado Rivers. Voeltz uses a more ecological approach, including stream areas between historic records, such as all of the mainstem Colorado, Gila, and Little Colorado Rivers, based on the absence of barriers, the probable historic presence of suitable habitat, and the scarcity of historic sampling. The Fish and Wildlife Service, which commissioned Voeltz's work, agreed with his approach and also recommended that appropriate sections of the Agua Fria, Hassayampa, and San Simon River basins be included in the report as part of the historic range (USFWS 2001b). Use of the broader approach is supported by the absence of early sampling in many areas, indications of historic accessibility and habitat suitability, and current presence of natural populations of native fish species in areas of the Gila River basin for which no records exist prior to 1960. Examples of natural populations of native fish that remained "undiscovered" until the late 1900's include loach minnow in the Blue and Black Rivers which were discovered in 1977 and 1996, respectively, and spikedace in Eagle Creek, which was found in 1985 (Anderson and Turner 1977, Bagley et al. 1996, Marsh 1990, Marsh et al. in press). Although as one of the larger native fishes, roundtail chub were more likely to be found, the species was not documented from the Bill Williams, Big Sandy, or Santa Maria Rivers until the 1970's (Voeltz 2002).

Bezzarides and Bestgen did not generate a total kilometer estimate for historic roundtail chub range. Voeltz (2002) estimated that the historic range of roundtail chub included 4,500 km of stream. Adding the Service's recommendation to that of Voeltz gives an estimated 4,700 km of stream that is believed to have comprised the historic range of roundtail chub.

Roundtail chub are now extirpated from large areas of their historic range in the lower Colorado River basin. These areas include the Colorado River mainstem; Gila River throughout Arizona and in its lower section in New Mexico; Agua Fria River; Big Sandy River; Bill Williams River mainstem; Blue River; Hassayampa River; Little Colorado River mainstem; San Francisco River; San Pedro River mainstem; San Simon River; upper Salt River; and Zuni River. Bezzarides and Bestgen (2002) and Voeltz (2002) estimate that roundtail chub has been extirpated from 68-70% of its historic range in the

Colorado River basin. Given the omission of several areas of historic range from their calculations, those estimates are conservative.

The known present range of the roundtail chub in the lower Colorado River basin includes 19 streams (Tables 4 and 5, Figure 1, Voeltz 2002). The status of roundtail chub is unknown in an additional 10 streams, where the species may or may not still exist. Areas of these streams where roundtail chub are known to exist and for which their status is known total 800 km (Voeltz 2002). Stream areas where roundtail chub may still persist, but where data is lacking, total 650 km. Thus, roundtail chub are known to persist only in 18% of their historic range.

Headwater chub. The historic range of the headwater chub was small and was limited to several headwater areas within the Gila River basin. Those included the Tonto Creek subbasin within the Salt River drainage, east-side tributaries in the middle Verde River basin, the upper Gila River and its forks, the San Carlos River basin, and possibly headwater portions of the Agua Fria and Hassayampa Rivers (USFWS 1981, Minckley and DeMarais 2000, Voeltz 2002). Voeltz estimated historic range of headwater chub to include approximately 500 km of stream.

Historic sampling tended to emphasize larger, more accessible streams and omit headwater areas, so that the historic distribution of headwater chub is poorly known. Insofar as is known, headwater chub has been extirpated in Christopher Creek, Horton Creek, and Rye Creek. Populations in other tributaries of the four documented basins are also thought to have been lost and many populations now occupy much smaller areas than historically. If the species was ever present in the Agua Fria or Hassayampa River basins, it has been extirpated. Voeltz (2002) estimates that headwater chub has been extirpated in 50% of its historic range.

The known present range of headwater chub includes 13 streams (Tables 4 and 5, Figure 1, Voeltz 2002). The status of the species in an additional 3 streams is unknown[1]. Areas

[1] See footnote 1.

of these streams where headwater chub is known to exist and for which its status is known total 200 km (Voeltz 2002). Stream areas where headwater chub may still persist, but where data is lacking, total 50 km. Thus, headwater chub is known to persist in only 40% of its historic range.

Table 3. Known and unknown populations of roundtail chub.

SUBBASIN	STREAM	STATUS
Little Colorado	Chevelon Creek	unstable-threatened
Little Colorado	East Clear Creek	stable-threatened
Bill Williams	Boulder Creek	stable-threatened
Bill Williams	Burro Creek	unstable threatened
Bill Williams	Conger Creek	unknown
Bill Williams	Francis Creek	stable-threatened
Bill Williams	Kirkland Creek	unstable-threatened
Bill Williams	Santa Maria River	unstable-threatened
Bill Williams	Sycamore Creek	unstable-threatened
Bill Williams	Trout Creek	unstable-threatened
Bill Williams	Wilder Creek	unknown
upper Gila	Eagle Creek	unknown
upper Gila	upper Gila River	unstable-threatened
San Pedro	Aravaipa Creek	stable-threatened
Salt	Black River	unknown
Salt	Canyon Creek	unknown
Salt	Carrizo Creek	unknown
Salt	Cedar Creek	unknown
Salt	Cherry Creek	stable-threatened
Salt	Cibecue Creek	unknown
Salt	Corduroy Creek	unknown
Salt	Salome Creek	unstable-threatened
Salt	Salt River	unstable-threatened
Salt	White River	unknown
Verde	Fossil Creek	unstable-threatened
Verde	Oak Creek	unstable-threatened
Verde	Verde River	unstable-threatened
Verde	West Clear Creek	stable-threatened
Verde	Wet Beaver Creek	unstable-threatened

Table 4. Known and unknown populations of headwater chub.

SUBBASIN	STREAM	KILOMETERS	STATUS
San Carlos	Ash Creek		Unknown
San Carlos	San Carlos River		Unknown
Gila	upper Gila River, inc. East, West, and Middle Forks		unstable-threatened
Salt	Buzzard Roost Creek		stable-threatened
Salt	Gordon Creek		stable-threatened
Salt	Gun Creek		unstable-threatened
Salt	Haigler Creek		stable-threatened
Salt	Marsh Creek		stable-threatened
Salt	Rock Creek		stable-threatened
Salt	Spring Creek		stable-threatened
Salt	Tonto Creek		unstable-threatened
Verde	Deadman Creek		stable-secure
Verde	East Verde River		unstable-threatened
Verde	Fossil Creek		unstable-threatened
Verde	Webber Creek		unstable-threatened
Verde	Wet Bottom Creek		unknown
Information taken from Voeltz 2002			

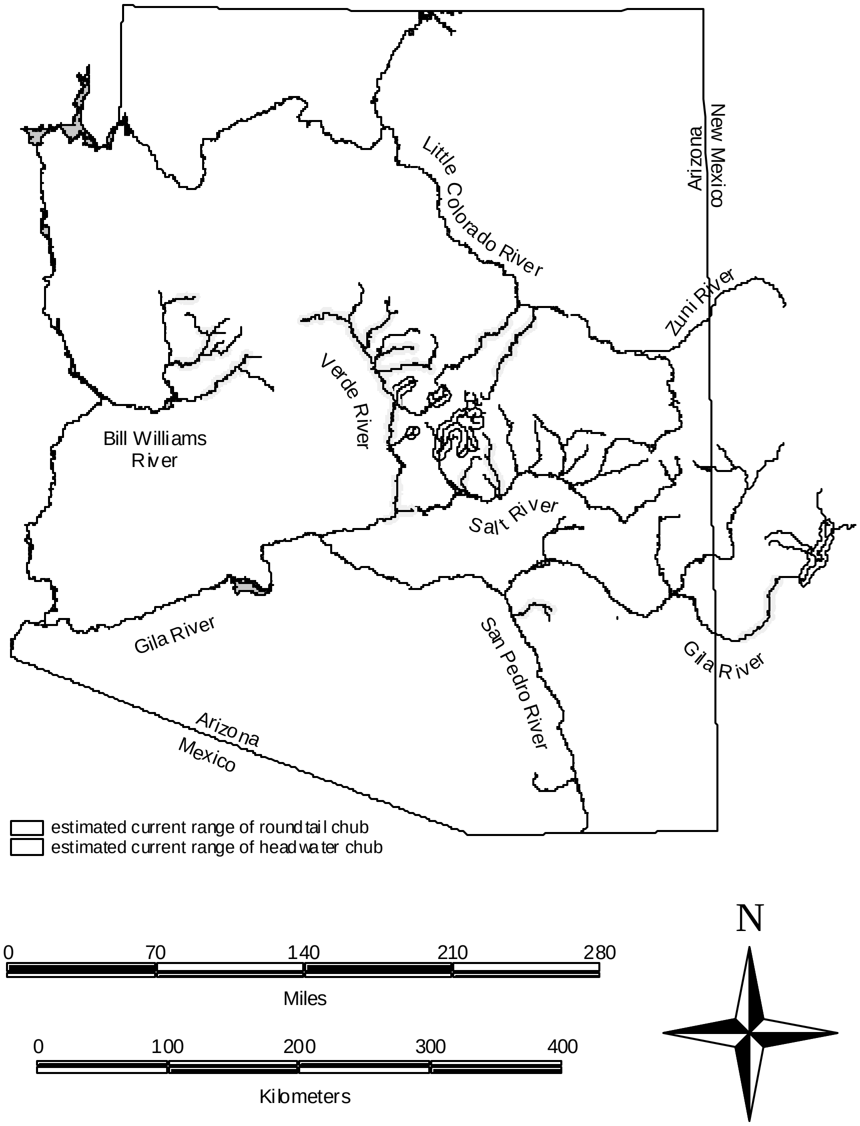

Figure 1. Estimated range of known populations of roundtail and headwater chub from Voeltz (2002).

I. The roundtail chub in the lower Colorado River Basin constitutes a distinct population segment

The U.S. Fish and Wildlife Service will consider a population to be a distinct population segment (DPS) if it is “discrete” in “relation to the remainder of the species to which it belongs" ***and*** it is "significant" to the species to which it belongs. According to Fish and Wildlife's current policy regarding recognition of distinct vertebrate populations (Federal Register V. 61, No. 26, February 7, 1996), a species is considered discrete if it is "markedly separated from other populations" because of "physical, physiological, ecological, or behavioral factors;" ***or*** it is "delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4 (a) (1) (D)." The policy further clarifies that a population need not have "absolute reproductive isolation" to be recognized as discrete. A population is considered significant based on, but not limited to, the following factors: 1) "persistence of the discrete population segment in an ecological setting unusual or unique for the taxon" 2) "loss of the discrete population segment would result in a significant gap in the range;" 3) the population "represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range ;" or 4) the population "differs markedly from other populations of the species in its genetic characteristics" (Federal Register V. 61, No. 26, February 7, 1996).

Discreteness. Historically, roundtail chub had a more-or-less continuous distribution throughout the upper and lower Colorado River Basins, connected by occupation of the mainstem Colorado River. Because of that, interbreeding occurred. Minckley (1979), however, believed that roundtail chub were never very common in the lower Colorado River mainstem, and thus interbreeding was probably minimal. Bezzerides and Bestgen (2002) mapped possible historic range based on collections, hypothesizing that two discrete population centers, one in the upper and one in the lower basin, exist and are presently separated by about 120 km. They conclude: "[a]lthough historically distributed throughout cool and warmwater reaches of the CRB [Colorado River basin], two roundtail chub population centers are evident."

Although roundtail chub in the upper and lower basins likely met the criteria of discreteness prior to construction of Glen Canyon Dam and Lake Powell in 1966, since that time reproductive isolation of roundtail chub in the lower and upper Colorado River basins has been complete. In theory unilateral flow of fish and genetic material is possible in a downstream direction, but it is highly unlikely due to the absence of roundtail chub in the mainstem Colorado River above and below Lake Powell, the presence of extensive predatory nonnative fish in Lake Powell, and the physical impediments to movement posed by the reservoir and dam.

The historic lack of substantial contact and genetic transport between the upper and lower Colorado River basins is supported by existing genetic data which show the upper and lower Colorado River basin roundtail chub to have significant genetic distinctiveness (DeMarais 1992b, Dowling and DeMarais 1993, Minckley and DeMarais 2000, Gerber et al. 2001) (see later discussion under signficance).

The pattern of distinctiveness between upper and lower Colorado River basin roundtail chub echoes the larger pattern of distinctiveness of fish faunas between the two basins. Of 54 fish species or subspecies in the Colorado River basin, only 8 were historically found in both the upper and lower basins (Carlson and Muth 1989). Two of these, the humpback chub and the bluehead sucker (*Catostomus discobolus*) entered the lower basin only in the Little Colorado and Grand Canyon areas at the extreme upper end.

Thus, roundtail chub in the lower Colorado River basin are “markedly separated” by physical, ecological, and behavioral factors from the other populations of the taxon in the upper basin. Further evidence of this separation is provided by quantitative measures of genetic discontinuity, which will be discussed further below.

Significance. Roundtail chub in the lower Colorado River Basin meets three relevant criteria for consideration of significance, including marked differences in genetic characteristics, occurrence in a unique ecological setting, and that loss of the population would result in a significant gap in the species range. The significance criterion which addresses remaining natural segments of widely introduced species does not apply to this species.

1. Listing of roundtail chub as a lower Colorado River basin DPS will provide for persistence of the species in an ecological setting that is unique for the taxon.

Although roundtail chub select relatively similar habitat types in the lower and upper Colorado River Basins (P.C. Marsh , AZ State Univ., pers, comm. 2002), there are broad ecological differences between the basins which lead to significant difference in the overall habitat of the species.

Bailey (1995) delineated ecoregions of the United States based on a combination of climate, vegetation, geology and other factors. Populations of roundtail chub in the lower basin are primarily found in the Tonto Transition and Painted Desert Sections of the Colorado Plateau Semi-Desert Province in the Dry Domain, and the White Mountain-San Francisco Peaks-Mogollon Rim Section of the Arizona-New Mexico Mountains Semi-Desert-Open Woodland-Coniferous Forest Province Dry Domain. Populations of roundtail chub in the upper basin are primarily found in the Northern Canyonlands and Uinta Basin Sections of the Intermountain Semi-Desert and Desert Province in the Dry Domain, and the Tavaputs Plateau and Utah High Plateaus and Mountains Sections of the Nevada-Utah Mountains Semi-Desert-Coniferous Forest Province in the Dry Domain (Bailey 1995). These ecoregion differences result in significant differences in hydrograph, sediment, substrate, nutrient flow, cover, water chemistry, and other habitat variables of roundtail chub.

Among broad differences in parent material, geomorphology, soil type, vegetation and climate between these provinces, differences in the type and timing of precipitation are probably most significant to roundtail chub. There are differences in precipitation amounts between the two basins, with the upper basin (6-60 inches/year [Miller and Hubert 1990]) somewhat less arid than the lower (5-25 inches/year [Sellers 1974]). But this is less important than the type and timing of precipitation, which are major factors in determining the pattern of streamflow, and which when plotted as the amount of runoff or discharge against time are known as a hydrograph (Dunne and Leopold 1978). The hydrograph of a stream is a major factor in determining habitat characteristics and their variability over space and time.

Habitats of roundtail chub in the lower basin have a monsoon hydrograph or a mixed monsoon-snowmelt hydrograph. A monsoon hydrograph results from distinctly bimodal annual precipitation, which creates large, abrupt, and highly variable flow events in late summer and large, longer, and less variable flow events in the winter (Burkham 1970, Sellers 1974, Minckley and Rinne 1991). Monsoon hydrographs are characterized by high variability, including rapid rise and fall of flow levels with flood peaks of one or more orders of magnitude greater than base, or "normal low" flow (Burkham 1970). As you can see in Table 4, in the unregulated upper portion of the Verde River in Arizona the average annual peak flood is 20 times greater than the annual mean flow (which is a little higher than base flow). In addition, the maximum recorded high flood is 12 times greater than the annual peak flood. Figure 1 shows the hydrograph of the Verde River and illustrates its high degree of variability.

In the upper basin, roundtail chub habitats have strong snowmelt hydrographs, with some summer/fall/winter precipitation, but with the majority of major flow events in spring and early summer (Bailey 1995, Carlson and Muth 1989, Miller and Hubert 1990). Snowmelt hydrographs are characterized by low variability, long, slow rises and falls in flow and peak flow events that are less than an order of magnitude greater than the base flow. As Table 4 shows, in Green River in Wyoming, Colorado, and Utah, prior to regulation by Flaming Gorge Dam, the average annual peak flood is only 5 times greater than the annual mean flow, and the maximum recorded high flood is only 2 times greater than the annual peak flood. The Green River hydrograph in Figure 2 illustrates the lesser degree of variability in the Green River than the Verde River.

Table 5. Comparison of hydrograph characteristics of representative upper and lower Colorado River basin roundtail chub habitats.

	Annual Mean Discharge (cfs)	Ave. Annual Peak Discharge (cfs)	Maximum Recorded Instantaneous Peak (cfs)	Watershed Size (square miles)	Period of Record
Verde River, above Horses-hoe Dam (near Tangle Creek)	591	12,410	145,000	5,858	52
Green River, near mouth (before Flaming Gorge Dam)	6492	32,000	68,100	44,850	61

data from Collier et al. 1996, Pope et al. 1998, USGS 2003 cfs = cubic feet per second

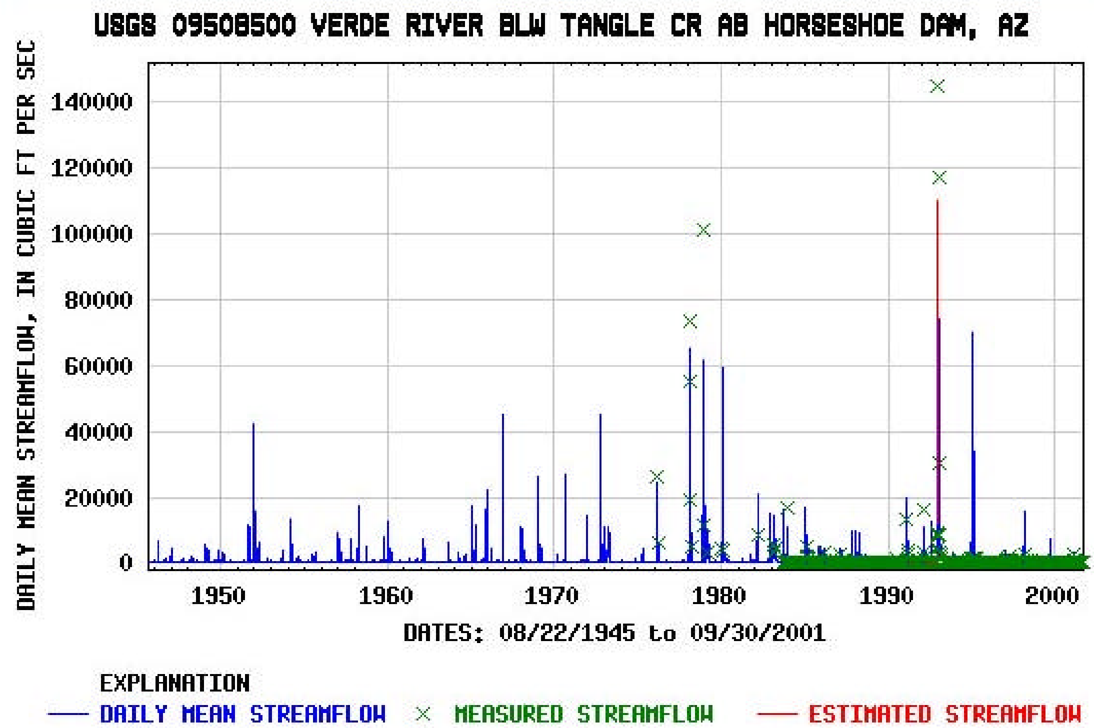

Figure 2. Verde River hydrograph.

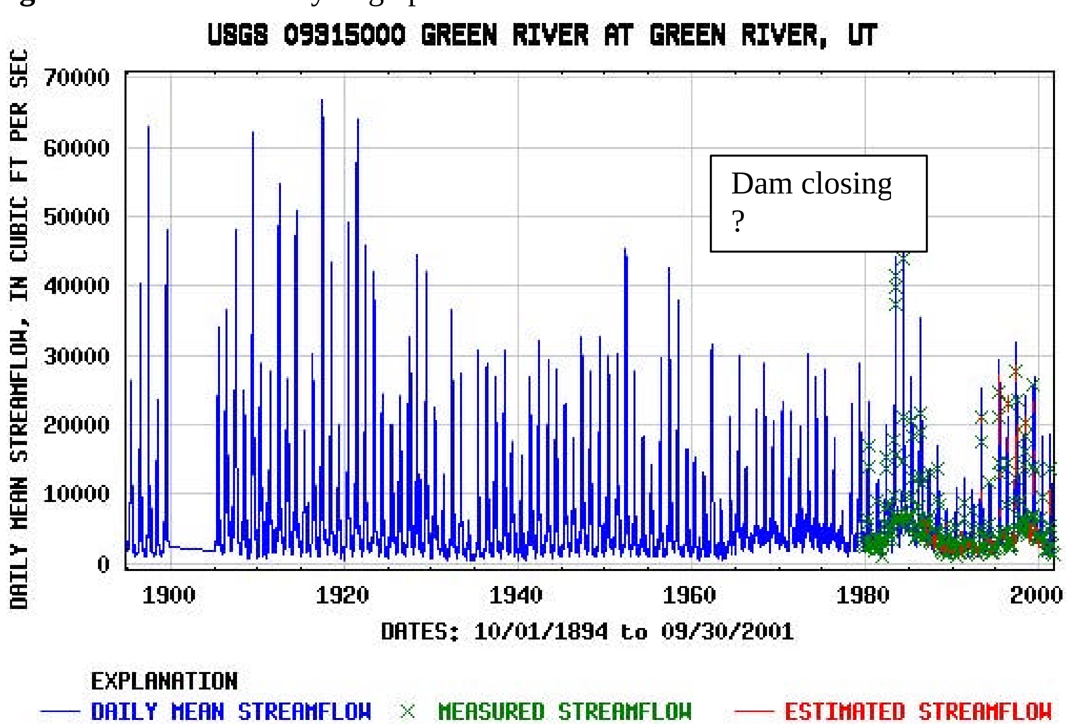

Figure 3. Green River hydrograph.

Despite the fact that the Green River is a much larger river at base flow (by a factor of 11), its average annual flood is only 2.5 times greater than that of the Verde River. And, although the Green River has a watershed 7.7 times larger than the Verde River (above Horseshoe Dam), it has a maximum flood of less than half the size of the Verde River. If the Verde River had similar precipitation patterns and hydrograph to the Green River, it would be a much larger river most of the time (likely about 45% more flow), but would have much smaller flood flows (likely about 35% less average annual flood and 95% less historic peak flood).

Regarding the differences between the two basins, Carlson and Muth, for example, conclude:

> "The upper basin produced most of the river's discharge, and peak flows occurred after snowmelt in spring and early summer. Maximum runoff in the lower basin often followed winter rainstorms."

This results in the differences illustrated by the Verde River and Green River comparison. Because the Verde watershed is more arid than the Green watershed, has a monsoonal precipitation pattern rather than a snowmelt one, and has two major precipitation seasons rather than one, it is a substantially different stream than the Green -- it has lower lows, higher highs, more sharp ups and downs in flows, and much more variation in the amount of water present from month to month and year to year.

Hydrographic differences can directly influence life history parameters of roundtail chub. As discussed earlier, spawning in roundtail chub is triggered, in part, by declining flows in the spring. The differing hydrograph patterns between upper and lower basin, along with other factors, result in differences in timing of spawning. Water temperature was also discussed earlier as a primary spawning factor, and water temperatures are heavily influenced by the hydrograph and by whether the source of spring flows is winter rain or melting snowpack. In addition, roundtail chub in the lower basin have to cope with low stream flows and warm temperatures in late spring and early summer; whereas this is typically the wettest period in the upper basin.

The greater variability in the hydrograph in the lower basin also directly influences the availability of habitat for roundtail chub, particularly larvae and juveniles. This variability may result in a greater variability in spawning and recruitment success, which may make the lower basin populations more vulnerable to human and other alterations of the stream systems. Vulnerability due to hydrogaphic differences may help account for the greater declines in roundtail chub in the lower basin than in the upper.

Hydrographic differences do not act alone in determining the shape and availability of habitat for roundtail chub. The form of a stream channel, and therefore of quantity, quality, and location of fish habitat, is based on the flow (amount and velocity), the geologic/vegetative structure, and the sediment moving through the system. (Leopold 1994, Rosgen, 1996). Geologic differences, such as the greater prevalence of narrow canyon reaches and steeper gradients in the upper basin, result in different proportions in habitat types available for use by roundtail chub in the two basins. Sediment loads vary substantially between streams in both basins, but are generally lesser in the upper basin than the lower (Carlson and Muth 1989), and patterning of sediment movement differs substantially because of the different hydrographs.

In general, roundtail chub habitat in the lower Colorado basin is of lower gradient, smaller average substrate size, higher water temperatures, higher salinity, smaller base flows, higher flood peaks, lesser channel stability and higher erosion, substantially different hydrographs, and higher variability in many of those factors. These differences indicate roundtail chub in the lower basin occupy a unique ecological niche and thus that it cannot be assumed that fish are easily transferable between basins. Loss of the lower basin roundtail chub would result in loss of significant local adaptation which has allowed the species to thrive in a setting unique from that found in the other half of its range. As Behnke (1995; page 41) points out:

> "The range of intraspecific, ecological life history adaptive capabilities has been evolutionarily programmed into the genome (the regulatory genome) by natural selection, but because of the relatively short evolutionary time span involved, and probable limited gene flow among populations, we should not expect that these adaptive properties can be detected or understood from the molecular genetic data (of the structural genome). These adaptive properties, however, are the most important attributes for defining the evolutionarily (or ecologically) significant unit if our goal is to preserve the range of adaptiveness within a species."

<u>2. The loss of the lower Colorado River DPS of roundtail chub would result in a significant gap in the range of the taxon.</u> The gap left by loss of the lower Colorado River roundtail chub DPS would include the majority of the species' range in two states (Arizona and New Mexico) and all of several major river systems, including the Little Colorado, Bill Williams, and Gila River basins. Overall, the lower Colorado River Basin constitutes roughly half the species historic range in the Colorado Basin. In support of these conclusions, the U.S. Fish and Wildlife Service (2002a) in a recent draft review of the roundtail chub for candidate status concluded:

> "Although the upper and lower Colorado basin population segments had limited genetic exchange prior to construction of Glen Canyon Dam, they are now completely isolated by the dam and Lake Powell. The roundtail chub of the upper and lower Colorado River basin are genetically distinct from each other at a relatively high level indicating long-term isolation and different evolutionary histories. In addition to being physically separated, the habitats of the roundtail chub population segments are substantially different in the upper and lower Colorado River basins and in the Mexican segment, as are the threats to the species and its habitat. The status of the species in the three population segments is also different. Although populations in the upper Colorado River basin are reported to also be declining, the species still remains in much of that areas historic range… The lower Colorado River basin population segment is the

center of the range of this species and encompasses about half the range within the Colorado Basin and more than a third of the entire range of the species. Thus, the loss of this segment will result in a significant gap, both in size and spatial position, in the range of this species."

3. The criterion for the DPS to represent the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, is not applicable to roundtail chub.

4. Data indicate the lower Colorado River DPS of roundtail chub differs markedly from other populations of the species in its genetic characteristics. Substantial genetic differences exist in *Gila robusta* in the lower Colorado River basin as compared to populations from the upper Colorado basin. Genetic work on both allozymes and mitochondrial DNA (mtDNA) have shown differences in the two population segments (DeMarais 1992b, Dowling and DeMarais 1993, Minckley and DeMarais 2000, Gerber et al. 2001). On the basis of this work, the upper basin "complex" can be characterized as a *G. robusta/elegans/cypha* complex while the lower basin is a *G. robusta/intermedia/nigra* complex. Allozymes of *Gila robusta* in the upper basin are a mix of *robusta* and *cypha* types indicating an evolutionary path that included mixing between those two species. *G. robusta* in the upper basin have mtDNA typical of *Gila cypha,* also indicating influence of ancient introgression with *Gila cypha*. MtDNA of *Gila robusta* from the lower basin is entirely absent from the upper basin. Allozymes of *Gila robusta* in the lower basin have low variation compared to those in the upper basin. Lower basin *Gila robusta* mtDNA is entirely of a type that represents ancestral *Gila robusta* or possibly *intermedia*, with the exception of Little Colorado River populations. The Chevelon Creek population a tributary of the Little Colorado River has allozyme alleles that are a mix of *G. robusta, G. cypha,* and *G. elegans.* The mtDNA in the Little Colorado River population is of *Gila cypha*.

The genetic differences between upper and lower basin *Gila robusta* are hypothesized to have resulted from Pleistocene extirpation and post-Pleistocene reoccupation of the upper

Colorado basin by the various species of the *Gila robusta* complex, resulting in mixing of the species and complete loss of the *Gila robusta* mtDNA through a combination of founder effect, directional introgression, and/or selection (Gerber et al. 2001). Similarly, Pleistocene-related events may have resulted in the distinct genetic makeup of the Little Colorado River *Gila robusta,* which have been isolated from upstream movement since the late Pleistocene (250,000 years ago) (Wolfe 1984, as cited in Gerber et al. 2001).

<u>5. Other considerations for significance of the lower Colorado River roundtail chub DPS to the taxon to which it belongs include: a) scientific information available through study of its unique evolutionary trajectory, and b) differences in status and management needs between the two distinct population segments.</u>

The species of the *Gila robusta* complex of chub provide a unique opportunity for insight into evolutionary processes. In particular, the evolutionary history of the complex has been important in studies exploring the role of hybridization events in evolution of species and the implications of such evolutionary processes to conservation efforts (DeMarais et al. 1992, Dowling and DeMarais 1993, Dowling and Secor 1997, Allendorf et al. 2001, Gerber et al. 2001). Loss of half of the range of the most widespread of the species in the complex, along with its unique adaptations, genetics, habitat, and life history, will also result in irreplaceable loss of scientific knowledge.

This petition requests Federal listing of headwater chub and the discrete population segment of roundtail chub in the lower Colorado River basin. The status of roundtail chub in the upper Colorado River basin is also of concern but we agree with the Fish and Wildlife Service that the two roundtail chub populations should be considered for listing as distinct population segments (USFWS 1999c, USFWS 1999d, USFWS 2002). The differences in biology, habitat, status, threats, stressors, and management needs between the two populations indicate that separate listing would best meet the needs of the species and provide for optimum recovery strategies.

Although the status of the species is not good in either basin, it is much worse in the lower basin. In the lower basin, roundtail chub has been extirpated in about 70% of its range as opposed to 45% in the upper basin (Bezzarides and Bestgen 2002). The rate of decline in the lower basin also appears to be higher than in the upper basin, and has been quite steep in the past two decades (Desert Fishes Recovery Team 1993).

Threats to the continued survival of roundtail chub are substantially different in the upper basin than in the lower. To a large extent this reflects many of the geologic and hydrographic differences between the basins discussed earlier. Settings of streams of the upper basin are primarily rural and many are quite remote, often in deep canyons that have little access except by water. The largest human populations centers in the species' upper basin range are Grand Junction, Colorado and Green River, Wyoming, with populations in the 10-50,000 range. Streams in the lower basin are also primarily rural in setting, but have a much higher incidence of human use and population along them. Inaccessible canyon reaches are rare, except in the upper Salt River basin. The largest human population center in the species' lower basin range is the Phoenix, Arizona metropolitan area, with a population of several million. Other major and rapidly expanding population centers are present on roundtail chub streams, including the Prescott-Chino Valley area, Sierra Vista-Tombstone area, Cottonwood-Camp Verde-Sedona area, Laughlin-Bullhead City area, and Yuma area; all with populations in the 30-100,000 range.

As a result of these geographic and human development differences, the human uses of the streams and their watersheds within the two basins are significantly different. In the upper basin the major human alterations of the streams and their watersheds come from water development (including impoundment), mining, roads, livestock grazing, agriculture, and introduction of nonnative species. Streams in the upper basin, while sometimes regulated, are in general unchannelized and retain flow year-round. In the lower basin, those same activities have caused stream and watershed alteration, but burgeoning urban and suburban development and groundwater pumping are major growing threats. Lower basin streams are often regulated, sometimes intensely so, such as the mainstem Colorado, the lower Salt and lower Verde Rivers. In addition, large reaches of stream in the roundtail chub range are dewatered perennially or seasonally and other reaches are heavily channelized. There are long reaches of irrigation canals occupied by roundtail chub.

In the upper basin, management of four Federally-listed fishes (Colorado squawfish *Ptychocheilus lucius*, razorback sucker *Xyrauchen texanus*, bonytail chub, and humpback chub) is being guided by two multi-agency efforts known as the Colorado River and San Juan River Recovery Programs. These programs are focused on dam reoperation and flow recommendations, fish passage, hatchery propagation and population augmentation, and control of additional flow depletions. Efforts to address nonnatives are targeted towards eradication efforts and habitat restoration on mainstem backwater areas (Modde and Crist 2000, Pfeifer 1999, 1998, 1997). Because these management activities focus on mainstem habitats, they are unlikely to benefit the many roundtail chub populations in tributary streams, which are not currently part of the Recovery Programs. Management needs in such streams may be less oriented toward water development regulation and more toward control of agricultural, road, and grazing impacts and control of nonnative aquatic species.

In the lower basin, there are no overarching programs to protect listed fish. Instead, there are a variety of programs aimed at species other than roundtail and headwater chub, or at general aquatic and riparian protection and restoration, which may or may not benefit the chubs. This lack of either coordinated management or management targeted specifically towards protection of roundtail and headwater chub is disturbing because the management needs of the species in the lower basin are broader than in the upper basin. There is more need for management of riparian and stream corridors to protect them from cumulative human effects through urban and suburban development, groundwater pumping, recreation, roads, grazing, channelization, and numerous other activities. Unlike the Upper Basin, dam reregulation and flow recommendations are likely to be a management issue for lower basin roundtail chub only on the mainstem Colorado River and the lower Salt-Verde River complex. While hatchery propagation may be necessary in the lower basin, augmentation of populations will not likely be a strategy. Instead, the focus will be repatriation of roundtail chub into streams from which it has been extirpated, using primarily fish moved from appropriate nearby populations, or in some cases hatchery stock. Because of the smaller nature of the streams in the lower basin, riparian and streambank restoration will likely play a much larger role in roundtail chub management in the lower basin than in the upper. Backwater habitats, which are a major upper basin issue, will not be a lower basin issue except along the lower mainstem Colorado River. Nonnative species management in the lower basin will not focus on mainstem backwaters, but will focus instead on small tributaries and will involve barrier construction, nonnative removal, and restoration of entire native fish communities.

In summary, the lower Colorado River basin roundtail chub population meets the criteria for significance due to its unique ecological setting for the taxon, the fact that it forms a major portion of the species range whose loss would result in a signficant gap in the species range, the genetic distinction of this population from other populations of the taxon, the high value of the species and its evolution to developing scientific thought, the substantially more degraded status than other populations of the taxon, and the significantly different management needs than other populations of the taxon. Listing as a DPS will help facilitate management and recovery and will benefit the entire species.

III. Population Status

The status of the roundtail chub[2] has been a cause for concern for several decades Its decline was noted as early as 1964 (Miller 1964). By 1979, there was concern for the status of both roundtail chub and headwater chub (as *Gila robusta grahami*) (Miller 1972, Deacon et al. 1979). Roundtail chub and headwater chub (as Gila roundtail chub, *G. r. grahami*) were included on a 1987 American Fisheries Society list of fishes receiving legal protection and of special concern (Johnson 1987). In 1989, the "Desert Fishes Recovery Team (DFRT)," a team of academic and agency scientists tasked by the

[2] In lists and DFRT discussions prior to 1999, roundtail chub was generally used as including headwater chub.

regional director of the U.S. Fish and Wildlife Service, with overseeing recovery for listed and candidate fish in the Gila River and adjacent basins recommended that "*G. robusta* be proposed as a candidate species." Over the years, these calls have continued to grow. In 1992, the DFRT recommended that roundtail chub be listed as endangered, noting that "the team believes there is sufficient data available to list both species [roundtail and Gila chub]." In 1993, the DFRT concluded:

> "The team discussed the rapid collapse of roundtail chub populations in the past decade in Arizona. Propst said that even in the San Juan, where there is no obvious predator load or dewatering, the roundtail population has collapsed in the past 15 to 20 years. Divine asked if anyone had an estimate of how long we have before this species becomes extinct, given current trends. W.L. Minckley hazarded a guess of about 10 years."

Calls to list the roundtail and headwater chubs by the DFRT were reiterated in 1996, 1999, 2001 and 2002.

Headwater chub (as *G. r. grahami*) was placed on the category 2 candidate list by the Fish and Wildlife Service in the late 1970's, a status that continued through the 1982, 1985, and 1989 notices of review of candidate species. In 1989, the roundtail chub (including headwater chub) was placed into category 2. Due to lack of funding to bring together the existing information on the two fishes, they remained in category 2 through the 1991 and 1994 notices of review. In 1995-96, category 2 was dropped from the Service's definition of "candidate" and roundtail and headwater chub no longer had any formal status under the candidate identification system.

Recent status surveys of the roundtail and headwater chubs support the DFRT's concern (Bestgen 1985, Girmendonk and Young 1997, Bezzarides and Bestgen 2002, Voeltz 2002). Voeltz (2002) compiled all historical records of roundtail chub in the lower Colorado River basin and attempted to verify their present status through survey. Based on this comprehensive review, Voeltz (2002) documented 19 streams in Arizona and

New Mexico still containing roundtail chub and 13 still containing headwater chub. Due to lack of access for survey, in 10 other streams it is unknown whether roundtail chub are still present and in 3 others the continued presence of headwater chub is unknown. There are at least 10 streams where roundtail have been extirpated, and 3 where headwater chub have been extirpated, although these numbers are likely low due to lack of data on historic localities.

Each of the 32 known extant chub populations was rated as stable-secure, stable-threatened, or unstable-threatened (see definitions in Table 2)(Voeltz 2002). Of the 19 extant roundtail chub populations, 13 (68%) are unstable-threatened, 6 (32%) are stable-threatened, and none (0%) are stable-secure. Of the 13 extant headwater chub populations, 6 (46%) are unstable-threatened, 6 (46%) are stable-threatened, and only 1 (8%) is stable-secure.

Table 6. Species status definitions from Voeltz (2002).

Status	Definition
Stable-Secure	Chubs abundant or common with a stable and reproducing population, including successful recruitment and no impacts from non-native species, or adverse land or water uses.
Stable-threatened	Chubs abundant or common with a reproducing population, but potentially limited recruitment and adverse impacts exist from non-native species and/or habitat altering land or water uses.
Unstable-threatened	Chubs uncommon or rare, with a limited distribution, declining population, limited recruitment and threatened by non-native species and/or habitat altering land and water uses.
Extirpated	Chubs no longer occur in the stream
Unknown	Lack of data

Populations of roundtail and headwater chub are found in six separate drainages that because of isolation can be considered separate sub-populations. Sub-populations are at risk of extirpation if there are fewer than a minimum of two stable-secure populations because any single population can be wiped out by stochastic events or catastrophic disturbance, such as fire (see Meffe 1994). According to information in Voeltz (2002) roundtail and headwater chub cannot be considered secure in any drainage. For headwater chub, only the Verde drainage can be considered marginally secure with one stable-secure population. The upper Gila has no stable populations of headwater chub and the Salt has six stable-threatened populations. For roundtail chub, the Little Colorado and lower Gila drainages have only one stable-threatened population each. The Bill Williams has two stable-threatened roundtail chub populations, the Verde and Salt drainages have one stable-threatened population each. Lack of stable-secure populations demonstrates that roundtail and headwater chubs are at risk of extinction in the vast majority of their range.

The above data show that the status of roundtail chub in the lower Colorado River basin is poor and declining. It has been extirpated from approximately 82% of its historic range and is likely to disappear from at least another 12% unless protection is put in place to ameliorate threats and promote recovery. No portion of its range is secure.

For headwater chub, the data show that its status is also poor and declining. It has been extirpated from approximately 50% of its historic range and is likely to disappear from at least another 23% without protective and recovery actions. Only in 4% of its historic range is its population secure.

IV. PRESENT OR THREATENED DESTRUCTION, MODIFICATION OR CURTAILMENT OF HABITAT OR RANGE

The recent draft reviews of both the roundtail and headwater chub for candidate status produced by the U.S. Fish and Wildlife Service (USFWS 2002a and 2002b) concluded:

> "Large portions of the historic lower Colorado basin range of the roundtail chub are now unsuitable due to dewatering, impoundment, channelization, and channel changes caused by alteration of riparian vegetation and watershed degradation. Habitat in substantial other portions of the range has been significantly altered by the same factors, plus mining, grazing, roads, water pollution, urban and suburban development, groundwater pumping, and other human actions. Remaining areas of roundtail occupation are subject to a number of threats to the habitat."

The following sections provide further detail demonstrating that the habitat of roundtail and headwater chub has been substantially reduced and continues to be impacted by the same factors that led to this reduction.

A. LIVESTOCK GRAZING

Livestock grazing has resulted in severe modification and loss of roundtail and headwater chub habitat throughout the lower Colorado River basin. Livestock grazing has both direct and indirect effects on chub habitat. Livestock directly affect chub habitat through removal of riparian vegetation (Clary and Webster 1989, Clary and Medin 1990, Schulz and Leininger 1990, Armour et al. 1991, Fleishner 1994). Loss of riparian vegetation in turn raises water temperatures, reduces bank stability and eliminates an important structural component of the stream environment that contributes to the formation of pools (Meehan et al. 1977, Kauffman and Krueger 1984, Swanson et al. 1982, Minckley and Rinne 1985, Platts 1990, Fleishner 1994, Belsky et al. 1999). Direct effects to roundtail and headwater chub habitat also occurs through increased instream sediment due to a variety of livestock actions, including streambank trampling and riparian vegetation loss (Weltz and Wood 1986, Waters 1995, Pearce et al. 1998). Livestock physically alter streambanks through trampling and shearing, leading to bank erosion (Armour 1977, Platts and Nelson 1989, Trimble and Mendel 1995). In combination, loss of riparian vegetation and bank erosion can alter channel morphology, including increased erosion and deposition, downcutting and an increased width/depth ratio, all of which lead to a loss of pool habitats required by the roundtail and headwater chubs and to loss of shallow side and backwater habitats used by larval chub (see Trimble and Mendel 1995, and Belsky et al. 1999).

Physical developments necessary to support livestock grazing can also have direct effects on roundtail and headwater chub. Literally thousands of earthen stock tanks have been constructed throughout the lower Colorado River basin (Haddock 1980). These and other water developments divert water from natural surface waters, including streams supporting roundtail and headwater chubs (Scott 1997). Livestock water developments, plus thousands of miles of fencing, require a substantial network of roads and tracks for servicing. These roads have been a major factor in altering the morphology and habitat of streams in the southwest (see later discussion of roads).

Livestock indirectly impact aquatic and riparian habitats by compacting soils, altering soil chemistry, damaging cryptobiotic crusts, and reducing vegetation cover in upland areas, leading to increased severity of floods and sediment loading, lower water tables and altered channel morphology (Cooperrider and Hendricks 1937, Rich and Reynolds 1963, Sartz and Tolsted 1974, Gifford and Hawkins 1976 and 1978, Blackburn et al. 1982, Ohmart and Anderson 1982,Harper and Marble 1988, Marrs et al. 1989, Orodho et al. 1990, Schlesinger et al. 1990, Elmore 1992, Belsky et al. 1999). One consequence of these impacts to watersheds is a reduction in the quantity and quality of pool habitat. A lowered water table, for example, results in direct loss of pool habitats, simply because water is not available to form pools. Increased erosion and sedimentation results in filling of pools with sediments. Channel incision and increased flood severity both can scour out pools, reducing habitat complexity and resulting in shallow, uniform streambeds (see Trimble and Mendel 1995, Belsky et al. 1999).

Livestock also indirectly impact native fish, including roundtail and headwater chub, by altering the composition and community structure of the aquatic fauna. The aquatic invertebrate community may change because of altered stream channel characteristics, sediment deposition or substrate size changes, or nutrient impoverishment or enrichment (Rinne 1988, Li et al. 1994, Tait et al. 1994, Jones et al. 1997). This change in the food base of many aquatic vertebrates, particularly fish, may contribute to a change in the vertebrate community (Covich 1999). These food web changes are cumulative and subtle and are seldom documented. Few detailed studies of aquatic faunal communities or invertebrate inhabitants of roundtail or headwater chub streams exist, but given the substantial changes in a wide variety of stream and habitat characteristics and vertebrate communities in most of the streams within historic range of the two chubs, there is little doubt that substantial changes have occurred to both invertebrate community structure and food webs.

In addition, livestock grazing can cause the structure and diversity of the fish community to shift due to changes in availability and suitability of habitat types (Storch 1979, Van Velson 1979, Li et al. 1987, Rahel and Hubert 1991). Livestock grazing results in loss of aquatic habitat complexity, thus reducing diversity of habitat types available and altering fish communities (Li et al. 1987, Pearsons et. al. 1992). In the arid west, loss of habitat complexity has been a major contributing factor in declines of native fishes and amphibians and in the displacement of native fish species by nonnatives (Bestgen 1986, Minckley and Rinne 1991, Pearsons et al. 1992, Baltz and Moyle 1993, Lawler et al. 1998). Livestock grazing has also contributed significantly to the introduction and spread of nonnative aquatic species through the proliferation of ponded water in stock tanks (Simms 1997, Sponholtz et al. 1997, USFWS 1999e).
Direct and indirect effects of livestock grazing on chub habitat have contributed to the significant diminution of range of both the roundtail and headwater chubs and are depressing existing populations. Voeltz (2002), for example, concluded:

> "Non-native fish introductions and habitat alterations are considered the main causes for roundtail chub population decreases in New Mexico (Bestgen and Propst 1989). As early as the turn of the century, Chamberlain (1904) identified cattle grazing, erosion, and water diversions for irrigation and mining as causes of water quality problems resulting in the decline of Southwestern fishes. Platts (1991) concluded that livestock grazing negatively impacts riparian habitats and fish populations."

Similarly, Girmendonk and Young (1997) concluded:

> "Another means of riparian protection is the control of use by cattle. Schuhardt (1989) stated that one of the major problems in the Verde River, especially from the headwaters to downstream of Sycamore Creek, was cattle grazing which

> destroys vegetation, alters the watercourse, and erodes streambanks. In many streams where livestock grazing has been limited or eliminated, native fish species are able to more effectively compete with non-native fish species. In riparian livestock exclosure studies, native fish species have been shown to increase populations by nearly 600% (Crispin 1981, Platts and Nelson 1985)."

Many have asserted that conditions are improving and livestock grazing is better managed, including the U.S. Fish and Wildlife Service in a recent decision to not list the Rio Grande cutthroat trout (FR June 11, 2002 V. 67, No. 112). Changes in management of livestock grazing, however, have typically focused on upland areas and in most cases ignore riparian areas, which require complete or near complete exclusion of livestock before recovery can occur. Ohmart (1996), for example concluded:

> "Unmanaged grazing of riparian systems has been and continues to be practiced. Today even though most allotments have management plans, all were designed to meet phenological growth requirements of upland vegetation. Watersheds may benefit from these grazing approaches, but riparian habitats are degraded under these plans and will continue to be until management changes are made… 'There is a general acceptance by managers today that most riparian areas are in an unacceptable condition and approaches to restoration in the past have had limited success' (Elmore and Kauffman 1994). The above statement is very true but instead of 'most riparian areas' my experiences are that almost all riparian areas are in an unacceptable condition."

Similarly, an extensive review of riparian restoration efforts on federal lands by the Government Accounting Office (GAO) determined that efforts to restore riparian areas have been extremely limited and most areas remain in a degraded state:

> "While successes have been achieved [riparian areas restored], their number is very small compared with the areas still needing restoration. The pace of restoring the large number of degraded riparian areas that remain is likely to be

very slow for two reasons. First, the number of skilled staff available to plan, implement, and monitor riparian improvements has been substantially reduced in recent years. Second, many of the field staff responsible for riparian improvement work, primarily in BLM, do not believe their work will be supported by agency management if it is opposed by ranchers using the public rangelands" (GAO 1988).

A 1997 report by four forest service fisheries biologists to the Southwest Regional Forester exemplifies the degree of resistance to removing cows to restore riparian habitats and imperiled fish (Cain et al. 1997). Their conclusions were remarkably candid and damning:

> "The cumulative and synergistic effects of Forest Service management is causing long-term degradation of the habitats of these species, and contributing to their endangerment and downward trend in range and abundance. Many of these effects are due to irreversible activities that occurred in the distant past. But some are due to current and deliberate action. During our interviews we heard time and again that the needs of the species were not fully considered during NEPA analysis. We heard that terms and conditions of the programmatic BAE for grazing weren't being followed. We heard that biologists were pressured into changing effects determinations so that targets could be met without having to undergo consultation. We heard that mitigation measures weren't applied. But we were always assured that there actually was no problem… We need incentives for line officers to commit to riparian area and endangered species management. We need to commit to management for forest health. Above all, we need a change in management attitude… For example, we found that range management is a chronic abuser of riparian habitats. Now range managers truly believe in their hearts that degraded riparian areas can be restored with cattle. And they have come up with an amazing variety of grazing systems to accomplish that...But evaluations of riparian area condition 5 or 10 years later seldom show an upward trend. Why is that? It's because cattle grazing is a core value of the agency, and

> riparian area health and endangered species management is not. Prescriptions are developed and applied to meet the needs of the rancher, the cattle, or the agency. Soil, vegetation, water, and wildlife resources are secondary considerations… Recovery of riparian areas with cattle hasn't worked in the past, is not working now, and won't work in the future. And this is where a change in management attitude is necessary. The only practical way to restore riparian areas supporting endangered species is through removal of cattle impact. And based on experience, we advocate that prescriptions that call for complete rest or nonuse be the first step."

Almost all recognize that livestock grazing destruction of western public lands was greatest in the late 1800's (Hastings and Turner 1980, Bahre 1991, Hadley et al. 1991, and many others). However, that does not mean that upland, riparian, and stream conditions on the rangelands have returned to pre-European conditions. Instead, current livestock grazing takes place on highly degraded areas, resulting in a greater level of adverse effects (including preventing or inhibiting recovery) than if livestock grazing was imposed on pristine environments. In fact, in the mid-1900's resource damage from livestock became more widespread due to technological improvements that allowed water developments throughout the uplands (McAuliffe 1997, Frasier 1997). The ability to increase water availability led to a 60% increase in cattle in the United States between 1940 and 1990, predominantly in the west (Trimble and Mendel 1995). That increase affected upland areas that had seldom been used by cattle, as well as the riparian corridors, the most desirable areas for cattle use.

Restoration and recovery of livestock damage can take decades, centuries, or in some cases may not be recoverable (Briggs et al. 1994, Briggs 1996, Krueper 1996, Rapport 1999). Even areas that have been excluded from livestock grazing for 30-40 years show continued deterioration from past livestock-induced changes (Stefferud and Stefferud 1994, Rutman 1997, McAuliffe 1997, Stefferud and Stefferud 1998). And problems continue. U.S. Forest Service range conservationists recognize that there are many ongoing range problems, despite recent improvements (Alford 1993). Others recognize that while improvements may have occurred in grazing management, those may or may not result in significant improvements in riparian conditions (GAO 1988, Elmore and Kauffman 1994). The Fish and Wildlife Service's 2002 Notice of Candidate status review for the Rio Grande cutthroat trout concludes that livestock grazing is not a threat to that species because "Livestock grazing practices on public lands in New Mexico have improved." but no citations or documentation are provided for that statement.

The Rio Grande cutthroat trout notice also concludes that "Changing livestock stocking levels and improved management practices have occurred and will continue to occur following current management direction." and "Restoration of riparian areas and maintaining healthy habitat is a priority for Forest Supervisors and Regional Foresters." Substantiation for those statements consist of what are apparently personal statements by three forest supervisors, including the Santa Fe National Forest Supervisor. However, as recently as June 2002, the Forest Service's Regional Director of Rangeland Management wrote a memorandum to line officers of the Santa Fe National Forest (which includes the Forest Supervisor) stating that ". . . what I observed on the Santa Fe National Forest on Thursday is the most horrible example of grazing administration I've ever experienced in 35+ years with the FS." (Stewart 2002). That observation included 10 allotments on the Santa Fe National Forest. His memorandum goes on to say:

> "With the exception of the San Diego and San Antonio/Cebolla, there has been little if no spring forage growth and cattle have currently consumed most of the previous years residual growth. Again, with the same exceptions, cattle should never have been allowed to enter these allotments for one simple reason, there is no forage growth! This is not advanced range management folks!!! . . . . .why are we willing to do things similar to this in obvious situations where they are just plain wrong?? In another situation (Chicoma), the Forest Staff Officer met with the District Ranger almost two weeks ago on-the-ground and agreed that cattle had to come off, but as of the day we were there, nothing had been

> done, with once again, cattle being allowed to simply pulverize the resource??"

Thus, the data, literature, experience, and statements of USFS staff indicate that the conclusions reached in the Rio Grande cutthroat trout notice are invalid. While improvement in livestock management may be occurring and while official positions and policies regarding that management may support amelioration of livestock impacts to natural resources, actual implementation of those improvements, positions, and policies is seriously flawed and their promised results lie in the future. Livestock grazing continues to have serious adverse impacts to southwestern streams and riparian areas with consequent adverse impacts to roundtail and headwater chubs.

Of the 30 streams with remnant roundtail or headwater chub populations, Voeltz (2002) documented that 29 of these are subject to active livestock grazing in the watershed. The remaining three (Aravaipa and Wet Bottom Creeks and the Salt River) also have grazing allotments along the river and/or within the watershed. Voeltz (2002) noted specific problems associated with livestock grazing at eight of the streams (Chevelon, East Clear, Burro, Salome, Tonto, Marsh, Rock and Gun Creeks). Other occupied streams, such as Eagle Creek, parts of the upper Gila River, the East Verde, Verde, Black, and White Rivers are also known to have significant problems associated with livestock grazing (USFWS 2000a, 2001d, 2002d, e). Voeltz (2002), for example, notes that stream evaluations of Chevelon Creek by ADEQ (1993) indicated: "water quality not meeting standards for sediments and turbidity, due to grazing and unknown sources," and "high channel erosion, habitat modification, and unsatisfactory watershed condition were reported for the watershed." Similarly, Voeltz (2002) concluded: "degradation of riparian areas and aquatic systems through continued access by livestock and burros" was a threat to roundtail chub in Burro Creek. Problems with livestock grazing have also been noted on the main Verde River. Other occupied streams, such as Eagle Creek, parts of the upper Gila River, the East Verde, Verde, Black, and White Rivers are also known to have significant problems associated with livestock grazing (USFWS 2000a, 2001d, 2002d, e). Girmendonk and Young (1997) note: "from Sullivan Lake downstream to

Cottonwood, cattle grazing appears to have a major impact on both upland and aquatic communities, as evidenced by trampled banks and heavily grazed vegetation." Livestock have since been excluded from national forest lands on portions of the upper Verde and upper Gila Rivers, primarily to protect loach minnow and spikedace. However, there is still some livestock use, on private lands, on Forest lands where livestock are driven across the river, and by trespass cattle which frequently access the stream through broken or cut fences and often are not removed for weeks or months. Livestock remain on other areas of national forest and private-lands on these systems, as well as on the remainder of roundtail streams that don't have loach minnow and spikedace. Clearly, livestock grazing is continuing to impact remnant populations and habitat of roundtail and headwater chub.

To assess ongoing impacts of livestock grazing on roundtail and headwater chub populations and habitat, we requested through the Freedom of Information Act all management documents, including biological evaluations and assessments, decision memos and notices, and environmental assessments, for livestock grazing allotments on both Forest Service and BLM lands with roundtail or headwater chub populations. Allotments were identified by comparing maps in Voeltz (2002) with a GIS coverage of allotment boundaries. Based on these documents, we determined for each allotment whether the Forest Service and BLM analyzed the effects of management on roundtail or headwater chub, the results of this analysis, whether specific management was enacted to benefit either of the chubs, how the allotment was being managed in general, and whether riparian condition was noted. Generally, biological evaluations and assessments contained the most information in relation to roundtail chub and their habitat.

Forest Service. We identified 58 allotments on five national forests that contained known populations of headwater or roundtail chub as identified by Voeltz (2002) (Appendix A). The Forest Service analyzed the effects of livestock grazing on the roundtail chub on 35 of the allotments, failed to analyze the effects on roundtail chub on 15 allotments, and we lacked sufficient documents to determine whether they analyzed effects on 8 allotments. Although we twice requested and received documents from each forest to ensure a thorough response, it is likely that the Forest Service analyzed effects on more of the allotments. Conversely, the most current documents provided by the Forest Service for a number of allotments dated from the mid- to late 1980s, none of which analyzed effects to roundtail chub. We suspect that in a number of these cases this represented the agency's most current analysis.

Of the 35 allotments where effects to roundtail chub were analyzed, the Forest Service concluded that livestock grazing "may affect individuals and eventually trend the species toward federal listing" on two allotments (Biological evaluation and Assessment for the Green Valley Complex, Tonto National Forest 2002), may affect or impact the roundtail or headwater chub, but either will not adversely affect or will not lead to a trend toward federal listing or loss of viability on 14 allotments, and would have indirect affects on chub habitat on one allotment. In addition, the Forest Service concluded recreational activities on two allotments may affect the roundtail or headwater chub. In sum, the Forest Service concluded the roundtail chub may be affected by management actions on 19 of the 35 allotments where effects were analyzed, indicating livestock grazing continues to harm the roundtail and headwater chubs, despite management efforts.

Problems related to riparian or watershed condition were noted in either the environmental assessment or biological evaluation on 40 of the 58 allotments (Appendix A), indicating habitat degradation related to livestock grazing continues to be a persistent problem within the current range of the roundtail chub and that Forest Service management has not succeeded in maintaining aquatic habitats. We lacked any documentation of habitat condition on 14 allotments. Only four allotments were listed as having proper functioning riparian areas and in three cases this was because livestock were excluded from riparian areas by steep topography. Some of the comments on riparian habitat include:

> "Unsatisfactory riparian conditions exist in most of the riparian communities within the allotment boundaries. Species diversity and age class distribution of

the woody species is lacking throughout the communities." (Environmental Assessment for the Buckhorn Allotment, Coconino National Forest)

"There is a need to restore the unsatisfactory riparian condition along Brock Canyon and Mogollon Creek to satisfactory condition… In addition to the unsatisfactory condition along Mogollon Creek and Brock Canyon over half of both the Brock Canyon and Watson Mountain allotments have been identified as being in poor range condition." (Environmental Assessment for Brock Canyon Allotment, Gila National Forest)

"The existing condition of most of the stream channels on the Cottonwwod and Cline Units is degraded and this has reduced their ability to function. Much of the degraded stream condition is attributable to past grazing management... Soil erosion, decreased infiltration, and increased run-off will continue to indirectly affect stream channels and riparian areas within the Cottonwood and Cline Units for many years" (Environmental Assessment for Cottonwood and Cline Units, Sunflower Allotment, Tonto National Forest)

Both the analysis of effects on the roundtail and headwater chub and comments on riparian condition indicate that ongoing livestock grazing, along with the long-term effects of past livestock grazing, continue to be a major threat to the continued existence of the roundtail and headwater chubs.

BLM. On BLM lands, we identified 15 allotments in Arizona and 3 in New Mexico with chub populations and obtained documents for nine of the 15 in Arizona and none of the three in New Mexico (Appendix B). These documents indicate that the BLM does not consider the effects of its management on the roundtail or headwater chub with none of the documents analyzing effects to the species. Moreover, few of the documents discussed riparian condition. In the three cases where it was discussed, however, it was to note that riparian areas were not in proper functioning condition. This information indicates the BLM is not taking action to ensure that livestock grazing does not harm populations or habitat of roundtail chub.

B. WATER WITHDRAWAL AND DIVERSION

Groundwater pumping and water diversions pose a significant threat to the continued existence of the roundtail and headwater chub by reducing the quantity and quality of habitat (Girmendonk and Young 1997), and by reducing the frequency and magnitude of floods. USFWS (1989) determined that roundtail chub habitat is essentially eliminated when flow drops below 0.3 cms (10 cfs). Girmendonk and Young (1997) concluded:

> "Lowering of the water level during summer irrigation season alters stream width and depth and changes the physical characteristics of the river… Large streambed areas in the urbanized Verde Valley area are often reduced to isolated pools (Hendrickson 1993)."

Diversions also impact roundtail chub populations by creating barriers to fish movement and by sucking fish into irrigation canals where they later perish. Girmendonk and Young (1997) note:

> "Presently, any fishes in the Verde drainage moving into reaches near TAPCO and the urban areas in the Verde Valley are confronted with numerous, significant diversion dams. These range from minor bulldozed cobble dams to steel and concrete structures producing 2-4 m vertical bank-to-bank drops. Ziebell and Roy (1989) noted that as water is diverted, fish may select or be swept into canal type habitats where they later perish because of intermittent draw-downs. USFS personnel have reported finding dead fishes in pastures after irrigation."

Finally, water withdrawal harms roundtail and headwater chub by reducing flooding (Rinne et al. 1998, Brouder 2001). Brouder (2001), for example, concludes:

> “Continued human population growth in this region will likely increase pressure for water development and possibly diversions in the upper Verde River. Construction of diversion and storage dams will likely reduce the magnitude and possible occurrence of flood events, which already occur infrequently. Altered flow regimes caused by dams and diversions have already been blamed for declines in native fishes elsewhere in the desert Southwest, and habitat loss or alteration is probably the greatest threat for many imperiled species… Precipitation and stream hydrographs are unpredictable, but floods occur in the upper Verde River on ca. 5 to 10 year cycles. Because roundtail chub live approximately 7 years, a decade long drought or a regulated discharge could severely reduce populations of these fish.”

Human populations are expected to grow rapidly in a number of the watersheds currently occupied by roundtail and headwater chub, likely resulting in increased demand for water. Girmendonk and Young (1997), for example, concluded:

> “Large-scale water withdrawals from the upper Verde are proposed (USFWS 1989). And, the widening gap between human population growth in the basin and present water supply clearly indicates that such proposals will continue to increase (Hendrickson 1993)… The Arizona Department of Economic Security projected that Verde Valley communities of Cottonwood, Clarkdale, and Camp Verde would have a combined population of 38,195 by the year 2030. The entire Verde Valley region’s population is projected to reach 98,620 by the year 2030. The Arizona Department of Water Resources (1994) projected the population in the entire watershed at 234,000 by the year 2040. Such expansive growth would increase recreational uses of the river and increase water demands. Groundwater pumping would also be expected to increase.”

Similarly, The U.S. Fish and Wildlife Service in their recent draft candidate status reviews for the roundtail and headwater chubs concluded:

> "Bureau of Reclamation predictions on groundwater pumping in the upper Verde River are that up to 20 miles of flow in the upper river will be totally lost unless current trends are reversed; yet human population growth in the area exceeds 4% per year and the water supply is almost exclusively from groundwater. On the Little Colorado River, much of the river is already dewatered and there are proposals to further channelize the river in conjunction with cloud seeding, to provide for enhanced water supplies for human uses."

According to information provided in Voeltz (2002) water diversions and/or groundwater pumping currently occurs in 19 of the 30 streams known to harbor roundtail or headwater chub populations and are known to be causing problems in 11 of these streams. Voeltz (2002), for example, notes "groundwater pumping for industrial and domestic use is a serious threat for all of the streams in the Burro Creek drainage." Similarly, in the upper Gila, Voeltz (2002) notes: "irrigation diversions in the vicinities of Cliff, Redrock, and Virden, New Mexico often completely draw off surface flow (Bestgen 1985)." Water diversions and/or ground water pumping also occur in at least 5 of the 14 streams where roundtail and headwater chub have an unknown status. Already existing problems with water-use are only likely to grow as the human population of Arizona and New Mexico continues to increase.

C. DAMS

Similar to water withdrawals and diversions, dams reduce the amount of downstream flow, eliminate or substantially reduce flood events and inundate stream habitats under reservoirs (Blinn and Cole 1991, Chart and Bergersen 1992, Blinn et al 1995, Ligon et al. 1995, Collier et al. 1996, McCully 1996, Pringle 1997, Clarkson and Childs 2000). Reservoirs are also typically sites for introduction and survival of non-native species (Rinne et al. 1998). Major dams have been constructed throughout the historic range of the roundtail and headwater chub, including 8 dams on the mainstem Colorado, 4 on the Gila, 4 on the Salt and 3 on the Verde River, and were a substantial cause in the decline of both species.

D. ROADS AND LOGGING

Road-building and logging, by altering the hydrology of watersheds, is well documented to be deleterious to fish and other aquatic life forms (e.g. Burns 1971, Eagin and Hubert 1993). Roads and logging increase surface runoff, sedimentation and debris avalanches, and destroy riparian vegetation. Roads require in-stream structures, such as culverts and bridges, that remove aquatic habitat and/or are barriers to fish (Barrett et al. 1992, Bryant 1981). Numerous studies have shown that increased surface runoff and decreased slope stability caused by road building and logging increases sediment production and the likelihood of major landslides (e.g. Amaranthus et al. 1985 and Megahan and Kidd 1972). All of these effects negatively impact roundtail chub by lowering water quality and reducing the quality and quantity of pools, either by filling them with sediments or by reducing the quantity of large woody-debris necessary to form pools. According to information in Voeltz (2002), logging is a land-use in the watersheds of 19 of the remaining 30 streams known to contain roundtail or headwater chub populations and 7 of the 14 watersheds where the status of roundtail or headwater chubs is unknown.

E. RECREATION

Recreation was noted as a land-use in the watersheds of 29 of the remaining 30 watersheds known to contain roundtail or headwater chubs and 14 of the 14 watersheds where roundtail or headwater chub have an unknown status (Voeltz 2002). The impacts of recreation are highly dependant on the type of activity, with activities such as bird-watching having little to no impact and activities such as ORV use potentially having severe impacts on aquatic habitats. Specific problems with recreation were noted in 4 of the streams with known remnant populations of headwater or roundtail chub (Upper Gila, Tonto, Oak and Webber Creeks)(Voeltz 2002). For example, Voeltz (2002) noted that in-channel vehicular traffic was a threat to headwater chubs in Tonto Creek and angling was a threat to headwater chubs in the upper Gila.

F. MINING

Mining can negatively impact roundtail or headwater chub populations by polluting streams, altering channel morphology or reducing stream flows through water use. Mining occurs in along 19 of the 30 watersheds with remnant populations of roundtail or headwater chubs and was noted as causing specific problems in 5 of the streams (Santa Maria River and Boulder, Burro, Tonto, and West Clear Creeks)(Voeltz 2002). In combination with all of the other threats to roundtail and headwater chubs, mining poses a substantial threat to the continued existence of these species.

G. URBAN DEVELOPMENT

Roundtail and headwater chub and their habitats are being increasingly threatened by urban and suburban growth. Although many of the extant populations are remote, some are adjacent to large human population centers. The lower Salt and Verde Rivers, both supporting extant populations of roundtail chub are located on the outskirts of the Phoenix metropolitan area, with its population of several million people. The upper Verde River, with its roundtail chub, is hemmed in by the burgeoning communities of the Prescott-Chino Valley on the upper end and the Cottonwood-Clarkdale-Camp Verde communities on the lower end. Oak, West Clear, and Wet Beaver Creeks are all the location of rapid human residential and small ranchette development. The roundtail chub unoccupied recovery habitat in the upper San Pedro River is rapidly being destroyed by the overheated growth of the Sierra Vista-Huachuca City-Tombstone area. Even on Aravaipa Creek, subdividing of lands and housing construction threaten roundtail chub.

For headwater chub, the East Verde River is adversely affected by the growth in the Payson area, both from housing and water withdrawal. The potential restoration of flows to Fossil Creek is threatened by water demands in the rapidly growing communities of Strawberry and Pine. Tonto Creek has large areas of ranchette and housing development.

Urban and suburban development affects roundtail and headwater chub and their habitats in a number of ways. There is the direct alteration of streambanks and floodplains by construction of buildings, gardens, pastures, roads, etc. (Tellman et al. 1997). Also very direct is the diversion of increased amounts of water, both from surface flows and connected groundwater (Folk-Williams 1991, Glennon 1995, Rojo et al. 1999). On a broader scale, urban and suburban development alters the watershed with consequent changes in the hydrology, sediment regimes, and pollution input (Dunne and Leopold 1978, Horak 1989, Medina 1990, Reid 1993, Waters 1995). Human occupation near the stream also raises the potential for the introduction of nonnative plants and animals that can adversely affect roundtail and headwater chubs (USFWS 2001a and b).

H. CHANNELIZATION

Channelization of streams has been a major factor in loss of habitat for roundtail and headwater chub. Channelization is sometimes a distinct activity, such as along the lower Colorado River where major efforts have been focused on straightening, deepening, and narrowing the river channel and eliminating marshes and backwaters to enhance water passage, transportation, flood control, and recreation (Beland 1953). In other areas channelization has not been a specific activity, but rather the result of many other activities that incrementally result in the same type of channelization found in the lower Colorado River. Early channelization was usually to drain marshes and reclaim bottomlands for agriculture or roads (Hendrickson and Minckley 1984). Construction of irrigation diversions also often resulted in channelization of the stream. Cienegas, marshes, and channel backwaters were also drained for mosquito control. In the mid-1900's extensive channelization was conducted along the Salt, Verde, and Gila Rivers in the name of reducing evapo-transpiration and speeding water delivery to the downstream metropolitan and agricultural areas (U.S. Soil Conservation Service 1949, Culler et al. 1970) . Flood control has been a major reason for incremental channelization that has affected almost all Arizona streams where humans have fields or buildings (Olmstead 1919, Pearthree and Baker 1987, Donegan 1997). Flood control channelization takes the form of riprap, gabions, jacks, and other channel constraints or methods for hardening the streambanks. Channelization has also been a byproduct of many of the other habitat altering activities within the habitat of roundtail and headwater chub (e.g. U.S. Forest Service 2001)

Taken in total, channelization has affected large portions of roundtail and headwater chub range. Channelization affects the two fish by, among other things, reducing the complexity of the habitat, eliminating cover, reducing nutrient input, improving habitat for nonnative species, changing sediment transport, altering substrate size, and reducing the length of the stream and therefore the amount of aquatic habitat available (Gorman and Karr 1978, Simpson et al 1982, Schmetterling et al. 2001). Incremental channelization is ongoing in many roundtail and headwater chub habitats, including, but not limited to the Gila, White, Black, Santa Maria, Verde and Salt Rivers, Aravaipa, Eagle, Oak, West Clear, Wet Beaver, and Tonto Creeks.

I. CUMULATIVE EFFECTS

River systems in the current and historic range of the roundtail and headwater chub have been impacted by a combination of the activities discussed above, leading to cumulative and synergistic effects that have resulted in substantial loss and degradation of habitat (Burns 1991, Reid 1993). For example, a recent draft biological opinion produced by the U.S. Fish and Wildlife Service concluded:

> "These lower portions of the Verde River are influenced by activities taking place upstream as well as those within the immediate area. In addition to the past impacts from long-term livestock grazing, land uses in the watershed that have had effects to the Verde River include mining (including sand and gravel), recreation, roads, irrigated agriculture, and urban development. Uses within the project vicinity include recreational uses such as off-highway vehicles, particularly along Red Creek and at Sheep Bridge Crossing, and grazing. It can be expected that these land uses alter the characteristics of the watershed through changes in vegetation cover and community components, compaction of soils, and

> the resultant changes to runoff and retention patterns for rainfall or snowmelt events" (U.S. Fish and Wildlife Service (2002) draft biological opinion on the Sears Club/Chalk Mountain Allotment).

Many if not most of these activities continue on the Verde and other systems occupied by the chubs. Reductions in any one activity, for example recent reductions in livestock grazing, are quickly offset by other activities, such as human population growth with concurrent increases in recreation pressure and groundwater pumping. As a result, recovery of the chubs will require a holistic approach to watershed management that can only be achieved through endangered species listing and the recovery process.

V. Other natural or manmade factors affecting the continued existence of the roundtail and headwater chubs

A. NONNATIVE SPECIES

"Introduced species carry a lasting legacy once they become established as reproducing populations and expand their ranges. They are biological pollutants which usually cannot be eliminated. In this respect, they differ from most other forms of environmental modification, which can, with time, be adjusted or corrected." From "Crimes against biodiversity: the lasting legacy of fish introductions," Courtenay and Moyle (1992).

Non-native fish that compete and/or prey on roundtail and headwater chub are a serious and persistent threat to the continued existence of these species (see USFWS 1999a,b, 2001a, b). Voeltz (2002) concludes:

> "Several non-native fish species have been documented to negatively affect native fish populations. The red shiner is known to compete with native southwestern cyprinids (Minckley and Deacon 1968, Minckley 1973, USFWS 1989, Douglas et al. 1994), and prey on larval fishes (Rupert et al. 1993). In some southwestern rivers, red shiners appear to be replacing native fishes within a short amount of

> time after their introduction into a system. Data taken from fixed stations on the upper Verde River shows an alarming trend with the reduction of native fish abundance corresponding with an explosion in population size of red shiners (Stefferud 2000). Bestgen and Propst (1989) reported that smallmouth bass, flathead catfish, and channel catfish were the species that most greatly impacted roundtail chub populations in New Mexico. M. Brouder (pers. comm.) found native fish remains in the stomachs of largemouth bass, smallmouth bass, green sunfish, channel catfish, and yellow bullhead. Recent surveys indicate a decline in roundtail chubs and other native fishes in the Salt River above Roosevelt Lake, with an increase in flathead and channel catfish numbers (Creef and Clarkson 1993, Jahrke and Clark 1999)."

Most streams within the present and historic range of the roundtail and headwater chub contain multiple non-native species (see USFWS 2001a and b). In a recent proposal to list the closely related Gila chub (*G. intermedia*), the U.S. Fish and Wildlife Service concluded that more non-native species continue to be introduced into streams:

> "In Arizona, release or dispersal of new nonnative aquatic organisms is a continuing phenomenon (Rosen et al. 1995)… Aquatic nonnative species are introduced and spread into new areas through a variety of mechanisms, both intentional and accidental, and authorized and unauthorized. Mechanisms for nonnative dispersal in the southwestern United States include interbasin water transfer, sport stocking, aquaculture, aquarium releases, bait-bucket release (release of fish used as bait by anglers), and biological control."

Non-natives are present and considered a problem in 28 of the 30 streams with remnant populations of roundtail or headwater chub (Voeltz 2002). Voeltz (2002), for example concludes: "at least 18 nonnative fish species have been recorded" in Chevelon Creek, and "impacts from nonnative green sunfish and black bullheads could pose a serious threat to roundtail chubs" in Francis Creek. There can be no question that non-native species are a serious threat to the continued existence of the roundtail and headwater chubs.

Significantly, Rinne et al. (1998) found a correlation between watershed condition and the proportion of non-natives to natives. In an analysis of 13 years of fish collection on the Verde River, AZ, that the proportion of natives to non-native substantially decreased moving downstream, corresponding to increasing impacts to the watershed. They conclude:

> "Based on a substantial database, over a considerable time period, it appears there is a distinct gradient from upstream to downstream in the ratio of native to non-native species… Changes in native fish populations in the Verde River appear to mirror human-induced changes in river systems on a regional basis."

In the lowest reaches, impacts stem from changes in the hydrograph related to two dams, a growing human population, water withdrawals, repeated stocking of non-natives, livestock grazing and others. These findings suggest that habitat protection may be key to maintaining native fish communities, including the roundtail and headwater chub.

B. STOCHASTIC DISTURBANCE AND POPULATION ISOLATION

Environmental perturbations, such as flood, drought and fire, are a normal part of the environment roundtail and headwater chubs evolved in. Historically, such events did not pose a threat because populations were interconnected and refugium habitat was widely available. Loss of any one stream population was balanced by recolonization from a nearby stream. On the present landscape, roundtail and headwater chub populations are isolated by a combination of physical structures, such as diversion dams, lack of habitat (e.g. dry streambeds), and presence of non-native species, leaving them vulnerable to extirpation with no chance of habitat recolonization. As individual populations are wiped out, a domino like effect brings the species ever closer to extinction. In-depth analyses of southwestern fish occurrence patterns led Fagan et al. (2002, page 3255) to conclude that the number of occurrences or populations of a species is far less significant in elevation of extinction risk than is fragmentation of the species. They conclude:

> "If our finding that the clustering of occurrences is key to species persistence over a wide range of landscape scales proves general, then the interplay between habitat fragmentation and habitat loss may be even more ruinous than currently predicted."

The probability of catastrophic stochastic events is exacerbated by a century of livestock grazing and fire suppression that have led to unnaturally high fuel loadings (Cooper 1960, Covington and Moore 1994, Swetnam and Baison 1994. Touchan et al. 1995, White 1985). Forests that once frequently burned at low intensities now rarely burn, often at stand-replacing intensity (Covington and Moore 1994). Fires in the Southwest frequently occur during the summer monsoon season. As a result, fires are often followed by rain that washes ash-laden debris into streams (Rinne 1996). It is such debris, rather than the fires themselves, that devastate fish populations. For example, the 1990 Dude Fire was known to severely impact fish in the East Verde River. Voeltz (2002) states:

> "Fish populations within the East Verde drainage were heavily impacted following the Dude Fire in 1990. Runoff from storms following the fire washed ash and sediments off of the burned slopes into the system, reducing or eliminating fish populations in many of the small tributary streams in the area of the fire."

Consequences of drought have been significantly increased through substantial changes in the natural hydrology of southwest rivers and streams, including increased peak flows and lowered water tables. The current serious drought being experienced in the southwest may cause increased declines in roundtail and headwater chub, particularly as human demand increases for the dwindling water supplies. The U.S. Fish and Wildlife Service in their recent draft candidate status review for the species concluded:

> "The extensive human alteration of watersheds that has occurred over the past 150 years in the lower Colorado River basin has resulted in changes in the hydrologic regimes of the rivers and in the geomorphology of the river channels. This human-initiated change is exacerbated by the naturally highly variable climate of the area. Peaks of flood flows have increased in volume while moving through the system more rapidly, so that damaging floods have become more frequent and more destructive. This increase in destruction is also tied to removal of riparian vegetation and encroachment of agricultural fields and buildings upon the floodplain. Flood destruction results in increased channelization and flood control measures which further alter the stream channel and hydrologic regime. On the other hand, low flows have become lower and last longer, thus decreasing habitat quantity and quality during critical times of the year for roundtail chub. The changes in hydrologic regime and the alteration of the floodplain and streambanks have been particularly adverse for roundtail chub. The resulting simplified streams, separated from their floodplain, tend toward wide channels with shallow riffles or runs over fine substrates and little instream cover. The deep pools and extensive cover needed by adult roundtail chub are among the first and most prominent features reduced or lost due to these channel changes."

Because of the reduced distribution and isolation of remaining roundtail and headwater chub populations in combination with increased severity of fire and altered hydrologic regimes, both species are at risk of extinction independent of any other factors, such as non-native fish or habitat degradation.

VI. DISEASE OR PREDATION

As noted above, a number of non-native species prey on roundtail and headwater chubs. The U.S. Fish and Wildlife, for example, reports that "mosquito fish are known to prey on eggs, larvae, and juveniles of various fishes" (USFWS 2002c). Largemouth bass (*Micropterus salmoides*), smallmouth bass, green sunfish, flathead catfish (*Pilodictus olivaris*), channel catfish, black bullhead (*Ameiurus melas*), and yellow bullhead

(*Ameiurus natalis*) are all known or suspected to prey on native fish and are to some degree sympatric with either roundtail or headwater chub (Girmendonk and Young 1997, Voeltz 2002). Girmendonk and Young (1997), for example, concluded:

> "Predation and or competition is a major threat to all native fishes in the Verde River and throughout most of the Verde Basin… Data suggests that native adult catostomids and roundtail chubs were significantly reduced from this reach [lower Verde], presumably by flathead catfish predation… Hendrickson (1993) predicted that nonnative predatory fish control could significantly increase native fish survivability."

Roundtail and headwater chubs are infected by a number of parasites, including protozoans (*Ichthyophthirius multifiliis*), trematodes (*Ornithodiplostomum ptychocheilus, Clinostomum marginatum* and *Plagioporus sp.*) cestodes (*Isoglaridacris bulboocirrus*), nematodes (*Dacnitoides sp.*, *Rhabdochona decaturensis,* and *Rhabdochona sp.*) and anchor worms (*Lernaea sp.*)(Girmendonk and Young 1997, James 1968, Mpoame 1981, Voeltz 2002). Some of these infections may have increased in recent years. James (1968) found that *Lernaea sp.* was very rare in museum specimens from prior to the 1930s, but increased in intensity from the 1930s to the 1960s with roundtail chubs exhibiting the greatest increase (10.8%). Severe *Lernaea sp.* infections have been noted in a number of chub populations. Hendrickson (1993) noted very high infections of *Lernaea sp.* during warm periods in the Verde River and Voeltz (2002) reported that headwater chubs found in Gun Creek in 2000, when surface flow was almost totally lacking, "showed signs of stress, and many had *Lernaea*, black grub, lesions and an unidentified fungus." Observations of increased rates of parasitic infection in recent decades combined with observations of infestation occurring in habitat stressed fish suggests that declining habitat quality may be increasing disease rates. Such increases in infection are likely negatively affecting roundtail and headwater chub populations with Girmendonk and Young (1997) concluding "parasitic infestations may greatly affect the health and thus population size of native fishes."

VII. INADEQUACY OF EXISTING REGULATIONS

Analyzing recovery and delisting of endangered and threatened species, Doremus and Pagel (2001) conclude that "Although the USFWS tends to focus on biological threats, it is logical that the inadequacy of existing regulatory mechanisms is decisive. Species adequately protected by background law or other means against habitat destruction, overexploitation, and other human activities do not decline to the point of endangerment."

There are at present no specific Federal protections for roundtail or headwater chub. Generalized Federal protections found in Forest plans, Clean Water Act dredge and fill regulations for streams, and other statutory, regulatory or policy provisions have been inadequate to check the rapid decline of these two fishes. In addition, a substantial body of Federal statutes, regulations and planning work against conservation of roundtail and headwater chubs and their habitat, a situation that can be remedied only through Federal listing. Relevant Federal statutes, regulations and plans are discussed, by agency, below.

Few State, Tribal, or local conservation efforts exist related to roundtail and headwater chub or their habitats, and those which do have been inadequate to prevent declines of the two fishes and some may have adverse affects to the two species. Future State, Tribal, and local planning specifically for the two species may occur that would assist in ameliorating threats to the two species, but no such planning has yet been finalized. Proleptic assumptions that such planning efforts will be satisfactorily completed, effectively implemented, and successful in protecting and recovering roundtail and headwater chub, would be inappropriate and not in keeping with Fish and Wildlife Service proposed regulations (65 FR 37102-37018, June 13, 2000) (see also Sidle 1998).

The Service has argued that if listing analyses consider future threats, then they must also consider future conservation efforts as potentially removing the need to list. We agree, but only if equal consideration is given to the level of knowledge regarding the likelihood and effectiveness of both. For southwestern fishes, including roundtail and headwater chub, the majority of the threats are ongoing (e.g. livestock grazing, timber, roads, urban and suburban development, mining, recreation, nonnative species, water development, etc.), so the likelihood they will continue is near certainty and their effectiveness in adversely effecting native fishes, including roundtail and headwater chub, is well known (see listing rules for southwestern fishes, also Voeltz 2002). Another large group of threats come from activities that have had similar effects to other fish or stream ecosystems, so that their effectiveness against fishes and streams are also well known (see listing rules for western fishes and amphibians). For most threats to southwestern fishes, there is a substantial body of literature providing information and linkages to support conclusions regarding the level and extent to which they affect native fishes and stream ecosystems, including roundtail and headwater chub and their habitats (see citations in other sections of this document). Only for threats still unknown or recently discovered (e.g. pollution by synthetic estrogen mimics in razorback sucker in the lower Colorado River) is there a significant level of uncertainty or lack of knowledge as to their effect. While such unknown threats undoubtedly play a part in the imperiled status of roundtail and headwater chub, it is unlikely that they are of greater magnitude than the already known or ongoing threats. The large losses of historic range and ongoing declines in populations of southwestern fishes, such as roundtail and headwater chub, are compelling indicators of the threat from past and ongoing adverse activities, and strong predictors of effects from future adverse activities.

On the other hand, techniques and systems that will be used for conservation efforts are often not well understood and many are unproven (see Griffith et al. 1989, Hilborn 1992a, Hendrickson et al. 1991, Minckley et al. 1991a, Tear et al. 1993, Rabeni and Jacobson 1993, Briggs et al. 1994, Beschta et al. 1995, Dombeck et al. 1997, Donegan 1997, Kauffman et al. 1997, Roper et al. 1997, Williams et al. 1997, Roni et al. 2002, Clarkson in press, Robinson in press). For some threats there are no known remedies, and the Endangered Species Act does not require that the cause of the species decline, or the means of removing the threats, be known before the species qualifies for Federal listing. The level of failure in protection and recovery actions is high and the efficacy of efforts are highly unpredictable, particularly for rare species where inherent flexibility within the populations has been depleted (Frissell and Nawa 1992, Hendrickson 1993, Minckley et al. 1991b, Minckley 1995, Meronek et al 1996, Wolden and Stromberg 1997, Comella and Fridell 1998, Allan 2000). In addition, implementation of protective and conservative measures is poor and funding is generally hard to obtain and of inadequate amount to accomplish necessary actions. There is a long history of inadequate implementation of statutes, regulations, policies, and plans by governmental bodies at all levels (GAO 1987, 1988a, 1988b, 1991, 1993, 1994, 1996, 2000a, 200b, 2001, 2002; Clark et al. 1989, USDOI Office of the Inspector General 1990, Sidle et al. 1991, USFWS 1993a, Stefferud 1995, Yaffee 1996, Pulliam 1998, Sidle 1998, Brower et al. 2001, Bulte and Van Kooten 2001, Stefferud and Stefferud in press).

The loss of historic range and ongoing species declines are often the best indicator that conservation implementation has been inadequate and success low. Of the fish species Federally listed within the lower Colorado River basin, most continue to decline and only two have shown any recovery, despite the fact that most have been listed for 10-30 years (Minckley and Douglas 1991, Propst 1999, Stefferud et al. in press). The two whose status have improved are Gila and Apache trout (*Oncorhynchus gilae* and *O. apache*) and the effectiveness of their recovery has been due to 1) they are potential sport fish and thus their recovery will directly benefit State and private interests, 2) the primary ongoing threat is hybridization and predation by nonnative trouts for which proven and relatively inexpensive remediation techniques exist, and 3) their currently occupied habitat is small headwater streams where fish communities are simple and human uses near the stream and in the watershed are limited in kind and effect. Species such as roundtail and headwater chub occupy streams where 1) species recovery is of no direct benefit to any governmental entity and may threaten many human uses, 2) the threats to the habitat and species are many and interactive and techniques for threat removal are often unknown or unproven and often highly expensive, and 3) their currently occupied habitat is of moderate to large size, with complex fish communities, and multiple, widespread, and synergistic human uses near the stream and within the watershed. Abbitt and Scott (2001) found these same differences to be significant in determining whether a species would recovery or continue to decline. Although fish species in the southwest have continued to decline despite Federal listing, only those with Federal listing, or imminent threat of Federal listing, have received any substantive protection or recovery actions.

In a recent legal decision, District Judge David Bury found that state, Tribal, and local programs, regardless of their value or efficacy, were not adequate substitutes for Federal protection under the Endangered Species Act (*Center for Biological Diversity v. Gale Norton, CV 01-409 TUC DCB* [Jan. 13, 2003]). This is particularly true in the case of roundtail and headwater chub where a large proportion of the present and historic range are on Federal lands or under Federal jurisdiction. Doremus and Pagel (2001) also found that State, local, and private laws and regulations were of substantially less effectiveness at conservation of imperiled species and concluded that "Background law generally does not protect species against either of these two primary threats (habitat degradation and exotic species). Even the ESA provides little protection against exotic species, but it does provide the strongest currently available protection against habitat degradation." It is clear that only Federal protection can provide an adequate basis for regulating Federal activities and regulations that negatively affect roundtail and headwater chub.

A. U.S. Fish and Wildlife Service

The Fish and Wildlife Service has no specific authority at present to take actions for recovery of roundtail or headwater chub. However, there are various Service authorities that provide for general conservation of fish and wildlife resources, such as the National Refuge system, the Fish and Wildlife Coordination Act of 1958, and the Fish and Wildlife Conservation Act of 1980. In addition, protection and recovery actions, under the Endangered Species Act, for other fishes in roundtail and headwater chub habitats may affect those two species. Few Fish and Wildlife Service regulations and policies work directly against roundtail and headwater chub and their habitat. However, the Service's sport fishing program and hatchery system, along with the current Director's policy statements regarding "getting back to our roots" in sport fishing advocacy, are actively adverse to roundtail and headwater chub, both of which are seriously threatened by the introduction, spread, management, and advocacy of nonnative sport fish and the accidental species introductions that accompany them.

Headwater chub is not found on any National Wildlife Refuge. Historic habitat for roundtail chub is found on the string of National Wildlife Refuges located along the lower Colorado River. In July 1993, the Fish and Wildlife Service relocated roundtail chub from Burro Creek into the Bill Williams River on the Bill Williams National Wildlife Refuge, but those fish are believed to have all died due to drying of the stream (USFWS 1993b, Voeltz 2002).

Most authorities of the Fish and Wildlife Service generally provide for technical assistance and consultation with State, Tribal, private, and Federal entities. However, even where consultation is mandatory, such as for Federal water development projects, consideration or implementation of Fish and Wildlife Service recommendations is discretionary on the part of the other agency or entity. In reality, few if any of those recommendations are implemented. Thus, Fish and Wildlife Service recommendations that might benefit roundtail or headwater chub, such as for water development mitigation under the Fish and Wildlife Coordination Act or modification or denial of dredge and fill permits under section 404 of the Clean Water Act, seldom actually result in preventing activities that adversely affect the two species. A good example of this can be seen in the large amount of permitted channelization and other channel modification that has occurred within the Verde Valley, within occupied roundtail chub habitat and in the loss of substantial chub habitat beneath Federally-constructed reservoirs on the Colorado, Salt, and Verde Rivers.

Several other fish species are listed as threatened or endangered in the lower Colorado River basin potentially providing collateral protection for populations of roundtail and headwater chubs, including the razorback sucker, Gila topminnow, Little Colorado spinedace, loach minnow and spikedace. To determine the degree of protection provided by these species, we assessed overlap in present range based on designated critical habitat if present and similarity of habitat requirements, since protections are in part based on the needs of each individual species. As primarily a large river fish, the humpback chub's critical habitat is restricted to mainstems of major rivers, such as the Colorado, where the roundtail chub is largely extirpated. The Gila topminnow does not have critical habitat and is mostly restricted to the heads of springs, where roundtail and headwater chubs do not occur. Critical habitat for the razorback sucker, Little Colorado River spinedace (*Lepidomeda vittata*), loach minnow and spikedace overlaps with 9 of the 19 known extant populations of roundtail chub and 3 of the 13 known extant populations of headwater chub (FR V. 59, No. 54, March 21, 1994, FR V. 65, No. 80, April 25, 2000, Voeltz 2002) (Table 3).

Table 7. Waters where critical habitat overlaps with known extant roundtail or headwater chub populations from Voeltz (2002)

Species	Waters
Razorback sucker	Verde River
Little Colorado River spinedace	Chevelon and East Clear Creek
Loach minnow and spikedace	Verde and upper Gila Rivers; Fossil, West Clear, Wet Beaver, Oak, Eagle, Tonto and Aravaipa Creeks.

The greatest degree of range overlap is with loach minnow and spikedace. But because these species have substantially different habitat requirements, selecting riffles and swift water rather than pools, the primary constituent elements of critical habitat do not correspond to those of habitats selected by roundtail and headwater chub, potentially resulting in protection and management of critical habitat that benefits loach minnow and spikedace, but not the chubs. In fact, because of the substantial differences in habitat, actions to benefit loach minnow and/or spikedace could actually adversely affect roundtail or headwater chub by increasing riffle habitat and decreasing pool habitat. Moreover, substantial portions of both chub species present ranges are not covered by any critical habitat, including half of the remaining roundtail chub and most headwater chub populations. Where critical habitat does overlap, it has not prevented the decline of roundtail and headwater chubs. In sum, protections for already listed species are not adequately protecting roundtail and headwater chub.

The Fish and Wildlife Service has demonstrated an inability to deal effectively with the nonnative species problem affecting native fishes, including roundtail and headwater chub. Inadequate enforcement of State and Federal regulations regarding transport and introduction of nonnative and invasive species is an issue of national importance (GAO 2002). For example, Service-led efforts to control the recent invasion of nonnative giant salvinia (*Salvinia molesta*) in the lower Colorado River have been marked by slow, lackluster implementation and are now apparently stalled. In addition to failure to effectively dealing with introductions by others, the Fish and Wildlife Service also continues to stock nonnative sport fish in or near roundtail chub habitat (USFWS 1994, 1995c). These continued stockings not only augment existing nonnative species, but also introduce additional nonnatives (see Rorabaugh et al. 2001). Technical and staff-education failures led to recent introduction by the Service of the nonnative gizzard shad (*Dorosoma cepedianum*) into Lake Powell at the upper-lower Colorado basin interface. This introduction occurred due to carelessness in ensuring that transbasin shipment of sport fish from a Federal hatchery contained only the desired species (Brooks and Mueller In press).

Deficiencies in the Fish and Wildlife Service staffing, budget, and administration have led to extensive delay in listing roundtail and headwater chub. These delays are not limited to these two fish and have been discussed extensively elsewhere (GAO 1993, Greenwald and Suckling in prep.) The Service first became aware of the declining and perilous status of roundtail chub (including headwater chub) in the early 1980's and was first advised of the need for its Federal listing in 1989 by the Service's own advisory Desert Fishes Recovery Team. Despite that, the Service has still not given the species (now two species) candidate status nor begun work on a listing proposal. This 13+ year delay has been a significant contributor to the present endangered status of both roundtail and headwater chub. Listing in the 1980's may have provided the means to prevent the declines which occurred to the species during those 13 years and stabilized its status at threatened. This delay and its consequences to the species demonstrate the inadequacy of existing regulatory mechanisms within the Fish and Wildlife Service.

B. U.S. Forest Service

The U.S. Forest Service is the largest landowner and manager of roundtail and headwater chub habitat. The Forest Service lists the roundtail chub (including headwater chub) as a sensitive species in the lower Colorado River basin in southwestern region (Arizona and New Mexico) but not in the upper Colorado River basin in the northern (Colorado and Wyoming) and intermountain regions (Utah) (U.S Forest Service 2000). Sensitive species designation provides little protection to the roundtail chub because it only requires the Forest Service to analyze the effects of their actions on sensitive species, but fails to require that they choose environmentally benign actions. The Forest Service does not provide any other protection specifically for the roundtail or headwater chub. Major Forest Service statutes that provide for general resource protection include the Federal Land Policy Management Act of 1976 and the National Forest Management Act of 1976. None of these statutes have forestalled declines in populations of roundtail and headwater chub. Some of the statutes that work against protection of roundtail and headwater chub include the Organic Administration Act of 1897, the 1872 Mining Law, and Public Rangelands Improvement Act of 1978.

Our analysis of management on 58 Forest Service allotments with known roundtail or headwater chub populations found that the agency failed to consider the effects of livestock grazing on chub in as many as 23 allotments (39.7%). Livestock grazing was considered to potentially impact individual chub or their or habitat on 20 of the other 35 (57%) allotments, and in two cases impacts were considered sufficient for the Forest Service to conclude that grazing would "eventually trend the species toward federal listing" (Appendix A). These assessments are conservative in considering impacts to fish, as Forest Service biologists are often pressured to downplay impacts in their assessments to avoid affecting consumptive uses such as grazing (Cain et al. 1997). Environmental assessments and biological evaluations from the 58 allotments indicated poor riparian and watershed conditions nearly rangewide, including 40 of the 58 (69%) allotments. Only four allotments were noted as having proper functioning riparian conditions.

In recent years, the Forest Service has taken some action to protect riparian areas, primarily in response to litigation over the effects of their actions on listed fish, including razorback sucker, loach minnow and spikedace. In particular, livestock have been removed from sections of the upper Verde and upper Gila Rivers, as well as other areas. Of the 58 allotments, cows have been excluded from the riparian area on 18 and removed entirely from three allotments. Despite these improvements, a majority of chub populations continue to be directly impacted by livestock grazing in the riparian area (37 of 58), or indirectly impacted by livestock grazing in the uplands (55 of 58 where livestock remain in the riparian area and/or uplands). As an example of the latter, the Coconino National Forest concluded in a 1999 biological evaluation that livestock grazing on the Thirteen Mile Allotment may impact individuals of roundtail chub "based on the potential indirect impacts of grazing on roundtail chub habitat, and the contribution of grazing to cumulative effects," even though riparian areas on the allotment are excluded from livestock. This data indicates that ongoing grazing management is failing to prevent further habitat loss and degradation for the roundtail and headwater chubs.

Six National Forests have historic or present range of roundtail and/or headwater chub on or adjacent to their lands. The Forest Plans of each of the forests presumably provides some protection for these two fishes through provisions such as this statement from the Tonto National Forest Plan (U.S. Forest Service 1985):

> "Wildlife and fish habitat elements will be recognized in all resource planning and management activities to assure coordination that provides for species diversity and greater wildlife and fish populations through improvement of habitat. Ensure that fish and wildlife habitats are managed to maintain viable populations of existing native vertebrate species. Improve habitat for selected species."

However, such statements are only guidance and the managers must continually choose which guidance to follow, as there is often incompatibility between various Plan statements. For example, for a roundtail chub occupied portion of the Verde River, the Tonto Plan also says:

> "Manage suitable rangelands at Level B." (Level B is defined as "Management controls livestock numbers so that livestock use is within present grazing capacity. Improvements are minimal and constructed to the extent needed to protect and maintain the range resource in presence of grazing.")

When applying contradictory statements, such as these, the predominant political pressure on Forest line officers is to choose in favor of consumptive use. This bias toward consumptive uses leads to ongoing problems, such as those on the lower Verde, where conflicts between the riparian, fish, and wildlife resource and livestock grazing have been the subject of extensive discussions between the Fish and Wildlife Service and the Forest Service (see documents for consultation 2-21-99-F-022, Red Creek allotment).

C. Bureau of Land Management

Management of roundtail and headwater chub on BLM lands is limited. The chub species are not given any special recognition and documents provided by the BLM in response to our Freedom of Information Act request indicated they failed to consider the chubs in management of allotments. Moreover, the documents indicated the BLM was not taking substantial action to monitor the conditions of riparian habitat or to exclude livestock from degraded riparian areas. These facts clearly indicate that management of roundtail and headwater chub habitat on BLM lands is inadequate to prevent further decline.

Major BLM statutes that provide for consideration or protection of natural resources include the Federal Land Policy and Management Act of 1976 and the National

Environmental Policy Act of 1969. None of these statutes provide specific protections for roundtail or headwater chub and have not prevented the decline of these species. The 1934 Taylor Grazing Act and other livestock grazing statutes, along with the 1872 Mining Act and other mineral-related laws have been among the most adverse statutes affecting roundtail and headwater chub on BLM lands.

The most outstanding roundtail chub population on BLM land is the one at Aravaipa Creek. Although BLM has removed livestock grazing from the riparian corridor (but not the watershed) and has instituted strong measures to control recreation impacts, the status of the chub there is still in danger. Upstream groundwater pumping, private land channelization, irrigation, suburban development, a county road, and other activities not under BLM control threaten the quantity and quality of roundtail chub habitat. Without Federal listing the Fish and Wildlife Service, Corps of Engineers and other regulatory agencies have little power to control those threats, which have the potential to eliminate the chub, and other native fish, from the BLM portion of the stream.

D. Bureau of Reclamation

The Bureau of Reclamation has a substantial role in the imperiled status of the roundtail chub and in conservation efforts for both roundtail and headwater chub. In the mainstem lower Colorado River, dam and reservoir construction and operation, and past and ongoing channelization have played the major role in extirpation of roundtail chub. Various water compacts, statutes, regulations, policies, and contracts guide Reclamation’s operation of water flow and stream channel in the lower Colorado River, and their purpose is to maximize water availability for human uses. Mitigative measures for fish and wildlife have been inadequate to prevent extirpation of several native fish species or to prevent the continuing decline of remaining species, such as razorback sucker and bonytail chub.

Within the Gila River basin, Reclamation has also played a role in the imperiled status of roundtail chub through dams and reservoirs and assistance to local government and private water development. At present, the most important role of Reclamation for roundtail and headwater chub is through the nonnative aquatic species control and native fish recovery programs under the 2001 biological opinion on the Central Arizona Project and its potential to introduce and spread nonnative aquatic species (USFWS 2001b). Under these programs, Reclamation is constructing fish barriers and providing funding to Fish and Wildlife Service to control and remove nonnative fish or other recovery activities. However, this program is aimed primarily at four Federally listed fishes (spikedace, loach minnow, Gila topminnow, and razorback sucker), and benefits to roundtail and headwater chub are only incidental. These incidental benefits will help remove some threats to roundtail and headwater chub, such as at Fossil Creek, but they do not broadly address removal of threats to roundtail and headwater chub, nor do they deal with range or populations of the chub outside the Gila River basin. In addition, the amount of funding for the Central Arizona Project program was calculated as a portion of the minimum needed for recovery of the four target species, and is insufficient to cover conservation of roundtail and headwater chub.

Reclamation also has ongoing activities in the Gila River basin that are adverse to roundtail and headwater chub. While the Central Arizona Project nonnative mitigation is working to restore flows and native fish in Fossil Creek, Reclamation programs to assist water development are providing assistance to local communities to study future ways to deplete the flow of Fossil Creek. Such conflicting purposes illustrate the inadequacy of existing Reclamation statutes, regulations, and policies for conservation of roundtail and headwater chub.

E. U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers administers issuance of dredge and fill permits under section 404 of the Clean Water Act. These permits regulate a wide variety of activities in streams in the both historic and extant range of roundtail and headwater chub. Under the regulations and policies governing implementation of this program, there is substantial latitude for allowing extensive destruction and degradation of stream habitats, including those supporting roundtail and headwater chub. The 404 program and its administration is clearly inadequate to maintain habitat that will support roundtail or headwater chub. A good example of the failures of the 404 program are the extensive incremental channelization that has been allowed along Aravaipa Creek, both permitted and without authorization (USFWS 1993a, c, d). Other examples are continuing gravel mining in the bed of Tonto Creek, and the issuance of a 404 permit for the construction of Rio Salado Town Lake which has already become a major habitat and staging area for nonnative aquatic species within the Gila River basin (USFWS 2000b). Existing regulations are clearly inadequate for the Corps to refuse permits for, or substantially alter, projects to avoid serious adverse effects to roundtail or headwater chub.

F. Other Federal Agencies

A number of other Federal agencies have programs or activities that are adversely affecting, or expected in the future to adversely affect, roundtail and/or headwater chub. These include, but are not limited to, the Natural Resource Conservation Service, Federal Highway Administration, Federal Emergency Management Agency, Environmental Protection Agency, Bureau of Indian Affairs, Animal and Plant Health Inspection Service, and Indian Health Services. The past, future and ongoing adverse impacts by these agencies to roundtail and headwater chubs and their habitat, despite over ten years of discussions regarding the declining and imperiled status of these fish, argue forcefully that the existing statutes, regulations and policies are inadequate to protect and recover the two fish.

G. States

Arizona. The state of Arizona has no substantial laws or regulations to protect the roundtail or headwater chub. The Arizona Game and Fish commission lists the roundtail chub (includes the headwater chub) as a species of special concern. This designation, however, provides little to no protection, lacking any provisions against take, and failing to include a requirement for the state to prepare a recovery plan. In addition, State listing provides for no protection for habitat of roundtail chub. The State of Arizona has designated the roundtail chub (including headwater chub) as a sport species and allows angling for the species (AZGFD 2002a). Take through angling is not believed to have substantial impact on the species. It was hoped that additional funds would become available for its conservation through sport fish funding sources. However, little funding has become available and to-date, only planning and studies have been conducted.

Arizona Game and Fish Department has indicated the State's opposition to candidate status for roundtail and headwater chubs (AZGFD 2002b). Their rationale is that "proactive opportunities are available to improve the species' status and thus preclude the need to list pursuant to ESA." They state "we *should be* pursuing those avenues" (emphasis added). They believe Federal listing would reduce funding for conservation of roundtail chub. And, although the description of headwater chub as a distinct species meets all accepted professional standards and was published by a prestigious scientific journal by a highly regarded taxonomist of national repute, the Arizona Game and Fish Department disputes the Fish and Wildlife Service's authority to recognize headwater chub and questions whether such recognition is within the law. The Department's position indicates they do not look favorably on providing all possible protection for roundtail chub and that they are unlikely to recognize, let alone protect, headwater chub.

Arizona Game and Fish Department's advocacy of pursuit of proactive opportunities in-lieu of Federal listing does not discuss or provide any record of such activities to-date. In fact, there have been no such activities. In 1996, the Arizona Nongame Branch Native Fish Program Manager stated that other than surveys, no action had been taken toward the previously expressed Department goal of taking enhancement actions for roundtail chub to improve its status to remove the need for listing (Desert Fishes Recovery Team 1996). Discussions during the September 2002 Desert Fishes Recovery Team meeting elicited no known conservation actions taken for roundtail or headwater chub. The only action in progress is native fish restoration in Fossil Creek, for which the Department has withheld its support (AZGFD 2001, U.S. Bureau of Reclamation 2002).

At the September 2002 Desert Fishes Recovery Team meeting, it was discussed that the Department is considering bringing roundtail chub into the hatchery for captive propagation and has contacted Arizona State University geneticists to ask if there was a single stock of roundtail chub that could be used for reintroduction stocking statewide. While the Team has always recognized a role for captive propagation in conservation of roundtail chub, Team members and attending biologists were alarmed at this information because such a single-stock approach could have serious adverse consequences to the species through loss of genetic diversity and local adaptation (Vrijenhoek et al. 1985, Echelle 1988, Busack and Currens 1995). It is particularly alarming in light of the Department's position that headwater chub are not a valid taxon, leading to concerns that they may fail to preserve separate roundtail and headwater chub genetic distinctions in captive propagation.

Information obtained since that meeting is that the Department is moving forward on bringing a stock of what they presume are roundtail chub (as opposed to headwater chub) into Bubbling Ponds Hatchery. The stock was obtained from canals in the Phoenix area. Despite advice from biologists, the Department is planning to breed this fish for repatriation into the Verde River on top of an existing population of roundtail chub. There is no written plan for this work and there has been no attempt to involve expertise from outside the Department in planning an effort that will be highly significant to the survival of roundtail chub. There are substantial issues that need to be established, using the best scientific expertise available, regarding what stock is best for the captive propagation program, where the captive stocks will be placed back into the wild, what level of genetic diversity has to be maintained in the hatchery, how domestication of the captive fish will be avoided, etc. (Echelle 1988, Stickney 1994, Busack and Currens 1995, Modde et al. 1995, Ham and Pearsons 2001). According to information we received, no consideration is being given to existing genetic diversity, required broodstock size, founder effect, inbreeding or outbreeding depression, or other important factors in captive propagation (see Echelle 1988, Meffe and Vrijenhoek 1988, Schramm and Piper 1995) . This is particularly important because augmentation of existing populations with hatchery stock can be detrimental to the natural populations and has been a contributing factor in species decline in other fish species (Allendorf and Leary 1988, Hilborn 1992b, Meffe 1992, McCracken et al. 1993, Fleming 1994, Moyle 1994, Stickney 1994, Campton 1995, Dowling et al. 1996, Independent Scientific Advisory Board 2002, Ford 2002, Moyle 2002). It is widely recognized that in use of captive stocks, it is important to ensure that existing natural populations remain genetically unaltered (Echelle 1988, Allendorf and Leary 1988, Modde et al. 1995), a principle which does not appear to be included in the Department's plans. Bubbling Ponds Hatchery is not presently equipped to prevent escapement of roundtail chub and their larvae from the hatchery into Oak Creek and the Verde River, and the current roundtail chub work does not provide for such prevention nor does it consider the consequences of such escapement.

An action taken by Arizona Game and Fish Department for roundtail chub that may be considered a conservation action, although its value to the species is minimal, is the stocking (beginning in 2001) of roundtail chub into Rio Salado Town Lake, an artificial impoundment in the otherwise dry Salt River bed in the town of Tempe in the center of the Phoenix metropolitan area (USFWS 2001f). The purpose of this project is to enhance urban fishing opportunities. Nonnative rainbow trout (*Oncorhynchus mykiss*) are also stocked. Roundtail chub were chosen for stocking only after the Fish and Wildlife Service opposed stocking of nonnative fish species.

The Arizona Game and Fish Department continues to take actions that have adverse consequences to the two native species. These include their opposition to barriers and nonnative removal on Fossil Creek, continued stocking of nonnative fish, and ongoing management for enhancement of nonnative sport fish throughout the state (USFWS 1995a, b, c, 2001f, g). Although a major Department mandate is sport fish management, this mandate and its substantial contribution to the Department's budget place the Department in a conflict of interest regarding native fish, including roundtail and headwater chub.

In addition to nonnative fish, the Arizona Game and Fish Commission continues to allow in the lower Colorado River and adjacent waters, the transport, sale, and possession of nonnative crayfish. Crayfish are a major threat to all native aquatic species in the lower

Colorado River basin and elsewhere (Fernandez and Rosen 1996, Gamradt and Kats 1996, Inman et al. 1998, Parmley and Brouder 1998, Carpenter 2000). This regulatory loophole was allowed despite opposition from the Fish and Wildlife Service (USFWS 2001h).

On a positive note, the Arizona Game and Fish Commission has in the past 10 years restricted the use of live nonnative bait. Only seven fish species, one genus, and one family group are allowed, in addition to crayfish and waterdogs (AZGFD 2002). Three of the species and the one genus are restricted to use along the lowermost part of the Colorado River. The other fish species and family group, as well as the waterdogs, are allowed throughout a large portion of the Gila River basin and entire lower Colorado River. Although use of live nonnative bait fish provides a low-level continuing augmentation of adverse effects, the current regulations are a significant improvement over the past, which reduces adverse impacts to roundtail and headwater chub.

Although the Arizona Game and Fish Department is responsible for enforcement of laws regarding public stocking of nonnative species, they have few resources for this work and effective enforcement is difficult. They are currently under contract with the Bureau of Reclamation, for $110,000, to undertake a public education campaign on the issue of nonnative impacts to native fishes. However, after 3 years of work little has been accomplished. Failure to effectively educate the public on this issue is a major threat to roundtail and headwater chub. Examples of the consequences of that failure are the recent unauthorized stockings of tilapia (*Tilapia* sp.) into Roosevelt Lake on the Salt River and northern pike (*Esox lucius*) into Parker Canyon Lake. In both cases, public education may have helped prevent the problem. At present, the Department has no plan to remove the nonnative in either circumstance. The inability of Arizona Game and Fish Department to deal with this problem is a serious inadequacy in the existing regulatory and management capability.

The Arizona Game and Fish Department also regulates what species of nonnatives can legally be brought into the state. Prohibited nonnative species are put onto the Restricted

Live Wildlife List (Commission Order 12-4-406). However, species are allowed unless they are prohibited by placement on the list, rather than the more conservative approach of prohibited unless specifically allowed. In addition, the Arizona Game and Fish Commission has been resistant to adding species to the list and has rejected recommendations from a number of parties, including the Fish and Wildlife Service (see USFWS 1998). This leaves a serious regulatory inadequacy that allows the opportunity for many noxious nonnatives to be legally imported and introduced into Arizona. At least some of these will have serious adverse consequences to native fish, including roundtail and headwater chub.

The Arizona Department of Agriculture also maintains a list of prohibited nonnative plants. Like the Restricted Live Wildlife List, it also allows species importation and introduction unless prohibited. Enforcement is difficult and inadequate. Giant salvinia continues to be sold in Phoenix nurseries despite having been placed on the list. Calls to the Department of Agriculture reporting such sales appear to have no effect, as the nurseries continue to carry the plant.

Arizona statutes, regulations, and policies are clearly inadequate to provide any significant protection to roundtail or headwater chub. The record of lack of positive actions and continuing implementation of adverse actions demonstrates clearly that the Arizona Game and Fish Department's belief that roundtail and headwater chub are being protected best without Federal listing is not supportable. There is nothing in the current Arizona State laws or regulations that meets the 14 criteria set forth in the Fish and Wildlife Service's proposed policy for evaluation of conservation efforts as possible alternatives to Federal listing (65 FR 37102-37108, June 13, 2000).

Under a Memorandum of Understanding signed by the Fish and Wildlife Service and Arizona Game and Fish Department in August 2002, the two agencies have agreed that the Department will be the lead in prelisting recovery actions. It is too early to tell if this MOU provision will result in any positive, or amelioration of adverse, actions by the Department for roundtail chub. The MOU also agrees to involvement of the Department in decisions on candidate status and listing. Given the Department's record of opposition to conservation of roundtail and headwater chub, this MOU contributes to the regulatory inadequacy for protection and recovery of those two species.

We are aware that Arizona Game and Fish Department is considering participation in a State of Utah-led conservation planning effort for roundtail chub and two other fish species. This effort will be discussed in the later section regarding the State of Utah.

New Mexico. The state of New Mexico lists the roundtail chub as an endangered species under its Wildlife Conservation Act. Although this Act does require development of a recovery plan, one has never been produced for the roundtail chub. The Act also has a provision against take (New Mexico Wildlife Conservation Act 17-2-41(B). Unlike the federal ESA, however, habitat destruction does not constitute take under New Mexico's law. Moreover, the provision has never been enforced to protect the roundtail chub and only very rarely to protect any other species (D. Propst New Mexico Department of Game and Fish personal communication). Listing of the roundtail chub as an endangered species in New Mexico is thus largely symbolic, lacking any substantive protection.

New Mexico allows use of live bait fish, a regulatory inadequacy that adversely affects roundtail and headwater chub in the upper Gila River (New Mexico Game and Fish Department 2003). Live bait use of two species of sunfish and all "minnows" are allowed. Goldfish (*Carassius auratus*), a nonnative formerly allowed for live bait use, is no longer allowed.

New Mexico also continues to stock nonnative fish within habitat of roundtail and headwater chub. Channel catfish are occasionally stocked into ponded waters, such as Lake Roberts, on Sapillo Creek. Rainbow trout are stocked annually in the Gila River and its tributaries.

New Mexico statutes, regulations, and policies are not adequate to provide any significant protection to roundtail or headwater chub. New Mexico is also considering participation in the State of Utah-led conservation planning effort for roundtail chub and two other fish species.

Nevada and California. These two states have historic range of roundtail chub in the lower Colorado River. Because they have only historic, and not currently occupied, range, we have not analyzed their laws, regulations, and policies for adequacy for conservation of roundtail chub. However, the adequacy of their laws and regulations will affect recovery of roundtail chub. We are not aware of any specific regulations or planning efforts in either state for roundtail chub. The Nevada Division of Wildlife is considering participation in the Utah-led conservation planning effort.

Utah. No lower Colorado River basin roundtail or headwater chub historic or present habitat is located in Utah. However, a large proportion of the upper Colorado River basin population of roundtail chub is in Utah.

The Utah Department of Natural Resources has drafted a document entitled "Range-wide conservation agreement and strategy for roundtail chub (*Gila robusta*), bluehead sucker (*Catostomus discobolus*) and flannelmouth sucker (*Catostomus latipinnis")*(UDWR 2002 draft). It is unclear what the document includes as part of the species roundtail chub. The only recognition of headwater chub is a statement that "Roundtail chub . . . was recently divided into three species, *Gila robusta, G. intermedia,* and *G. nigra*. .. " Regardless of the fact that the statement is incorrect, it appears the intent may be to include both headwater and Gila chub as part of the "roundtail chub" covered by the draft Agreement and Strategy.

The draft Agreement and Strategy, which was prepared for the Colorado River Fish and Wildlife Council (a multi-state working group), states as its purpose:

> "Threats that warrant the three species being listed as a sensitive species by state and federal agencies and/or as threatened or endangered under the Endangered Species Act of 1973, as amended (ESA), should be eliminated

> through implementation of this Agreement and the attached Conservation Strategy. "

Although the draft Agreement and Strategy generally discuss only the upper Colorado River basin, it is specifically entitled "Rangewide" and has listed as potential signatories three lower basin States. The Agreement and Strategy are only in draft and substantial parts are still unwritten. The draft Agreement and Strategy depends heavily on individual State plans. Inquiries as to the status, or availability, of the State plans have not yielded any draft plans and we are not sure if any have yet been drafted. However, it is our understanding that potential signatories hope to sign the Agreement and Strategy at the April 2003 meeting of the Colorado River Fish and Wildlife Council.

In considering the adequacy of this agreement, Fish and Wildlife Service must note that under the Endangered Species Act, the agency is not to consider planned and future management actions when determining whether a species meets the requirements of a threatened or endangered species, but instead only the current management and status of the species. In numerous cases, the Fish and Wildlife has been forced by judicial action to reverse decisions not to list species because they relied on promised management actions, including decisions over the Barton Spring's salamander, Queen Charlotte goshawk, jaguar, Alexander Archipelago wolf and coho salmon. This is not merely a legalistic technicality. There is good reason for considering only current management and status. States, Federal agencies and private interests can easily promise to protect and recover species in order to avoid or delay a listing that they consider potentially controversial. Despite the fact that the draft Agreement and Strategy should not be considered at this time, we are provide the following analysis to determine its likely effectiveness, and its conformance to proposed Fish and Wildlife Service standards.

The draft Range-wide Conservation Agreement and Strategy fails to meet almost all of the Fish and Wildlife Service's proposed criteria for Evaluation of Conservation Efforts when Making Listing Decisions (65 FR 37102-37108), for the following reasons:

<u>A. The certainty that the conservation effort will be implemented:</u>

<u>1. The conservation effort; the party(ies) to the agreement or plan that will implement the effort; and the staffing funding level, funding source, and other resources necessary to implement the effort are identified.</u> The draft Agreement and Strategy identifies these items only in a vague and generalized manner.

In the draft Agreement and Strategy, the objectives of the conservation effort for roundtail chub are identified as the establishment and maintenance of seven populations of roundtail chub in an estimated 280 miles of stream, apparently all in the upper Colorado River basin. A minimum viable population level is to be determined and maintained for each of these populations. Geographic management units, apparently all in the upper basin, are to be identified and population groups meeting some type of meta-population characteristics are to be established. It is not clear if these are part of the seven mentioned above, or in addition to those. Our description is not a summary of the stated objectives; this is the level of detail given in the draft Agreement and Strategy. No rationale is given for any of these objectives or why they omit half of the species' range.

Conservation actions call for conducting status assessments (apparently in addition to the two recent ones); establishment and maintenance of a database of information on the species; studies of demographics, life history, genetics, and habitat; population augmentation of existing populations and repatriations to historic areas (apparently from hatchery propagation); monitoring; control of nonnative species; and an information and education program. The one-sentence conservation action statements from the Agreement are expanded in the Strategy to include two to four bullet statements for each general category and total 3 pages for the combined actions for all three species. This brevity is in stark contrast to the complexity of range, habitat, land ownership, threats, genetic, and other roundtail and headwater chub issues and factors.

In addition, the draft Agreement and Strategy state that threats to the species will be eliminated, but fail to discuss what those threats are or how they will be eliminated. Coordination, meeting schedules, and team formation are described in more detail.

The draft Strategy describes itself as a “framework for the long-term conservation of roundtail chub . . . .” and says it only “outlines and summarizes the conservation measures that will be specified in each state conservation and management plan” and that “all of the specific task . . . are not reiterated in this document.” It goes on to say that these plans will be developed at some future time. Summaries of recovery actions taken to-date are said to be included in an Appendix, which is not available at this time. Likewise the Conservation Guidelines section of the draft Strategy is as yet unwritten. Apparently because of the range-wide approach, the Strategy mostly ignores the status review and report of Voeltz (2002).

The meager descriptions of the conservation effort, the failure to recognize headwater chub as a distinct entity, and the omission of major issues and information leave the draft Agreement and Strategy seriously flawed and completely inadequate to meet the Service’s criterion. While individual State plans may have more detail, promised future planning does not meet the criterion that conservation effort be spelled out to a certainty that the effort will be implemented.

The parties that will implement the agreement are specifically spelled out and consist of 6 State wildlife agencies. However, it is provided that any party can withdraw from the agreement upon 60 days notice, raising substantially the uncertainty that the conservation plan will be fully implemented. While the signatory parties represent all of the State’s with extant populations, California, which has historic (and potential recovery) range is not a party. Also missing are Federal agencies and Tribal governments, which are parties with significant roles in any overall conservation effort for roundtail chub. A conservation agreement without the major landowners and without major parties whose activities threaten the species, has little certainty of being effective at either protection or recovery.

Staffing is not addressed and funding level is addressed only in generalizations. Again, details are said to be identified in the unavailable or unwritten State plans. The draft Agreement simply identifies a number of parties that "will need to provide or secure funding" and some possible avenues they should explore. Other resources are addressed only as possible in-kind contributions to be made by "participating agencies." It is specifically stated that this is a voluntary non-binding agreement. Hence, if states or other parties to the agreement fail to provide funding or carry out activities prescribed in the Agreement, they can not be sued or in any other way held accountable. There is no attempt in the draft Agreement or Strategy to specifically identify funding sources or any certainty that adequate, or indeed any, funding will be made available.

The draft Agreement and Strategy does not clearly identify the conservation plan, the staffing, funding level or source, or other necessary resources and so fails to meet this criterion.

<u>2. The authority of the party(ies) to the agreement or plan to implement the conservation effort and the legal procedural requirements necessary to implement the effort are described.</u> The draft Agreement lists only section 4 of the Endangered Species Act as an authority. No State authorities are given for the conservation actions to be taken by the signatories. It is specifically recognized that "There may not be statutory authority to implement all actions. . " It is also recognized that the role of the team that will oversee the draft Agreement and Strategy is only advisory and they will have no authority to ensure implementation. Legal procedural requirements are not discussed. The draft Agreement and Strategy clearly do not meet this criterion.

<u>3. Authorizations (e.g., permits, landowner permission) necessary to implement the conservation effort are identified, and a high level of certainty that the parties to the agreement or plan that will implement the effort will obtain those authorizations is provided.</u> This criterion is only partly relevant to conservation efforts for roundtail chub. The States party to this draft Agreement have State and Federal permits for take and have

recognized roles for fish on Federal lands. However, the draft Agreement and Strategy do not identify those authorizations nor address what other authorizations will be needed. Neither do they address access to private or Tribal lands, which make up significant areas important for roundtail chub conservation efforts. The certainty of the States obtaining access to either private or Tribal lands in the lower Colorado basin is not high, which could cripple any effective implementation of the draft conservation plan. The draft Agreement and Strategy fail to meet this criterion.

4. The level of voluntary participation (e.g. by private landowners) necessary to implement the conservation effort is identified, and a high level of certainty that the party(ies) to the agreement or plan that will implement the agreement will obtain that level of voluntary participation is provided (e.g. an explanation of why incentives to be provided are expected to result in the necessary level of voluntary participation). The draft Agreement and Strategy do not address voluntary participation, except by the signatories, and do not address any measures by which private landowner participation will be sought. The draft Agreement and Strategy fail to meet this criterion.

5. All regulatory mechanisms (e.g. laws, regulations, ordinances) necessary to implement the conservation effort are in place. There is no discussion in the draft Agreement and Strategy of what regulatory mechanisms are needed to accomplish the stated goals. Because roundtail and headwater chub are found over such a large area, with many types of land ownership, under adverse impact from a multitude of different land and water uses, and have a large number of State, local, Tribal, Federal, and private jurisdictions, it would be difficult and time-consuming to identify all major regulatory mechanisms that are necessary to implement a full conservation effort. However, full identification is an important part of an adequate conservation agreement. It is likely that full conservation of roundtail and headwater chub may require changes to State, local, Federal, Tribal and other regulations and policies. For example, changes to Arizona groundwater law may be necessary to preserve several extant populations of roundtail and headwater chub, and changes in sport fishing and aquaculture regulations may be needed in several states. Because of the failure to describe pertinent regulatory mechanisms, address any

necessary changes, or establish that no such changes are necessary, the draft Agreement and Strategy do not meet the criterion, as described.

6. A high level of certainty that the party(ies) to the agreement or plan that will implement the conservation effort will obtain the necessary funding is provided. The draft Agreement and Strategy recognize that funding for this effort is uncertain and that funding is "subject to approval by the appropriate local, state or Federal appropriations." Since the draft Agreement and Strategy fail to identify which parties are responsible for obtaining appropriations and from what sources, it is clear that the level of uncertainty that the conservation effort will obtain the necessary funding is high. The goals of this draft Agreement and Strategy will be very expensive to accomplish and no source of such a large amount of funding is known to exist at present. The draft Agreement and Strategy fail to meet this criterion.

7. An implementation schedule (including completion dates) for the conservation effort is provided. A schedule is given for the Coordination Team leader election and meetings and for annual review of progress. Other than that, the draft Agreement and Strategy only identify a 10-year goal for anticipated completion of all actions. However, it is stated that activities expected during the first 3-5 years would be identified in the State conservation and management plans, not yet available. In contrast to the 10-year completion goal, the life of the Agreement is only 5 years, but has an option for a 7-year extension. It is highly unlikely that the wide-ranging and complex actions needed to reach draft Agreement and Strategy goals can be accomplished within 10 years. Perhaps if the parties to the agreement attempted to meet this criterion by setting out a schedule for actions, they would realize that their end-point is much further away than 10 years. The draft Agreement and Strategy fail to meet this criterion.

8. The conservation agreement or plan that includes the conservation effort is approved by all parties to the agreement or plan. The draft Agreement and Strategy are as yet unsigned. Therefore they fail to meet this criterion.

B. The certainty that the conservation effort will be effective.

1, The nature and extent of threats being addressed by the conservation effort are described. The draft Agreement and Strategy does not attempt to describe the nature and extent of threats to roundtail and headwater chub, although it calls for elimination of threats. Only the threat from nonnative species is addressed specifically, although without detail. Enhancement of fish passage is identified as a conservation action, implying that lack of passage is a threat to roundtail or headwater chub. However, at least in the lower Colorado River basin, roundtail and headwater chub are relatively sedentary species and lack of fish passage is not an issue in their conservation, and in fact impeding passage of nonnative species is a primary conservation need. No mention is made of the many threats from recreation, water development, groundwater pumping, roads, timber, mining, livestock grazing, urban and suburban development, etc., nor is there any mention of mechanisms or needs for dealing with those threats. The draft Agreement and Strategy fails to meet this criterion.

2. Explicit objectives for the conservation effort and dates for achieving them are stated. As discussed under A.7, above, only the final end-point of 10 years is stated in the draft Agreement. Objectives are stated and are specific, although extremely brief and unclear (see A.1 above). Unfortunately they address only half of the species range (the upper Colorado River basin). The draft Agreement and Strategy fails to meet this criterion.

3. The steps necessary to implement the conservation effort are identified. No steps are identified in the draft Agreement and Strategy. Perhaps those will be addressed in the, as yet unavailable, State plans. The draft Agreement and Strategy fails to meet this criterion.

4. Quantifiable, scientifically valid parameters that will demonstrate achievement of objectives and standards for these parameters by which progress will be measured, are identified. No such parameters or standards are addressed in the draft Agreement and Strategy. Thus it fails to meet this criterion.

5. Provisions for monitoring and reporting progress on implementation (based on compliance with the implementation schedule) and effectiveness (based on evaluation of quantifiable parameters) of the conservation effort are provided. The draft Agreement and Strategy provide for review and reporting on progress and effectiveness on a semiannual basis, although the schedule and parameters for measuring those are not addressed. The draft Agreement and Strategy marginally meets this criterion but only in procedure and not substance.

6. Principles of adaptive management are incorporated. The draft Agreement and Strategy provide for revision through adaptive management. The draft Agreement and Strategy meets this criterion.

In summary, evaluation of the draft Range-wide Conservation Agreement and Strategy for roundtail chub, bluehead sucker, and flannelmouth sucker reveals that the draft is inadequate in almost every aspect. It fails to meet 12 of the 14 proposed Fish and Wildlife Service criteria for such agreements. The draft Agreement and Strategy does not address and could not eliminate most, if any, of the threats to roundtail and headwater chub. Implementation of the draft Agreement and Strategy would not change the status of roundtail or headwater chub or eliminate the need for Federal listing as endangered (or threatened).

H. Private lands

Except for State regulation of fishing and other take, roundtail and headwater chub are currently not afforded any protection or management on private lands. Habitat for both species may receive some protection under section 404 of the Clean Water Act. However, application of section 404 has not been highly effective in conservation of native fish habitats (see section E above).

I. Tribal Lands

Because of the desire of many of the Native American Tribes to keep information on their natural resources private, little is known about the status or conservation of roundtail or headwater chub on Tribal lands. Any regulatory or other protective measures for the species on Tribal lands would be at the discretion of the individual Tribe and non-Tribal entities would not likely be privy to information on the adequacy of such measures.

VIII. REQUEST FOR CRITICAL HABITAT DESIGNATION

Petitioners request the designation of critical habitat for the roundtail and headwater chubs concurrent with their listing. Because of the critical status of the species and the need for restoration throughout large portions of its historic range, critical habitat should encompass all potential, suitable and occupied habitat within the historic range of the species in the lower Colorado River basin. All portions of the historic range must be included in the designation, including the lower Colorado mainstem, San Pedro, San Simon, upper Gila, middle Gila, San Francisco, Blue, Salt, Black, White, Verde, East Verde, and Agua Fria Rivers and appropriate tributaries.

We also request that designation of critical habitat for roundtail chub include at least the 100-year floodplain. A stream cannot be adequately managed without integrated management of the entire floodplain (Welcomme 1998) and the 100-year floodplain is the most identifiable and stable method of identifying the needed area. Roundtail and headwater chub use habitat in a manner that makes them highly dependent upon the structure and function of the floodplain and the stream channel and banks. It is important that the critical habitat designation adequately provide for that in both the designation of the floodplain and in the constituent elements.

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LITERATURE CITED

Abarca, F. J. and D. A. Weedman. 1993. Native fishes of Tonto Creek, Tonto National Forest, Arizona. Phoenix, AZ, Arizona Game and Fish Department.

Abbitt, R.J.F., and J.M. Scott. 2001. Examining the differences between recovered and declining endangered species. Conservation Biology 15(5):1274-1284.

Adil, A., J. DeGroot, J. Gillis, G. Lee, J. Sluyter, K. Veatch, R. Vrtis, and T.R. Jones. 1999. A comparison of fish communities at Fossil Creek. http://www.grand-canyon.edu/COS/jones/research.htm (2-10-2003).

Allendorf, F. W., and R. F. Leary. 1988. Conservation and distribution of genetic variation in a polytypic species, the cutthroat trout. Conservation Biology 2(2):170-184.

Alford, E. 1993. Tonto rangelands -- a journey of change. Rangelands 15(6):261-268.

Allan, N.L. 2000. Deterioration of Phantom Lake Spring, Jeff Davis County, Texas. Proceedings of the Desert Fishes Council: 32:50-51.

Amaranthus, M. P., R. M. Rice, N.R. Barr, R. R. Ziemer. 1985. Logging and forest roads related to increased debris slides in Southwestern Oregon. Journal of Forestry April: 229-233.

Anderson, R. M. 1978. The distribution and aspects of the life history of *Meda fulgida* in New Mexico. Unpublished Master's Thesis, New Mexico State University, Las Cruces.Anderson, R. and P. Turner. 1977. Stream survey of the San Francisco River. Report to New Mexico Department of Game and Fish. Department of Fisheries and Wildlife Sciences, New Mexico State University, Las Cruces, NM. 23 pp.

Arizona Game and Fish Department. 2001. Interoffice memorandum from Assistant Director to Habitat Branch Chief regarding recommendations relative to Fossil Creek Management Plan. March 27, 2001.

Arizona Game and Fish Department. 2002a. Arizona fishing regulations. AZGFD, Phoenix, AZ. 29 pp.

Arizona Game and Fish Department. 2002b. Letter to Fish and Wildlife Service commenting on draft Candidate and Listing Priority Forms for roundtail and headwater chub. August 21, 2002. AZGFD, Phoenix, AZ. 2 pp.

Armour, C.L. 1977. Effects of deteriorated range streams on trout. U.S. Bureau of Land Management, Boise, ID. 7 pp.

Armour, C. L., D. A. Duff, , and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16(1):7-11.

Bagley, B.E., G.H. Schiffmiller, P.A. Sowka, and P.C. Marsh. 1996. A new locality for loach minnow, *Tiaroga cobitis*. Proceedings of the Desert Fishes Council 28:8.

Bahre, C. J. 1991. A legacy of change. Historic human impact on vegetation in the Arizona borderlands. University of Arizona Press, Tucson, AZ

Bailey, R. G. 1995. Descriptions of the ecoregions of the United States, USDA Forest Service.

Baird, S. F., and C. Girard. 1853. Descriptions of new species of fishes collected by Mr. John H. Clark, on the U. S. and Mexican boundary Survey, under Lt. Col. Jas. D. Graham. Proceedings of the Academy of Natural Sciences,Philadelphia 4:387-390.

Baird, S. F., and C. Girard. 1854. Descriptions of new species of fishes collected in Texas, New Mexico and Sonora by Mr. John H. Clark, on the U.S. and Mexican boundary survey, and in Texas by Capt. Stewart Van Vliet, U.S.A. Proceedings of the Society of Natural Sciences 7:24-29.

Baltz, D.M., and P.B. Moyle. 1993. Invasion resistance to introduced species by a native assemblage of California stream fishes. Ecological Applications 246-255.

Barber, W.E., and W.L. Minckley. 1966. Fishes of Aravaipa Creek, Graham and Pinal counties, Arizona. Southwestern Naturalist 11:313-324.

Barrett, P.J., and O.E. Maughan. 1994. Habitat preferences of introduced smallmouth bass in a central Arizona stream. North American Journal of Fisheries Management 14:112-118.

Barrett, P. J. and O. E. Maughan 1995. Spatial habitat selection of roundtail chub (*Gila robusta*) in two central Arizona streams. The Southwestern Naturalist 40(3): 301-307.

Barrett, J. C., G. Grossman, J. Rosenfeld. 1992. Turbidity-induced changes in reactive distance of rainbow trout. Transactions of the American Fisheries Society 121(4): 437-443.

Behnke, R.J. 1995. Morphology and systematics. Pp 41-43 *in*: Evolution and the Aquatic Ecosystem. J.L. Nielsen ed. American Fisheries Society Symposium 17. Bethesda, MD.

Beland, R. D. 1953. The effect of channelization on the fishery of the lower Colorado River. California Fish and Game 39:137-139.

Belsky, A. J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation 54(1):419-431.

Beschta, R.L., W.S. Platts, J.B. Kauuman, and M.T. Hill. 1995. Artificial stream restoration: money well spent or an expensive failure? U.S. Forest Service Rocky Mountain Research Station. Stream Notes October 1-7.

Bestgen, K. R. 1985. Distribution, biology and status of the roundtail chub, *Gila robusta*, in the Gila River Basin, New Mexico. Department of Fishery and Wildlife Biology. Fort Collins, CO, Colorado State University.

Bestgen, K.R. 1986. Red shiner vs. native fishes: replacement or displacement? Proceedings of the Desert Fishes Council 18:209.

Bestgen, K. R. and D. L. Propst 1989. Distribution, status, and notes on the ecology of *Gila robusta* in the Gila River drainage, New Mexico. The Southwestern Naturalist 34(3): 402-412.

Blackburn, W. H., R. W. Knight, M.K. Wood. 1982. Impacts of grazing on watersheds: a state of knowledge. College Station, Texas, Texas Agricultural Experiment Station, Texas A&M University.

Blinn, D. W., and G. A. Cole. 1991. Algal and invertebrate biota in the Colorado River: comparison of pre- and post-dam conditions. Pages 102-123 *in* Colorado River ecology and dam management. Proceedings of a symposium May 24-25, 1990, Santa Fe, New Mexico. National Academy Press, Washington, D.C.

Blinn, D. W., J. P. Shannon, L. E. Stevens, and J. P. Carder. 1995. Consequences of fluctuating discharge for lotic communities. Journal of the North American Benthological Society 14(2):233-248.

Briggs, M. K. 1996. Riparian ecosytem recovery in arid lands. University of Arizona Press, Tucson, AZ.

Briggs, M. K., B. A. Roundy, and W. W. Shaw. 1994. Trial and error. Assessing the effectiveness of riparian revegetation in Arizona. Restoration and Management Notes 12(2):160-167.

Brooks, J. E., and G.A. Mueller. In press. Introduction of gizzard shad *Dorosoma cepedianum* into the Colorado River. Western North American Naturalist

Brouder, M. J. 2001. Effects of flooding on recruitment of roundtail chub, *Gila robusta*, in a southwestern River. The Southwestern Naturalist 46(3): 302-310.

Brouder, M. J., D. D. Rogers, et al. 2000. Life history and ecology of the roundtail chub, *Gila robusta*, from two streams in the Verde River Basin. Phoenix, AZ, Arizona Game and Fish Department.

Brower, A., C. Reedy, and J. Yelin-Kefer. 2001. Consensus versus conservation in the upper Colorado River basin recovery implementation program. Conservation Biology 15(4):1001-1007.

Bryan, S. D. and A. T. Robinson. 2000. Population characteristics and movement of roundtail chub in the lower Salt and Verde Rivers, Arizona. Phoenix, AZ, Arizona Game and FIsh Department.

Bryant, M. D. 1981. Poorly constructed road crossings of small streams can block upstream movement of juvenile salmonids, USDA Forest Service, Research Note PNW-384.

Bulte, E.H., and G.C. Van Kooten. 2001. State intervention to protect Endangered Species: why history and bad luck matter. Conservation Biology 15(6):1799-1803.

Burkham, D.E. 1970. Precipitation, streamflow, and major floods at selected sites in the Gila River drainage basin above Coolidge Dam, Arizona. U.S. Geological Survey Professional Paper 655-B. Washington, D.C.

Burns, D. C. 1991. Cumulative effects of small modifications to habitat. Fisheries 16(1):12-17.

Burns, J. W. 1971. The impacts of road construction and logging on salmon and trout populations, California Department of Fish and Game.

Busack, C.A., and K.P. Currens. 1995. Genetic risks and hazards in hatchery operations: fundamental concepts and issues. Pp. 71-80 *in:* Uses and Effects of Cultured Fishes in Aquatic Ecosystems. H.L. Schramm, Jr., and R.G. Piper eds. American Fisheries Society Symposium 15. Bethesda, MD.

Cain, T., J. N. Rinne, J. A. Stefferud, and A. Telles. 1997. Effects determinations for loach minnow, spikedace, Little Colorado spinedace, and Sonora chub on National Forests in the Southwest Region, USDA Forest Service. U.S. Forest Service, Albuquerque, NM. 56 pp + figs. Campoy-Favela, J., A. Varela-Romero, and L. Juarez-Romero. 1989. Observaciones sobre la ictiofauna nativa de la cuenca del Rio Yaqui, Sonora, Mexico. Ecologica 1(1):1-29.

Campton, D.E. 1995. Genetic effects of hatchery fish on wild populations of Pacific salmon and steelhead: what do we really know? Pp. 337-353 *in:* Uses and Effects of Cultured Fishes in Aquatic Ecosystems. H.L. Schramm, Jr., and R.G. Piper, eds. American Fisheries Society Symposium 15. Bethesda, MD.

Carlson, C. A. and R. T. Muth. 1989. The Colorado River: lieline of the American Southwest. Proceedings of the international large river symposium, Can. Spec. Publ. Fish. Aquat. Sci. 106.

Carpenter, J., and C. C. McIvor. 2000. Effect of introduced crayfish on growth of two native fishes of the Colorado River basin. Proceedings of the Desert Fishes Council 32:24-25.

Chart, T. E., and E. P. Bergersen. 1992. Impact of mainstem impoundment on the distribution and movements of the resident flannelmouth sucker (Catostomidae: Catostomus latipinnis) population in the White River, Colorado. The Southwestern Naturalist 37(1):9-15.

Clark, T. W., R. Crete, and J. Cada. 1989. Designing and managing successful endangered species recovery programs. Environmental Management 13(2):159-170.

Clarkson, R. In press. Effectiveness of electrical fish barriers associated with the Central Arizona Project. North American Journal of Fisheries Management.

Clarkson, R. W., and M. R. Childs. 2000. Temperature effects of hypolimnial release dams on early life stages of Colorado River basin big-river fishes. Copeia 2000(2):402-412.

Clary, W. P., B. F. Webster. 1989. Managing grazing of riparian areas in the Intermountain Region., USDA Forest Service.

Clary, W. P., D. E. Medin. 1990. Differences in vegetation biomass and structure due to cattle grazing in a northern Nevada riparian ecosystem., USDA Forest Service.

Collier, M., R.H. Webb., and J.C. Schmidt. 1996. Dams and rivers. A primer on the downstream effects of dams. U.S. Geological Survey Circular 1126. Denver, Co.

Comella, K. M., and R. A. Fridell. 1998. Virgin River treatment projects; March 1996, August 1996, December 1996. Utah Division of Wildlife, Salt Lake City, UT.

Cope, E. D., and H. C. Yarrow. 1875. Report upon the collections of fishes made in portions of Nevada, Utah, California, Colorado, New Mexico, and Arizona during the years 1871, 1872, 1873, and 1874. Pages 635-703 *in* Report of geographic and geologic explorations and surveys west of the 100th meridian (Wheeler survey). United States Army Engineers Dept.

Cooper, C. F. 1960. Changes in vegetation, structure and growth of Southwestern pine forests since white settlement. Ecological Monographs 30: 129-164.

Cooperrider, C. K. and B. A. Hendricks. 1937. Soil erosion and streamflow on range and forest lands of the upper Rio Grande watershed in relation to land resources and human welfare, USDA Technical Bulletin 567.

Courteney, W. R. and P. B. Moyle. 1992. Crimes against biodiversity: the lasting legacy of fish introductions. Fisheries Management and Biological diversity Trans. 57th N.A. Wildl & Nat. Res. Conf.

Covich, A.P. 1999. The role of benthic invertebrate species in freshwater ecosystems: zoobenthic species influence energy flows and nutrient cycling. BioScience:Febrary 1999.

Covington, W. W., M. M. Moore. 1994. Southwestern ponderosa forest structure: Changes since Euro-American settlement. Journal of Forestry, January.

Crispin, V.A. 1981. Stream rehabilitation of the West For, Deer Creek, Nevada. Bureau of Land Management, Elko, NV.

Cross, J. N. 1978. Status and ecology of the Virgin River roundtail chub, *Gila robusta seminuda*,. The Southwestern Naturalist 23(3): 519-528.

Culler, R. C., and others. 1970. Objectives, methods, and evironment -- Gila River phreatophyte project, Graham County, Arizona. U.S. Geological Survey Professional Paper 655-A, Washington, D.C.Czech, B. 2000. Economic growth as the limiting factor for wildlife conservation. Wildlife Society Bulletin 28(1):4-15.

Deacon, J.E., G. Kobetich, J.D. Williams, S. Contreras, and other members of the Endangered Species Committe of the American Fisheries Society. 1979. Fishes of North America. Endangered, threatened, or of special concern: 1979. Fisheries 4(2):29-44.

DeMarais, B. D. 1986. Morphological variation in Gila (Pisces: Cyprinidae) and geologic history: lower Colorado River basin. Arizona State University, Tempe, AZ.

DeMarais, B. D. 1992a. Genetic relationships among fishes allied to the genus *Gila* (Teleostei: Cyprinidae) from the American southwest. Unpublished PhD. dissertation, Arizona State University, Tempe.

DeMarais, B. D. 1992b. Genetic relationships among fishes allied to the genus Gila (Teleostei: Cyprinidae) from the American southwest. Arizona State University, Tempe, AZ.

DeMarais, B. D. 1995. Taxonomic history and status of the Gila chub, Gila intermedia (Girard). Arizona Game and Fish Department, Phoenix, AZ.

DeMarais, B.D., Dowling, T.E., M.E. Douglas, W.L. Minckley, and P.C. Marsh. 1992. Origin of *Gila seminuda* (Teleostei:Cyprinidae) through introgressive hybridization: implications for evolution and conservation. Proceedings of the National Academy of Science USA 89:2747-2751.

Desert Fishes Recovery Team. 1989. Minutes from the 26-27 January 1989 meeting in Tempe, Arizona. U.S. Fish and Wildlife Service, Phoenix, AZ. 9 pp.

Desert Fishes Recovery Team. 1992. Minutes from the 5-6 February, 1992 meeting in Tempe, Arizona. U.S. Fish and Wildlife Service, Phoenix, AZ. 12 pp.

Desert Fishes Recovery Team. 1993. Minutes from the 24 February, 1993 meeting in Tempe, Arizona. U.S. Fish and Wildlife Service, Phoenix, AZ. 8 pp.

Desert Fishes Recovery Team. 1996. Minutes from the 25 June, 1996 meeting in Tempe, Arizona. U.S. Fish and Wildlife Service, Phoenix, AZ. 10 pp.

Desert Fishes Recovery Team. 1999. Minutes from the 10-11 June, 1999 meeting in Tempe, Arizona. U.S. Fish and Wildlife Service, Phoenix, AZ. 7 pp.

Desert Fishes Recovery Team. 2001. Minutes from the 22 October, 2001 meeting in Tempe, Arizona. U.S. Fish and Wildlife Service, Phoenix, AZ. 12 pp.

Desert Fishes Recovery Team. 2002a. Minutes from the 4 March 2002 meeting in Tempe, Arizona. U.S. Fish and Wildlife Service, Phoenix, AZ. 11pp.

Desert Fishes Recovery Team 2002b. Minutes from the 16 September 2002 meeting in Tempe, Arizona. U.S. Fish and Wildlife Service, Phoenix, AZ. 17 pp.

Dombeck, M. P., J. E. Williams, and C. A. Wood. 1997. Watershed restoration: social and scientific challenges for fish biologists. Fisheries 22(5):26-27.

Donegan, D. G. 1997. Lessons learned. Gila River, New Mexico local protection projects. U.S. Army Corps of Engineers, Albuquerque, NM.

Doremus, H., and J.E. Pagel. 2001. Why listing may be forever: perspectives on delisting under the U.S. Endangered Species Act. Conservation Biology :15(5):1258-1268.

Douglas, M. E., R. R. Miller, and W. L. Minckley. 1998. Multivariate discrimination of Colorado Plateau Gila spp.: The "art of seeing well" revisited. Transactions of the American Fisheries Society 127(2):163-173.

Douglas, M. E., W. L. Minckley, and H. M. Tyus. 1988. Qualitative characters, identification of Colorado River chubs (Cyprinidae: genus Gila), and the "Art of seeing well". submitted to Copeia,

Dowling, T. E., and B. D. DeMarais. 1993. Evolutionary significance of introgessive hybridization in cyprinid fishes. Nature 362:444-446.

Dowling, T.E., W.L. Minckley, P.C. Marsh, and E.S. Goldstein. 1996. Mitochondrial DNA variability in the endangered razorback sucker (*Xyrauchen texanus*): analysis of hatchery stocks and implications for captive propagation. Conservation Biology 10(1):120-127.

Dowling, T.E., and C.L. Secor. 1997. The role of hybridization in the evolutionary diversification of animals. Annual review of Ecological Systematics 28:593-619.

Dunne, T. and L.B. Leopold. 1978. Water in environmental planning. W.H. Freeman and Co., New York.

Eaglin, G. S. and W. A. Hubert 1993. Effects of logging and roads on substrate and trout in streams of the Medicine Bow National Forest, Wyoming. North American Journal of Fisheries Management 13(4): 844-846.

Echelle, A. A. 1988. Review of genic diversity and conservation genetics in fishes of the U.S. Fish and Wildlife Service, Region II, with a suggested program of conservation genetics. U.S. Fish and Wildlife Service, Albuquerque, NM.Elmore, W. 1992. Riparian response to grazing practices. Pp. 442-457 *in*: Watershed Management; Balancing Sustainability and Environmental Change. R.J. Naiman ed. Springer-Verlag, New York, NY.

Elmore, W., and B. Kauffman. 1994. Riparian and watershed systems: degradation and restoration. Pp 212-231 *in* M. Vavra, W. A. Laycock, and R. D. Pieper, editors. Ecological implications of livestock herbivory in the west. Society for Range Management, Denver, CO.

Fagan, W.F., P.J. Unmack, C. Burgess, and W.L. Minckley. 2002. Rarity, fragmentation, and extinction risk in desert fishes. Ecology 83(2):3250-3256.

Fernandez, P. J., and P. C. Rosen. 1996. Effects of the introduced crayfish Oronectes virilis on native aquatic herpetofauna in Arizona. Arizona Game and Fish Department, Phoenix, AZ.

Fleischner, T. L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology 8(3): 629-644.

Fleming, I.A. 1994. Captive breeding and the conservation of wild salmon populations. Conservation Biology 8(3):886-888.

Folk-Williams, J. 1991. The Gila basin and the waters of southern Arizona. A guide to decision making. Western Network, Santa Fe, NM.

Ford, M.J. 2002. Selection in captivity during supportive breeding may reduce fitness in the wild. Conservation Biology 19(3):815-825.

Frasier, G.W. 1997. Water harvesting for rangeland water supplies: a historic perspective. Pp 17-24 *in* Environmental, economic, and legal issues related to rangeland water developments, Proceedings of a symposium, Nov. 13-15, Tempe, AZ. Arizona State University, Tempe, AZ.

Frissell, C. A., and R. K. Nawa. 1992. Incidence and causes of physical failure of artificial habitat structures in streams of western Oregon and Washington. North American Journal of Fisheries Management 12:182-197.

Gamradt, S. C., and L. B. Kats. 1996. Effect of introduced crayfish and mosquitofish on California newts. Conservation Biology 10(4):1155-1162.

GAO. 1987. Endangered Species. Limited effect of consultation requirements on western water projects. U.S. General Accounting Office GAO/RCED-87-78, Washington D.C.

GAO 1988a. Public Rangelands: Some Riparian Areas Restored but Widespread Improvement Will Be Slow, U.S. General Accounting Office.

GAO. 1988b. Wetlands. The Corps of Engineer's administration of the section 404 program. U.S. General Accounting Office GAO/RCED-88-110, Washington, D.C.

GAO. 1988c. Endangered species. Management efforts could enhance recovery program. U.S. General Accounting Office GAO/RCED-89-5, Washington, D.C.

GAO. 1991. Public land management. Attention to wildlife is limited. U.S. General Accounting Office GAO/RCED-91-64, Washington, D.C.

GAO. 1993. Endangered species. Factors associated with delayed listing decisions. U.S. General Accounting Office GAO/RCED-93-152, Washington, D.C.

GAO. 1994. Ecosystem management. Additional actions needed to adequately test a promising approach. U.S. General Accounting Office GAO/RCED-94-308, Washington, D.C.

GAO. 1996. Water pollution. Many violations have not received appropriate enforcement attention. U.S. General Accounting Office GAO/RCED-96-23, Washington, D.C.

GAO. 2000a. National fish hatcheries. Authority needed to better align operations with priorities. U.S. General Accounting Office, GAO/RCED-00-151. Washington, D.C.

GAO. 2000b. Forest Service. Actions needed for the agency to become more accountable for its performance. U.S. General Accounting Office, GAO/T-RCED-00-236. Washington, D.C.GAO. 2001. Invasive Species. Obstacles hinder Federal rapid response to growing threat. U.S. General Accounting Office, GAO-01-724, Washington, DC.

GAO. 2002. U.S. Army Corps of Engineers. Scientific panel's assessment of fish and wildlife mitigation guidance. U.S. General Accounting Office, GAO-02-574, Washington, D.C.

Gerber, A. S., C.A.Tibbets, and T.E.Dowling. 2001. The role of introgressive hybridization in the evolution of the *Gila robusta* complex (Teleostei:Cyrpinidae). Evolution 55(10):2028-2039.

Gifford, G. F. and R. H. Hawkins. 1976. Grazing systems and watershed management: a look at the record. Journal of Soil and Water Conservation 31(6): 281-283.

Gifford, G. F., R. H. Hawkins. 1978. Hydrologic impact of grazing on infiltration: a critical review. Water Resources Research 14: 305-313.

Girard, C. 1856. Researches upon the cyprinoid fishes inhabiting the fresh waters of the United States of America, west of the Mississippi Valley, from specimens in the Museum of the Smithsonian Institution. Proceedings of the Academy of Natural Sciences 8:165-213.

Girmendonk, A. L. and K. L. Young. 1997. Status review of the roundtail chub (*Gila robusta*) in the Verde River Basin. Phoenix, AZ, Arizona Game and FIsh Department.

Glennon, R. J. 1995. The threat to river flows from groundwater pumping. Rivers 5(2):133-139.

Gorman, O. T., and J. R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59(3):507-515.

Griffith, B., J. M. Scott, J. W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: status and strategy. Science 245:477-480.

Haddock, P. 1980. Compendium of water projects: lower Colorado River basin (Preliminary edition, excluding the Salton Sea basin). Report to U.S. Fish and Wildlife Service, Albuquerque, NM.

Hadley, D., P. Warshall, and D. Bufkin. 1991. Environmental change in Aravaipa, 1870-1970. An ethnoecological survey. Bureau of Land Management, Cultural Resources Series No. 7, Phoenix, AZ.Hamm, K.D., and T.N. Pearsons. 2001. A practical approach for containing ecological risks associated with fish stocking programs. Fisheries 26(4):15-23.

Harper, K.T., and J.R. Marble. 1988. A role for nonvascular plants in management of arid and semiarid rangelands. Pp. 137-169 *in*: Vegetation Science Applications for Rangeland Analysis and Management. P.T. Tueller ed. Kluwer Academic Publishers, Boston, MA.

Hastings, J. R., and R. M. Turner. 1980. The changing mile. University of Arizona Press, Tucson, AZ.

Hendrickson, D. A. 1983. Distribution records of native and exotic fishes in Pacific drainages of northern Mexico. Journal of the Arizona-Nevada Academy of Science 18:33-38.
Hendrickson, D. A. 1993. Evaluation of the razorback sucker (Xyrauchen texanus) and Colorado squawfish (Ptychocheilus lucius) reintroduction programs in central Arizona based surveys of fish populations in the Salt and Verde Rivers from 1986 to 1990. Arizona Game and Fish Department, Phoenix, AZ.

Hendrickson, D. A., and J. E. Brooks. 1991. Transplanting short-lived fishes in North American deserts: Review, assessment, and recommendations. Pp 283-298 *in:* W. L. Minckley and J. E. Deacon, editors. Battle against extinction; Native fish management in the American west. University of Arizona Press, Tucson, AZ.

Hendrickson, D. A., and W. L. Minckley. 1984. Cienegas -- vanishing climax communities of the American southwest. Desert Plants 6(3):131-175.

Hendrickson, D. A., W. L. Minckley, R. R. Miller, D. J. Siebert, and P. H. Minckley. 1981. Fishes of the Rio Yaqui basin, Mexico and United States. Journal of the Arizona-Nevada Academy of Sciences 15:65-106.

Hilborn, R. 1992a. Can fisheries agencies learn from experience? Fisheries 17(4):6-14.

Hilborn, R. 1992b. Hatcheries and the future of salmon in the Northwest. Fisheries 17(1):5-8.

Holden, P. B. 1968. Systematic studies of the genus Gila (Cyprinidae) of the Colorado River basin. Utah State University, Logan, Utah.

Holden, P. B., and C. B. Stalnaker. 1970. Systematic studies of the cyprinid genus Gila in the upper Colorado River basin. Copeia 1970(3):409-420.

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.

Horak, G. C. 1989. Integrating riparian planning in the urban setting. Pp 41-44 *in* R. E. Gresswell, B. A. Barton, and J. L. Kershner, editors. Practical approaches to riparian resource management. An educational workshop. May 8-11, 1989. Billings, Mont. U.S. Bureau of Land Management, Billings, Mont.

Independent Scientific Advisory Board. 2002. Hatchery surpluses in the Pacific Northwest. Fisheries 27(12):16-27.

Inman, T. C., P. C. Marsh, B. E. Bagley, and C. A. Pacey. 1998. Survey of crayfishes of the Gila River basin, Arizona and New Mexico, with notes on occurrences in other Arizona drainages and adjoining States. U.S. Bureau of Reclamation, Phoenix, AZ

James, A. E. 1968. *Lernaea* (copepod) infection of three native fishes from the Salt River basin, Arizona. Tempe, AZ, Arizona State University.

Johnson, J.E. 1987. Protected fishes of the United States and Canada. American Fisheries Society, Bethesda, MD. 42 pp.

Jones, J.B., Jr., J.D. Schade, S.G. Fisher, and N.B. Grimm. 1997. Organic matter dynamics in Sycamore Creek, a desert stream in Arizona, USA. Journal of the North American Benthological Society 16(1):78-82.

Kaeding, L. R., B. D. Burdick, et al. 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.

Kauffman, J. B., R. L. Beschta, N. Otting, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. Fisheries 22(5):12-24.

Kauffman, J. B., W. C. Krueger. 1984. Livestock impacts on riparian plant communities and streamside management implications...a review. Journal of Range Management 37(5): 430-438.

Krueper, D. J. 1996. Effects of livestock management on Southwestern riparian ecosystems. Pp 281-301 *in* D. W. Shaw and D. M. Finch, editors. Desired future conditions for Southwestern riparian ecosystems: bringing interests and concerns together. September 18-22, 1995. U.S. Forest Service Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-GTR-272, Ft. Collins, CO.Kynard, B.E. 1976. A study of the pollution sources and their effect on the aquatic habitat of Eagle Creek watershed, Apache-Sitgreaves National Forest, Arizona. University of Arizona, School of Renewable Natural Resources, Tucson.

Ladyman, J.A.R., and E. Muldavin. 1996. Terrestrial cryptogams of pinyon-juniper woodlands in the southwestern United States: a review. General Technical Report RM-GTR-280. USDA Forest Service Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO. 33 pp.

Lawler, S.P., D. Dritz, R. Strange, and M. Holyoak. 1999. Effects of introduced mosquitofish and bullfrogs on the threatened California red-legged frog. Conservation Biology 13(3):613-622.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, J.R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. North Carolina Biological Survey Publication 1980-12.

Leopold, L.B. 1994. A view of the river. Harvard University Press. Cambridge. Mass.

Li, H.W., G. A. Lamberti, R.N. Pearsons, C.K. Tait, J.L. Li, and J.C. Buckhouse. 1994. Cumulative effects of riparian disturbances along high desert streams of the John Day Basin, Oregon. Transactions of the American Fisheries Society 123:627-640.

Li, H.W., C.B. Schreck, C.E. Bond, and E. Rexstad. 1987. Factors influencing changes in fish assemblages of Pacific Northwest streams. Pp 193-202 *in*: Community and evolutionary ecology of North American stream fishes. W.J. Matthews and D.C. Heins eds. University of Oklahoma Press, Norman, OK.

Ligon, F. K., W. E. Dietrich, and W. J. Trush. 1995. Downstream ecological effects of dams. BioScience 45(3):183-192.

Marrs, R.H., A. Rizand, and A.F. Harrison. 1989. The effects of removing sheep grazing on soil chemistry, above-ground nutrient distribution, and selected aspects of soil fertility in long-term experiments at Moor House National Nature Preserve. Journal of Applied Ecology 26:647-661.

Marsh, P.C., B. E. Bagley, G.W. Knowles, G.H. Schiffmiller, and P.A. Sowka. In press. New and rediscovered populations of loach minnow *Tiaroga cobitis* (Cyprinidae) in Arizona. Western North American Naturalist.

Marsh, P.C., J.E. Brooks, D.A. Hendrickson, and W.L. Minckley. 1990. Fishes of Eagle Creek, Arizona, with records for threatened spikedace and loach minnow (Cyprinidae). Journal of the Arizona-Nevada Academy of Science 23(2):107-116.

Marsh, P.C., and W.L. Minckley. 1982. Fishes of the Phoenix metropolitan area in central Arizona. North American Journal of Fisheries Management 4:395-402.

Mayden, R. L., M. B. Burr, L. M. Page, and R. R. Miller. 1992. The native freshwater fishes of North America. Pages 827-863 *in* R. L. Mayden, editor. Systematics, historical ecology, and North American freshwater fishes. Stanford University Press, Stanford, California.

McAuliffe, J. R. 1997. Rangeland water developments: Conservation solution or illusion? Pp 310-359 *in* Environmental, economic, and legal issues related to rangeland water developments, Proceedings of a symposium, Nov. 13-15, Tempe, AZ. Arizona State University, Tempe, AZ.

McCracken, G.F., C.R. Parker, and S.Z. Guffey. 1993. Genetic differentiation and hybridization between stocked hatchery and native brook trout in Great Smoky

Mountains National Park. Transactions of the American Fisheries Society 122:533-542.

McCully, P. 1996. Silenced rivers. The ecology and politics of large dams. Zed Books, London, England.

Meehan, W. R., F.J. Swanson, and J.R. Sedell. 1977. Influences of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply, U.S.D.A. Forest Service.

Medina, A. L. 1990. Possible effects of residential development on streamflow, riparian plant communities, and fisheries on small mountain streams in central Arizona. Forest Ecology and Management 33/34:351-361.

Meffe, G. K. 1992. Techno-arrogance and halfway technologies: Salmon hatcheries on the Pacific Coast of North America. Conservation Biology 6(3):350-354.

Meffe, G.K., and C.R. Carroll. 1994. Principles of conservation biology. Sinauer Associates, Inc.

Meffe, G. K., and R. C. Vrijenhoek. 1988. Conservation genetics in the management of desert fishes. Conservation Biology 2(2):157-169.

Megahan, W. F. and W. J. Kidd. 1972. Effects of logging and logging roads on erosion and sediment deposition from steep terrain. Journal of Forestry 70(3): 136-141.

Meronek, T. G., P.M. Bouchard, E.R. Buckner, T.M. Burri, K.K. Demmerly, D.C. Hatleli, R.A. Klumb, S.H. Schmidt, and D.W. Coble. 1996. A review of fish control projects. North American Journal of Fisheries Management 16(1):63-74.

Miller, A.S., and W.A. Hubert. 1990. Compendium of existing knowledge for use in making habitat management recommendations for the upper Colorado River basin. U.S. Fish and Wildlife Service, Denver, CO. 470 pp.

Miller, R. R. 1945. A new cyprinid fish from southern Arizona, and Sonora, Mexico, with the description of a new subgenus of Gila and a review of related species. Copeia 1945(2):104-109.

Miller, R.R. 1946. *Gila cypha,* a remarkable new species of cyprinid fish from the Colorado river in Grand Canyon, Arizona. Journal of the Washington Academy of Sciences. 36:409-415.

Miller, R.R. 1950. Notes on the cutthroat and rainbow trouts with the description of a new species from the Gila River, New Mexico. Occasional Papers of the Museum of Zoology,University of Michigan 529:1-43.

Miller, R.R. 1961. Man and the changing fish fauna of the American southwest. Papers of the Michigan Academy of Science, Arts, and Letters 46:365-404.

Miller, R.R. 1964. Extinct, rare and endangered American freshwater fishes. Proceedings of the 16th International Congress of Zoology 8:4-16.

Miller, R.R. 1972. Threatened freshwater fishes of the United States. Transactions of the American Fisheries Society 2:239-252.

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

Minckley, W. L. 1979. Aquatic habitats and fishes of the lower Colorado River, southwestern United States. Tempe, AZ, Arizona State University.

Minckley, W. L. 1981. Ecological studies of Aravaipa Creek, central Arizona, relative to past, present, and future uses. Tempe, AZ, Arizona State University.

Minckley, W.L. 1985. Native fishes and natural aquatic habitats in U.S. Fish and Wildlife Service Region II west of the continental divide. Final Report for U.S. Fish and Wildlife Service, Albuquerque, NM. Arizona State University, Tempe.

Minckley, W. L. 1995. Translocation as a tool for conserving imperiled fishes: experiences in western United States. Biological Conservation 72(1995):297-309.

Minckley, W.L. 1999. Ecological review and management recommendations for recovery of the endangered Gila topminnow. Great Basin Naturalist 59(3):230-244.

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

Minckley, W. L., and M. E. Douglas. 1991. Discovery and extinction of western fishes: a blink of the eye in geologic time. Pp 7-17 *in:* W. L. Minckley and J. E. Deacon, editors. Battle against extinction: Native fish management in the American west. University of Arizona Press, Tucson, AZ.

Minckley, W. L., P. C. Marsh, J. E. Brooks, J. E. Johnson, and B. L. Jensen. 1991a. Management toward recovery of the razorback sucker. Pp 303-357 *in:* W. L. Minckley and J. E. Deacon, editors. Battle Against Extinction. University of Arizona Press, Tucson, AZ.

Minckley, W. L., G. K. Meffe, and D. L. Soltz. 1991b. Conservation and management of short-lived fishes: The Cyprinodontoids. Pp 247-282 *in:* W. L. Minckley and J. E. Deacon, editors. Battle against extinction; Native fish management in the American west. University of Arizona Press, Tucson, AZ.

Minckley, W.L., and J.N. Rinne. 1985. Large woody debris in hot-desert streams: an historical review. Desert Plants 7(3):142-153.

Minckley, W.L., and J.N. Rinne. 1991. Native fishes of arid lands: A dwindling resource of the desert southwest. USDA Forest Service General Technical Report RM-206:1-45.

Modde, T., A.T. Scholz, J.H. Williamson, G.B. Haines, B.D. Burdick, and F.K. Pfeifer. 1995. An augmentation plan for razorback sucker in the upper Colorado River basin. Pp. 102-111 *in:* Uses and Effects of Cultured Fishes in Aquatic Ecosystems. H.L. Schramm, Jr., and R.G. Piper eds. American Fisheries Society Symposium 15. Bethesda, MD.

Modde, T., and L. Crist. 2000. Upper Colorado River Basin area report. Proceedings of the Desert Fishes Council 32:7-8.

Moyle, P.B. 1994. The decline of anadromous fishes in California. Conservation Biology 8(3):869-870.

Moyle, P.B. 2002. Inland fishes of California. University of California Press. Berkeley, CA.

Mpoame, M. 1981. Parasites of some fishes native to Arizona and New Mexico, with ecological notes. Tempe, AZ, Arizona State University.

Mueller, G. 1984. Spawning by *Rhinichthys osculus* (Cyprinidae) in the San Francisco River, New Mexico. Southwestern Naturalist 29:354-356.

Muth, R. T., C. M. Haynes, et al. 1985. Culture of roundtail chub, *Gila robusta, robusta* through the larval period. Southwestern Naturalist 30: 152-154.

Neve, L. L. 1976. The life history of the roundtail chub, Gila robusta grahami, at Fossil Creek, Arizona. Flagstaff, AZ, Northern Arizona University.

New Mexico Game and Fish Department. 2003. New Mexico fishing rules and regulations. NMGF, Santa Fe, NM. 19 pp.

Ohmart, R. D. 1996. Historical and present impacts of livestock grazing on fish and wildlife resources in western riparian habitats. Rangeland Wildlife. P. R. Krausman. Denver, CO, Society for Range Management.

Ohmart, R. D. and B. W. Anderson 1982. North American desert riparian ecosystems. Reference handbook on the deserts of North America. G. L. Bender. Westport, CT, Greenwood Press.

Olmstead, F. H. 1919. A report on flood control of the Gila River in Graham County, Arizona. U.S. Congress. Sixty-fifth - third session. Senate Document 436., Washington, D.C.

Orodho, A.B., M.J. Trlica, and C.D. Bonham. 1990. Long-term heavy-grazing effects on soil and vegetation in the four corners region. The Southwestern Naturalist 35(1):9-15.

Parmley, D. D., and M. J. Brouder. 1998. Potential predation on native roundtail chub, Gila robusta , by non-native fishes in the Verde River, Arizona. Proceedings of the Desert Fishes Council XXX:32

Pearce, R.A., M.J. Trlica, W.C. Leininger, D.E. Mergen, and G. Fraser. 1998. Sediment movement through riparian vegetation under simulated rainfall and overland flow. Journal of Range Management 51(3):301-308.

Pearsons, T.N., and H.W. Li. 1991. Habitat complexity protects trout from flash floods in high desert streams of eastern Oregon. U.S. Fish and Wildlife Service Research information bulletin 91-33:1-2.

Pearthree, M. S., and V. R. Baker. 1987. Channel change along the Rillito Creek system of southeastern Arizona 1941 through 1983. AZ Bureau of Geology & Mineral Technology, Special Paper 6, Tucson.

Pfeifer, F.K. 1997. Endangered Colorado River fishes (upper basin) annual report. Proceedings of the Desert Fishes Council 29:43-44.

Pfeifer, F.K. 1998. Report on recovery activities in the upper Colorado River - 1998. Proceedings of the Desert Fishes Council 30:33-34.

Pfeifer, F.K. 1999. Annual report on endangered Colorado River fishes -- upper basin. Proceedings of the Desert Fishes Council 31:13-14.

Platania, S.P., K.R. Bestgen, M.A. Moretti, D.L. Propst, and J.E. Brooks. 1991. Status of Colorado squawfish and razorback sucker in the San Juan River, Colorado, New Mexico, and Utah. Southwestern Naturalist 36:147-150.

Platts, W.S., and R.L. Nelson. 1985. Stream habitat and fisheries response to livestock grazing and instream improvement structures, Big Creek, Utah. Journal of Soil and Water Conservation 40(4):374-379.

Platts, W. S. and R. L. Nelson. 1989. Stream canopy and its relationship to salmonid biomass in the intermountain west. North American Journal of Fisheries Management 9: 446-457.

Platts, W. S. 1990. Managing fisheries and wildlife on rangelands grazed by livestock: A guidance and reference document for biologists, Unpublished document, Nevada Department of Wildlife.

Platts, W.S. 1991. Livestock grazing. Pp 389-426. *in*: Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, Bethesda, MD.

Pope, G.L., P.D. Rigas, and C.F. Smith. 1998. Statistical summaries of streamflow data and characteristics of drainage basins for selected streamflow-gaging stations in Arizona through water year 1996. U.S. Geological Survey Water-Resources Investigations Report 98-4225. Tucson, AZ.

Pringle, C. M. 1997. Exploring how disturbance is transmitted upstream: going against the flow. Journal of the North American Benthological Society 16(1):425-438.

Propst, D. L. 1999. Threatened and endangered fishes of New Mexico. New Mexico Game and Fish Department, Santa Fe, NM.

Pulliam, H. R. 1998. The political education of a biologist, part II. Wildlife Society Bulletin 26(3):499-503.

Rabeni, C.F., and R.B. Jacobson. 1993. The importance of fluvial hydraulics to fish-habitat restoration in low-gradient allubial streams. Freshwater Biology 29:211-220.

Rapport, D. J. 1999. How ecosystems respond to stress. BioScience March:1999.

Reid, L. M. 1993. Research and cumulative watershed effects. U.S. Forest Service General Technical Report PSW-GTR-141, Albany, CA. Rich, L. R., and H.G. Reynolds. 1963. Grazing in relation to runoff and erosion on some chaparral watersheds of central Arizona. Journal of Range Management 6: 322-326.

Rahel, F.J., and W.A. Hubert. 1991. Fish assemblages and habitat gradients in a Rocky Mountain - Great Plains stream: bioltic zonation and additive patterns of community change. Transactions of the American Fisheries Society 120:319-332.

Rinne, J. N. 1969. Cyprinid fishes of the genus Gila from the lower Colorado River basin. Arizona State University, MS Thesis, Tempe, Arizona.

Rinne, J. N. 1976. Cyprinid fishes of the genus Gila from the lower Colorado River basin. The Wasmann Journal of Biology 34(1):65-107.

Rinne, J.N. 1988. Effects of livestock grazing exclosure on a montane stream, New Mexico. Great Basin Naturalist 48:146-153.

Rinne, J. N. 1992. Physical habitat utilization of fish in a Sonoran Desert stream, Arizona, southwestern United States. Ecology of freshwater fish 1992(1): 35-41.

Rinne, J. N. and J. A. Stefferud. 1996. Relationships of native fishes and aquatic macrohabitats in the Verde River, Arizona. Proceedings of the 1996 meetings of the Arizona section, American Water Resources Association and the hydrology section, Tucson, AZ, Arizona-Nevada Academy of Sciences.

Rinne, J.N., and J.A. Stefferud. 1997. Factors contributing to collapse yet maintenance of a native fish community in the desert Southwest (USA). Pages 157-162 *in* D. A. Hancock, D. C. Smith, A. Grant, and J. P. Beumer, editors. Developing and sustaining world fisheries resources, 2nd World Fisheries Congress.

Rinne, J. N., J. A. Stefferud, et al. 1998. Fish community structure in the Verde River, Arizona, 1974-1997. Proceedings of the 1998 meetings of the hydrology section Arizona-Nevada Academy Sciences: hydrology and water resources in Arizona and the southwest, Glendale, AZ.

Rinne, J.N., J.A. Stefferud, D.A. Clark, and P.J. Sponholtz. 1998. Fish community structure in the Verde River, Arizona, 1974-1997. Hydrology and Water Resources in Arizona and the Southwest 28:75-80.

Robinson, A. In press. How effective are constructed barriers at protecting Apache trout? Proceedings of the Desert Fishes Council 34.

Rojo, H. A. and coauthors. 1999. Sustaining and enhancing riparian migratory bird habitat on the upper San Pedro River. Commission for Environmental Cooperation, Washington, D.C.

Roni, P., T.J. Beechie, R.E. Bilby, F.E. Leonetti, M.M. Pollock, and G.R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management 21:1-20. Roper, B. B., J. J. Dose, and J. E. Williams. 1997. Stream restoration: is fisheries biology enough? Fisheries 22(5):6-11.

Rorabaugh, J. C., M. J. Sredl, V. Miera, and C. A. Drost. *In press*. Continued invasion by an introduced frog (Rana berlandiera): southwestern Arizona, southeastern California, and Rio Colorado, Mexico. The Southwestern Naturalist.

Rosenfeld, M. J., and J. A. Wilkinson. 1989. Biochemical genetics of the Colorado River Gila complex (Pisces: Cyprinidae). The Southwestern Naturalist 34(2):232-244.

Rosgen, D. 1996. Applied river morphology. Wildland Hydrology. Pagosa Springs, CO.

Rutman, S. 1997. dirt is not cheap: livestock grazing and a legacy of accelerated soil erosion on Organ Pipe National Monument, Arizona. Pp 360-375 *in*: Environmental , economic, and legal issues related to rangeland water developments. Proceedings of a symposium, November 13-15, 1997. Tempe, AZ.

Sartz, R. S., and D.N. Tolsted. 1974. Effect of grazing on runoff from two small watersheds in southwestern Wisconsin. Water Resources Research 10(2): 354-356.

Schmetterling, D. A., C. G. Clancy, and T. M. Brandt. 2001. Effects of riprap bank reinforcement on stream salmonids in the western United States. Fisheries 26(7):6-13.

Schramm, H.L., Jr., and R.G. Piper. 1995. Uses and effects of cultured fishes in aquatic ecosystems. American Fisheries Society Symposium 15. Bethesda, MD.

Schreiber, D. C. and W. L. Minckley 1981. Feeding interrelations of native fishes in a Sonoran Desert stream. Great Basin Naturalist 41(4): 409-426.

Schuhardt, S. 1989. Stream survey report, 1989, Verde River, Oak Creek, and tributaries of the Verde River literature review. U.S. Forest Service, Flagstaff, AZ. 40 pp.

Schulz, T. T., and W.C. Leininger. 1990. Differences in riparian vegetation structure between grazed areas and exclosures. Journal of Range Management 43(4): 295-299.

Schlesinger, W.H., J.R. Reynolds, G.L. Cunningham, L.F. Huenneke, W.M. Jarrell, R.A. Virginia, and W.G. Whitford. 1990. Biological feedbacks in global desertification. Science 246:1043-1048.

Scott, J.E. 1997. Do livestock waters help? Pp 493-507 *in:* Symposium on environmental, economic, and legal issues related to rangeland water developments. Nov. 13-15, 1997, Tempe, AZ. Arizona State University, Tempe, AZ.

Sellers, W.D., and R.H. Hill. 1974. Arizona climate 1931-1972. University of Arizona Press, Tucson.

Sidle, J.G. 1998. Arbitrary and capricious species conservation. Conservation Biology 12(1):248-249.

Sidle, J. G., K. Mayne, and E. N. McPhillips. 1991. Protecting the piping plover under section 7 of the Endangered Species Act. Environmental Management 16(3):349-356.

Siebert, D. J. 1980. Movements of fish in Aravaipa Creek, Arizona. Tempe, AZ, Arizona State University.

Sigler, W.F. and R.R. Miller. 1963. Fishes of Utah. Utah State Department of Fish and Game, Salt Lake City, Utah.

Sigler, W.F., and J.W. Sigler. 1996. Fishes of Utah. University of Utah Press, Salt Lake City.

Simms, J. R. 1997. Some effects of stock tanks on aquatic biodiversity in Arizona streams. Pp 203-210 *in* Symposium on environmental, economic, and legal issues related to rangeland water developments. Nov. 13-15, 1997, Tempe, AZ. Arizona State University, Tempe, AZ.

Simpson, P. W., J. R. Newman, M. A. Keirn, R. M. Matter, and P. A. Guthrie. 1982. Manual of stream channelization impacts on fish and wildlife. U.S. Fish and Wildlife Service, Washington, D.C.

Smith, G. R., R. R. Miller, and W. D. Sable. 1977. Species relationships among fishes of the genus Gila in the upper Colorado River drainage. Proceedings of the First Conference on Scientific Research in the National Parks, USNPS Transactions and Proceedings Series 1:613-623.

Sponholtz, P. J., D. C. Redondo, B. P. Deason, L. M. Sychowski, and J. N. Rinne. 1997. The influence of stock tanks on native fishes: upper Verde River, Arizona. Pp 156-179 *in:* Symposium on environmental, economic, and legal issues related to rangeland water developments. Nov. 13-15, 1997, Tempe, AZ. Arizona State University, Tempe, AZ.

Stefferud, J.A., and J.N. Rinne. 1995. Sustainability of fishes in a desert river: preliminary observations on the roles of streamflow and introduced fishes. Hydrology and Water Resources in Arizona and the Southwest 22-25:25-32.

Stefferud, J.A., and J.N. Rinne. 1997. Effects of floods on fishes in the upper Verde River, Arizona. Proceedings of the Desert Fishes Council 28:80.

Stefferud, J., S. Stefferud, R. Clarkson, R. Heinrich, J. Slaughter, and R. Bettaso. In press. Area report: Lower Colorado. Proceedings of the Desert Fishes Council 34

Stefferud, J.A., and S.E. Stefferud. 1994. Status of Gila topminnow and results of monitoring the fish community in Redrock Canyon, Coronado National Forest, 1979-1993. Pp 361-369 *in* P. F. Ffolliott, editor. Biodiversity and management of the Madrean Archipelago: the sky islands of southwestern United States and Northwestern Mexico. Sept. 19-23, 1994. Tucson, AZ. U.S. Forest Service Rocky Mountain Forest and Range Experiment Stateion, General Technical Report Rm-GTR264, Ft. Collins, CO.

Stefferud, J. A., and S. E. Stefferud. 1998. Influence of low flows on abundance of fish in the upper San Pedro River, Arizona. Pp 167-181 *in* Cross Border Waters: Fragile Treasures for the 21st Century. Ninth U.S./Mexico Border States Conference on Recreation, Parks, and Wildlife. Tucson, AZ. June 3-6, 1998.

U.S.Forest Service Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO.

Stefferud, S.E. 1995. The tangled web: translocation, bureaucracy and politics. Proceedings of the Desert Fishes Council:27:84-85.

Stefferud, S.E., and J.A. Stefferud. 2002. In press. Can conservation be achieved through section 7 (ESA)? Gila topminnow in Redrock Canyon (AZ) -- a case study. Meeting Resource Management Information Needs; Proceedings of the Fourth Conference on Research and Resource Management in the Southwestern Deserts. May 2000, Tucson, AZ.

Stewart, D.M. 2002. Memorandum on grazing administration responsibilities. June 2002. U.S. Forest Service, Region 3, Albuquerque, NM. 3 pp.

Stickney, R.R. 1994. Use of hatchery fish in enhancement programs. Fisheries 19(5):6-13.

Storch, R.L. 1979. Livestock/streamside management programs in Eastern Oregon. Pp. 56-60 *in*: Forum -- grazing and riparian/stream ecosystems. E.B. Cope ed. Trout Unlimited, Denver, CO. Sublette, J. E., M. D. Hatch, and M. Sublette. 1990. The fishes of New Mexico. University of New Mexico Press, Albuquerque, New Mexico.

Swanson, F.J., S.V. Gregory, J.R. Sedell, and A.G. Campbell. 1982. Land-water interactions: the riparian zone. Pp 267-291 *in*: Analysis of Coniferous Forest Ecosystems in the Western United States. R.L. Edmonds, ed. Hutchinson Ross Pub. Co. New York, NY.

Swetnam, T. W. and C. H. Baisan 1994. Historical fire regime patterns in the Southwestern United States since AD 1700. Fire effects in Southwestern forests: proceedings of the second La Mesa Fire symposium. USDA Forest Service Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-GTR-286, Los Alamos, New Mexico, USDA Forest Service Rocky Mountain Forest and Range Experiment Station.

Tait, C.K., J.L. Li, G.A. Lamberti, T.N. Pearsons, and H.W. Li. 1994. Relationships between riparian cover and community structure in high desert streams. Journal of the North American Benthological Society 13(1):45-56.

Tanner, V.M. 1950. A new species of *Gila* from Nevada (Cyprinidae). Great Basin Naturalist 10(1-4):31-36.

Tear, T.H., J.M. Scott, P.H. Hayward, B. Griffith. 1993. Status and prospects for success of the Endangered Species Act: a look at recovery plans. Science 262:976-977.

Tellman, B., R. Yarde, and M. G. Wallace. 1997. Arizona's changing rivers: how people have affected the rivers. University of Arizona, Tucson, AZ.

Touchan, R., Swetnam, T. and Grissino-Meyer, H. 1995. Effects of livestock grazing on pre-settlement fire regimes in New Mexico, USDA Forest Service General Technical Report INT-GTR-320; Intermountain Research Station; Ogden UT PP 268-272.

Trimble, S.W., and A.C. Mendel. 1995. The cow as a geomorphic agent -- a critical review. Geomorphology 13(1995):233-253.

UDWR 2002. Draft range-wide conservation agreement and startegy for roundtail chub, bluehead sucker, and flannelmouth sucker. Salt Lake City, UT, Utah Division of Wildlife Resources.

U.S. Bureau of Reclamation. 2001. Letter to Director, Arizona Game and Fish Department re Request for meeting to discuss Arizona Game and Fish Department (AZGFD) executive staff recommendations against construction of fish barriers and application of piscicides to assist recovery of native fishes. May 3, 2001. USBR, Phoenix, AZ. 3 pp.

U.S. Bureau of Reclamation. 2002. Final meeting summary. Contingency planning for Fossil Creek fish renovation. June 28, 2002. USBR, Phoenix, AZ. 9 pp.

U.S.Dept.of the Interior Office of the Inspector General. 1990. Audit report. The endangered species program. U.S. Fish and Wildlife Service. Report No. 90-98. September 1990. USDI, Washington, D.C.U.S. Fish and Wildlife Service. 1993a. Memorandum to FWS Regional Director re unregulated activities adversely affecting listed fish in Arizona. July 30, 1993. USFWS, Phoenix, AZ. 2 pp.

U.S. Fish and Wildlife Service. 1993b. Memorandum from Project Coordinator, Parker FRO to Project Leader AZFRO re reintroduction of native fish into the Bill Williams River. USFWS, Parker, AZ. 1 pp.

U.S. Fish and Wildlife Service. 1993c. Biological opinion to Soil Conservation Service on emergency flood control on Aravaipa Creek. 2-21-93-F-140. October 20, 1993. USFWS, Phoenix, AZ. 9 pp.

U.S. Fish and Wildlife Service. 1993d. Biological opinion to Soil Conservation Service on emergency flood control on Aravaipa Creek. 2-21-93-F-166. October 20, 1993. USFWS, Phoenix, AZ. 10 pp.

U.S. Fish and Wildlife Service. 1994. Biological opinion on intra-Service consultation on stocking of catchable size rainbow trout and channel catfish into selected areas of the lower Colorado River. 2-21-94-F-244. July 1, 1994. USFWS Albuquerque, NM. 22 pp.

U.S. Fish and Wildlife Service. 1995a. Letter of informal consultation to Arizona Game and Fish Department re rainbow trout stocking in Verde River. February 6, 1995. USFWS, Albuquerque, NM. 7 pp.

U.S. Fish and Wildlife Service. 1995b. Biological opinion on Federal Aid's transfer of funds to the Arizona Game and Fish Department for exotic fish stocking in Nelson Reservoir, Blue Ridge Reservoir, and Knoll Lake. 2-21-F-92-403. August 5,1995 and Nov. 20, 1995. USFWS, Phoenix, AZ. 20 pp.

U.S. Fish and Wildlife Service. 1995c. Memorandum of informal consultation to Assistant Regional Director, Federal Aid re intra-Service section 7 evaluations (Federal Aid) on stocking sportfish into waters in Arizona. October 31, 1995. USFWS, Albuquerque, NM. 7 pp.

U.S. Fish and Wildlife Service. 1998. Letter to Arizona Game and Fish Department re recommendations for additions to Restricted Live Wildlife List. November 3, 1998. USFWS, Phoenix, AZ. 3 pp.

U.S. Fish and Wildlife Service. 1999a. Background document for May 1999 draft biological opinion on impacts of the Central Arizona Project (CAP) to Gila topminnow in the Santa Cruz River subbasin through introduction and spread of nonnative aquatic species. August 17, 1999. USFWS, Phoenix, AZ. 106 pp.

U.S. Fish and Wildlife Service. 1999b. Draft biological opinion on impacts of the Central Arizona Project (CAP) to Gila topminnow in the Santa Cruz River basin through introduction and spread of nonnative aquatic species. Sent to U.S. Bureau of Reclamation June 11, 1999. USFWS, Phoenix, AZ. 60 pp.

U.S. Fish and Wildlife Service. 1999c. Memorandum from Regional Director, Region 2 to Regional Director, Region 6, re roundtail chub status. July 27, 1999. USFWS, Albuquerque, NM. 1pp.

U.S. Fish and Wildlife Service. 1999d. Memorandum from Regional Director, Region 6 to Regional Director, Region 2, re roundtail chub status. August 26, 1999. USFWS, Denver, CO. 1 pp.

U.S. Fish and Wildlife Service. 1999e. Biological Opinion to U.S. Forest Service on ongoing and long-term grazing on the Coronado National Forest. AESO/SE2-21-98-F-399. USFWS, Phoenix, AZ. 379 pp.

U.S. Fish and Wildlife Service. 2000a. Biological Opinion to the U.S. Forest Service on livestock grazing on the Red Creek allotment, Verde River. December 19, 2000. USFWS, Phoenix, AZ. 81 pp.

U.S. Fish and Wildlife Service. 2000b. Memorandum to Regional Director re Rio Salado Town Lake Fish Stocking Section 7 consultation. 2-21-00-I-099. January 18, 2000. USFWS, Phoenix, AZ. 7 pp.

U.S. Fish and Wildlife Service. 2001a. Background information on the Central Arizona Project and nonnative aquatic species in the Gila River Basin (excluding the Santa Cruz River Subbasin). April 2000. USFWS, Phoenix, AZ. 159 pp.

U.S. Fish and Wildlife Service. 2001b. Revised biological opinion on transportation and delivery of Central Arizona Project water to the Gila River Basin (Hassayampa, Agua Fria, Salt, Verde, San Pedro, Middle and upper Gila Rivers, and associated tributaries) in Arizona and New Mexico and its potential to introduce and spread nonnative aquatic species. 2-21-90-F-119. Sent to U.S. Bureau of Reclamation April 17, 2001. USFWS, Phoenix, AZ. 81 pp.

U.S. Fish and Wildlife Service. 2001c. Letter to Arizona Game and Fish Department transmitting comments on the draft report for the Roundtail chub (*Gila robusta*) Status Survey of the Lower Colorado River Basin (a part of contract No. 1448-0002-96-0814). December 21, 2001. USFWS, Phoenix, AZ. 21 pp.

U.S. Fish and Wildlife Service. 2001d. Biological Opinion to the U.S. Forest Service on livestock grazing on the Black River, Boneyard, Nutrioso Summer, and Williams Valley allotments. 2-21-00-F-286. February 26, 2001. USFWS, Phoenix, AZ. 35 pp.

U.S. Fish and Wildlife Service. 2001e. Letter to Secretary, Federal Energy Regulatory Commission re Childs-Irving Hydropower Project in support of Sept. 15, 2000 Offer of Settlement and Settlement Agreement. August 7, 2001. USFWS, Phoenix, AZ. 3 pp.

U.S. Fish and Wildlife Service. 2001f. Informal consultation concurrence for stocking rainbow trout and roundtail chub into Rio Salado Town Lake. 2-21-00-I-099. USFWS, Phoenix, AZ. 10 pp.

U.S. Fish and Wildlife Service. 2001g. Biological opinion on intra-Service section 7 consultation for rainbow trout stocking into Nelson, Knoll, and Blue Ridge reservoirs. 2-21-92-F-403R. May 25, 2001. USFWS, Phoenix, AZ. 21 pp.

U.S. Fish and Wildlife Service. 2001h. Letter to Arizona Game and Fish Department re proposed prohibitions on importation and transport of live crayfish. February 22, 2001. USFWS, Albuquerque, NM. 2 pp.

U.S. Fish and Wildlife Service. 2002a. Draft candidate and listing priority assignment form, *Gila robusta* - population in the lower Colorado River basin. May 2002. USFWS, Phoenix, AZ. 9 pp.

U.S. Fish and Wildlife Service. 2002b. Draft candidate and listing priority assignment form, *Gila nigra*. May 2002. USFWS, Phoenix, AZ. 8 pp.

U.S. Fish and Wildlife Service. 2002c. Endangered and threatened wildlife and plants; listing the Gila chub as endangered with critical habitat. Federal Register 67(154):51948-51985.

U.S. Fish and Wildlife Service. 2002e. Biological Opinion to the U.S. Forest Service on livestock grazing on the Udall , P.S., and Hayground allotments, Black River, Arizona. 2-21-90-F-120R, 2-21-01-F-305, 2-21-01-F-313. February 28, 2002. USFWS, Phoenix, AZ. 55 pp.

U.S. Fish and Wildlife Service. 2002e. Biological Opinion to the U.S. Forest Service on livestock grazing on the Tule, Mud Springs, Double Circles, East Eagle, Baseline/Horsesprings, and Dark Canyon allotments, Eagle Creek, Arizona. 2-21-01-F-105. February 26, 2002. USFWS, Phoenix, AZ. 88 pp.

U.S. Forest Service. 1985, and amendments. Tonto National Forest Plan. Tonto National Forest, Phoenix, AZ. 257 pp.

U.S. Forest Service. 2000. Forest Service roadless area conservation, final environmental impact statement, biological evaluation attachment S2: sensitive species national master list by region and species group. Internet URL: http//roadless.fs.fed.us/documents/feis/specrep/be/BE_Attachment_S2

U.S.Forest Service. 2001. Report on compliance monitoring for biological opinion on Eagle Creek bank stabilization project at Honeymoon campground. USFS, Clifton, AZ.

U.S. Geological Survey. 2003. National water information system data on the web. http://waterdata.usgs.gov/ut/nwis

U.S. Soil Conservation Service. 1949. Survey report, upper Gila Rivers watershed, New Mexico and Arizona. Program for runoff and waterflow retardation and soil erosion prevention. And Appendix. U.S. Soil Conservation Service, Washington, D.C.

Van Velson, R, 1979. Effects of livestock grazing upon rainbow trout in Otter Creek. Pp. 53-55 *in*: Forum -- grazing and riparian/stream ecosystems. O.B. Cope, ed. Trout Unlimited, Denver, CO.

Vanicek, C. D. and R. B. Kramer. 1969. Life history of the Colorado squawfish, *Ptychocheilus lucius*, and the Colorado chub, *Gila robusta*, in the Green River in Dinosaur National Monument, 1964-1966. Transactions of the American Fisheries Society 98(2): 193-208.

Velasco, A.L. 1997. Fish population response to variance in stream discharge, Aravaipa Creek, Arizona. Arizona State University, MS Thesis. Tempe, AZ.

Voeltz, J. B., and R. J. Timmons. 2001. Roundtail chub (*Gila robusta*) status survey of the lower Colorado River basin. Arizona Game and Fish Department,Technical Report 186:1-213.

Voeltz, J. B. 2002. Roundtail chub (*Gila robusta*) status survey of the lower Colorado River basin. Arizona Game and Fish Department, Phoenix, AZ.

Vrijenhoek, R. C., M. E. Douglas, and G. K. Meffe. 1985. Conservation genetics of endangered fish populations in Arizona. Science 229:400-402.

Waters, T.F. 1995. Sediment in streams. Sources, biological effects and control. American Fisheries Society, Monograph 7. Bethesda, MD. 251 pp.

Welcomme, R.L. 1998. Principles and approaches for river fisheries management. International Symposium and Workshop on Management and Ecology of River Fisheries. 29 March - 3 April 1998. University of Hull, Hull, England.

Welz, M., and M.K. Wood. 1986. Short duration grazing in central New mexico: effects on infiltration rates. Journal of Range Management 39:365-368.

White, A. S. 1985. Presettlement regeneration patterns in a Southwestern ponderosa pine stand. Ecology 66(2): 589-594.

Williams, J.E., C.A. Wood, M.P. Dombeck. 1997. Watershed restoration: priniciples and practices. American Fisheries Society. Bethesda, MD.

Wolfe, E.W. 1984. The volcanic landscape of the San Francsico volcano field. Pp. 111-136 *in* T. Smiley, J. Nations, T. Pewe, and J. Schafer, eds. Landscapes of Arizona, Univ. Press of America, New York.

Wolden, L. G., and J. C. Stromberg. 1997. Experimental treatments (and unplanned natural events) for restoration of the herbaceous understory in an arid-region riparian ecosystem. Restoration and Management Notes 15(2):161-167. Yaffee, S. L. 1997. Why environmental policy nightmares recur. Conservation Biology 11(2):328-337.

Ziebell, C.D., and R.R. Roy. 1989. Distribution and angler use of the roundtail chub (*Gila robusta*) in the upper Verde River. Arizona Cooperative Fish and Wildlife Research Unit, University of Arizona, Tucson.