American Fisheries Society Symposium 45:157–204, 2005


# Ecology and Conservation of Native Fishes in the Upper Colorado River Basin

RICHARD A. VALDEZ*
*SWCA, Inc., 172 W. 1275 S., Logan, Utah 84321, USA*

ROBERT T. MUTH
*Upper Colorado River Endangered Fish Recovery Program, 44 Union Boulevard, Suite 120, Lakewood, Colorado 80228, USA*

*Abstract.*—The upper Colorado River basin supports a native ichthyofauna of 14 species or subspecies that have been impacted by poor land-use practices, altered flows, physical habitat fragmentation, competition and predation from nonnative fish species, and degraded water quality. Five taxa are federally endangered, including the large-river species, Colorado pikeminnow *Ptychocheilus lucius*, humpback chub *Gila cypha*, bonytail *G. elegans*, razorback sucker *Xyrauchen texanus*, and a warm-stream subspecies, Kendall Warm Springs dace *Rhinichthys osculus thermalis*. Two recovery programs, formed through cooperative agreements among federal, state, tribal, and private agencies and stakeholders, coordinate activities in the upper basin that have helped to resolve water resource issues, implement management actions to minimize or remove threats, and conserve endangered species. A cooperative biological management program among state and federal agencies works to protect the Kendall Warm Springs dace. Conservation agreements have also been established for the other native fish species. Continued public and institutional support for these programs is vital to species recovery and to the balance between long-term species conservation and human demands on the Colorado River system.

## Introduction

The upper Colorado River basin lies within the states of Colorado, Wyoming, Utah, and New Mexico (Figure 1). Upper basin drainage area is about 289,540 km$^2$, or less than half the total area of the Colorado River system; average annual historic upper basin discharge is about 93% of average total basin volume (i.e., 12.93 million acre-feet of 13.90 million acre-feet). The upper basin includes the upper Colorado River, Green River, and San Juan River subbasins. Evidence suggests that the Colorado River in the upper basin has been in its present course for more than 5 million years and flowed into one or more closed basins near the upper end of present-day Grand Canyon (Minckley et al. 1986). About 5 million years ago (i.e., late Miocene/early Pliocene), the river began carving its way through the Colorado Plateau forming Grand Canyon, and joined with a lower, more dispersed drainage within the last 2–3 million years (McKee et al. 1967; Luchitta 1990). The ancestral upper Colorado River consisted primarily of a single large river and tributaries in contrast to more dispersed smaller tributaries in the lower basin. Fish species that evolved in the upper basin were mostly large riverine forms and those that evolved in the lower basin were small stream forms. Connection between these two ancestral basins, marked by the river cutting through Grand Canyon, allowed for inter-basin movement of the larger, more mobile species, particularly from the upper basin. These

* Corresponding author: valdezra@aol.com

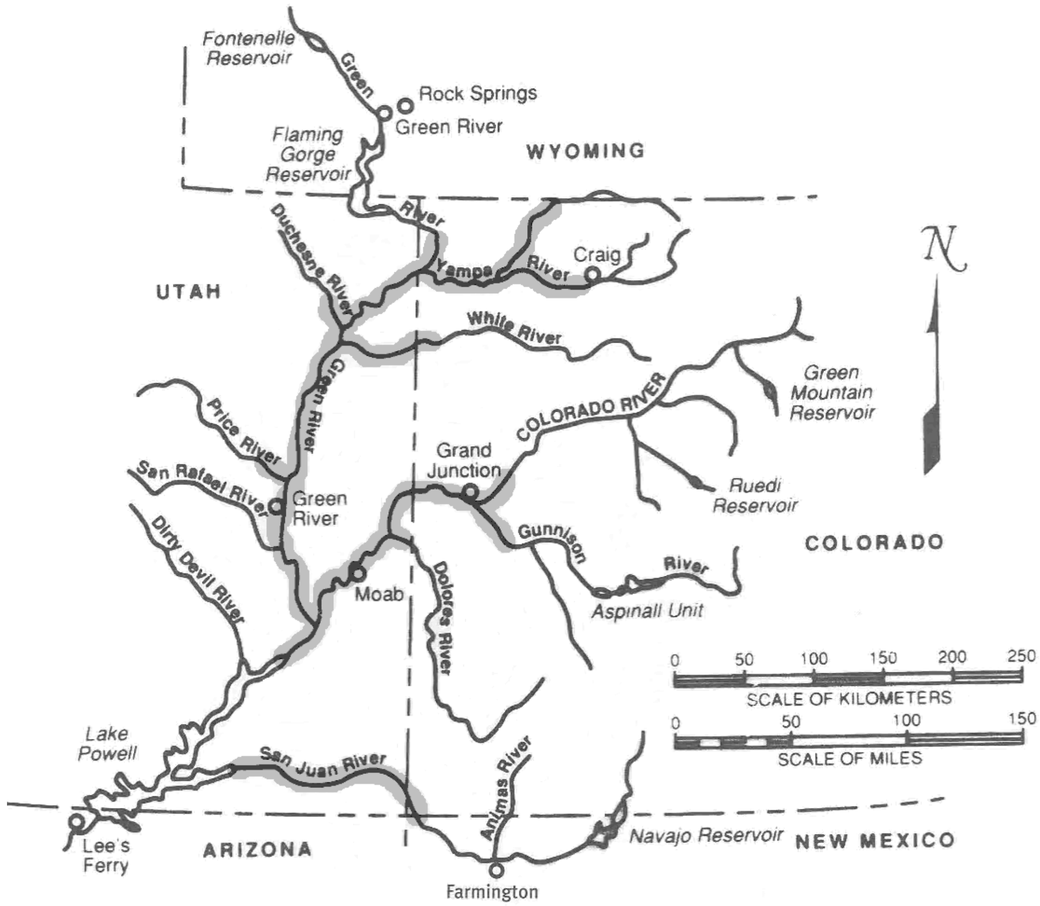


Figure 1.—The upper Colorado River basin and present distribution of wild Colorado pikeminnow *Ptychocheilus lucius* (shaded).

progenitors of modern-day forms further evolved as the Colorado River became a single basin. Many small forms found in the lower basin are unique and have been unable to disperse upstream into the upper basin.

Today, the upper basin originates at elevations of 3,000–4,000 m in high mountain meadows, and the Colorado River flows through a series of mid-elevation sandstone canyons (Figure 2) and intervening deep canyons with isolated upthrusts of hard Precambrian schist and gneiss. The characteristic geomorphic features of the upper basin provide diverse and unique habitats to which the native fishes have adapted over several million years. A long period of geologic isolation, steep stream gradient, high levels of water turbidity and conductance, and extreme seasonal variation in water temperatures and flows have led to unique morphologic and physiologic adaptations. These specialized adaptations, together with low levels of competition and predation, have rendered native fish species highly susceptible to ecological changes from human activities including (a) flow regulation and diversion, (b) physical habitat destruction, alteration, and fragmentation, (c) introduction of nonnative fishes, and (d) degraded water quality (Miller 1961; Carlson and Muth 1989).

## Current Status and Ecology

Fourteen species or subspecies of native fishes inhabit the upper basin of which eight (57%) are

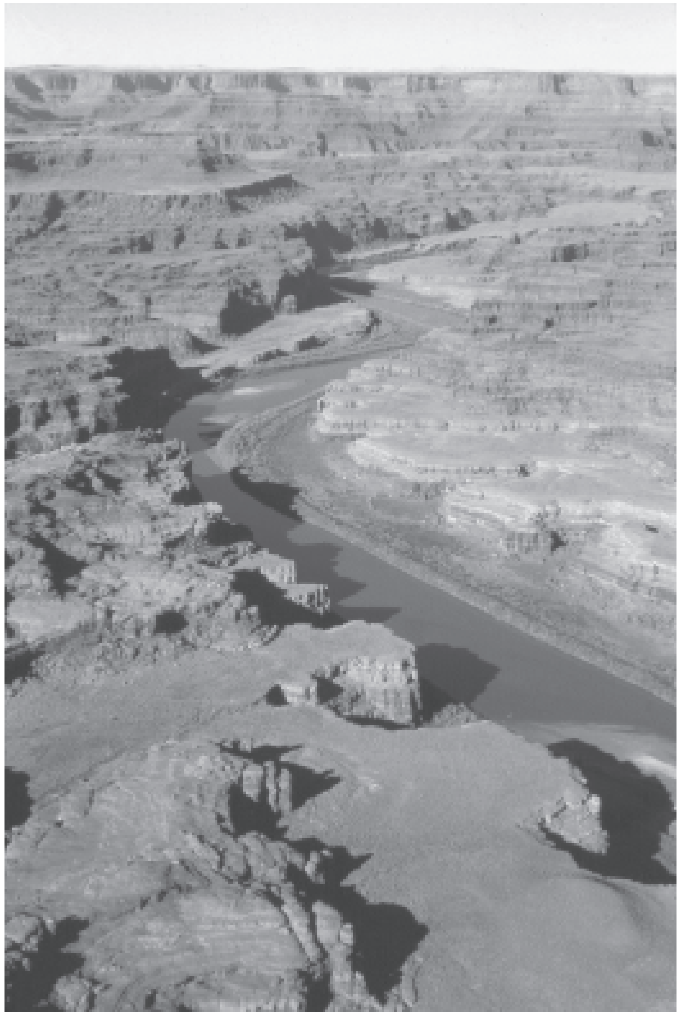

Figure 2.—The upper Colorado River downstream of Moab, Utah, December 1981. Photo by R. A. Valdez.

endemic; eight are primarily large-river warmwater inhabitants, five are coolwater or coldwater tributary inhabitants, and one is found in a warm stream (Tyus et al. 1982; Muth et al. 2000; McAda 2003; Table 1). Many native fishes in the upper basin have declined in range and abundance since the early 1900s (Carlson and Muth 1989). Five are federally endangered: Colorado pikeminnow, humpback chub, bonytail, razorback sucker, and Kendall Warm Springs dace. Concerns over declines in native fish populations in the mid-1900s prompted studies to assess the status and life history of these little-known southwestern fishes (e.g., Miller 1955, 1959, 1961; Vanicek 1967; Holden 1973), and passage of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et seq.), led to initiation of more comprehensive studies in the late 1970s (e.g., U.S. Fish and Wildlife Service 1982a).

## *Colorado Pikeminnow*

Colorado pikeminnow is the largest minnow in North America, with estimated maximum size of 1.8 m total length (TL) and 36 kg (Miller 1961); largest confirmed weights are 12.2 and 15.5 kg from the lower basin (Wallis 1951), and about 12 kg from the upper basin (Figure 3). Maximum age,

Table 1.—Common and scientific names, legal status, current distribution, and relative abundance of native fish of the upper Colorado River basin.

| Species | Status[a] | Distribution and abundance |
|---|---|---|
| **Cyprinidae (minnows)** | | |
| Colorado pikeminnow *Ptychocheilus lucius* Girard, 1856 | EN<br>En-NM<br>Th-CO<br>Sp-UT | Found as two populations: Green River and upper Colorado River subbasins. Wild fish incidental in San Juan River. |
| humpback chub *Gila cypha* Miller, 1946 | EN<br>Th-CO<br>Sp-UT | Found as five populations: Black Rocks, Westwater, Cataract, Desolation/Gray, Yampa canyons |
| bonytail *G. elegans* Baird and Girard, 1853 | EN<br>Ex-NM<br>En-CO<br>Sp-UT | Wild fish incidental; fewer than 15 specimens from Black Rocks, Cataract and Desolation/Gray canyons since 1980 |
| roundtail chub *G. robusta* Baird and Girard, 1853 | En-NM<br>Co-CO, NM, UT, WY | Common to locally abundant in mid-elevation rivers |
| speckled dace *Rhinichthys osculus* Girard, 1856 | | Common to abundant throughout |
| Kendall Warm Springs dace *R. o. thermalis* (Hubbs and Kuhne, 1937) | EN<br>En-WY | Found as single population only in Kendall Warm Springs Creek, Wyoming |
| **Catostomidae (suckers)** | | |
| razorback sucker *Xyrauchen texanus* (Abbott, 1860) | EN<br>En-CO<br>Sp-UT | Wild fish incidental to rare in upper Colorado, Gunnison, Green, Yampa, Duchesne, San Juan rivers |
| flannelmouth sucker *Catostomus latipinnis* Baird and Girard, 1853 | Co-CO, NM, UT WY | Common to abundant in mid- and low elevation rivers |
| bluehead sucker *C. discobolus* Cope 1871 | Co-CO NM, UT WY | Common to abundant in rocky riffles of mid-elevation rivers |
| mountain sucker *C. platyrhynchus* (Cope, 1874) | Sp-CO | Common in high and mid-elevation streams |
| **Cottidae (sculpins)** | | |
| mottled sculpin *Cottus bairdii* Girard, 1850 | | Common to abundant in mid- and high elevation streams and rivers |
| Paiute sculpin (*Cottus beldingii*) Eigenmann, 1891 | | Uncommon in mid- and high elevation streams and rivers |
| **Salmonidae (trout and salmon)** | | |
| mountain whitefish *Prosopium williamsoni* (Girard, 1856) | Sf-CO, UT, WY | Common to abundant in high elevation streams |

Table 1.—Continued.

| Species | Status[a] | Distribution and abundance |
|---|---|---|
| Colorado River cutthroat trout *Oncorhynchus clarkii pleuriticus* | Co-CO, UT, WY Sf-CO | Small local populations in high elevation streams |

[a] EN = federally endangered; status by indicated state: En = endangered, Ex = extirpated, Th = threatened, Sp = species of special concern or sensitive species, Co = conservation species; Sf = sport fish.

determined from scale annuli, is up to 18 years (Vanicek and Kramer 1969; Seethaler 1978; Musker 1981; Hawkins 1992). However, Osmundson et al. (1997) cautioned that scale-based estimations are probably unreliable for Colorado pikeminnow beyond about age 10, and concluded that growth-rate data indicated that large fish (e.g., more than 900 mm TL) averaged 47–55 years old with a minimum of 34 years. Growth and size in the upper basin appear limited by colder temperatures and a shorter growing season (Kaeding and Osmundson 1989). The species was listed as endangered in 1967 (32 FR 4001), and protected by the ESA in 1973 (39 FR 1175), with critical habitat designated in 1994 (59 FR 13374). A recovery plan was approved in 1978 (U.S. Fish and Wildlife Service 1978), revised in 1991 (U.S. Fish and Wildlife Service 1991), and amended and supplemented with recovery goals in 2002 (U.S. Fish and Wildlife Service 2002a). As for humpback chub, bonytail, and razorback sucker, these recovery goals provide demographic criteria and management actions to minimize or remove threats.

Colorado pikeminnow is endemic to the Colorado River system, and was once widespread and abundant in warm main-stem rivers and tributaries (Kirsch 1889; Evermann and Rutter 1895; Jordan and Evermann 1896; Banks 1964; Vanicek 1967; Holden and Stalnaker 1975a; Holden and Wick 1982; Tyus 1991; Quartarone 1995). In the upper basin, the species was first reported in 1825 by Colonel William H. Ashley (Morgan 1964; Seethaler

Figure 3.—Adult Colorado pikeminnow captured in the Redlands fish passage on the Gunnison River in 2002, approximate weight 12 kg. Photo courtesy of Bob Burdick, U.S. Fish and Wildlife Service.

1978). In the upper Colorado River subbasin, it was historically found as far upstream as Rifle, Colorado, on the upper Colorado River (Beckman 1963); Delta, Colorado, on the Gunnison River (Burdick 1995); and Paradox Valley on the Dolores River (Lynch et al. 1950). In the Green River subbasin, it was reported as far upstream as Green River, Wyoming, on the Green River (Ellis 1914; Baxter and Simon 1970); Craig, Colorado, on the Yampa River; Rangely, Colorado, on the White River; and in the lower Price and Duchesne rivers (Tyus and Haines 1991; Cavalli 1999). In the San Juan River subbasin, Colorado pikeminnow were historically found upstream to Farmington, New Mexico, and the lower Animas River (Holden 1999).

Wild populations of Colorado pikeminnow are presently found only in the upper basin in about 25% of historic range basin-wide (Figure 1). Adults occur in the Green River from Lodore Canyon to the confluence of the Colorado River (Tyus 1991; Bestgen and Crist 2000); Yampa River downstream of Craig, Colorado (Tyus and Haines 1991); Little Snake River into Wyoming (Marsh et al. 1991; Wick et al. 1991); White River downstream of Taylor Draw Dam , Colorado (Tyus and Haines 1991); lower 143 km of the Price River (Cavalli 1999); lower Duchesne River; upper Colorado River from Palisade, Colorado, to Lake Powell (Valdez et al. 1982b; Osmundson et al. 1997, 1998); lower 54 km of the Gunnison River (Valdez et al. 1982a; Burdick 1995); lower 2 km of the Dolores River (Valdez et al. 1992); and 241 km of the San Juan River from Shiprock, New Mexico, to the Lake Powell inflow (Jordan 1891; Koster 1960; Propst 1999; Holden 1999).

Colorado pikeminnow is adapted to warm rivers and requires uninterrupted passage and a hydrologic cycle characterized by large spring peaks of snowmelt runoff and lower, relatively stable base flows. Adults are potadromous and may move up to 950 km to and from spawning sites in summer (Tyus and McAda 1984; Tyus 1990; Irving and Modde 2000). Juveniles and adults use deep, low-velocity eddies, pools, and runs, but move into flooded habitats and bottomlands during spring runoff (Tyus and McAda 1984; Valdez and Masslich 1989; Tyus 1990, 1991; Osmundson et al. 1995). Average fecundity is about 66,000–77,000 eggs/female (Hamman 1986), and females broadcast adhesive eggs over cobble bars during June–August at water temperatures of 16°C or higher (Vanicek and Kramer 1969; Hamman 1981). The eggs incubate for 90–121 h at 20–24°C (Hamman 1981; Marsh 1985), and larvae drift up to 200 km to nursery backwaters where survival is critical to recruitment (Holden 1977; Tyus and Karp 1989; Haines and Tyus 1990; Tyus 1991; Tyus and Haines 1991; Bestgen et al. 1997, 1998; Converse et al. 1999). Young Colorado pikeminnow consume zooplankton and midge (chironomid) larvae (Vanicek 1967; Jacobi and Jacobi 1982; Muth and Snyder 1995), and piscivorous adults eat soft-rayed native and nonnative fish (Osmundson 1999), as well as a variety of insects and animals, including Mormon crickets *Anabrus migratorius* (Tyus and Minckley 1988), mice, birds, and rabbits (Beckman 1963).

### *Humpback Chub*

Humpback chub is an endemic cyprinid of the Colorado River system with an evolutionary history of about 3 million years (Miller 1946, 1955; Minckley et al. 1986). Maximum size is 480 mm TL and 1,165 g (Valdez and Ryel 1997), and maximum age is over 20 years (Hendrickson 1993). The body is deep and laterally-compressed, tapering abruptly to a narrow caudal peduncle with a deeply forked tail fin and large falcate paired fins. Head length divided by caudal peduncle depth is usually less than 5.0, compared to greater than or equal to 5.0 for bonytail, and greater than or equal to 3.0 for roundtail chub (Minckley 1973). Introgressive hybridization may be part of their evolutionary history (Dowling and DeMarais 1993), and high phenotypic plasticity exists with morphologic intergrades in all sympatric populations of humpback chub, bonytail, and roundtail chub (Holden 1968; Holden and Stalnaker 1970; Smith et al. 1979; Valdez and Clemmer 1982; Kaeding et al. 1990; Wick et al. 1991; McElroy and Douglas 1995; Douglas et al. 1989, 1998). Humpback chub was listed as endangered in 1967 (32 FR 4001) and protected by the ESA in 1973 (39 FR 1175), with critical habitat designated in 1994 (59 FR 13374). A recovery plan was approved in 1979 (U.S. Fish and Wildlife Service 1979), revised in 1990 (U.S. Fish and Wildlife Service 1990a), and amended and supplemented with recovery goals in 2002 (U.S. Fish and Wildlife Service 2002b).

Historic abundance of humpback chub is unknown, and historic distribution is surmised from various reports and collections, which indicate the species presently occupies about 68% of its historic habitat of about 756 km of river. The species exists primarily in relatively inaccessible canyons of the Colorado River basin and was rare in early collections (Tyus 1998). Common use of the name "bonytail" for all six Colorado River species or subspecies of the genus *Gila* confounded an accurate early assessment of distribution and abundance (Holden and Stalnaker 1975a, 1975b; Valdez and Clemmer 1982). Also, human alterations throughout the basin prior to faunal surveys may have depleted or eliminated the species from some river reaches before its occurrence was documented.

Five populations of humpback chub are currently known in the upper basin (i.e., Black Rocks, Westwater Canyon, Cataract Canyon, Desolation/Gray Canyons, Yampa Canyon; Figure 4), and one from Grand Canyon in the lower basin (U.S. Fish and Wildlife Service 2002b). Small numbers have also been reported from Moab Canyon (Taba et al. 1965; Valdez and Clemmer 1982), Debeque Canyon (Valdez and Clemmer 1982), Cross Mountain Canyon (Wick et al. 1981), Whirlpool and Split Mountain canyons (Holden and Stalmaker 1975a), Little Snake River (Wick et al. 1991), and White River (Lanigan and Berry 1979; U.S. Fish and Wildlife Service 1982a). Based on historic collections, populations have been extirpated from Hideout Canyon in Flaming Gorge (Bosley 1960; Gaufin et al. 1960; McDonald and Dotson 1960; Smith 1960), and

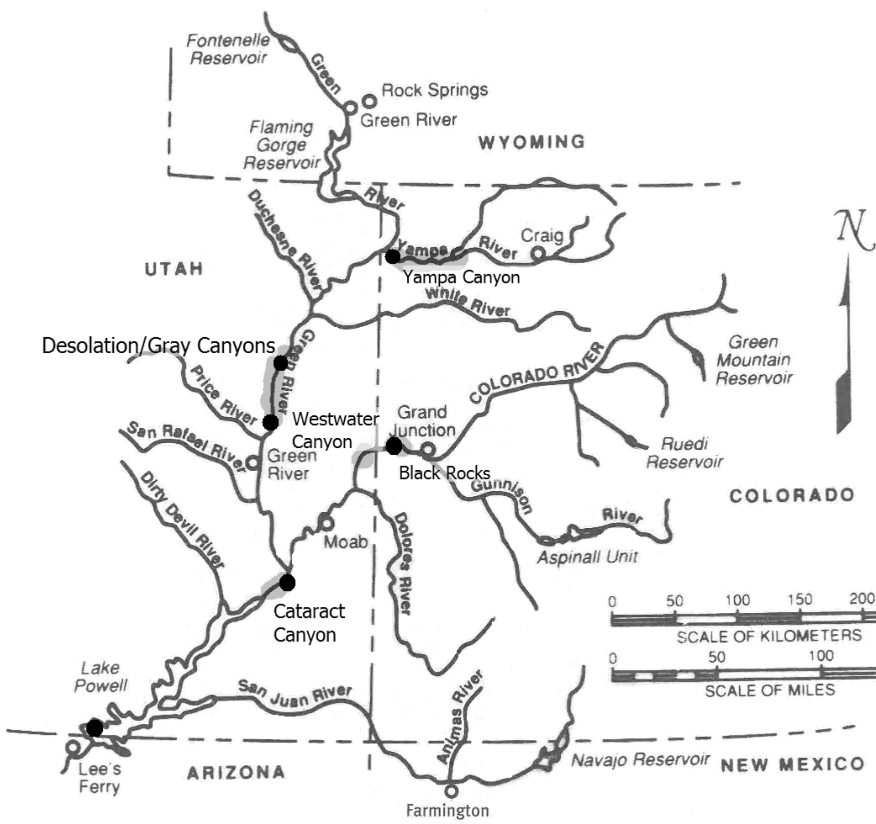


Figure 4.—Humpback chub populations (shaded) and recent capture locations of wild bonytail (filled circles) in the upper Colorado River basin.

Narrow and lower Cataract canyons (Holden and Stalnaker 1970, 1975a; Valdez 1990).

Humpback chub evolved in seasonally warm and turbid water and is highly adapted to extreme hydrologic conditions (Valdez and Carothers 1998). Although not a strong swimmer (Bulkley et al. 1982), the species is extraordinarily specialized for life in torrential water of canyon-bound reaches with a fusiform body, expansive fins, enlarged stabilizing nuchal hump, coarse skin, deeply embedded scales, and small eyes. Adults and juveniles in the upper basin occupy deep eddies and pools along rocky shores, and young use sheltered shorelines and low-velocity habitats (Valdez and Clemmer 1982; Karp and Tyus 1990a; Valdez et al. 1990; Chart and Lentsch 2000). Humpback chub move substantially less than other Colorado River native fishes and exhibit strong fidelity for restricted reaches of river, generally less than 2 km (Valdez and Clemmer 1982; Kaeding et al. 1990; Valdez and Ryel 1997).

Humpback chub mature in 2–3 years at 200 mm TL, and average fecundity is about 2,500 eggs per female (Hamman 1982). Spawning occurs during spring runoff at water temperatures of 16–22°C on large cobble bars or shorelines (Valdez and Clemmer 1982; Kaeding et al. 1986; Tyus and Karp 1989; Karp and Tyus 1990a; Valdez and Williams 1993). Larvae hatch at 18–21°C in about 6 d (Muth 1990) but do not drift extensively and use shorelines close to natal areas. Humpback chub feed opportunistically on drifting food entrained in recirculating eddies, as well as invertebrates or detritus on the river bottom, including planktonic crustacea, larvae of blackfly (simulid) and midges, filamentous green algae (primarily *Cladophora glomerata*), aquatic invertebrates, terrestrial invertebrates, and occasionally other fish and reptiles (Minckley 1973; Kaeding and Zimmerman 1983; Kubly 1990; Valdez and Ryel 1997). They become engorged by feeding on emergences of aquatic insects (e.g., mayfly hatches), grasshopper infestations, or migrations of Mormon crickets (Tyus and Minckley 1988). Parasites include the external parasitic copepod *Lernaea cyprinacea* and Asian tapeworm *Bothriocephalus acheilognathi* (Brouder and Hoffnagle 1997; Clarkson et al. 1997).

### *Bonytail*

Bonytail attain a maximum size of 550 mm TL and 1,100 g (Vanicek 1967). Originally collected and described from the Zuni River, New Mexico (Sitgreaves 1853; Girard 1856), the species is commonly called "bonytail chub," a name that has also been applied to humpback chub and roundtail chub and led to taxonomic confusion. Bonytail are streamlined with a small head, slender body, and thin caudal peduncle. Maximum age of fish from the Green River was 7 years (Vanicek 1967), and bonytail from Lake Mohave in the lower basin were 32–49 years (Ulmer 1983; Rinne et al. 1986). Bonytail was listed as federally endangered in 1980 (45 FR 27710) with critical habitat designated in 1994 (59 FR 13374). A recovery plan was approved in 1984 (U.S. Fish and Wildlife Service 1984), revised in 1990 (U.S. Fish and Wildlife Service 1990b), and amended and supplemented with recovery goals in 2002 (U.S. Fish and Wildlife Service 2002c).

Bonytail was once reported from various regions of the Colorado River system (Cope and Yarrow 1875; Jordan 1891; Jordan and Evermann 1896; Gilbert and Scofield 1898; Kirsch 1889; Chamberlain 1904). The species experienced an apparently dramatic but poorly documented decline starting in about 1950 that was attributed to construction of main-stem dams, introduction of nonnative fishes, poor land-use practices, and degraded water quality (Miller 1961). Its population trajectory over the past century is unclear because of a lack of quantitative, historic basin-wide fishery investigations. Interchangeable nomenclature between "bonytail" and sympatric *Gila* species (Valdez and Clemmer 1982; Quartarone 1995) has also led to confusion in species status. Ellis (1914) synonymized bonytail with roundtail chub "...since intermediate forms and those agreeing with the descriptions of both species were taken from the same station in the Grand [Colorado] River at Grand Junction."

The first record of bonytail from the upper basin was "One specimen taken in the Gunnison at Delta; five in the Green River..." (Jordan 1891; Bookstein et al. 1985). Gaufin et al. (1960) and Smith (1960) reported bonytail from Hideout Canyon before it was inundated by Flaming Gorge Reservoir, but numbers and sizes are unknown because they were grouped with humpback chub and roundtail chub. "Bonytail chub," roundtail chub, and humpback chub were reported in the Green River from the mouth of the Black's Fork River downstream through Flaming Gorge (Bosley 1960), and composed 7.3% of all fish from Green River, Wyoming, to the Utah–Colorado state line (McDonald and Dotson 1960). Individuals collected from the base of Flaming Gorge Dam and from Little Hole (10 km below the dam) in 1962 are held at the University of Michigan (R. Miller, University of Michigan, personal communication; Bookstein et al. 1985). Bonytail outnumbered roundtail chub in the Green River for the 1959, 1960, and 1961 year classes with 67 bonytail more than 200 mm TL collected during 1964–1966 (Vanicek and Kramer 1969). Holden and Stalnaker (1975b) reported 36 bonytail from the lower Yampa River and middle and lower Green River during 1967–1973. Bonytail declined dramatically in the Green River through the 1960s. Reasons for the decline are unknown, but were likely related to the closure of Flaming Gorge Dam in 1964. Before filling Flaming Gorge Reservoir, about 725 km of the Green River and its tributaries were treated with rotenone to poison nonnative carp, catfish, shiners, and perch in advance of stocking the reservoir with rainbow trout *Oncorhynchus mykiss* and kokanee *O. nerka* (Holden 1991). Fish surveys after the closure of Flaming Gorge Dam revealed that the rotenone had not killed all of the fish in the treatment area and did not eliminate the native forms, including bonytail, roundtail chub, humpback chub, Colorado pikeminnow, and razorback sucker (Banks 1964). These surveys concluded that subsequent reductions in native fish populations occurred primarily as a result of reservoir flooding of habitat, and changes in river flows and water temperatures from dam operations.

By the late 1970s, few bonytail were reported from the upper basin (Figure 4), including two from the Green River below Jensen, Utah (Joseph et al. 1977). Bonytail were seen in Lake Powell soon after Glen Canyon Dam was closed in 1962 (K. Miller, Utah Division of Wildlife Resources, personal communication), and two (330 and 380 mm TL) were caught by anglers near Wahweap Bay on September 4, 1977 (Gustafeson et al. 1985) and in 1985 (R. Radant, Utah Division of Wildlife Resources, personal communication); the latter fish was identified by Dr. Mark Rosenfeld (University of Utah, personal communication), and a taxidermy mount is on display at the university's natural history museum. One adult bonytail was captured in the lower Yampa River in 1979 (Holden and Crist 1981), and one adult was caught and released at Coal Creek Rapid in the Green River in Gray Canyon in 1981 (Tyus et al. 1982). Kaeding et al. (1986) captured and released one adult bonytail (458 mm TL) in the Colorado River at Black Rocks on July 17, 1984. Two adult bonytail were captured, photographed, and released in Desolation/Gray Canyons in 1985 (Moretti et al. 1989), and four adults and one juvenile were reported from Cataract Canyon in 1985–1988 (Valdez 1990; Valdez and Williams 1993).

Preferred habitat of bonytail is undetermined, but large fins and a streamlined body suggest adaptation to torrential flows (Beckman 1963). Of 11 wild adults captured in the upper basin since 1977, nine were in deep, swift, rocky canyons (i.e., Yampa Canyon, Black Rocks, Cataract Canyon, and Coal Creek Rapid), and two were in Lake Powell. Vanicek (1967) reported that bonytail were generally found with roundtail chub in pools and eddies in the absence of, but adjacent to, strong current and at varying depths over silt and boulder substrates. Natural reproduction of bonytail was last documented in the Green River for the year classes 1959, 1960, and 1961 (Vanicek and Kramer 1969). Ripe spawning adults, 5–7 years of age, were captured from mid-June to early July at a water temperature of 18°C (Vanicek 1967). Average fecundity is about 25,090 eggs per female, and incubation was shortest (99–174 h) and egg survival, hatching success, and larval survival were highest at 20–21°C (Hamman 1985).

### *Razorback Sucker*

Razorback sucker is a robust fish with maximum size of 1 m TL and 5–6 kg (Minckley 1973; Minckley et al. 1991); maximum age is up to 44 years

(McCarthy and Minckley 1987). Adults are slightly compressed laterally with a bony, predorsal keel behind the occiput. The keel is formed by the growth and fusion of interneural bones. Size and shape of these bones are diagnostic characteristics for young of the species (Snyder and Muth 2004). Scales are well developed with 68–87 in the lateral line. Razorback sucker hybridizes with native flannelmouth sucker and bluehead sucker (Hubbs and Miller 1953; Suttkus et al. 1976; Maddux et al. 1987; Douglas and Marsh 1998), as well as with nonnative white sucker *C. commersonii* (McAda and Wydoski 1980; Buth et al. 1987). Razorback sucker was listed as federally endangered in 1991 (56 FR 54957) with critical habitat designated in 1994 (59 FR 13374). A recovery plan was completed in 1998 (U.S. Fish and Wildlife Service 1998a), and amended and supplemented with recovery goals in 2002 (U.S. Fish and Wildlife Service 2002d).

Razorback sucker was historically common to abundant in most warm regions of the Colorado River system during the 19th and 20th centuries (Jordan and Evermann 1896; Minckley et al. 1991). In the upper basin, the species was common in the Green and upper Colorado rivers and in some warm tributaries, including the White, Duchesne, Little Snake, Yampa, and Gunnison rivers (Burdick 1995; Holden 1999), and possibly as far up the San Juan River as the Animas River (Jordan 1891; Minckley et al. 1991; Holden 2000). Razorback sucker declined throughout the 20th century, and the species now exists naturally in only a few locations. Natural reproduction has occurred with little recruitment over the past 40–50 years, and wild populations are composed primarily of old, senescent adults (Bestgen 1990; Bestgen et al. 2002). Reproduction has been documented in the Green River with collection of larvae (Muth et al. 1998; Chart et al. 1999). Small numbers of juveniles and young adults provide evidence of some recruitment attributed to unusually high spring flows during 1983–1986 that provided critical floodplain nurseries (Modde et al. 1996).

Numbers of wild razorback sucker captured in the upper basin have decreased dramatically since 1974. Razorback sucker are found in small numbers in the middle Green River and in lower reaches of the Yampa, Duchesne, White, and San Rafael rivers (Tyus 1987; Figure 5). The middle Green River population was estimated at 1,000 wild adults in 1985 (Lanigan and Tyus 1989) and 524 in 1995 (Modde et al. 1996), and data from 1998–1999 suggest that about 100 wild adults remained at that time (Bestgen et al. 2002). The wild population is considered extirpated from the Gunnison River, where only two fish were reported in 1976 (Burdick and Bonar 1997). Only 52 individuals, all old adults, were captured during a 3-year study (1979–1981) in 465 km of the upper Colorado River from Hite, Utah, to Rifle, Colorado (Valdez et al. 1982b); and only 12 were captured in the Grand Valley, Colorado, during 1984–1989 (Osmundson and Kaeding 1989). Wild razorback sucker in the San Juan River are limited to two fish captured in 1976 in a riverside pond near Bluff, Utah, and one fish captured in the river in 1988, also near Bluff (Ryden 2000). Large numbers were anecdotally reported in a drained pond near Bluff in 1976, but identification was not verified. Wild razorback sucker were not found in a 7-year study of the San Juan River (1991–1997; Holden 1999).

Adult razorback sucker in the upper basin occupy low-velocity pools, runs, and slackwaters in alluvial reaches and less frequently in canyon-bound areas (Tyus 1987; Lanigan and Tyus 1989; Tyus and Karp 1990; Bestgen 1990). Adults summer in deep eddies, slow runs, and backwaters with silt or sand substrate, depths of 0.6–3.4 m, and velocities of 0.3–0.4 m/s (Valdez et al. 1982b; Tyus 1987; Tyus et al. 1987; Osmundson and Kaeding 1989; Tyus and Karp 1990; Osmundson et al. 1995). During winter, adults use depths of 0.6–2.16 m in slow runs, pools, eddies, and slack water (Osmundson and Kaeding 1989; Valdez and Masslich 1989). Razorback sucker is a moderately migratory, potadromous species that moves to and from spawning and overwintering areas (Tyus and Karp 1990; Modde and Wick 1997; Modde and Irving 1998). Greatest movements are associated with spawning in spring and may account for historic reports of large concentrations of adults (Jordan 1891; Hubbs and Miller 1953; Sigler and Miller 1963; McAda and Wydoski 1980). Adults are relatively sedentary outside of

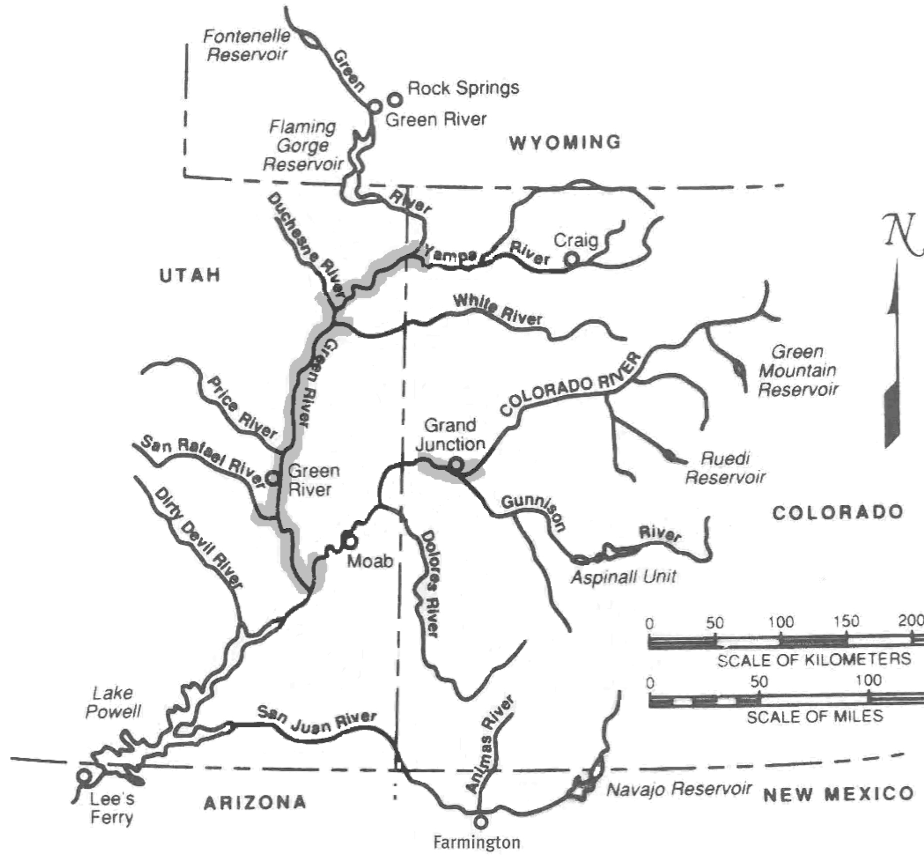


Figure 5.—Present distribution of wild razorback sucker (shaded) in the upper Colorado River basin.

spawning periods (Tyus 1987; Valdez and Masslich 1989; Tyus and Karp 1990). In upper basin riverine environments, spawning is during spring runoff from mid-April to June. Average fecundity is about 46,740 eggs per female and maximum is 103,000 (Inslee 1982; McAda and Wydoski 1980). Adults stage in floodplains, gravel pits, large backwaters, and impounded tributaries near spawning sites (Holden and Crist 1981; Valdez and Wick 1983; Tyus 1987; Osmundson and Kaeding 1989; Tyus and Karp 1990; Modde and Wick 1997; Modde and Irving 1998; Osmundson et al. 1995), and spawn over large mid-channel cobble bars at an average water temperature of about 15°C in velocities less than 1.0 m/s and depths of less than 1.0 m (McAda and Wydoski 1980; Tyus 1987; Tyus and Karp 1990; Bestgen 1990; Wick 1997). Incubation at 18–20°C is 6–7 d (Snyder and Muth 2004), and larvae drift with river currents into food-rich floodplains, where densities of benthos and zooplankton may be 157 times greater than in the main channel (Mabey and Shiozawa 1993). Razorback sucker are omnivorous and consume principally insects, zooplankton, phytoplankton, algae, and detritus (Bestgen 1990). Larvae develop a terminal mouth at 10–11 mm TL and feed on planktonic cladocerans, rotifers, algae and midge larvae that decrease in importance as the mouth migrates to a subterminal position for benthic feeding (Marsh and Langhorst 1988; Muth et al. 1998). Pathogens include bacteria *Erysipelothrix rhysiopathiae,* protozoa (*Myxobolus* sp., can cause blindness; Minckley 1983) and the parasitic copepod *Lernaea cyprinacea* (Flagg 1982).

### *Roundtail Chub*

Roundtail chub have a cylindrical body that is slightly compressed laterally and is silvery-green with a reddish nuptual tint. The back and belly/breast regions are moderately to heavily scaled and a nuchal hump is absent or poorly developed. Maximum size is 500 mm TL; there are 75–85 scales on the lateral line that are small, thin, and slightly imbricated. Roundtail chub does not receive federal protection under the ESA, but is one of three species (also flannelmouth sucker and bluehead sucker) included in a conservation agreement among six western states (Colorado Fish and Wildlife Council 2004).

Roundtail chub was historically distributed in upper reaches of main rivers and throughout most tributaries up to about 2,300 m elevation. In the upper basin, roundtail chub was widely distributed and abundant until the early 1960s, when construction of main-stem dams fragmented and inundated habitats, and altered flow regimes.

Roundtail chub in the upper basin remains as 15 populations in about 55% of its historic habitat (Bezzerides and Bestgen 2002), and is found in the Green, Colorado, and San Juan River drainages (Lentsch et al. 1998; Propst 1999; Bestgen and Crist 2000). It is abundant in the upper Colorado River from Rifle, Colorado, downstream to Moab, Utah, and in the Gunnison and Dolores rivers in Colorado (Valdez 1990; Valdez and Williams 1993). It is rare in Lake Powell and occurs in small numbers in the San Juan River, Utah, and as enclaves in the Animas, La Plata and Mancos rivers. In the Green River, the species occurs in low to moderate numbers. Roundtail chub was once common in the Price, Duchesne, San Rafael, Dirty Devil, and Fremont rivers (McAda et al. 1980), but water depletion, nonnative fish species, and degraded water quality have nearly eliminated it from these tributaries.

Roundtail chub use rocky shorelines and substrate and are rare in sand-bed reaches, and young may use backwaters, if available. Adults occur at depths of up to 20 m, and typically suspend themselves in low-velocity regions of large eddies adjacent to shear zones. Adults are generally sedentary, except for spawning-related movements (Kaeding et al. 1990), although some may make extensive movements at night (Beyers et al. 2001). Maximum reported movement is 80 km in one year (Holden and Crist 1981). Spawning in the upper basin is in May and June, shortly after peak runoff. Adhesive eggs are broadcast over cobble and gravel at 14–22°C (Sigler and Miller 1963; Vanicek and Kramer 1969; Holden 1973; Kaeding et al. 1990; Karp and Tyus 1990b; Brouder et al. 2000), and hatch as 6–7 mm TL larvae in about 5 d (Muth 1990). Roundtail chub typically mature in 3–5 years at 150–300 mm TL, and average life span is 8–10 years (Sigler and Sigler 1996; Brouder et al. 2000). Fecundity of young adults is 1,000–4,300 eggs per female (100–260 mm TL; Neve 1976) and about 14,160–45,120 eggs for fish 4–7 years old (Bestgen 1985). Newly emerged larvae feed on diatoms and filamentous algae (Neve 1976), and juveniles eat mainly immature midges and mayflies (Vanicek and Kramer 1969), but may also consume algae, caddisflies, and ostracods (Bestgen 1985). Juveniles and adults consume aquatic insects, crustaceans, fish, plant matter, snails, ants, beetles, crickets, grasshoppers, and lizards (Koster 1957; McDonald and Dotson 1960; Vanicek and Kramer 1969; Schreiber and Minckley 1981; Tyus and Minckley 1988; Karp and Tyus 1990b).

### *Flannelmouth Sucker*

Flannelmouth sucker is a large, streamlined fish that commonly reaches lengths of 435–500 mm TL with a maximum of 765 mm TL and 3.5 kg in favorable habitat. Flannelmouth sucker mature at age 4–6 and may live 15 or more years (McAda and Wydoski 1980; Douglas and Marsh 1998). The caudal peduncle is thick and robust, and the mouth of adults is subterminal, enlarged, and covered by large fleshy papillae. There are 90–116 small, embedded scales along the lateral line. Flannelmouth sucker hybridizes with sympatric native bluehead sucker and razorback sucker (Hubbs et al. 1942; Hubbs and Miller 1953; Holden 1973; Holden and Stalnaker 1975a; Minckley 1973; McAda and Wydoski 1980; Holden and Crist 1981; Buth et al. 1987), and nonnative white sucker. Flannelmouth sucker does not currently receive federal protection under the ESA, but is one of three species included in a conservation agreement among six western states (Colorado Fish and Wildlife Council 2004).

In the upper basin, flannelmouth sucker was historically found in the upper Colorado, Green, and San Juan river drainages (Bezzerides and Bestgen 2002). It currently occupies about 50% of historic upper basin habitat where it persists as eight populations in the upper Colorado, Green, and San Juan rivers and their tributaries, including the Escalante, Fremont, San Rafael, Price, Duchesne, White, Yampa, Little Snake, Animas, and La Plata rivers (Bezzerides and Bestgen 2002). It is found in the upper Colorado River from Glenwood Springs, Colorado, to Lake Powell; the Green River from Daniel, Wyoming, to the Colorado River confluence (except Flaming Gorge and Fontenelle reservoirs); and the San Juan River from Bloomfield, New Mexico, to Lake Powell. Temperature range of flannelmouth sucker is 10–27°C (Sublette et al. 1990).

Flannelmouth sucker typically occupy pools, eddies, and deep runs and may congregate to feed at the base of cobble riffles (McAda et al. 1980; Valdez et al. 1982a; Sublette et al. 1990). Larvae and young use low-velocity habitats along shallow shorelines and backwaters, eddies, and side channels over silt substrates (Banks 1964; Minckley 1973; McAda 1977; Snyder and Muth 2004; Childs et al. 1998; Gido and Propst 1999). Juveniles use deep shorelines and shallow gravel/cobble riffles, and adults are common over rocky substrates (Holden and Stalnaker 1975a; McAda et al. 1980). Flannelmouth sucker were found in newly formed impoundments, such as Flaming Gorge Reservoir, Lake Powell, and Kenny Reservoir, but declined dramatically from predation, and reproductive and recruitment failure (Baxter and Stone 1995; Binns 1967; Minckley 1973; McAda 1977; Chart 1987). It is a moderately migratory, potadromous species with long-distance movements usually associated with spawning (Vanicek 1967; Holden 1973; Holden and Crist 1981; Chart and Bergersen 1992; Douglas and Marsh 1998; Beyers et al. 2001). Movements of up to 62 km were reported between the Price River and the Green River in 1997 and 1998 (Cavalli 1999). Fecundity is 4,000–33,000 eggs per female (McAda 1977; McAda and Wydoski 1980), and spawning in the upper basin is in May and June at water temperatures of 16–18.5°C (Holden 1973; Minckley 1973; Snyder and Muth 2004). Adhesive eggs are deposited over sand and gravel bars, they incubate 6–7 d at 15.5–17.8°C, and larvae hatch at 10–11 mm TL (Snyder and Muth 2004). Larvae emerge from cobble substrates and are transported downstream by river currents to low-velocity, sheltered, shoreline nursery habitats (Childs et al. 1998) with greatest drift densities at night and along shorelines (Valdez et al. 1985). Flannelmouth sucker are omnivorous and consume seeds, plant debris, algae, aquatic invertebrates, phytoplankton, and organic detritus (Minckley 1973; Grabowski and Hiebert 1989; Muth and Snyder 1995).

### *Bluehead Sucker*

Bluehead sucker is a small to medium size fish (300–450 mm TL) with a short, broad, bluish head. The sucker mouth is subterminal with strong jaws and cartilaginous scraping ridges, more pronounced on the maxillary. The body is elongate and tapers to a caudal peduncle of varying thickness, generally more robust and deep in fish from tributaries and low-velocity regions than the more slender, streamlined form from mainstream habitats. Bluehead sucker hybridizes with native flannelmouth sucker, razorback sucker, and mountain sucker, and nonnative white sucker (Hubbs et al. 1942; Smith 1966; Holden and Stalnaker 1975a, 1975b; Holden and Crist 1981). The species does not currently receive federal protection under the ESA, but is one of three species included in a conservation agreement among six western states (Colorado Fish and Wildlife Council 2004).

In the upper basin, bluehead sucker was found up to about 2,300 m elevation in the upper Colorado, Green, and San Juan river drainages (Smith 1966; Sublette et al. 1990; Baxter and Stone 1995). It currently occurs as 10 populations in approximately 45% of historic upper basin habitat (Bezzerides and Bestgen 2002). Reservoir inundation and cold releases from dams account for most losses of abundance and distribution. Some populations have been fragmented or isolated by dams and reservoirs, including the upper Green River above Flaming Gorge Reservoir, Gunnison River above the Aspinall Unit, and White River above Taylor Draw Dam (Martinez et al. 1994).

Bluehead sucker feed in cobble/gravel riffles and rest in pools, eddies, and deep runs (Beyers et al. 2001). Larvae and juveniles use shallow, low-velocity shorelines and backwaters (Haines and Tyus 1990; Robinson et al. 1998). Adults prefer large cool streams of 20°C or less and occupy areas with moderate to fast current and rocky substrates (Banks 1964; Vanicek 1967; Holden and Stalnaker 1975b; McAda et al. 1980; Tyus et al. 1982; Sublette et al. 1990). Adults move little and tend to remain in home ranges (Vanicek 1967; Holden and Crist 1981; Cavalli 1999; Beyers et al. 2001). Spawning in the upper basin occurs in spring and early summer at water temperatures of 15.6–24.6°C (Holden 1973; Sigler and Sigler 1996). Females broadcast adhesive eggs over mid-channel cobble/gravel bars that incubate 7–8 d at 15.6–17.7°C, and emerging larvae 9–11 mm TL are transported downstream by river currents (Valdez et al. 1985). Fecundity is 5,000–20,000 eggs per female (Smith 1966; McAda and Wydoski 1980). Larvae and young feed primarily on diptera larvae, diatoms, and zooplankton (Maddux et al. 1987; Grabowski and Hiebert 1989; Muth and Snyder 1995; Childs et al. 1998). Juveniles and adults use the cartilagenous ridge inside each lip to scrape algae, organic and inorganic debris, and small aquatic insects from rocks and boulders (Simon 1935; Banks 1964; Vanicek 1967; Maddux and Kepner 1988; Muth and Snyder 1995).

### *Mountain Sucker*

Mountain sucker reach a maximum size of 305 mm TL (Sigler and Sigler 1996). The body is elongate with a moderately thickened caudal peduncle, and the mouth is subterminal and sucker-like with distinct lateral notches. Like the bluehead sucker, it has cartilagenous scraping ridges inside each lip. Mountain sucker is a species of special concern in Colorado and has no direct federal protection.

Mountain sucker was once common in high elevation streams of the Colorado River system. In the upper basin, it is found in many tributaries at elevations of 1,220–3,050 m (Tyus et al. 1982). Its popularity as a forage and baitfish expanded its range, and by 1940, mountain sucker was in many reservoirs and tributaries (Sigler and Miller 1963). During 1950–1970, mountain sucker expanded its range to drainages of the upper Green River subbasin, including Ashley Creek, White River, and Price River. Adults inhabit cool, clear tributaries where they are tolerant to occasional turbidity and are common over gravel, rubble, or boulder substrates. Mountain sucker does not occur naturally in lakes but survives in lakes if introduced. Adults in winter and early spring are found adjacent to pools in velocities of 0.5 m/s and depths of 1.5 m (Sigler and Sigler 1987). Fecundity is 2,100–4,000 eggs per female, and spawning is in late spring and early summer when water temperatures are 17–19°C (Hauser 1969). Males mature at ages 2–4 and 127–145 mm TL; and females mature at ages 3–5 and 122–130 mm TL. The diet of young and adults is mostly algae and diatoms scraped from rock surfaces; and diptera, higher plants, animals, and debris (Sigler and Sigler 1996).

### *Speckled Dace*

Speckled dace is a small fish with an elongate body, rounded fins, and a strong, thick caudal peduncle. The mouth is subterminal, often with a small barbel at the end of each maxillary. Adults rarely exceed 75 mm TL. The species has no special state or federal protection. Its status in the upper basin is not well known, but genetic clades unique to specific drainages may be threatened by habitat alterations, stream impoundment and dewatering, degraded water quality, and nonnative fishes (Oakey et al. 2004).

Speckled dace is widespread in the upper basin, except where habitat has been eliminated or degraded. The species has been extirpated locally by predation and competition from nonnative species, although its tolerance to low flows, high temperatures, and low oxygen enables it to persist where other species might perish. It is found in a variety of habitats and tolerates a wide range of water conditions, including cool mountain streams, medium and large rivers, small impoundments, small isolated desert springs, and intermittent streams.

Speckled dace mature at 2 years of age, and fecundity is 174–514 eggs per female (Sigler and Sigler 1987). Spawning in the upper basin occurs in summer with peak activity in June and July at 18.3°C. It often spawns in sequence with two distinct high water events, spring runoff and late summer rain spates. Fertilized eggs are deposited over a large spawning bed and hatch in 6 d at 11–19°C. Larvae remain in the gravel an additional 7–8 d before emerging to congregate in warm shallows. Young fish feed on midwater zooplankton and algae, whereas juveniles and adults are bottom dwellers and feed on benthic insects or plant material (Sigler and Sigler 1996).

### *Kendall Warm Springs Dace*

Kendall Warm Springs dace has a similar shape, size, and appearance to speckled dace (Baxter and Simon 1970; U.S. Fish and Wildlife Service 1982b). Kendall Warm Springs dace was listed as federally endangered in 1970 (35 FR 16047–16048) and received protection under the ESA in 1973. Critical habitat was designated in 1975 (40 FR 21499), and a recovery plan was approved in 1982 (U.S. Fish and Wildlife Service 1982b).

The species is endemic to one small stream, Kendall Warm Springs Creek, Wyoming, which flows into the Green River near Pinedale, Wyoming (U.S. Fish and Wildlife Service 1982b). The stream flows about 300 m before dropping over a travertine embankment into the Green River that naturally provides isolation and protection from predator invasion. The species is associated with numerous seeps and springs and the outflow stream along the north face of a small limestone ridge. Little information is available on the species' life history, and the population is believed to be stable with several thousand individuals. Kendall Warm Springs dace occur in pools and eddies (Binns 1978). Instream plants provide important escape cover, protection from the main current, and nursery areas for larvae (Gryska et al. 1998). Average stream width is 1.8 m, depth is less than 0.31 m, gradient is about 4%, and average streamflow is about 0.2 $m^3/s$. Kendall Warm Springs dace are absent at the spring source and increase in numbers downstream with increased dissolved oxygen (DO) and decreased carbon dioxide. Kendall Warm Springs dace are nonmigratory and remain within the 300-m length of stream, although individuals usually form small schools that may reflect behavior or space limitations (U.S. Fish and Wildlife Service 1982b). The temperature of the springs is a constant 29.5°C, and spawning may occur year around. Individuals raised in a laboratory matured at 2 years of age, and the number of eggs was generally several hundred per female (Baxter and Simon 1970). Kendall Warm Springs dace are omnivorous but prefer vegetable matter and insects (U.S. Fish and Wildlife Service 1982b).

### *Mottled Sculpin and Paiute Sculpin*

Mottled sculpin and Paiute sculpin are small, stout fish with a large dorso-ventrally compressed head and slender tapering body (Sigler and Sigler 1996). They are usually 100–150 mm TL, their heads are large and proportionate to their bodies, and they have large mouths and eyes. Mottled sculpin lack scales and have small prickles that give the body a rough texture, whereas Paiute sculpin have a smooth body free of prickles. Paiute sculpin have a single, large preopercular spine that is upturned, flattened, and sharp, instead of the two short blunt preopercular spines of mottled sculpin. These species have no special state or federal protection and do not appear to be in decline in the upper basin, although their status is generally unknown.

Mottled sculpin inhabit cool tributaries of the upper basin at elevations of 1,500–3,000 m (Tyus et al. 1982). The species is rare in warm reaches but increasingly abundant in higher elevation streams with rocky substrates. Paiute sculpin inhabit cool streams and deep cold lakes. The species prefers moderate stream gradients, and is not found in headwaters with extreme gradient or in warm areas with low gradient. Males and females of both species mature at 2 years of age. Both species spawn at about 12°C in May and June (Ebert and Summerfelt 1969) in specific habitat along rocky lakeshores and on stream riffles composed of gravel and cobble 20–30 cm diameter. Females typically attach clusters of 100–200 eggs to the underside of stones where they are kept clean and aerated by the male who generally remains until the fry disperse. Eggs incubate 3–4 weeks, and larvae 10 mm TL remain in gravel interstices for about 2 weeks until the yolk sac is absorbed. Nocturnal drift of young occurs in streams and may be followed by a second drift period in response to population density (Sigler and Miller 1963). Mottled sculpin and Paiute sculpin are bottom dwellers and feed mostly at night on snails, amphipods, oligochaetes, insect larvae, and planktonic crustaceans, incidentally consuming detritus, and filamentous green algae (Sigler and Sigler 1996).

### *Mountain Whitefish*

Mountain whitefish are typically 150–450 mm TL and 500–1,300 g (Sigler and Sigler 1996). The species is trout-like in appearance, but has a much smaller head, larger adipose fin, large scales, and no teeth. The snout is pointed and extends past the mouth. Mountain whitefish is a game fish with bag and possession limits in most upper basin states. It is found in cold mountain streams and is common to abundant above 2,100 m elevation. Mountain whitefish inhabits swift streams and cold, deep lakes. Newly hatched fry use shallow water along shorelines, at stream edges, or in protected backwaters, but they move into deeper water as they grow. Mountain whitefish prefers temperatures of 14–16°C, but tolerates temperatures far above and below this range, which gives it greater survival abilities than trout or salmon. It is also able to thrive in water with lower DO than most trout species. Mountain whitefish usually mature in 3–4 years and live up to 17–18 years. Spawning occurs at night between October and December over gravel or rocks in streams or in shallow lake shores at water temperatures of 5–6°C. Fecundity is about 1,500–7,000 eggs per female. Eggs are broadcast over cobble substrate and hatch in early spring after about 5 months of incubation. Mountain whitefish usually eat aquatic insect larvae, small molluscs, eggs, and sometimes fish.

### *Colorado River Cutthroat Trout*

Colorado River cutthroat trout are currently a conservation species in Utah, Colorado, and Wyoming. A conservation agreement and strategy was developed to provide a collaborative strategy for conservation and to allow more flexibility in management (CRCT Task Force 2001). The Colorado River cutthroat trout is classified as a sensitive species by Regions 2 and 4 of the U.S. Forest Service (USFS) and by the Bureau of Land Management (BLM).

Colorado River cutthroat trout historically occupied portions of the Colorado River system in Wyoming, Colorado, Utah, Arizona, and New Mexico (Behnke 1992), including portions of larger streams, such as the Green, Yampa, White, Colorado, and San Juan rivers, but it was probably absent from the lower reaches of many large rivers because of high summer temperatures (Simon 1935; Behnke 1979). Distribution and abundance of Colorado River cutthroat trout have declined, and the species is limited to small populations in less than 1% of its historic range (Binns 1977; Behnke 1979; Martinez 1988; Young 1995). Like other inland forms, this subspecies evolved in the absence of other trouts. It is highly susceptible to hybridization with rainbow trout and competitive replacement by brown trout *Salmo trutta* and brook trout *Salvelinus fontinalis*. Pure Colorado River cutthroat trout remain as small populations in Colorado, Utah, and Wyoming (Behnke 1992). Many adfluvial stocks have been lost (Young 1995), and some populations have been reestablished. The largest pure population of Colorado River cutthroat trout in Trapper's Lake, Colorado, was recently hybridized by rainbow trout (Behnke 2002). Fortunately, a 1931 shipment of pure Trapper's Lake fish was traced to Williamson Lakes, California, and 300 fish were procured for transport to Bench Lake, Colorado, for development of pure populations (Martinez 1988; Pister 1990). Remaining populations of Colorado River cutthroat trout occur mostly in headwater streams and lakes. Most lotic populations are in isolated headwater streams with average daily flow less than 0.85 $m^3/s$, stream gradients that usually exceed 4%, and elevations above 2,290 m (Young 1995).

Colorado River cutthroat trout hybridizes with other subspecies of cutthroat trout or with rainbow trout in many areas of its historic range, compromising genetic integrity. The Colorado River cutthroat trout conservation team has developed a database that is updated annually to track genetic information for each population. Seven categories have been identified for determining the genetic status of each population and a determination of appropriate management actions. Populations with genetic purity ratings of B, B+, A- or A (i.e., slightly hybridized to essentially pure) are defined as conservation populations for which management actions are implemented, and in 2003 included totals of 1,648 km (1,024 stream miles) and 455 ha (1,124 acres of lakes). These results show that both pure and essentially pure populations are still present in many waters in Utah, Colorado, and Wyoming.

Spawning occurs in spring in streams and tributary inflows, and eggs hatch in 28–40 d at 8–12°C. Colorado River cutthroat trout feed largely on plankton throughout life, and their growth is slower than that of Yellowstone cutthroat trout *O. clarkii bouvieri*. Maximum growth in Trapper's Lake was in midsummer (Drummond 1966). Colorado River cutthroat trout is susceptible to common salmonid diseases, especially whirling disease *Myxobolus cerebralis* (Nehring 1998). Transmission of diseases to wild populations by hatchery stocks is recognized as the most significant threat, and policies and regulations in Wyoming and Utah address fish health status, disease certification of stocked and imported fish, and stocking protocols. Fish testing positive for whirling disease in Utah and Wyoming hatcheries are not stocked, and in Colorado, a policy clearly designates native cutthroat trout waters and other wild trout habitats that are negative for whirling disease as the most protected category.

## Threats to Native Fishes

The following threat descriptions apply primarily to endangered and other native fishes in the main rivers and tributaries of the upper basin. Threats to the Kendall Warm Springs dace and Colorado River cutthroat trout are described under *Current Status and Ecology* and *Species Conservation Programs*.

### *Flow Regulation and Diversion*

Flow regulation in the upper basin began in the mid-1800s as small tributary impoundments and irrigation diversions. Ratification of the Colorado River Compact of 1922 by the seven basin states divided the Colorado River into upper and lower basins and allocated 7.5 million acre-feet of water to each basin, based on estimated annual flow of 16.8 million acre-feet for the period 1896–1921 (Fradkin 1981; Reisner 1986). However, average annual flow of the Colorado River, 1922–1976, was only 13.9 million acre-feet, and compact allocation was based on an overestimate of available water. The Upper Basin Compact of 1948 further apportioned water to each of the upper basin states by percentage of available annual volume (i.e., Colorado, 51.75%; Utah, 23%; Wyoming, 14%; New Mexico, 11.25%). All seven basin states faced the problem of constructing costly storage and delivery systems to realize their full compact allocation.

Completion of Boulder (Hoover) Dam in 1935 marked the beginning of dam construction on the Colorado River. Thirteen main-stem dams regulate flow of the Colorado River and hundreds of smaller dams control virtually every stream in the basin. Major dams in the upper basin include Flaming Gorge on the Green River; Blue Mesa, Morrow Point, and Crystal (Aspinall Unit) on the Gunnison River; Dillon, Green Mountain, Shadow Mountain, and Ruedi on tributaries of the upper Colorado River; McPhee on the Dolores River; Taylor Draw on the White River; and Glen Canyon on the main-stem upper Colorado River. The larger dams were completed in the early 1960s under authority of the Colorado River Storage Project Act of 1956. Glen Canyon Dam is the largest in the upper basin and is located 25 km upstream of Lees Ferry, the Compact dividing point between upper and lower basins. Annual discharge from the upper basin at Lees Ferry exceeded 18 million acre-feet in 1929, and lowest discharge was only 4.4 million acre-feet in 1934.

The historic upper basin was characterized by dramatic annual and seasonal flow variation (i.e., exceptionally high flows in spring and early summer, and lower flows in late summer through winter). Flows typically began rising in March with low elevation snowmelt, were highest in late May and early June with snowmelt runoff, receded in late June and July, and were relatively low and stable from August through March, except for flow spikes from periodic storms. Year-to-year flow variation depends on mountain snowpack. Historic average annual flow at Lees Ferry, 1922–1962, was highly variable from about

150 m³/s to nearly 800 m³/s. Closure of Glen Canyon Dam in spring 1963 interrupted river flows, and dam releases no longer reflect natural flows.

Mean daily flow for the Green River at Green River, Utah (1923 and 1997) reflects changes to seasonal flow patterns as a result of human activities in the upper basin (Figure 6). Average peak flows of the Green River in June have decreased by 31% (631 to 433 $m^3/s$) and base flows in January have increased by 81% (48 to 87 $m^3/s$). Average peak flows of the upper Colorado River near Cisco, Utah, in June have decreased by 30% (759 to 530 $m^3/s$) and average base flows in January have increased by 40% (72 to 101 $m^3/s$). These changes in stream hydrology have affected various parts of the river ecosystem on which the native fauna and flora depend.

### *Physical Habitat Destruction, Alteration, and Fragmentation*

Dams, diversions, and local channelizations account for most aquatic habitat destruction or modification in the upper basin. Nine dams impounded major rivers or tributaries of the upper basin starting in 1962 and inundate a total of about 940 km of riverine habitat. These dams, years of completion, and length of inundation are: Glen Canyon Dam (1963, 325 km of the upper Colorado River), Flaming Gorge Dam (1964, 265 km of the Green River), Navajo Dam (1962, 120 km of the San Juan River), Aspinall Unit (i.e., Blue Mesa, Crystal, and Morrow Point dams; 1965, 60 km of the Gunnison River), Taylor Draw Dam (1984, 60 km of the White River), McPhee Dam (1984, 80 km of the Dolores River), and Fontenelle Dam (1964, 30 km of the Green River). These dams have also disrupted the river continuum and converted about 300 km of seasonally warmed river reaches into cold, isothermal tailwaters. Dams have fragmented habitats, blocked passage of migrating fish, reduced high channel reshaping flows, and increased base flows. Local channelizations for highway construction, flood control, and community development have straightened the river channel, further reducing habitat diversity.

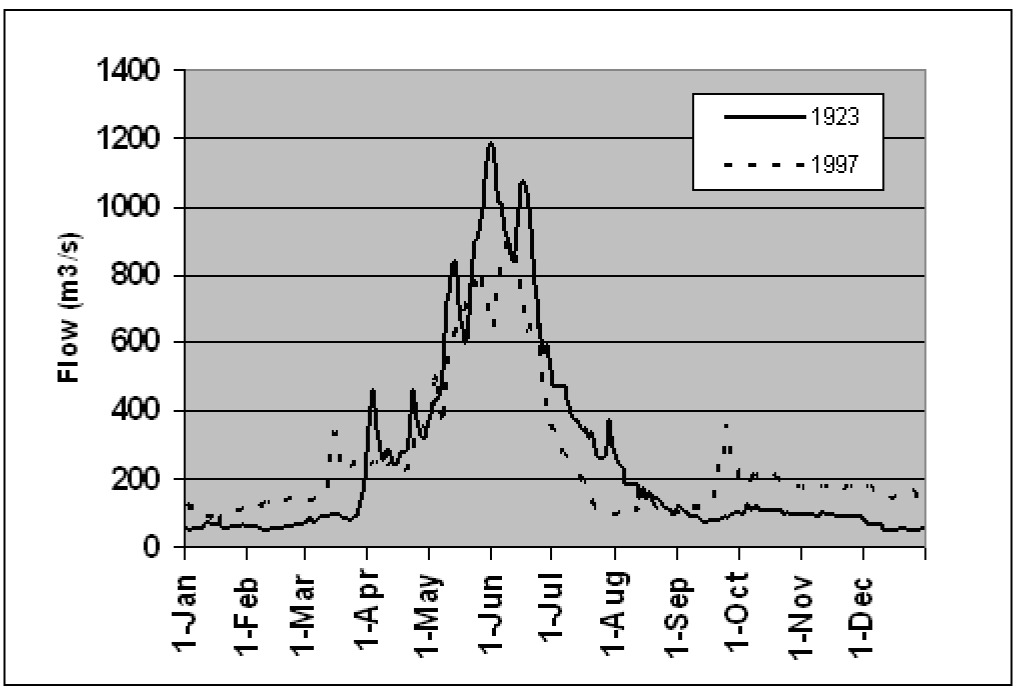


Figure 6.—Daily historic and recent flows for representative years of similar flow volume for the Green River at Green River, Utah. U.S. Geological Survey stream gage data.

### *Nonnative Fish*

Nonnative fishes currently dominate the ichthyofauna of the Colorado River system, and certain species have been implicated in reductions of native fish populations (Carlson and Muth 1989). At least 67 species of nonnative fish have been introduced into the Colorado River system during the last 100 years (Tyus et al. 1982; Carlson and Muth 1989; Minckley 1991; Minckley and Deacon 1991; Lentsch et al. 1996; Pacey and Marsh 1998). About 50 are found in the upper basin (Table 2; e.g.,Tyus et al. 1982; Lentsch et al. 1996). Many of these species were intentionally introduced as game or forage fish and others inadvertently gained access with game fish stockings and baitfish releases. Channel catfish were introduced into the upper basin in 1892 (Tyus and Nikirk 1990) and are now widespread and common to abundant with documented predation on native species (Tyus et al. 1982; Hawkins and Nesler 1991; Nelson et al. 1995; Lentsch et al. 1996; Tyus and Saunders 1996; Brooks et al. 2000; Chart and Lentsch 2000). Northern pike escaped from Elkhead Reservoir into the Yampa River in the early 1980s and have expanded into the middle Green River (Wick et al. 1985; Tyus and Karp 1989; Tyus and Beard 1990; Hawkins and Nesler 1991; Nesler 1995). Smallmouth bass also escaped from upstream reservoirs and riverside ponds, and have increased in distribution in the Yampa, Green, and upper Colorado rivers.

Negative effects of nonnative fishes are principally predation, competition, antagonistic behavior, and vectors of parasites and diseases (Karp and Tyus 1990b; Hawkins and Nesler 1991; Tyus 1991; Muth and Nesler 1993; Muth and Snyder 1995; Lentsch et al. 1996; Tyus and Saunders 1996; Bestgen 1997; Bestgen et al. 1997; Holden 1999; McAda and Ryel 1999; Valdez et al. 1999). Red shiner, common carp, fathead minnow, channel catfish, northern pike, green sunfish, black bullhead, and largemouth bass were of greatest concern because of suspected or documented negative interactions with native fish (Osmundson 1987; Hawkins and Nesler 1991; Ruppert et al. 1993; Lentsch et al. 1996). Recent increases in distribution and abundance of smallmouth bass and northern pike have raised concern over the impact of these predators on native fish communities and launched more aggressive management efforts. White sucker have also increased in numbers in the upper basin and incidence of hybridization with native suckers may be increasing.

### *Degraded Water Quality*

Water quality in the upper basin has been substantially altered since the late 1800s. Land-use practices have increased sedimentation; agricultural returns have increased concentrations of pesticides and herbicides and other elements through leaching; water diversion has reduced the dilution capacity of the river; and dams have trapped elements and nutrients in reservoirs and changed element concentrations and water temperatures below outlets. The greatest changes in water quality have occurred in tailwaters below main-stem dams, where there is a measurable reduction in seasonal variability of streamflow and temperature, increase in daily stream fluctuation, reduction in sediment load, and increased nutrient and ionic concentrations (Carlson and Muth 1989; Muth et al. 2000). For example, before Flaming Gorge Dam on the Green River, river temperature ranged from summer highs of 28°C to persistent ice cover in winter (Vanicek et al. 1970). After the dam, hypolimnetic releases have ranged from 4–13°C (Muth et al. 2000).

High spring snowmelt flows and spurious, intense late-summer rainstorms within a sparsely vegetated and arid basin have historically produced high sediment loads and low water clarity. Historically, suspended sediment was highest during three distinct periods. Spring runoff produced a consistent period of moderate sediment from late February through June; summer (July–September) rainstorms produced short, spurious, and sometimes high sediment loads; and midwinter rainstorms or intermittent snowmelt produced minor peaks in suspended sediment. Before Glen Canyon Dam, average sediment load at Lees Ferry (i.e., total upper basin load) was about 140 million tons per year (range, 50–500 million tons); average postdam load is about 15 million tons per year, or a reduction of 89% (Cole and Kubly 1976). Sediments once carried by the Colorado River are now deposited in Lake Powell, and in 1986 ranged in depth

Table 2.—Common and scientific names and relative abundance of nonnative fishes in the upper Colorado River basin.

| Common name | Scientific name | Relative abundance |
|---|---|---|
| **Catostomidae (suckers)** | | |
| Utah sucker | *Catostomus ardens* Jordan & Gilbert, 1881 | Common in some reservoirs; incidental to rare in some river reaches |
| longnose sucker | *C. catostomus* (Forster, 1773) | Incidental to rare in some reservoirs; locally common in some river reaches |
| white sucker | *C. commersonii* (Lacepède, 1803) | Common in some reservoirs; locally common in some river reaches |
| **Centrarchidae (sunfishes)** | | |
| green sunfish | *Lepomis cyanellus* Rafinesque, 1819 | Locally common |
| bluegill | *L. macrochirus* Rafinesque, 1819 | Common in some reservoirs; incidental to rare in some river reaches |
| smallmouth bass | *Micropterus dolomieu* Lacepède, 1802 | Abundant in some reservoirs; common to abundant in some river reaches |
| largemouth bass | *M. salmoides* (Lacepède, 1802) | Abundant in some reservoirs; incidental to rare in some river reaches |
| white crappie | *Pomoxis annularis* Rafinesque, 1818 | Incidental |
| black crappie | *P. nigromaculatus* (Lesueur, 1829) | Abundant in some reservoirs; incidental to rare in some river reaches |
| **Clupeidae (herrings)** | | |
| gizzard shad | *Dorosoma cepedianum* (Lesueur, 1818) | Found in Lake Powell |
| threadfin shad | *D. petenense* (Günther, 1867) | Found in Lake Powell and tributary inflows |
| **Cyprinidae (minnows)** | | |
| goldfish | *Carassius auratus* (Linnaeus, 1758) | Incidental |
| grass carp | *Ctenopharyngodon idella* (Valenciennes, 1844) | Incidental |
| red shiner | *Cyprinella lutrensis* (Baird & Girard, 1853) | Widespread, common to abundant |
| common carp | *Cyprinus carpio* Linnaeus, 1758 | Widespread, common to abundant |
| Utah chub | *Gila atraria* (Girard, 1856) | Abundant in Flaming Gorge Reservoir; incidental to rare in some river reaches |
| brassy minnow | *Hybognathus hankinsoni* Hubbs, 1929 | Incidental |
| plains minnow | *H. placitus* Girard, 1856 | Incidental |
| golden shiner | *Notemigonus crysoleucas* (Mitchill, 1814) | Incidental |
| sand shiner | *Notropis stramineus* (Cope, 1865) | Common to abundant |
| fathead minnow | *Pimephales promelas* Rafinesque, 1820 | Widespread, common to abundant |
| bullhead minnow | *P. vigilax* (Baird & Girard, 1853) | Incidental |
| longnose dace | *Rhinichthys cataractae* (Valenciennes, 1842) | Incidental |
| redside shiner | *Richardsonius balteatus* (Richardson, 1836) | Rare to common in upper reaches of some rivers |

Table 2.—Continued.

| Common name | Scientific name | Relative abundance |
|---|---|---|
| creek chub | *Semotilus atromaculatus* (Mitchill, 1818) | Incidental to rare |
| leatherside chub | *Snyderichthys copei* (Jordan & Gilbert, 1881) | Incidental |
| **Cyprinodontidae (pupfishes)** | | |
| plains topminnow | *Fundulus sciadicus* Cope, 1865 | Incidental |
| plains killifish | *F. zebrinus* Jordan & Gilbert, 1883 | Incidental |
| rainwater killifish | *Lucania parva* (Baird & Girard, 1855) | Incidental |
| **Esocidae (pikes)** | | |
| northern pike | *Esox lucius* Linnaeus, 1758 | Common in the Yampa River, rare in the middle Green River |
| **Gadidae (cods)** | | |
| burbot | *Lota lota* (Linnaeus, 1758) | Incidental in Flaming Gorge Reservoir and river upstream |
| **Gasterosteidae (sticklebacks)** | | |
| brook stickleback | *Culaea inconstans* (Kirkland 1840) | Locally incidental |
| **Ictaluridae (catfishes)** | | |
| black bullhead | *Ameiurus melas* (Rafinesque, 1820) | Incidental to locally common |
| yellow bullhead | *A. natalis* (Lesueur, 1819) | Found in Lake Powell |
| brown bullhead | *A. nebulosus* (Lesueur, 1819) | Incidental |
| channel catfish | *Ictalurus punctatus* (Rafinesque, 1818) | Widespread, common to abundant |
| **Moronidae (temperate basses)** | | |
| white bass | *Morone chrysops* (Rafinesque, 1820) | Incidental to rare |
| striped bass | *M. saxatilis* (Walbaum, 1792) | Found in Lake Powell and tributary inflows |
| **Percidae (perches)** | | |
| Iowa darter | *Etheostoma exile* (Girard, 1859) | Incidental |
| johnny darter | *E. nigrum* Rafinesque, 1820 | Incidental |
| yellow perch | *Perca flavescens* (Mitchill, 1814) | Common in some reservoirs; incidental to rare in some river reaches |
| walleye | *Sander vitreus* (Mitchill, 1818) | Common in some reservoirs; incidental in some river reaches |
| **Poeciliidae (livebearers)** | | |
| western mosquitofish | *Gambusia affinis* (Baird & Girard, 1853) | Incidental to locally common |
| **Salmonidae (trout and salmon)** | | |
| Yellowstone cutthroat trout | *Oncorhynchus clarkii bouvieri* | Incidental to rare in cool streams |
| greenback cutthroat trout | *O. c. stomias* | Incidental to rare in cool streams |
| coho salmon | *O. kisutch* (Walbaum, 1792) | Found in cold reservoirs |
| rainbow trout | *O. mykiss* (Walbaum, 1792) | Rare to common in cool river reaches |
| kokanee | *O. nerka* (Walbaum, 1792) | Common in cold reservoirs |
| brown trout | *Salmo trutta* Linnaeus, 1758 | Rare to common in cool river reaches |
| brook trout | *Salvelinus fontinalis* (Mitchell, 1814) | Rare to common in cool streams |
| lake trout | *S. namaycush* (Walbaum, 1792) | Found in cold reservoirs |

from 11 m near the base of Glen Canyon Dam to 55.5 m near the mouth of Dark Canyon, about 290 km upstream of the dam (Ferrari 1988).

Other water-quality parameters have been variously affected by human activities in the upper basin. High concentrations of radionuclides (i.e., uranium and uranium daughter products) were reported from uranium mill wastes that spilled and killed fish in the San Miguel and Dolores rivers in the 1960s (Sigler et al. 1966), and the Atlas Mills tailings pile on the banks of the Colorado River near Moab, Utah, releases ammonia and other toxins. Heavy metals, such as mercury, lead, zinc, iron, copper, and cadmium were released in high concentrations by extensive mining activities in the San Miguel River and Red Creek, tributaries of the Dolores River in Colorado. High concentrations of polyaromatic hydrocarbons (PAHs) are associated with oil and gas extraction in the San Juan River subbasin (Holden 1999), and high concentrations of selenium are in the San Juan, Green, and upper Colorado rivers in drainages, seeps, and floodplains associated with Mancos Shale formations. Selenium is hypothesized as an inhibitor of reproduction and studies suggest deleterious effects on razorback sucker and possibly Colorado pikeminnow (Hamilton and Wiedmeyer 1990; Stephens et al. 1992; Hamilton and Waddell 1994; Hamilton et al. 1996; Stephens and Waddell 1998; Osmundson et al. 2000).

## Species Conservation Programs

Four species conservation programs currently coordinate activities in the upper basin to protect and conserve five federally endangered fishes and one unlisted subspecies. Two of these are recovery programs that encompass much of the upper basin. The Upper Colorado River Endangered Fish Recovery Program (UCRRP) and the San Juan River Basin Recovery Implementation Program (SJRIP) were formed in 1988 and 1992, respectively, under cooperative agreements to resolve water resource issues in concert with conservation of endangered species. The UCRRP is working to recover the Colorado pikeminnow, humpback chub, bonytail, and razorback sucker. The SJRIP focuses on recovery of the Colorado pikeminnow and razorback sucker. Public laws 106-392 and 107-375 provide authorities for capital construction projects and ongoing operations and maintenance funding for both recovery programs. Costs of these programs are shared and total agency contributions for the UCRRP from 1989 through 2005 were about $150 million, and about $27 million for the SJRIP from 1992 through 2005. Kendall Warm Springs dace is managed under an endangered species management program. Conservation agreements have been developed among state and federal agencies for unlisted species. One agreement and strategy includes Colorado River cutthroat trout, and another agreement includes roundtail chub, flannel-mouth sucker, and bluehead sucker, with strategies to be developed by the states.

### *Upper Colorado River Endangered Fish Recovery Program (UCRRP)*

The UCRRP was established under a cooperative agreement in 1988 as a coordinated effort of state and federal agencies, water users, energy distributors, and environmental groups to recover four species of endangered fish in the upper basin while water development proceeds in compliance with federal and state laws (U.S. Department of the Interior 1987; Wydoski and Hamill 1991; Evans 1993). Activities and progress of the UCRRP are intended to serve as the reasonable and prudent alternative to avoid the likelihood of jeopardizing the continued existence of the endangered fishes and destruction or adverse modification of critical habitat. The UCRRP is coordinated by the U.S. Fish and Wildlife Service (USFWS) and functions under the principles of adaptive management. A Recovery Implementation Program Recovery Action Plan (RIPRAP) provides an operational plan to implement the UCRRP, including development of the work plan and future budget needs. The RIPRAP includes the following six program elements.

*Habitat management*.—Identification, acquisition, and legal protection of instream flows are key elements to secure, protect, and manage habitat for self-sustaining populations of endangered and other native fishes (Tyus 1992; Stanford 1994). The first step in instream-flow protection is identification of flows necessary for species' life histories. Necessary flow regimes seek to mimic natural flow patterns including high spring runoff to reshape the habitat and lower stable flows the remainder of the year. Flow recommendations are developed, implemented, and evaluated through scientific investigations (often include test releases from dams) and adaptive management. Flow recommendations have been developed for most reaches in the upper basin, including the Green River (Muth et al. 2000), Yampa River (Modde and Smith 1995; Modde et al. 1999; Roehm 2004), Duchesne River (Modde and Keleher 2003), White River (Irving et al. 2003), and upper Colorado and Gunnison rivers (Osmundson et al. 1995; McAda 2003).

Water for endangered fishes in the upper basin is being managed through a variety of means, including water leases and contracts, coordinated releases from upstream reservoirs, improvements to irrigation systems, and reoperation of federal facilities (e.g., Flaming Gorge Dam, Aspinall Unit). Legal protection of flows is consistent with state and federal laws related to the Colorado River system (referred to as "Law of the River"), including the ESA, state water laws, and interstate compacts.

In the Green River subbasin, the USFWS entered into a cooperative agreement in January 2005 with the Colorado River Water Conservation District (District) and the states of Colorado and Wyoming to implement the *Management Plan for Endangered Fishes* in *the Yampa River Basin* (Roehm 2004). The plan will help ensure that current and future water needs are met for people and endangered fishes in the Yampa River basin in northwest Colorado. The UCRRP is funding 5,000 acre-feet (permanent water for endangered fish) of a 12,000 acre-foot enlargement of Elkhead Reservoir in northwest Colorado to make water available to augment late-summer flows in the Yampa River (Modde and Smith 1995; Modde et al. 1999). The District is funding the remaining 7,000 acre-feet, which will help meet future human demands in the Yampa River basin. Construction was initiated in 2005 with completion scheduled for 2007. Local irrigation companies and state and federal agencies formed a work group to implement flow recommendations for the Duchesne River in northeast Utah (Modde and Keleher 2003), and an updated biological opinion was completed in 2005. A final environmental impact statement (EIS) and biological opinion on the operation of Utah's Flaming Gorge Dam on the Green River to meet flow and temperature recommendations for the endangered fishes (Muth et al. 2000) are slated for completion in 2005. Also, the state of Utah has implemented a policy that prioritizes water rights appropriations for endangered fish during certain seasons in the middle Green River (Utah Division of Water Rights 1994).

In the upper Colorado River subbasin, coordinated reservoir operations allow upstream reservoir owners and operators to voluntarily bypass inflows, without affecting project yield, to enhance spring peaks in habitat occupied by endangered fish. The Bureau of Reclamation (BOR) is near completion of the Grand Valley Water Management Project. This project improves water delivery efficiency and plays a major role in managing water resources to meet human and endangered fish needs recommended for the Colorado River (Osmundson et al. 1995; McAda 2003). The Grand Valley Project canal system in western Colorado was retrofitted with internal canal flow control structures and automation, which reduced irrigation diversions by 16% or 45,000 acre-feet in 2002, 12% or 33,000 acre-feet in 2003, and 10% or 29,000 acre-feet in 2004, while meeting all irrigation demands. With completion of the Highline Lake pump station in 2005 and full automation of the seven canal checks, additional water will be saved each year. The state of Colorado has secured two instream flow rights for endangered fish, and continues to evaluate future filing options. An EIS is being developed for releases from the Aspinall Unit to meet flow recommendations for the Gunnison River (McAda 2003). Flow management alone is not sufficient to ensure self-sustaining populations of the endangered fishes and combined flow and non-flow actions are necessary.

*Habitat development*.—Human activities in the upper basin since the mid-1850s have modified, destroyed, or fragmented historic riverine fish habitat. Dam construction and reservoir inundation account for the majority of habitat loss. Strategies to improve fish habitat include providing fish passage to restore access to historic habitat and complete life histories, screening canals and water outtakes to minimize loss of fish from the main stem, acquiring and restoring floodplain habitats, and remediating contaminants. Historic river habitat is being made accessible by building fish passages around dams and diversions, enabling endangered and other native fish to migrate up and downstream. A 107-m selective fish passage was built at the Redlands Diversion Dam on the lower Gunnison River in 1996, giving endangered and native fishes access to 92 km of historic habitat. The fish passage is operated annually by the USFWS, and as of 2004, 67 Colorado pikeminnow, 9 razorback sucker, 1 bonytail, and more than 62,000 other native fish had passed through the facility, and thousands of nonnative fish had been selectively removed.

Fish passage is also being reinstated for the first time in nearly a century to 90 km of historic habitat in the upper Colorado River above Grand Junction, Colorado, with modification of three diversion dams. The Grand Valley Irrigation Company (GVIC) Diversion Dam was modified for fish passage in January 1998. In 2005, a 4-m wide notch was cut in the concrete crest of the Grand Valley Project Diversion Dam to facilitate construction of a 113-m long selective fish passage. The UCRRP funded the $4.5 million construction project, which is a cooperative effort of the Grand Valley Water Users Association, UCRRP, BOR, and USFWS. Construction of fish passage at the intervening Price-Stubb Diversion Dam is scheduled for the near future.

Canals and water outtakes are also being screened to minimize entrainment and loss of fish from the river. A fish screen was installed at the head of the GVIC canal in 2002 to prevent fish entrainment and similar screens are being constructed in 2005 at the Grand Valley Project and Redlands canals. Design of a fish screen for the Tusher Wash diversion canal on the Green River in eastern Utah is completed and construction is scheduled for the near future.

Floodplains are being made accessible to all life stages of endangered fish by breaching or removing natural or man-made levees on property leased by, or under agreement with, the UCRRP. From 1992 through 2002, the UCRRP inventoried floodplains in the upper basin (Valdez and Nelson 2004, 2005) and acquired 13 private property sites totaling 440 ha (Nelson and Soker 2002). An additional easement on 184 ha (134 ha of floodplain) was acquired in 2003 for Thunder Ranch on the Green River, the first major floodplain downstream of the known spawning bar of razorback sucker. Four floodplain sites on the upper Colorado River have been restored, perpetual easements have been acquired on four other properties (32 ha), and two properties have been acquired in fee (69 ha). Perpetual easements have also been acquired on three properties (80 ha) on the Gunnison River.

Floodplains acquired by the UCRRP have been evaluated to ensure suitable water quality for the endangered fish. High levels of selenium have been found in some floodplains and remediation has been implemented to reduce these levels. A joint effort of the UDWR, BOR, and USFWS at the Stewart Lake Waterfowl Management Area near Jensen, Utah, involves inlet and outlet channels with water control gates, drainage tiles, and water management, all designed to reduce concentrations of selenium and detrimental effects on fish and wildlife. Studies are ongoing to evaluate fish use, growth, and survival in these floodplains.

*Nonnative species and sportfishing*.—Negative interactions with certain warmwater nonnative fish species have contributed to declines in endangered and other native fish populations. For several years, the UCRRP has worked cooperatively with state and federal partners to identify management actions to minimize the threat of nonnative fish to survival of endangered fish. In spring 2004, UCRRP partners adopted a policy to identify and implement nonnative fish management actions needed to recover the endangered fishes. The policy was a landmark event demonstrating that these diverse organizations recognize that management of nonnative fish is essential to achieve and sustain recovery of the endangered fishes. The policy also recognizes the dual responsibilities of state and federal fish and wildlife agencies to conserve listed and other native fish species while providing recreational sportfishing opportunities.

The UCRRP has implemented several actions to reduce threats from nonnative fishes, including mechanical removal, screening off-river impoundments to prevent escapement of fish to the river, chemical removal of nonnative fish in small off-river impoundments, implementation of nonnative fish stocking procedures, and changes in state bag and possession limits. Scientific evidence demonstrates that northern pike, smallmouth bass, and channel catfish are nonnative fish species that pose significant threats to survival of endangered fish because they prey upon them and compete for food and space. In 2004, the UCRRP revised its nonnative fish management program using what was learned in 2002 and 2003. Biologists from the states of Colorado and Utah, USFWS, and Colorado State University conducted work in 772 km of the Colorado, Green, and Yampa rivers in Colorado and Utah to reduce the abundance of northern pike and smallmouth bass. Efforts to manage channel catfish continued in Yampa Canyon, where effective removal has been demonstrated, but were postponed in other river reaches until methods to improve sampling efficiency are developed. Management of northern pike in the Yampa and Green rivers showed signs of success during 1999–2002. Biologists reported a 60–68% within-year decrease in abundance of northern pike in the targeted river sections, and have implemented studies to determine if these reductions will persist, or if northern pike populations will rebound as fish are replaced through natural production or movement into the targeted river sections from upstream areas. Where feasible, nonnative fish are relocated to area ponds to provide sportfishing opportunities.

Efforts to manage smallmouth bass have had mixed results. Depending on the section of river and methods being employed, within-year reductions in numbers of smallmouth bass in 2004 ranged from 8% to 69%. Biologists use different sampling methods to increase capture efficiency and improve overall catch rates. These changes include the use of new sampling gear to collect fish more effectively in shallow-water habitats and during times of low river flows, extending the sampling period into the fall when smallmouth bass are more vulnerable to capture, and expanding management efforts to include smaller smallmouth bass.

The UCRRP funded placement of a barrier net at Highline Lake State Park in western Colorado in 1999. The net was designed to control escapement of nonnative fish into critical habitat in the upper Colorado River and to ensure that sportfishing opportunities continue at this popular reservoir. A nonnative fish control structure was also installed at Bottle Hollow Reservoir near Roosevelt, Utah, to prevent escapement of fish into the middle Green River and allow the Ute Indian Tribe to place sportfish in its Elders Pond. Fish screens will be installed on outlets of the enlarged Elkhead Reservoir to prevent escapement to the Yampa River. Chemical reclamation has been used to reduce sources of nonnative fish to riverine habitats. Altogether, 104 ponds were surveyed and 19 were chemically treated to remove nonnative fish along the upper Colorado and Gunnison rivers in 1998–1999.

Current stocking of nonnative fish species (mostly sportfish) in the upper basin is generally confined to areas where there is little potential conflict with endangered fish. In 1996, federal and state wildlife agencies in Colorado, Utah, and Wyoming finalized an agreement on stocking nonnative sportfish (U.S. Fish and Wildlife Service 1996). This agreement prohibits stocking of nonnative fish within the 100-year floodplain in designated critical habitat, but does not affect trout stocked in dam tailwaters where native fish are uncommon. Another aspect of nonnative fish management is removal of bag and possession limits for nonnative fish in designated critical habitat. The state of Colorado has removed bag and possession limits on all nonnative, warmwater sportfish in critical habitat. Colorado also has closed river reaches to angling where, and when, angling mortality to native fish is determined to be significant.

*Endangered fish propagation and stocking.*—The endangered fish propagation program in the upper basin has evolved over the past decade based on initial needs for research and later needs for population augmentation. Initially, hatcheries were designed to maintain razorback sucker in refuges and begin development of broodstocks for the upper Colorado River and Green River subbasins. In the mid 1990s, hatcheries produced various sizes of razorback sucker and bonytail for experimental stocking to evaluate size at stocking, cohort survival, and time of stocking. In the late 1990s, the program increased production of large numbers of small razorback sucker, bonytail, and Colorado pikeminnow for individual state stocking plans. These plans were revised and hatcheries were asked to produce larger fish for greater survival in the wild. Smaller fish were marked with coded wire tags and larger fish (greater than 150 mm TL) were marked with PIT tags. Since 2003, the hatcheries have been producing fish to meet the current integrated stocking plan (Nesler et al. 2003) and to maintain broodstocks.

A genetics management plan (Czapla 1999) provides guidance for culture, propagation, and stocking, and annual operations plans identify numbers of fish to be stocked. The UCRRP funds operations of four hatchery facilities in Colorado and Utah that culture and raise endangered fish:

1. The state of Colorado's J.W. Mumma Native Aquatic Species Restoration Facility (Alamosa, Colorado) raises bonytail andColorado pikeminnow.
2. The state of Utah's Wahweap Fish Hatch ery (Big Water, Utah) raises bonytail.
3. The Ouray National Fish Hatchery (Ouray, Utah) raises razorback sucker.
4. The Recovery Program's Grand Valley Endangered Fish Facility (Grand Junction, Colorado) raises razorback sucker.

Guidance for stocking endangered fish is provided by an integrated stocking plan (Nesler et al. 2003) for the upper Colorado River basin designed primarily to expedite reestablishment of razorback sucker and bonytail populations and to reestablish Colorado pikeminnow in presently restricted or inaccessible reaches of historic habitat. This stocking plan integrates the separate state stocking plans and ensures consistency throughout the upper Colorado River basin for stocking endangered fish and evaluating success. Stocking priorities are:

- Razorback sucker are to be reestablished in the upper Colorado River and Green River subbasins (i.e., one population in the Colorado and Gunnison rivers, one in the middle Green River, and a redundant population in the lower Green River). Target size of stocked razorback sucker is 300 mm TL (i.e., age 2+), and stocking is scheduled for fall with 9,930 fish stocked per population annually for 6 years.
- Bonytail populations are to be reestablished in alluvial reaches of the upper Colorado River and Green River subbasins (i.e., one population in the Colorado River, one in the middle Green River, and a redundant population in the lower Green River). Target size of stocked bonytail is 200 mm TL (i.e., age 2+), and stocking is scheduled primarily in fall with 5,330 fish stocked per population annually for 6 years. By accepting the State of Colorado's stocking plan, the UCRRP has deemed that stocking bonytail in the proximity of existing humpback chub populations is an "acceptable" risk regarding the potential of hybridization between the species.
- Colorado pikeminnow are stocked in restricted or inaccessible reaches of historic habitat in the Colorado River above the Grand Valley Water Project Diversion Dam and in the Gunnison River above the Redlands Diversion Dam. Target size of stocked Colorado pikeminnow is 150 mm TL (i.e., age 3+), and stocking is scheduled primarily in fall with 1,125 fish stocked per reach annually for 8 years. This effort will be reevaluated if stocked Colorado pikeminnow are not retained within the stocking reaches.
- Humpback chub is not anticipated to be stocked. However, augmentation of existing small populations may become necessary. Relocation of young from nearby populations or stocking to expand populations of humpback chub into the Yampa, Lodore, Whirlpool, and Split Mountain complex may be desirable in the future to meet recovery needs.

Stocking of hatchery fish is an important element of recovery program activities, and the most suitable stocking strategies and growth and survival of stocked fish continue to be evaluated. Razorback sucker were first stocked in the Gunnison River near Delta, Colorado, in 1995, and 5 stocked fish used the Redlands fish passage in 2001 and one in 2002. Stocking plans were revised to stock fewer but larger fish in 2001, and larval razorback sucker were discovered in the Gunnison River in 2002 and 2003, indicating that stocked fish had successfully reproduced. Ripe stocked adults have been found on the spawning bar in the Green River near Jensen, Utah, and the presence of razorback sucker larvae suggests successful reproduction by these hatchery fish. Bonytail were first reintroduced in the Green River in 2000 and 2001, in Lodore Canyon in 2000, and in the upper Colorado River in 1996. These fish are being recaptured indicating survival, but reproduction has not been confirmed. During September–November, 2003, 16 stocked bonytail were recaptured in large recirculating eddies and talus shores in Cataract Canyon after about 1 year in the wild, providing evidence of survival by stocked fish (Utah Division of Wildlife Resources 2004). Total numbers of PIT-tagged razorback sucker, bonytail, and Colorado pike-minnow stocked in the upper basin from 1995 through 2004 are 89,730; 44,472; and 4,772, respectively.

*Research, monitoring, and data management.*—Ongoing research, reliable population monitoring, and assimilation and management of data are vital to UCRRP success. Results of research and monitoring are used to measure progress toward achieving recovery criteria for self-sustaining populations. Considerable research has been conducted in the upper basin and an electronic database is maintained for all data and reports. Results of studies are also available in open literature for a better understanding of life history requirements and conservation strategies. The UCRRP has an ongoing monitoring program to assess population status and trends in response to management actions, including flow protection, habitat restoration, nonnative fish management, and stocking of hatchery fish. Monitoring includes annual sampling of age-0 Colorado pikeminnow and regular mark-recapture population estimates for all populations of Colorado pikeminnow and humpback chub. Survival of hatchery-reared razorback sucker and bonytail released into the upper basin is evaluated to identify and implement stocking strategies that yield maximum growth and survival.

*Information, education, and public involvement.*—An effective public relations program ensures public awareness, understanding, involvement, and support of UCRRP activities. The UCRRP works with local communities to establish interpretive exhibits and participate in public events that offer opportunities to observe and learn about the endangered fishes. It also provides information at major water user conferences in Colorado, Utah, and Wyoming. The UCRRP holds public meetings and produces a wide range of educational materials, including newsletters, fact sheets, interpretive exhibits, and a web site. The UCRRP issues an annual publication, *Swimming Upstream*, that provides updates of recovery activities.

### *San Juan River Basin Recovery Implementation Program (SJRIP)*

The SJRIP was established under a cooperative agreement in 1992 to conserve populations of Colorado pikeminnow and razorback sucker in the San Juan River subbasin (U.S. Department of the Interior 1995). The SJRIP is coordinated by the USFWS. Program elements, actions, and accomplishments, as defined in the Long Range Plan, are intended to assist species recovery and provide reasonable and prudent alternatives that avoid the likelihood of jeopardy and/or destruction or adverse modification of critical habitat. The SJRIP goals are:

- To conserve populations of Colorado pikeminnow and razorback sucker in the San Juan River subbasin consistent with recovery goals established under the ESA.
- To proceed with water development in the San Juan River subbasin in compliance with federal and state laws, interstate compacts, Supreme Court decrees, and federal trust responsibilities to the Southern Ute, Ute Mountain Ute, Jicarilla, and Navajo tribes.

The following are the main program elements of the SJRIP:

*Protection of genetic integrity and management and augmentation of populations.*—This element involves completing genetics management and augmentation plans, establishing refuges with wild broodstock, and augmenting wild populations of endangered fish species. Most fish for the SJRIP are produced at the Dexter National Fish Hatchery and Technology Center. A genetics management plan (Crist and Ryden 2003) provides guidance for maintaining genetic integrity of hatchery broodstock and fish stocked into the wild, and a razorback sucker augmentation plan (U.S. Fish and

Wildlife Service 1997) provides guidance on best stocking strategies. In 1999, about 1,000 Colorado pikeminnow were captured from age-0 fish stocked in 1996 and 1997 (Archer et al. 2000). To date, about 10,850 subadult and adult razorback sucker have been stocked in the San Juan River. Larval razorback sucker, which have been found in the river for the last 7 years, indicate that previously stocked fish are surviving and spawning at separate locations (Ryden 2000). Since 2002, over 668,000 juvenile Colorado pike-minnow have been stocked in the San Juan River, and about 300,000 are scheduled to be stocked in fall 2005. Survival of stocked fish provides encouraging prospects for establishing populations of razorback sucker and Colorado pikeminnow in the San Juan River.

*Protection, management, and augmentation of habitat.*—This element involves identifying important reaches of the San Juan River for different life stages of the endangered fishes by mapping current conditions, determining relationships between flow and habitat, and determining flow needs. Flow recommendations for the San Juan River have been developed (Holden 1999) and provide flow criteria for flushing of sediments and channel reshaping, adult and juvenile habitat, and nursery habitat for Colorado pikeminnow and razorback sucker. A final EIS and biological opinion on operation of New Mexico's Navajo Dam and Reservoir to implement the San Juan River flow recommendations for endangered fish are slated for completion in 2005. The proposed preferred alternative in the EIS will fully meet the flow recommendations. The biological opinion will address the issue of "ongoing effects" of reservoir operations.

Another important component of habitat augmentation is providing fish passage around migration barriers (Masslich and Holden 1996). The Cudei Diversion has been removed, and the Hogback Diversion was modified with a rock channel to provide non-selective fish passage. The Public Service Company of New Mexico (PNM) Weir was fitted with a 122-m selective fish passage, and similar structures are being considered for the Arizona Public Service Company (APS) Weir and the Fruitland Diversion. These modifications will allow for range expansion of Colorado pikeminnow, razorback sucker, and other native fishes. In 2004, 5 razorback sucker and 4 Colorado pikeminnow used the fish passage at the PNM Weir. Some of the Colorado pikeminnow that used the ladder in 2003 were collected more than once indicating that there was downstream movement over the PNM Weir by fish released upstream. All razorback sucker collected in the fish passage in 2004 were captured for the first time.

Entrainment of fish in diversion canals is also considered a threat to native fish. In 1996 and 1997, age-0 Colorado pikeminnow stocked near the Hogback Diversion, about 4.8 km below Shiprock, New Mexico, became entrained in the diversion canal (Trammell and Archer 2000). The effect of this entrainment to the overall population is unclear and construction of a fish screen in the canal is planned.

*Water quality protection and enhancement.*—This element involves monitoring water quality conditions, evaluating historic information, identifying types and sources of contaminants, investigating changes in water chemistry, and pursuing actions to diminish or eliminate water quality problems that limit recovery. A review of water quality and contaminants, and a detailed study of selenium and selected constituents in water, sediment, soil, and biota in irrigation drainages of the San Juan River subbasin were conducted in 1991–1995. Water quality monitoring is conducted at 5-year intervals.

*Interactions between native and nonnative fish species.*—This element involves determining the distribution and abundance of nonnative fish species, identifying and characterizing habitats used by nonnative fish, discontinuing stocking of nonnative fish species in areas where endangered fish occur, and control of nonnative fishes through removal. Although 19 of 26 species in the San Juan River are nonnative (Ryden 2000), native fish comprised 75% of all fish collected in primary channels from 1991 to 1997. The most abundant nonnative species were channel catfish (13%), common carp (9%), and red shiner (2%; Ryden 2000). Small numbers of walleye and striped bass were collected in 1995–1997 after gaining access from Lake Powell following inundation of a waterfall barrier in 1995.

Efforts to control nonnative fishes have been underway in the San Juan River since 1998 and are showing signs of success. Some species, such as channel catfish, striped bass, walleye, and common carp are being removed by raft-mounted electrofishing, whereas control of other species, such as red shiner, is being attempted through restoration of natural flow regimes and river habitat. The SJRIP continues to work with the Navajo Nation and the state of New Mexico to translocate channel catfish from the river to area lakes to enhance recreational fishing opportunities. Totals of 12,660 channel catfish and 10,016 common carp were removed during 1995–1997 (Brooks et al. 2000; Ryden 2000), and over 9,000 channel catfish were translocated during 1998–2004. A shift toward smaller channel catfish was noted by 1997 and was attributed to more efficient capture of large fish by electrofishing (Propst and Hobbes 2000). Results indicate that those efforts have successfully reduced river-wide abundance of channel catfish to the lowest level ever observed, changing the size structure of the channel catfish population to one now dominated by juvenile fish, thereby lessening the potential for channel catfish reproduction and predation on large native fish.

Another nonnative fish control strategy implemented in the San Juan River in 1992 was release of high flows from Navajo Dam to reduce numbers of red shiner, channel catfish, and other nonnative fish species. Nonnative fish species are ill-adapted to flooding characteristics of southwestern streams where native species evolved (Meffe and Minckley 1987; Minckley and Meffe 1987). Declines in red shiner, sand shiner, and fathead minnow were reported in the upper basin following high flows of 1983–1985 (McAda and Kaeding 1989; Osmundson and Kaeding 1989; Valdez 1990; Muth and Nesler 1993; Lentsch et al. 1996; McAda and Ryel 1999). Propst and Hobbes (2000) noted reduced red shiner numbers in secondary channels of the San Juan River in years when a summer flood event occurred.

*Monitoring and data management.*—Monitoring is necessary to evaluate status and trends of endangered fishes as well as other native and nonnative fish species to assure the SJRIP's overall success in achieving recovery. A long-term monitoring plan provides for native fish assemblage monitoring, including larvae, young, and adults; physical-feature monitoring related to key habitat maintenance; and continued evaluation of flow recommendations. The monitoring plan defines baseline monitoring approaches for fish and habitat, especially those related to flow recommendations. The SJRIP has developed an electronic database of all data and reports.

### *Kendall Warm Springs Dace Biological Management Program*

The USFWS and USFS are responsible for management and conservation of the endangered Kendall Warm Springs dace. The USFWS is responsible for species conservation under the ESA, and the USFS is responsible for integrating management, protection, and conservation of federally listed species into the Forest Planning Process (36 CFR 219.19 and 219.20). Management practices are prohibited that may cause detrimental changes in water temperature or composition, water course blockage, or sediment deposits within 30 m of perennial streams, lakes, or other water bodies (36 CFR 219.27(e)). The Kendall Warm Springs dace recovery plan (U.S. Fish and Wildlife Service 1982b) contains the following recovery efforts and recovery objectives:

1. Maintain the existing population and habitat by monitoring population levels and maintaining biological and physical integrity of stream habitat;
2. Determine the taxonomic status of the Kendall Warm Springs dace; and
3. Complete additional research needs.

In the past, Kendall Warm Springs was subject to human activities within the Bridger-Teton National Forest. Cattle grazed and trampled plant life in and around the spring area. Passage was blocked by rock dams built to create small pools for bathing and washing clothes, and soaps and detergents in the water harmed aquatic organisms. A road built across the spring in 1934 includes a 7.5-m section of culverts that may have prevented the Kendall Warm Springs dace from moving upstream and isolated the upper half of the population. The species was used as bait by anglers for many years and "take" was not regulated because of inadequate laws (Baxter and Simon 1970; U.S. Fish and Wildlife Service 1982b). Recently, these activities have been regulated and new provisions implemented to protect the species. The Wyoming Game and Fish Department stopped issuing permits to seine dace for bait in the 1960s. The USFS has identified 158 acres as the Kendall Warm Springs Biological Management Unit. This area was fenced to prevent cattle access and the springs are closed to wading, bathing, and the use of soap or detergents. Vehicle access has also been blocked along the stream (U.S. Fish and Wildlife Service 1982b).

### *Colorado River Cutthroat Trout Conservation Agreement and Strategy*

A conservation agreement (Agreement) was developed for the Colorado River cutthroat trout in 1999 by Colorado, Wyoming, and Utah; the USFS; BLM; and USFWS (CRCT Task Force 2001). This Agreement was developed to expedite implementation of conservation measures for the Colorado River cutthroat trout in Colorado, Utah, and Wyoming as a collaborative and cooperative effort. Funding for the Agreement is provided by a variety of sources, including federal, state, and local. Threats that warrant listing of Colorado River cutthroat trout as a state special status species could lead to listing under the ESA, and will be eliminated or reduced through implementation of this Agreement and a related conservation strategy (Strategy). The goals of this Agreement are to:

1. Rehabilitate Colorado River cutthroat trout throughout its historic range by establishing two self-sustaining meta populations, each consisting of five separate, viable but interconnected subpopulations, in each Geographic Management Unit (GMU) within the historic range. The short-term goal is to establish one metapopulation in each GMU;
2. Maintain areas that currently support abundant Colorado River cutthroat trout and manage other areas for increased abundance;
3. Maintain the genetic diversity of the species; and
4. Increase the distribution of Colorado River cutthroat trout, where ecologically, sociologically, and economically feasible.

Objectives of the Agreement are:

1. Maintain and restore 383 conservation populations in 2,822 km (1,754 stream miles) and 18 populations in 264 ha (652 lake acres) in 15 GMUs within historic range; and
2. Eliminate or reduce threats to Colorado River cutthroat trout and its habitat to the greatest extent possible.

The Agreement is administered by a Coordination Team, that consists of one designated representative from each signatory and may include technical and legal advisors and others as deemed necessary by the signatories. A total of 10 years is anticipated for completion of all actions described in the Strategy. Conservation actions are scheduled and reviewed annually by the signatory agencies based on recommendations from the Coordination Team.

Aquatic biologists have initially selected a total of 126 streams and lakes in Colorado, 52 in Utah, and 223 in Wyoming for protection, restoration, or conservation planning. A total of 26 strategies within the conservation strategy address threats identified under each of the five listing factors from Section 4 of the ESA. Stream habitat protection and enhancement by the USFS and BLM have greatly increased opportunities to recover the Colorado River cutthroat trout in many historic streams. This has led to increased stream surveys and genetic testing to better define genetic purity of existing stocks.

The long-term objectives set in 1998 (i.e., 2,822 stream km of Colorado River cutthroat trout conservation populations; 523 Colorado, 864 Utah, and 1,437 Wyoming) were exceeded in 2003 in Colorado, but not in Wyoming. Utah exceeded objectives for all GMUs except one. The number of Colorado River cutthroat trout conservation populations increased by 49% from 843 stream km (161 waters) and 243 lake ha (12 waters) in 1998 to 1,648 km and 455 ha in 2003. These increases were due primarily to restoration efforts (160 km) and genetic results identifying pure populations.

Conservation populations continue to be found mainly in short headwater stream sections.

### *Rangewide Conservation Agreement for Roundtail Chub, Flannelmouth Sucker, and Bluehead Sucker*

Six basin states signed a conservation agreement in 2004 (Colorado Fish and Wildlife Council 2004) to expedite implementation of conservation measures for roundtail chub, flannelmouth sucker, and bluehead sucker, and to ensure persistence of these species throughout their ranges. Signatories include Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. Each state will develop conservation and management strategies for any or all three species that occur naturally within its authority. Each signatory agrees to (a) develop and finalize a conservation and management strategy, (b) establish and/or maintain populations of all three species to ensure persistence, (c) establish and/or maintain viable metapopulations, and (d) identify, significantly reduce, and eliminate threats. It is believed that conservation actions to protect and enhance these species and their habitats will contribute to conservation of other native fish species with similar distributions.

## Conservation and Recovery Prospects

### *Colorado Pikeminnow*

According to the 2002 recovery goals (U.S. Fish and Wildlife Service 2002a), recommended criteria for recovery and long-term conservation of bonytail are:

1. Finalization and implementation of site-specific management tasks to minimize or remove threats to attain necessary levels of protection.
2. Maintenance of an upper basin metapopulation with two genetically and demographically viable, self-sustaining populations, one each in the Green River subbasin and upper Colorado River subbasin, as well as the San Juan River subbasin, if target numbers are not met in the upper Colorado River subbasin. Each population is maintained such that:
   - trends in annual adult (age 7+) point estimates do not decline significantly,
   - mean estimated recruitment of age-5 and age-6 naturally produced fish equals or exceeds average annual adult mortality, and
   - each annual point estimate for the Green River subbasin exceeds 2,600 adults.

Habitat of Colorado pikeminnow in the lower basin is too fragmented and modified to allow completion of life history needs, and recovery of this species in the upper basin is believed to provide long-term species viability.

Colorado pikeminnow persist as self-sustaining populations in the Green River and upper Colorado River subbasins, and concerted efforts are underway to restore the species in the San Juan River subbasin. Preliminary numbers of adults in 819 km of the Green River subbasin range from about 2,300 in 2003 to 3,100 in 2001; and from about 450 in 1992 to 780 in 2003 in 282 km of the upper Colorado River subbasin. Numbers of young and juveniles vary within and between years. Populations in the Green River and upper Colorado River subbasins increased following a series of wet years during 1983–1986, and a population viability analysis declared that the species was viable for 200 years (Gilpin 1993). Similar pulses in recruitment were seen following subsequent high water years (e.g., 1993). These population increases appear linked to high water years, and are attributed to high channel reshaping flows that diversified habitat, cleansed the substrate of sediment, infused large amounts of food into the river, and diminished nonnative fish populations (Osmundson and Burnham 1998). Reoperation of Flaming Gorge Dam at about the same time provided less fluctuating flows in summer that stabilized nursery backwaters and increased survival of young. An apparent recent decline in Colorado pikeminnow remains unexplained but may be attributed to periods of low flows since the late 1980s and drought conditions since 2000. This drought has allowed increases in nonnative predatory fish, and populations of most native fish have declined (Anderson

2004). Population estimates are available for the upper Colorado River subbasin for 1992–1994, 1998–2000, and 2003–2004; and for the Green River subbasin for 2000–2003. This history of estimates is insufficient to determine if recent declines are attributable to normal population cycles or environmental threats.

The life history of Colorado pikeminnow is reasonably understood and environmental stressors that affect populations continue to be investigated. The upper basin recovery programs have implemented aggressive management actions to address threats, but response by endangered species may not be direct or immediate because of the complexity of environmental correlates that affect population dynamics. Application and evaluation of management actions are on parallel courses such that when threats are removed or minimized, populations are expected to increase.

### *Humpback Chub*

According to the 2002 recovery goals (U.S. Fish and Wildlife Service 2002b), recovery and long-term conservation of humpback chub depend on:

1. Finalization and implementation of site-specific management tasks to minimize or remove threats to attain necessary levels of protection.
2. Maintenance of six genetically and demographically viable, self-sustaining populations, including five in the upper Colorado River basin and one in the lower basin. Each population is maintained such that:
   - trends in annual adult (age 4+) point estimates do not decline significantly,
   - mean estimated recruitment of age-3 naturally produced fish equals or exceeds average annual adult mortality, and
   - three genetically and demographically viable, self-sustaining core populations are maintained, such that each annual point estimate exceeds 2,100 adults.

Concurrent estimates are not available for all five populations, but preliminary numbers of adults during 1998–2003 are Black Rocks (478–921); Westwater Canyon (2,201–4,744); Desolation/Gray Canyons (948–2,193); Yampa Canyon (391); and Cataract Canyon (150). Population estimates for humpback chub tend to be less precise than for Colorado pikeminnow because of the logistical difficulty of sampling whitewater canyons inhabited by this species. As with Colorado pikeminnow, numbers of adult humpback chub apparently declined recently concurrent with extended periods of low flow and increases in nonnative predatory fish. However, linkages between year-class strength and river flow are less clearly defined as for Colorado pikeminnow. A primary threat to humpback chub in the upper basin is predation by channel catfish and smallmouth bass in Desolation/Gray and Yampa canyons. Efforts to mechanically remove nonnative fish from these population centers are ongoing and are being evaluated.

### *Bonytail*

Bonytail is the most imperiled fish species of the Colorado River system. Wild populations are biologically extinct in the upper basin and only a few wild fish remain in the lower basin. According to the 2002 recovery goals (U.S. Fish and Wildlife Service 2002c), recovery and long-term conservation of bonytail depend on:

1. Finalization and implementation of site-specific management tasks to minimize or remove threats to attain necessary levels of protection.
2. Establishment and maintenance of four genetically and demographically viable, self-sustaining populations, two in the lower Colorado River basin and two in the upper basin; one each in the Green River subbasin and upper Colorado River subbasin. Each population is maintained such that:
   - trends in annual adult (age 4+) point estimates do not decline significantly,
   - mean estimated recruitment of age-3 naturally produced fish equals or exceeds average annual adult mortality,
   - annual point estimates for each of the four populations exceeds 4,400 adults, and

- a genetic refuge is maintained in the lower basin.

Use of hatchery fish is vital to recovery of bonytail. A broodstock has been developed from a small number of wild fish that is believed to represent the wild genome for establishment of new populations (Minckley et al. 1989), and fish are being successfully cultured in hatcheries (Hamman 1985). Initial releases of large fish into the wild were unsuccessful (Chart and Cranney 1991), but smaller fish released more recently are being recaptured after 1–2 years in the river, indicating good growth and survival in the wild. Specific life history aspects of bonytail are unknown, such as habitat requirements. It is hypothesized that bonytail use inundated floodplains as nursery areas and that restoration of these habitats will benefit most native species.

### *Razorback Sucker*

According to the 2002 recovery goals (U.S. Fish and Wildlife Service 2002d), recommended criteria for recovery and long-term conservation of razorback sucker are:

1. Finalization and implementation of site-specific management tasks to minimize or remove threats to attain necessary levels of protection.
2. Establishment and maintenance of four genetically and demographically viable, self-sustaining populations, two in the lower Colorado River basin and two in the upper basin; one each in the Green River subbasin and upper Colorado River subbasin, as well as the San Juan River subbasin, if target numbers are not met in the upper Colorado River subbasin. Each population is main tained such that:
   - trends in annual adult (age 4+) point estimates do not decline significantly,
   - mean estimated recruitment of age-3 naturally produced fish equals or exceeds average annual adult mortality,
   - annual point estimates for each of the four populations exceed 5,800 adults, and
   - a genetic refuge is maintained in Lake Mohave.

The population of the middle Green River in 1999 was fewer than 100 wild adults, and numbers of wild fish throughout the upper basin are few and scattered. Large numbers of hatchery fish have been released in the upper basin since 1995 to augment wild populations and some of these fish have been recaptured as ripe adults on an established spawning bar in the middle Green River. Increased collection of larvae in the Green River and first collections of larvae in the Gunnison River indicate successful reproduction by the stocked fish.

The principal reason for decline of razorback sucker in the upper basin is believed to be reduced availability of floodplains that are used by all life stages and serve as nurseries for larvae emerging from mid-channel cobble bars during spring runoff. Levees have been breached to allow the river to connect and inundate these floodplains during critical larval stages and some recruitment is evident. Floodplain management plans for the Green River subbasin (Valdez and Nelson 2004) and the upper Colorado River subbasin (Valdez and Nelson 2005) provide guidance and strategies for maximizing available floodplain habitat. Implementation of flow recommendations is necessary to floodplain restoration so that releases from Flaming Gorge Dam can coincide with Yampa River flows to maximize flooding over breached levees. The current strategy allows floodplains to become inundated seasonally for 2–3 flood cycles to allow for entrainment of larvae and 1–2 years of growth that minimizes the threat of predation by large main-stem predators. Tests with hatchery-reared fish stocked in floodplains show good growth and moderate survival (Birchell and Christopherson 2004). The alternative strategy of repatriation by isolating floodplains and removing or poisoning nonnative fish before release of hatchery razorback sucker (Minckley et al. 2003) is not currently being used in the upper basin.

### *Kendall Warm Springs Dace*

The only population of Kendall Warm Springs dace is extremely localized and prospects for recovery and long-term conservation of this species have been greatly improved with establishment of the Kendall Warm Springs Biological Management Unit. The unit is surrounded with fencing that protects the springs, stream, and riparian area from grazing and human activity. Signs describe this unique species and the importance of protecting the area, and there is general public support for this conservation action. The population is self-sustaining and viable, and sampling and analytical techniques continue to be refined for a better understanding of population dynamics (Gryska 1997).

### Other Species

*Colorado River cutthroat trout*.—Considerable progress has been made toward the long-term goals and objectives of the conservation agreement and strategy for Colorado River cutthroat trout in Colorado, Utah, and Wyoming. Known stream populations in 1998 were about 30% of the long-range objectives for stream miles. All three states increased occupied stream miles by at least 29% and the overall increase was 95% between 1998 and 2003. Conservation populations (less than 10% introgression with nonnative trout) increased much more in lakes and reservoirs than anticipated. Eighty-seven percent of conservation populations occupied streams less than 11 km long, and 96% were in streams 16 km or less; some populations occupied streams up to 34 km in length. Seventy-one percent of known conservation populations are core populations with less than 1% introgression. Efforts are underway to establish two metapopulations consisting of five interconnected populations in each GMU, but these have been difficult to establish because of the simple and limited structure of the drainages. Each state has, or is working to, establish a brood population for each GMU, and distribution of Colorado River cutthroat trout has increased by reduced stockings of nonnative trout, removal of nonnative fishes from occupied waters, and use of brood or donor populations to expand and increase numbers within historic range.

The combined efforts of the conservation agreement and strategy signatories have greatly expanded the number of populations and occupied stream miles of Colorado River cutthroat trout since the agreement was formalized in 1999. Many long-range objectives have been met and all signatories continue to work toward achieving remaining objectives and ensuring long-term species conservation. State administrators continue to support and fund these conservation efforts and promote the success of the program. Because Colorado River cutthroat trout is not listed under the ESA, local governments and private landowners continue to support these conservation efforts and have become important partners in this effort.

*Roundtail chub, flannelmouth sucker, and bluehead sucker*.—Six western states have signed a conservation agreement to expedite and implement conservation measures for these three species throughout their respective ranges as a collaborative and cooperative effort among resource agencies. Conservation strategies are being developed by each state and an assessment of conservation prospects is not possible at this time. Studies to assess status and trends of these three species in the upper basin are few and localized, and these strategies will help to synthesize information about the species and develop and implement appropriate conservation measures.

## Discussion

Species conservation takes time and money, especially in highly altered aquatic systems replete with complex institutional and legal constraints and difficult biotic logistics, such as the Colorado River system. Human changes to the system over the last 150 years have led to the endangerment of some native fishes, and it will take substantial effort to restore habitat components necessary for their recovery and long-term conservation. It is a foregone conclusion that species recovery on the scale and complexity of the Colorado River system will require ongoing public involvement and commitment with reliable support and funding. It is also evident that large-scale ecosystem restoration is not achievable for the Colorado River system, given the long history of complex habitat changes and ongoing human demands, and the most prudent approach to long-term species conservation is wise management of available resources through involvement by all parties with vested interests. Species recovery programs in the upper basin have adopted a multi-stakeholder approach in which federal and state agencies work cooperatively and collaboratively with public and private interests. These stakeholders have realized that a balanced approach is necessary to conserve imperiled fish species while providing for human needs. The most effective stakeholder union is represented by federal and state agencies, local governments, and various land, water, electrical power, wildlife, and environmental interests that can substantially benefit species by providing vital habitat elements through management of resources under their respective authorities.

No single restoration or rehabilitation strategy will simultaneously improve the status of every riverine resource and hence, managers are faced with an intractable dilemma that requires wise choices and ongoing management decisions (Schmidt et al. 1998). An important component of recovery programs in the upper basin has been implementation of the general principles of adaptive management (Walters 1986), whereby stakeholders learn by doing and refine decisions and directions according to the outcome of prior management actions. Recovery programs have succeeded in bringing stakeholders together, uniting conservation efforts, and striking necessary balances between species conservation and human needs, and the ongoing success of these programs is testimony to their effectiveness (Poff et al. 2003). This paradigm of natural resource management in balance with human needs is vital in today's society.

Stakeholder involvement is vital even prior to federal listing of species. Conservation agreements and strategies are being developed and implemented for unlisted species to expedite actions that remove or minimize threats. Federal and state agencies, as well as stakeholders have discovered that species can sometimes be more effectively managed and conserved before they are federally listed. Conservation agreements and strategies require continued and long-term stakeholder involvement and commitment, especially by state wildlife agencies that have the vested authority to manage those species within their jurisdictional boundaries. The Colorado River cutthroat trout conservation agreement and strategy is an example of a multi-stakeholder program working to improve the status of a species and preclude the need for federal listing. Of particular importance and key to the success of these conservation agreements will be a demonstrated and ongoing commitment by the states to assure the public that these species will continue to be protected and conserved in the future. The rangewide conservation agreement and individual state strategies for roundtail chub, flannelmouth sucker, and bluehead sucker are expected to have similar success, given the involvement by many of the same stakeholders and individuals responsible for the success of the Colorado River cutthroat trout conservation agreement and strategy.

Recovery programs are not without difficulties and they will continue to receive a great deal of attention and scrutiny from stakeholders, the American public, and the U.S. Congress that currently helps to fund them. Public skepticism and mistrust for these programs has turned to increasing support with a better understanding of achievements in species conservation, and an increasing recognition that public involvement is vital to species conservation. Critics view participation by water user groups and public utilities in these programs as compromising to the principles of species conservation, since these groups sponsor activities that may have contributed to species decline (Brower et al. 2001). However, it is this realization that has prompted various stakeholders to form these recovery programs and work jointly toward species conservation. Given the complex human interests and demands on the Colorado River system, this balanced approach to species conservation and meeting human needs is vital and increases the scale and magnitude of available management options.

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