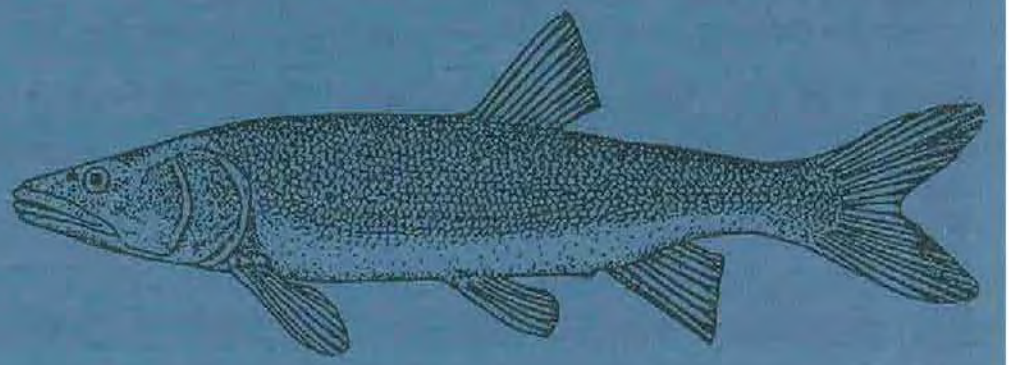
R. W. CLARKSON

Colorado Squawfish Recovery Plan



COLORADO SQUAWFISH

Revised
RECOVERY PLAN

(Original Approval: March 16, 1978)

Prepared by the Colorado River Fishes Recovery Team

For
Region 6
U.S. Fish and Wildlife Service
Denver, Colorado

Approved: Galen L. Buterbaugh
Regional Director, U.S. Fish and Wildlife Service

Date: AUGUST 6, 1991

DISCLAIMER PAGE

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect the species. Plans are published by the U.S. Fish and Wildlife Service, sometimes prepared with the assistance of recovery teams, contractors, State agencies, and others. Objectives will only be attained and funds expended contingent upon appropriations, priorities, and other budgetary constraints. Recovery plans do not necessarily represent the views nor the official positions or approvals of any individuals or agencies, other than the U.S. Fish and Wildlife Service, involved in the plan formulation. They represent the official position of the U.S. Fish and Wildlife Service only after they have been signed by the Regional Director or Director as approved. Approved recovery plans are subject to revision, update, or modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

Literature Citations should read as follows:

U.S. Fish and Wildlife Service. 1990. Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Denver, Colorado. 56 pp.

Additional copies may be purchased from:

The Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814

(301) 429-6430
or
1-800-582-3421

The fee for the plan varies depending on the number of pages in the plan.

Artist Credit: The drawing on the cover is by Brett Morrison, Giraffiks, Glenwood Springs, Colorado.

EXECUTIVE SUMMARY

Current Species Status: The Colorado squawfish (*Ptychocheilus lucius*) was listed as endangered on March 11, 1967. The original recovery plan was approved on March 16, 1978. This is a revision of that plan. The Colorado squawfish population has declined from historic levels. This decline may be due to various human-caused physical and biological changes in the Colorado River system where the fish occurs.

Habitat Requirements and Limiting Factors: The present range of natural populations of the Colorado squawfish is restricted to the Upper Colorado River Basin (Upper Basin) in Colorado, New Mexico, Utah, and Wyoming, although hatchery reared Colorado squawfish have been reintroduced into the Salt and Verde Rivers in Arizona. The decline in the numbers and distribution of Colorado squawfish is due to physical changes in the river system, including stream alteration and habitat fragmentation as a result of dam construction, irrigation, dewatering, and channelization. Biological changes including competition with and predation by introduced nonnative fish also are factors in the squawfish decline.

Recovery Objective: Delisting. Each Colorado Squawfish Recovery Area (Recovery Area) can be delisted as recovery objectives are achieved.

Recovery Criteria: Each Recovery Area will remain listed until such time as their recovery criteria are met. The species can be downlisted or delisted when all Recovery Areas have been downlisted or delisted. The Colorado squawfish will be considered eligible for reclassification to threatened when naturally self-sustaining populations are maintained in the Upper Basin in the following Recovery Areas:

(a) the Green River subbasin including the Green River from its confluence with the Colorado River to its confluence with the Yampa River, the lower 220 km (137 miles) of the Yampa River, and the lower 240 km (150 miles) of the White River;

(b) the Colorado River from Palisade, Colorado, to Lake Powell; and

(c) the San Juan River from Lake Powell upstream to the confluence of the Animas River near Farmington, New Mexico.

(The Colorado squawfish may be downlisted separately by Recovery Area with the Green River and Colorado River areas being downlisted concurrently.)

The Colorado squawfish will be considered eligible for delisting when:

(a) downlisting criteria have been met;

(b) a population in either the Salt River from a diversion dam upstream of Roosevelt Lake to Apache Falls or in the Verde River from Horseshoe Reservoir upstream to Paulden, Arizona, is reestablished and habitats and flows are protected. Feasibility of this effort will be reevaluated at the conclusion of the 1995 Lower Basin Agreement. At that time, the need for inclusion of these areas in the delisting criteria will be reconsidered;

(c) the threat of significant fragmentation (e.g., fragmentation that would impair the reproductive success of the population or limit/impact the adult population size) is removed;

(d) essential habitats, primary migration routes, required streamflows, and necessary water quality are legally protected; and

(e) other identifiable threats, if any, which may significantly affect the population are removed.

(The Colorado squawfish may be delisted separately by Recovery Area, with the Green River and Colorado River areas being delisted concurrently.)

Actions Needed: Major actions needed to achieve the recovery of the Colorado squawfish are:

1. Monitor population status and define the life history requirements of the Colorado squawfish.

2. Implement management plans to protect and maintain Colorado squawfish populations and their habitat.

3. Reintroduce Colorado squawfish into their historic range.

4. Promote and encourage improved communication and information dissemination.

5. Determine biological criteria/objectives for downlisting/delisting the Colorado squawfish.

Date of Recovery: The Colorado squawfish is being recovered in correlation with the bonytail chub, the humpback chub, and the razorback sucker. This recovery plan addresses the recovery needs of the Colorado squawfish in both the upper and lower basins of the Colorado River. The "Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin" (Recovery Program) identifies specific recovery tasks and strategies to be employed in recovering the Colorado River fishes in the Upper Basin, excluding the San Juan River. The goal of the implementation program is to recover these Colorado River fishes in the Upper Basin area in 15 years at an estimated cost of $53 million. The Recovery Program will be considered a stepdown effort of the Colorado Squawfish Recovery Plan and will provide the primary mechanism for implementing the recovery plan in the Upper Basin. A recovery program specifically covering the San Juan River is currently being developed. Development of an endangered fishes management program for the lower basin is being planned.

ACKNOWLEDGEMENTS

The Colorado Squawfish Recovery Plan was prepared by the Colorado River Fishes Recovery Team, composed of the following individuals:

Jim St. Amant, Team Member, California Department of Fish and Game, 1975-1982, Team Leader, 1982-1989,
Steve Petersburg, Team Secretary, National Park Service, 1976-1989, Team Leader 1989-present,
Harold Tyus, Team Member, U.S. Fish and Wildlife Service, 1979-present
Reed Harris, Team Member, Bureau of Reclamation, 1980-1990
Jim Bennett, Team Member, Colorado Division of Wildlife, 1982-present
Gerry Burton, Team Member, U.S. Fish and Wildlife Service, 1982-1988
Randy Radant, Team Member, Utah Division of Wildlife Resources, 1982-1989
Dave Buck, Team Member, Nevada Department of Wildlife, 1984-present
Dean Hendrickson, Team Member, Arizona Department of Game and Fish, 1987-1990
Denise Knight, Team Member, Utah Division of Wildlife Resources, 1988-1990
Frank Baucum, Team Member, U.S. Fish and Wildlife Service, 1988-present
David Probst, Team Member, New Mexico Department of Game and Fish, 1988-present
Glenn Black, Team Member, California Department of Fish and Game, 1988-present

Numerous other persons provided reviews and/or information for the preparation of this plan. The Fish and Wildlife Service greatly appreciates the invaluable assistance provided by team members (past and present), consultants, and other individuals who contributed to the preparation of this document.

TABLE OF CONTENTS

DISCLAIMER..... i

EXECUTIVE SUMMARY.....iii

ACKNOWLEDGMENTS..... v

PART I. INTRODUCTION..... 1

History..... 1
General Description..... 2
Distribution and Abundance..... 2
Historic Distribution..... 2
Present Distribution and Abundance..... 4
Life History..... 6
Habitat Preference..... 6
Temperature Preference..... 6
Reproduction and Migration..... 8
Growth..... 11
Food Habits..... 12
Cultural, Economic, and Biological Importance..... 13
Importance of Tributaries..... 14
Reasons for Decline..... 14
Sensitive Areas and Priority Recovery Areas..... 17
Sensitive Areas..... 17
Priority Areas for Recovery..... 17

PART II. RECOVERY..... 20

Objective..... 20
Downlisting Criteria..... 21
Delisting Criteria..... 21
Stepdown Outline..... 23
Narrative..... 27

LITERATURE CITED..... 40

PART III. IMPLEMENTATION SCHEDULE..... 51

PART I
INTRODUCTION

History

The Colorado squawfish (Ptychocheilus lucius) is the largest of four living species of the genus Ptychocheilus. Although the specific name lucius means "pike like," the Colorado squawfish is taxonomically placed in the large and diverse minnow family Cyprinidae. It is the largest cyprinid in North America (Miller 1961), a voracious predator, and the top native carnivore of the Colorado River system. Maximum weights exceeding 36 kg (79 lbs) and lengths of nearly 1.8 m (71 in.) have been recorded; however, specimens weighing more than 7 kg (15 lbs) have been rare in recent times (Minckley 1973; Behnke and Benson 1980). Its substantial size and migratory habit resulted in use of the common names "white salmon," "Colorado salmon," or simply "salmon" in early literature (Minckley 1973; Behnke and Benson 1980).

The evolutionary history of Ptychocheilus lucius has been marked by scores of oscillations between pluvial- and arid-dominated habitats caused by climatic fluctuations during the Miocene, Pliocene, and early Pleistocene epochs (G. Smith 1981). P. lucius was adapted to swift water by the mid-Pliocene (Uyeno and Miller 1965), but fossil evidence indicates that it may have used lakes as well as rivers (G. Smith 1975, 1981; M. Smith 1981). The species may have developed the capability to survive in either lakes or rivers, depending on prevailing climatic conditions (Tyus 1986). Large size, great mobility, and spawning migrations would be adaptations to drier seasons when suitable spawning habitats are limited or far-removed from other adult habitats (G. Smith 1981). These adaptive life strategies that formerly benefited the fish (Tyus and McAda 1984; Tyus 1986) may now be contributing to its decline.

The other three living members of the genus Ptychocheilus include the Sacramento squawfish (P. grandis) of the Sacramento-San Joaquin, Pajaro, Salinas, and Russian Rivers in California; the Northern squawfish (P. oregonensis) of the Columbia River Basin in Nevada, Oregon, Washington, Idaho, and Montana, north to the Nass River, British Columbia; and the Umpqua squawfish (P. umpquae) in the Umpqua and Suislaw Rivers in Oregon (Lee et al. 1980). Unlike the Colorado squawfish, these three species remain common in their native waters.

The Colorado squawfish was listed as endangered by the U.S. Fish and Wildlife Service (Service) in the Endangered Species List published in the Federal Register (Vol. 32[43]:40001) on March 11, 1967. Full protection under the Endangered Species Act of 1973, as amended, occurred upon its listing in the Federal Register (Vol. 39[3]:1175) on January 4, 1974. The States of California, Arizona, New Mexico, Utah, and Colorado each have laws protecting the Colorado squawfish within State waters.

General Description

The Colorado squawfish is an elongated pike-like fish. The mouth is large and nearly horizontal, with a pharyngeal tooth formula of 2,5-4,2; the long, slender pharyngeal teeth are adapted for grasping and holding prey. The anal and dorsal fin each have nine principal rays and the dorsal fin originates slightly posterior to the insertion of the pelvic fins. The scales are small and embedded on the belly, breast, and nape, and number 80-95 in the lateral line. Adults are strongly countershaded with a dark, olivaceous back; lighter sides; and a white belly. Young are silvery and usually have a dark, wedge-shaped spot at the base of the caudal fin.

Distribution and Abundance

Historic Distribution

The Colorado squawfish is endemic to the Colorado River basin. Early records indicate it was abundant in the mainstem Colorado River, most of its major tributaries, and in the Colorado River delta in Mexico (Jordan and Evermann 1896) (Figure 1). Colorado squawfish have been reported at the following locations:

1. Arizona: Gila River and its tributaries, the San Pedro, Salt, and Verde Rivers; the Colorado River mainstem from the United States-Mexico border to the Utah-Arizona State line and the lower most Little Colorado River (Minckley 1973, 1985).

2. California: Colorado River mainstem from the United States-Mexico border to the Nevada State line and the Salton Sea, which was sporadically filled with water from the Colorado River (Minckley 1973, 1985; Moyle 1976).

3. Colorado: Colorado River and lower reaches of the Gunnison, White, Yampa, Little Snake, Dolores, San Juan, Uncompahgre, and Animas Rivers (Jordan 1891; Ellis 1914; Beckman 1952; Lemons 1954; Johnson 1976; Valdez et al. 1982a), and Plateau Creek, a tributary of the Dolores River (Bob Burdick, U.S. Fish and Wildlife Service, pers. comm. 1990.).

4. Nevada: Colorado River mainstem (La Rivers 1962).

5. New Mexico: San Juan and Animas Rivers (Koster 1957, 1960; Platania 1990).

6. Utah: Colorado, Green, Duchesne, San Juan, White, and Dolores Rivers, and probably numerous smaller streams (Ellis 1914; Holden 1973; Seethaler 1978).

7. Wyoming: Green River mainstem (Baxter and Simon 1970; Bosley 1960; Johnson and Oberholtzer 1987) and Little Snake River (Marsh et al. 1991).

8. Mexico: Mainstem Colorado River and its tributaries and sloughs from the United States-Mexico border to the Gulf of California (Sonora and Baja California del Norte) (Follett 1961; Minckley 1979).

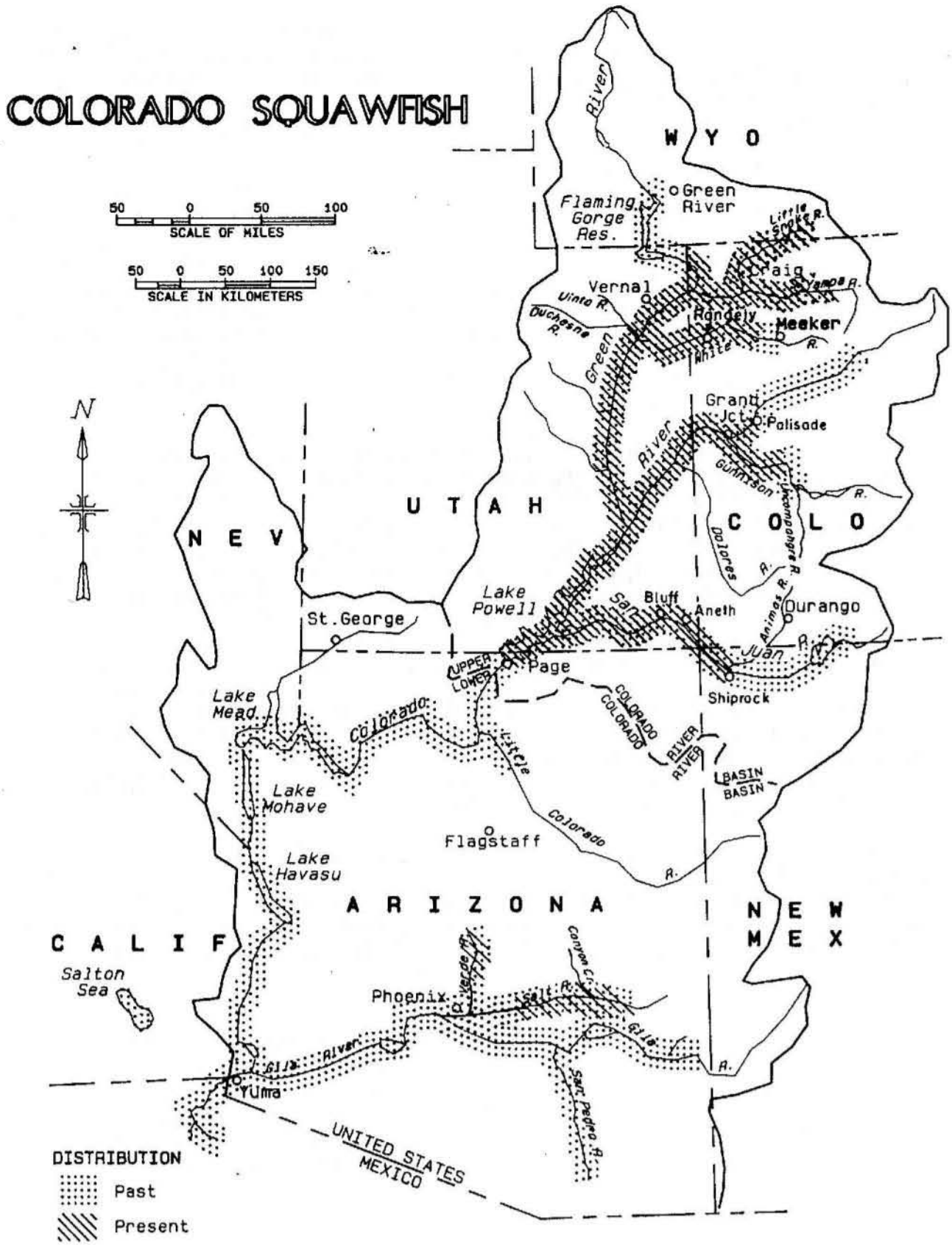


FIGURE 1. Past and Present Distribution of the Colorado Squawfish in the Colorado River System.

An indication of the prior abundance of Colorado squawfish was its use for food and fertilizer (Miller 1961; Minckley 1973) and its widespread favorable reputation with early settlers as a food and game fish from Colorado downstream into Arizona (Ellis 1914; Dill 1944; Carhart 1950; Rostlund 1952; LaRivers 1962; Sigler and Miller 1963; Minckley 1965, 1973.).

Present Distribution and Abundance

Natural populations of the Colorado squawfish are restricted to the Upper Colorado River Basin (Upper Basin) in Wyoming, Colorado, Utah, and New Mexico. The species is most abundant in the Green River below the confluence with the Yampa River; the Yampa River from near Hayden, Colorado, to the confluence of the Green River; the White River from Taylor Draw Dam near Rangely, Colorado, downstream to the confluence with the Green River; and mainstem Colorado River from Palisade, Colorado, downstream to Lake Powell (Holden and Wick 1982; Miller et al. 1982b; Tyus et al. 1982b, Tyus et al. 1987; Wick et al. 1985, 1986; Archer et al. 1985.

Catches of young, juvenile, and adult Colorado squawfish are reported to be an order of magnitude higher in the Green River subbasin of Colorado and Utah than elsewhere (Tyus et al. 1986; Tyus 1990). Recent investigations have found many young, juveniles, and adults in the Green River from the mouth of the Yampa River to its confluence with the Colorado (Holden 1973; Holden and Stalnaker 1975a, 1975b; Tyus et al. 1982a, 1982b, 1987; Archer et al. 1985). Adults have been captured in the lower 199 km (124 miles) of the Yampa River and in Lodore Canyon of the Green River (Tyus et al. 1982a; Miller et al. 1982b), and larvae were identified from the lower 30 km (19 miles) of the Yampa River in Dinosaur National Monument (Wick et al. 1981, 1985, 1986; Haynes et al. 1984; Tyus and Haines 1991). Two adult Colorado squawfish implanted with radio transmitters ascended the Little Snake River in 1988 (Wick and Hawkins 1989). Investigation of the Green and Little Snake Rivers in Wyoming in 1986 failed to produce any Colorado squawfish, (Johnson and Oberholtzer 1987); however, an adult Colorado squawfish was found in the Little Snake River in Wyoming in 1990 (Marsh et. al. 1991).

Colorado squawfish have been found in the lower 243 km (151 miles) of the White River in Utah and Colorado (Prewitt et al. 1978; Wick et al. 1979, 1981; Carlson et al. 1979; Lanigan and Berry 1981; Miller et al. 1982a; Martinez 1986a). In the Duchesne River, a fisherman caught a Colorado squawfish at the mouth of the Uinta River in 1975 (Seethaler 1978) and a specimen implanted with a radio transmitter ascended the Duchesne River in 1980 (Tyus et al. 1982b).

Adult and young Colorado squawfish still inhabit Lake Powell (Minckley 1973; Wick et al. 1981; Valdez et al. 1982b; Miller et al. 1984). Adult Colorado squawfish were captured in the riverine portion of the reservoir in 1980 (Persons and Bulkley 1982). Valdez (1990) also reported both adult and juvenile Colorado squawfish in Cataract Canyon at the inlet of Lake Powell, indicating that the species is reproducing in or above that reach.

A small reproducing population of Colorado squawfish exists in the San Juan River. A single juvenile squawfish was captured in the San Juan River just below the confluence of McElmo Creek near Aneth, Utah, in 1978 (Minckley and Carothers 1980; VTN 1978). Platania et al. (1991) summarized captures of squawfish in New Mexico and Utah from 1987 to 1989. Eight adults and nineteen young-of-the-year were captured (two additional adults were observed but not captured). Except for one adult captured in the San Juan arm of Lake Powell, the adults were captured in the San Juan River between River Mile (RM) 89 near Bluff, Utah, and RM 163 near Shiprock, New Mexico. In 1987, 18 young-of-the-year were collected from the San Juan River. Two were collected downstream of Shiprock, New Mexico (Platánia et al. 1991), six near Bluff, Utah, and ten in the Lake Powell inflow area. A young-of-the-year captured in 1988, also was taken from this inflow area. In 1990, another young-of-the-year was collected near Bluff, Utah (Bill Bates, Utah Division of Wildlife, pers. comm. 1990).

In the Lower Colorado River Basin (Lower Basin), Miller and Lowe (1964), and Minckley and Deacon (1968) considered Colorado squawfish extirpated from the Gila River system, and Minckley (1973, 1979) later expanded this to include all Arizona waters except above Glen Canyon Dam in Lake Powell. No Colorado squawfish (other than stocked fish) have been taken from the Gila River basin since 1950 (Miller 1961); a 1958 record of this species from the Salt River, Arizona (Branson et al. 1966), was based on misidentified roundtail chub (Gila robusta) (R.R. Miller pers. comm. to W.L. Minckley). The last adult squawfish from the mainstem lower Colorado River was taken by a fisherman in 1967 in Lake Mohave (Minckley and Deacon 1968).

Although natural populations of the species were extirpated from the Lower Basin, hatchery-reared Colorado squawfish have been introduced in several locations. More than 96,000 fingerling and 442 larger Colorado squawfish, 355-405 mm (14-16 in.) total length (TL), were introduced at six locations on the Salt and Verde Rivers, Arizona, in 1985 (Brooks 1986). Seven of the larger squawfish were captured in experimental trammel nets within 10 days after stocking, and five more fish of the larger size group were captured about 5 months after stocking. In 1987, 31,750 fingerling Colorado squawfish from Dexter National Fish Hatchery were stocked at two sites in the Salt River drainage (including 6,750 into Canyon Creek) and 100 Colorado squawfish were stocked into the Verde River. Arizona Game and Fish Department biologists recaptured three in Canyon Creek, and one in the Salt River. In 1988, Dexter National Fish Hatchery personnel stocked 20,000 fingerlings into the Salt River, 18,000 into Canyon Creek, and 89,303 into the Verde River. Bubbling Ponds State Fish Hatchery personnel stocked 120,604 fingerlings into the Verde River and 1,194 into Sycamore Creek, a tributary to the Verde River. In 1988, 57 Colorado squawfish were recaptured on Verde River, and six from the Salt River. Recaptures during both years included fish which had been at large for 3 months to 1 year (Dean Hendrickson, Arizona Game and Fish, pers. comm. 1990). Colorado squawfish stockings continue in the Salt and Verde Rivers, and expansion of the program is planned.

Life History

Habitat Preference

Colorado squawfish are adapted to rivers with seasonally variable flow, high silt loads, and turbulence. Young-of-the-year (up to 64 mm [2.5 in.] TL), juveniles (65-200 mm [2.5-8 in.]), and subadults (200-400 mm [8-16 in.]) live in shallow backwater areas, with little or no current over silt and sand bottoms (Haines and Tyus 1990; Holden 1973; Holden and Stalnaker 1975a, 1975b; Holden and Twedt 1980; Miller et al. 1982a, 1982b; Tyus and Haines 1991; Valdez et al. 1982b; Valdez and Wick 1983; Wick et al. 1979, 1981). There is a change in habitat preference at about 200 mm (8 in.) TL (Miller et al. 1982a), with larger fish selecting deeper water of at least some velocity. Adults are large-river fish, found in a variety of depths and velocities over silt, sand, gravel, and boulder substrates (Holden 1973; Holden and Twedt 1980; Holden and Wick 1982; Miller et al. 1982a, 1982b; Tyus et al. 1982a, 1984; Valdez et al. 1982b; Wick et al. 1979, 1981).

Radiotelemetry studies (Miller et al. 1983; Tyus 1985, 1986; Tyus and McAda 1984; Tyus et al. 1982b; Wick et al. 1983) have provided considerable information on habitat usage of adult Colorado squawfish. Adults use various habitats depending upon season, streamflow, water temperature, and availability (Holden and Wick 1982; Tyus and McAda 1984; Tyus 1990; Wick et al. 1983, 1985, 1986). During peak runoff, adults move into backwater areas or flooded riparian areas where velocity is lower and water temperatures are higher than in the main channel (Wick et al. 1983). During the decline in water level following peak runoff, spawning adult fish move into run-riffle areas and also occupy run, eddy, and pool habitats (Tyus 1990). Adult Colorado squawfish exhibited little movement during winter (October-April) in the upper Green River (Valdez and Masslich 1989). Of 20 adults radio-tagged in October, 15 moved less than 5 km by the end of the following March. The fish occupied primarily slow runs, slackwater, eddies, and backwaters.

Temperature Preference

The thermal tolerance of Colorado squawfish is broad, as evidenced by the range of temperatures to which the species was presumably adapted. Summer water temperatures in the vicinity of Yuma, Arizona, for example, commonly approach or exceed 35°C (95°F) and may drop to lower than 10°C (50°F) in winter (Minckley 1979). In the Upper Basin, water temperatures generally range from 25°C (77°F) during the summer to freezing (0°C [32°F]) in winter.

Tyus (1990) summarized the water temperatures associated with prespawning, migratory, and spawning periods for adult Colorado squawfish in the Upper Green River Basin. Spawning migrations were initiated at water temperatures of 14-20°C (57°-68°F), and spawning occurred at temperatures of 22°C (72°F) (range 15-27.5C [59°-82°F]). In the Yampa River, migrations and spawning periods varied between years. Migrations were initiated from May 12 to June 10, associated with a mean water temperature of about 14°C (57°F), and spawning occurred at 21°C (70°F) (Table 1) (Tyus and Karp 1989). However, Tyus et al. (1987) and Wick et al. (1985) cautioned that main channel

estimated age from I to XI and the results were: I=44 mm (1.7 in.); II=95 mm (3.7 in.); III=162 mm (6.4 in.); IV=238 mm (9.4 in.); V=320 mm (12.6 in.); VI=391 mm (15.4 in.); VIII=499 mm (19.6 in.); and X=600 mm (23.6 in.). Seethaler (1978) found similar growth rates for Colorado squawfish in both the Green and Colorado Rivers. However, the accuracy of using scales for aging this species has not been verified. At Willow Beach National Fish Hatchery, Colorado squawfish hatched in the summer of 1980 doubled their length in 14 days and attained a size of 48-50 mm (1.9-1.96 in.) in 110 days (Hamman 1981). Growth of broodstock held in cold water (10°C [50°F]) at Willow Beach National Fish Hatchery in 1973 and 1974 was slow. Seven adult fish gained a total of only 0.64 kg (1.41 lbs) over a 9-month period after being fed 40.8 kg (90 lbs.) of live fingerling trout (Toney 1974). Length-weight relationships of these fish was similar to that for wild fish reported by Vanicek and Kramer (1969) and Seethaler (1978).

Fingerling Colorado squawfish (50-91 mm [2-3.6 in.] TL) stocked in grow-out ponds near Grand Junction, Colorado, grew to a range of 185-304 mm (7.3-12 in.) TL in 1 year (Osmundson 1987). Similar sizes were attained by Colorado squawfish in the adjacent Colorado River in about 4 years (Kaeding and Osmundson 1988). The difference in growth was attributed to warmer water temperatures (about 1.8 times more degree-days than the river), lack of competitors, and an abundant food supply in the pond. Growth was slower and more variable in other ponds in the same area, which was probably due to the variation in food availability, because temperature regimes were similar among ponds. Tyus and Haines (1991) found that growth of age-0 Colorado squawfish was related to the amount of available habitat, but reduced growth at lower temperatures was not detected.

Food Habits

Food of young Colorado squawfish consists mainly of zooplankton and insect larvae. Other fish species feed on the same food items as young-of-the-year Colorado squawfish (McAda and Tyus 1984). Fry at Willow Beach National Fish Hatchery fed on zooplankton in fertilized raceways (Hamman 1981). Colorado squawfish become predatory at a very early age. Fish as small as 30 mm (1 in.) have been documented to eat other fish (Tyus and Karp 1991). Nearly 86 percent of the diet of juvenile Colorado squawfish is fish, with the major prey being red shiner (Cyprinella lutrensis) an introduced cyprinid (Jacobi and Jacobi 1982). Adults are almost exclusively piscivorous, feeding on most native and many introduced fishes present in the river (Vanicek and Kramer 1969). Nonnative fish presumably have entered their diet more frequently as native fishes have declined (Holden and Wick 1982). However, Beckman (1952) reported that jackrabbits and other animals were used historically by anglers as bait for Colorado squawfish. Minckley (pers. comm.) observed a large Colorado squawfish eat two newly hatched American coots (Fulica americana) at Dexter National Fish Hatchery, New Mexico. Tyus and Minckley (1988) reported four Colorado squawfish feeding on Mormon crickets in Dinosaur National Monument, Colorado, and speculated on the significance of large outbreaks of crickets as food for the native fish fauna.

Larval drift may be an important part of the Colorado squawfish life cycle (Tyus and Haines 1991) and laboratory studies indicate that "drift" may be active rather than a passive response to water current (Paulin et al. 1991). Larval squawfish drift downstream after hatching in the Green and Yampa Rivers and rear in reaches of the river that are different from those in which spawning occurred (Haynes et al. 1984; Tyus and Haines 1991).

The most important rearing area in the Colorado River for young-of-the-year Colorado squawfish is between Moab, Utah, and the confluence with the Green River (RK 0-96 [RM 0-60]) (Archer et al. 1985). Other nursery areas in the Colorado River have been found: (1) in the upper Professor Valley (RK 112-129 [RM 70-81]); (2) between the confluence with the Dolores River and Westwater Canyon (RK 144-175 [RM 90-109]); (3) between Black Rocks and Loma (RK 225-241 [RM 140-150]); and (4) downstream from the confluence with the Gunnison River (RK 257-273 [RM 160-170]).

No larval Colorado squawfish have been found in the White River. Some adults that were tagged in the White River have been recaptured or radio-tracked to the Yampa and Gray Canyon spawning sites (Tyus 1990). Osmundson and Kaeding (1989) reported the capture of a single larval Colorado squawfish in the lower 3 km (1.9 miles) of the Gunnison River.

In 1987, a total of 18 young-of-the-year Colorado squawfish were captured in the San Juan River at various locations. These fish were collected from backwaters of the river: 2 were taken from the area downstream of Shiprock, New Mexico, at RK 222 (RM 139) and RK 228 (RM 143); 6 near Bluff, Utah, at RK 150-161 (RM 94-101); and 10 were taken in the lowermost 38 river kilometers immediately upstream from Lake Powell. An additional young-of-the-year also was taken from this lowermost river area in 1988, collected from backwaters at RK 18 (RM 11) (Platania et al. 1991). In 1990, a young-of-the-year Colorado squawfish was collected from backwaters near Bluff, Utah (Bill Bates, Utah Division of Wildlife, pers. comm. 1990).

Colorado squawfish were first successfully propagated at Willow Beach National Fish Hatchery in 1974. Progeny since have been obtained by both artificial and natural spawning (Hamman 1981; Toney 1974). Wild Colorado squawfish obtained from the Green and Colorado Rivers in autumn 1979 spawned over filter gravel in raceways. Wild-caught and hatchery-produced broodstock at Dexter National Fish Hatchery, New Mexico, spawned in May and June after an injection of pituitary extract; production was primarily limited by the physical constraints of the facility for holding and growing young (Hamman 1986).

Growth

As with most fishes, Colorado squawfish growth rates are variable and dependent upon water temperature, food, water quality, age, and numerous other parameters. Tyus (1988) reported that the growth rate of 59 tagged and recaptured adult fish in the Green River averaged 10.2 mm/year (.4 in./year). Vanicek and Kramer (1969) back-calculated mean TL's at annulus formation for 182 Colorado squawfish from the upper Green River, Utah. The fish ranged in

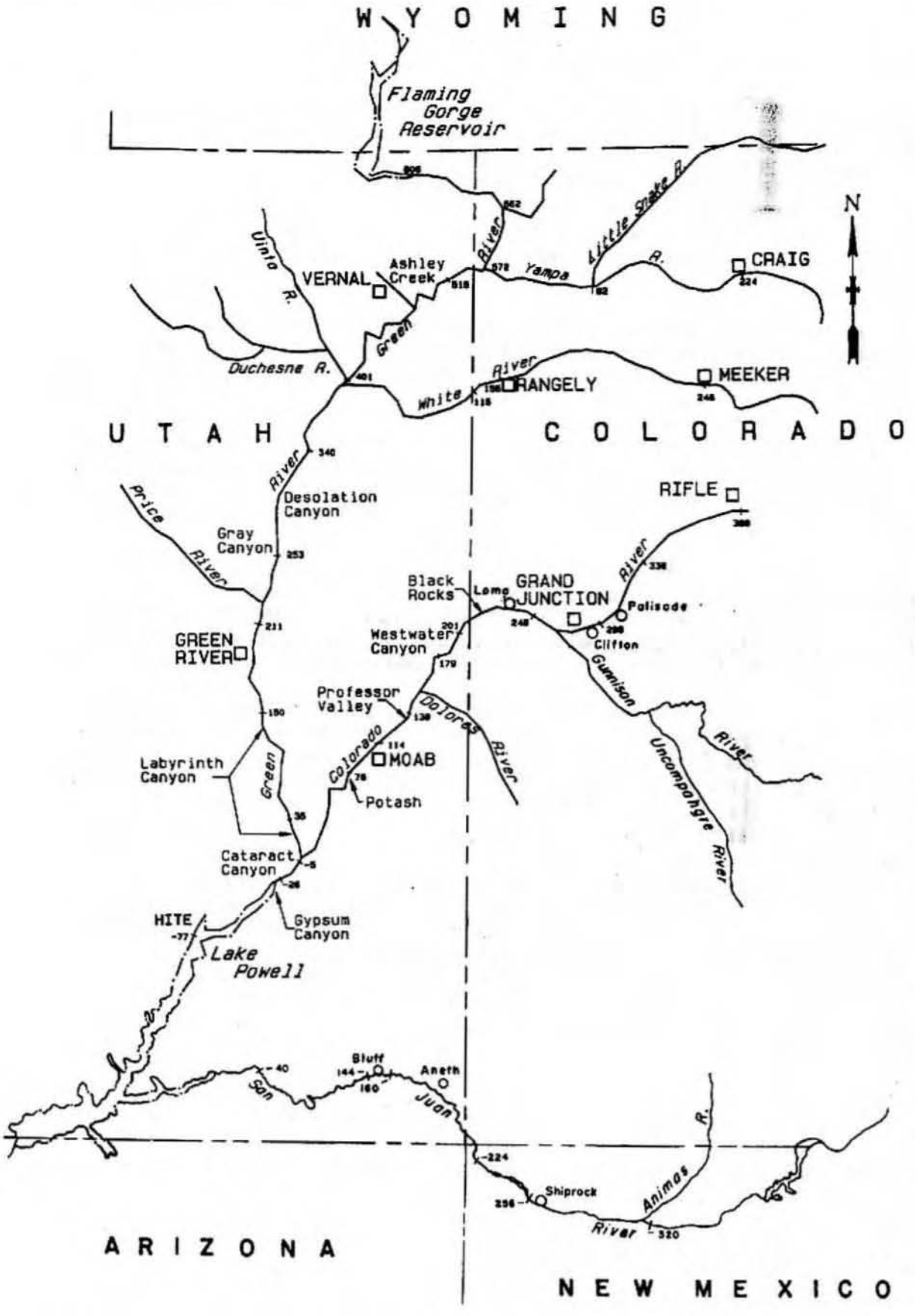


FIGURE 2. Upper Colorado River Basin showing river kilometers and major canyon areas.

squawfish were radio-tracked by Service personnel from 1980-88 (Tyus 1990) and five were tracked by National Park Service and Colorado Division of Wildlife workers in 1982 (Wick et al. 1983). Collections made on the two known spawning grounds during 1981-88 produced 308 Colorado squawfish, of which 208 were ripe and an additional 67 fish showed secondary sex characteristics associated with breeding condition (Tyus 1990). Four fish tagged in the White River were recaptured at the Yampa and Gray canyons spawning areas, and the recapture of five fish tagged and recaptured in the Yampa River spawning grounds after 2 or more years indicate a fidelity to that area (Tyus 1985, 1990).

It is possible that the Yampa spawning aggregation is historical; Holden and Stalnaker (1975b) reported increased numbers of ripe Colorado squawfish in the lower Yampa River in July 1968-70, and Seethaler (1978) reported ripe fish there in 1974-75. Successful reproduction was substantiated when larval Colorado squawfish (9 to 13 mm [.35-.51 in] TL) were taken below river kilometer (RK) 32 (rivermile [RM] 20) on the Yampa and downstream Green River in 1980, 1981, and 1982, and below RK 40 (RM 25) in 1983; however, only one has been collected upstream from these points (Haynes et al. 1984; Tyus et al. 1987).

Gray Canyon of the Green River was suspected as a spawning site in 1981 when a radio-implanted Colorado squawfish from the White River was tracked to that location (Radant et al. 1983; Tyus et al. 1982a). Spawning was confirmed there in 1983 (Tyus 1985). Additional Colorado squawfish have been tracked to Gray Canyon, and 111 ripe fish were collected there in 1981-88 (Tyus 1990).

Radiotelemetry studies also show upstream and downstream movement of adult Colorado squawfish in the upper mainstem Colorado River. One dramatic example was provided by a fish radio-tagged in Gypsum Canyon of upper Lake Powell on April 5, 1982. On July 9, 1982, the fish was located in the lower Cataract Canyon area. The next contact was made above the Black Rocks area of the Colorado River some 258 km (161.25 miles) upstream. This movement was accomplished in 41 days and was believed related to spawning. At the end of September, the fish was located in the Colorado River near Clifton, Colorado, approximately 320 km (200 miles) from its furthest documented downstream location. However, not all radio-tagged fish in the mainstem Colorado River have displayed such dramatic migratory behavior. Radiotelemetry studies conducted by the Colorado River Fishery Project from 1982-85 (Archer et al. 1985; Miller et al. 1983) in the Grand Valley region of the Colorado River found that movement during April to October was generally limited to 40-48 km (25-30 miles).

Two reaches of the Colorado River containing suspected spawning areas are Black Rocks to Loma (RK 217-233 [RM 135-145]) and Grand Junction to Clifton (RK 257-290 [RM 160-181]) (Archer et al. 1985). Location of larval squawfish aggregations and the presence of suitable spawning habitat in the Colorado River near Cataract Canyon 22-29 km (14-18 miles) below the confluence of the Green River, in Professor Valley at above the confluence of the Green River at RK 121-137 (RM 75-85), and upstream from the Dolores River confluence at RK 160-185 (RM 100-115) indicate spawning is occurring in or near these areas as well (Archer et al. 1985; Valdez 1990).

Reproduction and Migration

In the wild, male Colorado squawfish do not mature until they reach or exceed 400 mm (15.7 in.) TL and (based on scale ageing techniques) attain an age of at least 6 years; females mature a year later (Seethaler 1978). Tyus (1990) found that ripe males averaged 555 mm (21 in.) TL (n=194), but ripe females averaged 654 mm (26 in.) TL (n=14) on spawning grounds in the Green River basin. Hatchery-reared males matured at 5 years and females at 6 years of age (Hamman 1981). Some of these hatchery fish matured naturally while others produced gametes only after an injection of carp pituitary extract (Hamman 1981).

Colorado squawfish gonads ripen during spring runoff (May-June). Laboratory and field studies indicate that spawning begins when water temperatures reach about 21°C (70°F) (Hamman 1981; Miller et al. 1982a; Toney 1974; Vanicek and Kramer 1969). Archer et al. (1985), Haynes et al. (1984), and Tyus (1990) found that spawning occurred between late June and mid-August when water temperature reached 18-25°C (64°-77°F), with peak spawning activity occurring between 22-25°C. Although turbidity has precluded direct observation of spawning behavior, radiotracking and collection data suggest similarities to the northern squawfish (Beamesderfer and Congleton 1981; Patten and Rodman 1969).

Radiotelemetry studies and collections of spawning fish have added to the knowledge of Colorado squawfish spawning activities, seasonal movements, and habitat use (Miller et al. 1984; Radant et al. 1983; Tyus and McAda 1984; Tyus et al. 1982b; Tyus 1990; Wick et al. 1983). During the spawning season, adult Colorado squawfish have been known to migrate up to 320 km (200 miles), upstream or downstream, to reach spawning areas in the Green River Basin (Miller et al. 1983; Tyus 1985; Tyus 1990). Homing behavior and fidelity to spawning locations has been indicated for Colorado squawfish in the Green and Yampa Rivers (Tyus 1985; Tyus 1990; Wick et al. 1986). Some authors suggest that repeated use of the same spawning areas may reflect a limited availability of spawning habitats rather than true homing (Archer et al. 1985; O'Brien 1984); however, Tyus (1990) reported that migrating Colorado squawfish pass through many miles of potential spawning habitat to reach specific spawning areas in Yampa Canyon. However, all adult-sized Colorado squawfish may not spawn annually, and a lack of long-distance migratory behavior has been associated with less than annual spawning and sexual immaturity (Tyus 1990; Wick et al. 1983).

Radiotelemetry studies in the Green River basin suggest that spawning is concentrated in two major sites: (1) the lower 32 km (20 miles) of Yampa River canyon; and (2) Gray Canyon of the Green River (Tyus 1985; Tyus and McAda 1984; Tyus 1990; Wick et al. 1985) (see Figure 2). Spawning also is suspected in Labyrinth Canyon in the Green River about 50 km (31.25 miles) upstream of the Colorado River confluence (Tyus et al. 1987). This is supported by the capture of many young larval fish (protolarvae) immediately downstream of this reach (Valdez 1990). Radiotelemetry, collections of ripe fish, and recaptures have confirmed long-distance migration to these locales. These migrations average about 90 miles, and include both upstream and downstream movements (Tyus 1990; Wick et al. 1983). A total of 153 Colorado

temperatures may not accurately portray temperature preferences of Colorado squawfish because the species frequently utilized habitats outside the main river channel, such as large backwaters, gravel pits, and flooded bottomlands, which may be controlled more by ambient air temperatures and solar radiation. In laboratory experimentation, Marsh (1985) found that optimal temperatures for embryo development and hatching of Colorado squawfish was near 20°C (68°F). Percentage hatch was highest and incidence of abnormalities lowest at that temperature. Tyus (1991) found that young Colorado squawfish moved in and out of backwater habitats as water temperatures fluctuated. The young fish apparently moved into backwaters that were warmer that the river channels, but moved back into the river as backwater temperatures declined.

Temperature preferences have been determined in the laboratory for Colorado squawfish reared at Willow Beach National Fish Hatchery in Arizona. Juvenile Colorado squawfish acclimated to 20°C (68°F) selected a higher temperature (26.6°C [80°F]) than those acclimated to either 26°C (78°F) or 14°C (57°F); fish acclimated at 26°C (78°F) selected 23.7°C (75°F); and those acclimated at 14°C (57°F) selected 21.9°C (71°F). Adults selected temperatures ranging from 21.5° (71°F) to 25.7°C (78°F), with a final temperature preference of 25.4°C (78°F) (Bulkley et al. 1982). Maximum growth of 45 to 100 mm (1.7-4 in.) TL Colorado squawfish in a laboratory study occurred at 25°C (77°F), while growth at 20°C (68°F) and 30°C (86°F) was about 50 percent of the maximum (Black and Bulkley 1985).

Table 1. Temperatures associated with Colorado squawfish migration and spawning periods in the Yampa River, 1981-88 [adapted from Tyus and Karp (1989)].

Year	Type Water Year	Migration			Spawning		
		Period Dates	Temp.(mean) C°	F°	Period Dates	Temp.(median) C°	F°
1981	Low	5-12 to 6-20	13.8°	57°	6-19 to 7-20	21.8°	71°
1982	Average	6-10 to 6-20	12.7°	55°	7-4 to 8-8	22.0°	72°
1983	High	6-10 to 7-10	13.4°	56°	7-12 to 8-18	22.5°	73°
1984	High	--	--		7-10 to 8-17	22.0°	72°
1985	High	--	--		6-21 to 7-25	20.0°	68°
1986	High	--	--		6-27 to 8-5	20.8°	69°
1987	Low	--	--		6-3 to 7-16	20.5°	69°
1988	Average	6-8 to 6-30	16.9°	62°	6-20 to 7-24	21.5°	71°

Cultural, Economic, and Biological Importance

Historically, the Colorado squawfish was an important source of food for human residents. American Indians caught them along the lower Colorado River and its larger tributaries in Arizona (Miller 1955, 1961; Minckley 1965, 1973; Minckley and Alger 1968; Rostlund 1952). The species was reported from the Upper Basin as early as 1825, when Colonel W.H. Ashley's party subsisted on fish caught by angling in the Green River (Morgan 1964). Dellenbaugh (1908) also reported the capture of Colorado squawfish during the 1871 Powell expedition. Jordan (1891) identified Colorado squawfish as the largest and best food fish of the lower Colorado River. Commercial anglers operated on the lower Salt River from the time of settlement until about 1910, and within the Salt River Canyon until the 1930's and perhaps longer (Chamberlain 1904; Minckley 1965). The species was widely sought by anglers prior to its precipitous decline in the period 1930-50 in the Gila River at Dome (Richardson in Miller 1961) and Safford (Chamberlain 1904), Salt River Canyon (Dammann in Minckley 1965), and Roosevelt Lake (Frazier in Miller 1961).

Individuals weighing 2.7 to 15.4 kg (6 to 34 pounds) were commonly caught along the lower Colorado River prior to 1949 (Moffett 1942, 1943; Wallis 1951). Minckley (1973) stated, "It is notable that the name 'salmon,' in some context or alone, was used exclusively for Ptychocheilus, and that no other names for the species were known to the [12] persons interviewed." His information was collected through interviews with "old-timers" along the Gila and lower Colorado Rivers; the common name presumably was derived from the size, appearance, and palatability of the species, as well as its migratory tendency in the spring. Residents of Vernal, Utah, remarked about the former abundance of the fish, which reached sizes of 23.6 kg (52 pounds), in the Green River (Vanicek 1967). Seethaler (1978) summarized interviews with local people who reported specimens of up to 13.6 kg (30 pounds) from the upper Green River in Colorado and Wyoming. Seethaler (1978) included a report of a Colorado squawfish 1.7-1.8 m (5 1/2 to 6 feet) in length caught in 1911 just below the confluence of the Green and Yampa Rivers in Dinosaur National Monument, and included a photograph of a 11.3 kg (25 pound) adult taken in Dinosaur National Monument in 1928.

Miller (1961), Wick et al. (1981), and others reported that Colorado squawfish may have sportfishing potential. The Colorado squawfish has the potential to attain a large size, takes artificial lures readily, and has been reported as "good-eating" in historic accounts. The State of Arizona and the Service are formulating plans to reintroduce and manage Colorado squawfish for sportfishing in the lower Colorado River. A fishery management plan for Kenney Reservoir on the White River in Colorado similarly includes development of an experimental sport fishery for Colorado squawfish (Martinez 1986b). Approximately 17,000 Colorado squawfish fingerlings were stocked into Kenney Reservoir in April of 1988, about 33,000 in 1989, and about 36,000 in 1990 as part of a 3-year experimental program to establish a sportfishery. The success of this stocking program will be evaluated through 1992. No further stockings are planned, pending completion of the evaluation.

Importance of Tributaries

Tributaries of the Green and Colorado Rivers may be especially important to the continued survival of the Colorado squawfish. Colorado squawfish historically or presently occupy tributaries of the Green and Colorado Rivers, including the Yampa, Duchesne, White, Gunnison, Dolores, and San Juan Rivers in the Upper Basin, the Gila River and its tributaries, the Salt, Verde, and other rivers in the Lower Basin. Tagging and telemetry studies indicate the Colorado squawfish moves long distances from spawning areas in the mainstem Green River to feeding and overwintering areas in the Yampa, White, and Duchesne Rivers (Miller et al. 1982a, 1982b, 1983; Radant et al. 1983; Tyus et al. 1982a, 1982b, 1987). Tyus (1986) suggested that tributaries play an important role in the life history strategy of the Colorado squawfish and perhaps serve to reduce intraspecific competition.

Miller et al. (1982a) reported a net movement of juveniles from the Green River to the White River, while Radant et al. (1983) documented movement of adult fish between the White and Green Rivers and Green and Yampa Rivers during the spawning season. There also is a downstream movement of larval Colorado squawfish from the Yampa River to the Green River (Haynes et al. 1984; Miller et al. 1982b; Tyus and Haines 1991). Furthermore, a net upstream movement of adult and juvenile Colorado squawfish from the Green River into the Yampa River has been suggested by Miller et al. (1982b) and Tyus (1986, 1990).

Colorado squawfish larvae have been collected from the Yampa River within Dinosaur National Monument each year during the period 1980-88 (Nesler et al. 1988; Tyus and Haines 1991; Wick et al. 1981), and spawning migrations into the lower Yampa were observed in 1981-88 (Wick et al. 1983; Tyus 1990). Holden (1980) and Tyus and Karp (1989) indicated that flows from the Yampa River were important to the recruitment of Colorado squawfish in the Green River. Analysis of the hydrographs indicates that the Yampa River is the primary contributor of high spring flows in the Green River which generally exceeded 12,000 cfs at the Jensen gage. Spring flows of the Yampa River affect the timing of Colorado squawfish spawning migrations (Tyus 1990).

Reasons for Decline

Historically, the Colorado River was characterized as a river with wide seasonal flow fluctuations (Waters 1946). It was known as Rio Colorado, the great Red River of the West. Over 2,700 km (1,687 miles) long, it is cliff bound in canyons throughout much of its course. It drops over 3.2 km (2 miles) in its journey to the Gulf of California, thereby creating some of the most turbulent waters found on earth. At Lee's Ferry, Colorado River streamflows varied from 750 cfs in 1924 to an estimated 300,000 cfs in 1884 (White and Garrett 1988). Few rivers were so laden with silt. Averaging 0.62 percent silt content by volume, it formerly carried more than 100,000 acre-feet (12,000 ha-meter) of soil to the Gulf of California each year. It also is high in mineral salts: carbonates; sulfates; and chlorides of calcium, sodium, and magnesium.

The Colorado River has changed dramatically since the turn of the century. More than 20 dams have been constructed on the mainstem and tributaries since 1913. Declines of native fishes directly downstream from reservoirs are clearly related to colder water temperatures (Vanicek et al. 1970). Other, more subtle factors include changes in stream nutrients, altered seasonal and daily discharge patterns, and lowered turbidity. Nutrients that once occurred in the rivers now are retained in the phytoplankton and zooplankton populations of reservoirs. Water from the hypolimnetic layer of deep reservoirs carries far less dissolved materials and fine particulates to fertilize downstream river reaches. Sediments are trapped by reservoirs so that downstream channel bottoms transform from sand to armored cobble and boulder. Channelization below dams has reduced the number and size of backwaters and sloughs that are sought after by Colorado squawfish and other native fishes for nursery and resting areas. The natural cycle of flood and drought is replaced by stable discharges and water levels; seasonal fluctuations are replaced by variable demands for irrigation water or hydroelectric power. This combination of factors effectively eliminated Colorado squawfish and most other native species in 105 km (65.6 miles) of the Green River below Flaming Gorge Dam (Vanicek and Kramer 1969; Vanicek et al. 1970), caused vast biological modification in essentially the entire 389-km (243-mile) reach of the Colorado River mainstem in Marble and Grand canyons below Glen Canyon Dam (Carothers and Minckley 1981), and resulted in the exclusion of most warm-water fishes, both native and introduced, from long reaches of the Colorado below Davis Dam (Minckley 1979).

Specific streamflows and water temperatures are particularly important for young Colorado squawfish. Representative shallow, ephemeral backwater and shoreline habitats in the Green River have been seined from 1979-88 to determine the growth and relative abundance of larval Colorado squawfish (Tyus and Haines 1991). The lowest relative larval growth and fish abundance were observed in 1983 and 1984, and were correlated with abnormally high summer flows from Flaming Gorge Dam that inundated nursery habitat (Tyus and Haines 1991). Streamflow modifications below major Federal reservoirs are currently being evaluated by the Bureau of Reclamation and the Service to determine the relationship between flows and survival of young Colorado squawfish.

Kaeding and Osmundson (1988) provided data indicating a relationship between slow growth of Colorado squawfish in the Colorado River above Lake Powell and the limited availability of warm water temperatures to support growth. They suggested that slow growth decreases reproductive potential by lengthening the time it takes an individual to reach sexual maturity. Also, this long growth period may increase the susceptibility of young Colorado squawfish to mortality. During recent times, mortality rates have probably increased due to habitat changes and the competition by nonnative fish species.

Higher spring flows may be beneficial to Colorado squawfish and detrimental to introduced fishes. Wick et al. (1983) suggested a relationship between spring flows and fish abundance in the Yampa River. Catch rates of young squawfish in the Colorado River are lower in years of low spring flow while numbers of introduced minnows greatly increase (Osmundson and Kaeding 1989; McAda and Kaeding 1989). Higher spring flows also may provide terrestrial food for

Colorado squawfish (Tyus 1986; Tyus and Karp 1989). Minckley and Meffe (1987) reported that native fishes in the American Southwest are favored by flooding in streams. Periodic high flows in six unregulated Arizona streams reduced the number of sunfish and catfish, while native fishes were almost unaffected.

The introduction of nonnative fishes also is implicated in the decline of the Colorado squawfish. The quiet waters of the first reservoirs constructed in the Lower Basin were inhabited initially by native fishes, including Colorado squawfish. Substantial catches of Colorado squawfish were made from Roosevelt Lake from 1913 through 1937 (Frazier in Miller 1961), and mainstem reservoirs on the lower Colorado River yielded Colorado squawfish of considerable size (Dill 1944; Wallis 1951) until the 1960's (Minckley and Deacon 1968). By the time lakes Roosevelt and Mead were filled, however, impounded waters became populated by a variety of introduced species (Minckley 1973) whose range expanded rapidly as additional reservoirs were built. In Arizona, about 28 fresh-water and 3 salt-water native species have been joined since the turn of the century by at least 60 introduced fishes (Minckley 1973). Of 55 fish species currently found in the Upper Basin, 42 were introduced (Tyus et al. 1982b). In the 1960's, programs were undertaken in various locations in the Colorado River to eradicate or reduce fish populations to improve opportunities for establishment of trout. During these eradication programs numerous Colorado squawfish along with other native and nonnative fish were killed (John Hamill, U.S. Fish and Wildlife Service, 1991, pers. comm.).

Introduced fish may have subjected Colorado squawfish to biological interactions to which the latter were poorly adapted due to their previous isolation (Molles 1980). In this respect, the Colorado squawfish may be comparable to some geographically isolated island faunas that were quickly decimated by competition or predation with nonnative species (Molles 1980). Mortality as a result of Colorado squawfish choking, when preying on channel catfish, has been discussed by McAda (1983), Pimental et al. (1985), and others. The nature of interaction among native and introduced fish species is not well known. However, Karp and Tyus (1990) reported that age-0 Colorado squawfish may be negatively affected by small, nonnative fishes, particularly red shiner, flathead minnow, and green sunfish. Haines and Tyus (1990) found that age-0 Colorado squawfish were sympatric with 15 nonnative fishes, including red shiner and flathead minnow. They detected no segregation in habitat use between Colorado squawfish and nonnative fishes.

Loss of fish habitat and habitat fragmentation due to stream blockage could pose a threat to the recovery effort and has been implicated in the systematic loss of the fish. Sheldon (1988) found that alterations of river drainages by fragmentation leads to a reduction of species diversity and species extinction. In the upper Colorado River, blockage of the Gunnison and upper mainstream by diversion dams have no doubt restricted access of the fish to presumed habitats (Valdez et al. 1982a). Construction of Flaming Gorge Dam inundated spawning habitats and blocked upstream passage. Construction of Taylor Draw Dam on the White River has blocked the movement of upstream, return migrants (Martinez 1986a) and resulted in a loss of about 80 km (50 miles) of adult habitat from which mature fish contributed to the spawning aggregations in both Gray and Yampa canyons (Tyus et al. 1987). Fragmentation of the rivers in the Lower Basin undoubtedly restricted movement over much of the historic range of the Colorado squawfish.

In September 1962, the area of the Green River now impounded by Flaming Gorge Dam was treated with rotenone in order to establish more favorable conditions for game fish species. This poisoning effectively eliminated Colorado squawfish in the reservoir basin, and an accident occurred in which a small proportion of the toxic substance apparently travelled downstream past a detoxification station to the vicinity of Dinosaur National Monument. Banks (1964) noted a significant reduction in the number of species captured at four stations within Dinosaur National Monument shortly after the accidental treatment. The greatest reduction appeared to occur at the Gates of Lodore in the northern and most upstream portion of Dinosaur National Monument, while the least impact was noted at a downstream site. However, Binns et al. (1963) concluded that little long-term impact to the fish species composition had resulted from the treatment.

Colorado squawfish have disappeared from areas upstream of reservoirs (e.g., Salt River above Roosevelt Lake, Arizona; Green River above Fontenelle and Flaming Gorge dams, Wyoming; San Juan River above Navajo Reservoir, New Mexico) and in reaches that appear little changed from predevelopment conditions. Reasons for these disappearances or declines are not fully understood, but probably involve subtle changes in habitat, competition and predation from introduced species, blockage of spawning migrations, lack of suitable spawning habitat, post-dam eradication programs, and/or loss of adult fish from angling. In summary, the absolute cause for the decline of Colorado squawfish is not fully understood but is probably related to a combination of factors, including direct loss of habitat, changes in flow and temperature, blockage of migration routes, and interactions with introduced fish species.

Sensitive Areas and Priority Recovery Areas

Sensitive Areas

The Biological Subcommittee of the Upper Colorado River Coordinating Committee developed criteria and prepared a list of sensitive areas depicting the location of important spawning, nursery, juvenile, and adult habitats, both past and present, in the Upper Basin (U.S. Fish and Wildlife Service 1987) (Figure 3). The Recovery Team has adopted this report and has recommended that a similar document based on appropriate criteria be developed for the Lower Basin. Because Colorado squawfish have been extirpated from the Lower Basin, criteria would be established primarily to identify priority areas for research and recovery.

Priority Areas for Recovery

The highest priority Colorado squawfish recovery areas occur in the Upper Basin, and include, in order of importance, the Green, Colorado, and San Juan subbasins. The Green River subbasin includes the mainstem Green, Yampa, Little Snake, White, and Duchesne Rivers. The Colorado River subbasin includes the Gunnison and the Dolores Rivers, and the San Juan subbasin includes the Animas River. The Green River subbasin contains the largest and most viable population of squawfish in the Colorado River basin (Tyus 1991b). As such, the Green River and its tributaries constitute the highest priority site for recovery and maintenance of Colorado squawfish.

Fewer squawfish are found in the Colorado River. However, occurrence of adult and larval fish has been documented annually since at least 1979 (Valdez et al. 1982b). Recovery of the species in the Colorado subbasin requires the protection of the Colorado River. If stocking proves to be a successful technique, then augmentation of existing populations in the Colorado River may be necessary to provide sufficient numbers of fish for successful reproduction and effective management.

Recent studies indicate that the San Juan River contains a small, reproducing population of Colorado squawfish. This river will be especially important if recovery efforts fail on the Colorado or portions of the Green Rivers. Augmentation of existing populations of Colorado squawfish in the San Juan River also may be necessary to provide sufficient numbers of fish for successful reproduction and effective management.

Stocking of fish in the San Juan subbasin or in the Green/Upper Colorado subbasin should only be done after the genetics are documented (to determine if a number of genetically separate populations are present) and if it is determined that the current population is not viable. If there are genetically separable populations, then broodstock should be taken from the resident population and young reared for eventual reintroduction into the resident reach. However, such stocking should occur only in accordance with an integrated management and restoration plan.

The Lower Basin no longer has naturally occurring Colorado squawfish. Much of the habitat in the Lower Basin has been severely altered and contains relatively large populations of introduced fishes. Of the remaining habitat in the Lower Basin, the upper Verde and upper Salt Rivers are most pristine, and thus offer the best opportunities for reestablishment of Colorado squawfish. Colorado squawfish in those rivers have been designated nonessential experimental populations (U.S. Fish and Wildlife Service 1985). In addition, there is an active proposal by the Service to reintroduce Colorado squawfish into the mainstem Colorado River between Parker and Imperial dams and designate them a nonessential experimental population. The nonessential experimental designation allows stocked fish to be treated as threatened species. For purposes of Section 7, any experimental population occurring within a National Park or National Wildlife Refuge is treated as threatened. Outside of National Parks or National Wildlife Refuges, any experimental population is treated as a proposed species for Section 7 purposes.

Lower Basin rivers also provide opportunities to conduct valuable research and experimentation that may not be feasible or desirable in the Upper Basin. Ongoing stocking and monitoring efforts by Lower Basin researchers could lead to a better understanding of the habitat requirements, homing behavior, and factors limiting Colorado squawfish survival. These activities will add to our understanding of squawfish biology and support recovery efforts throughout the Colorado River basin.

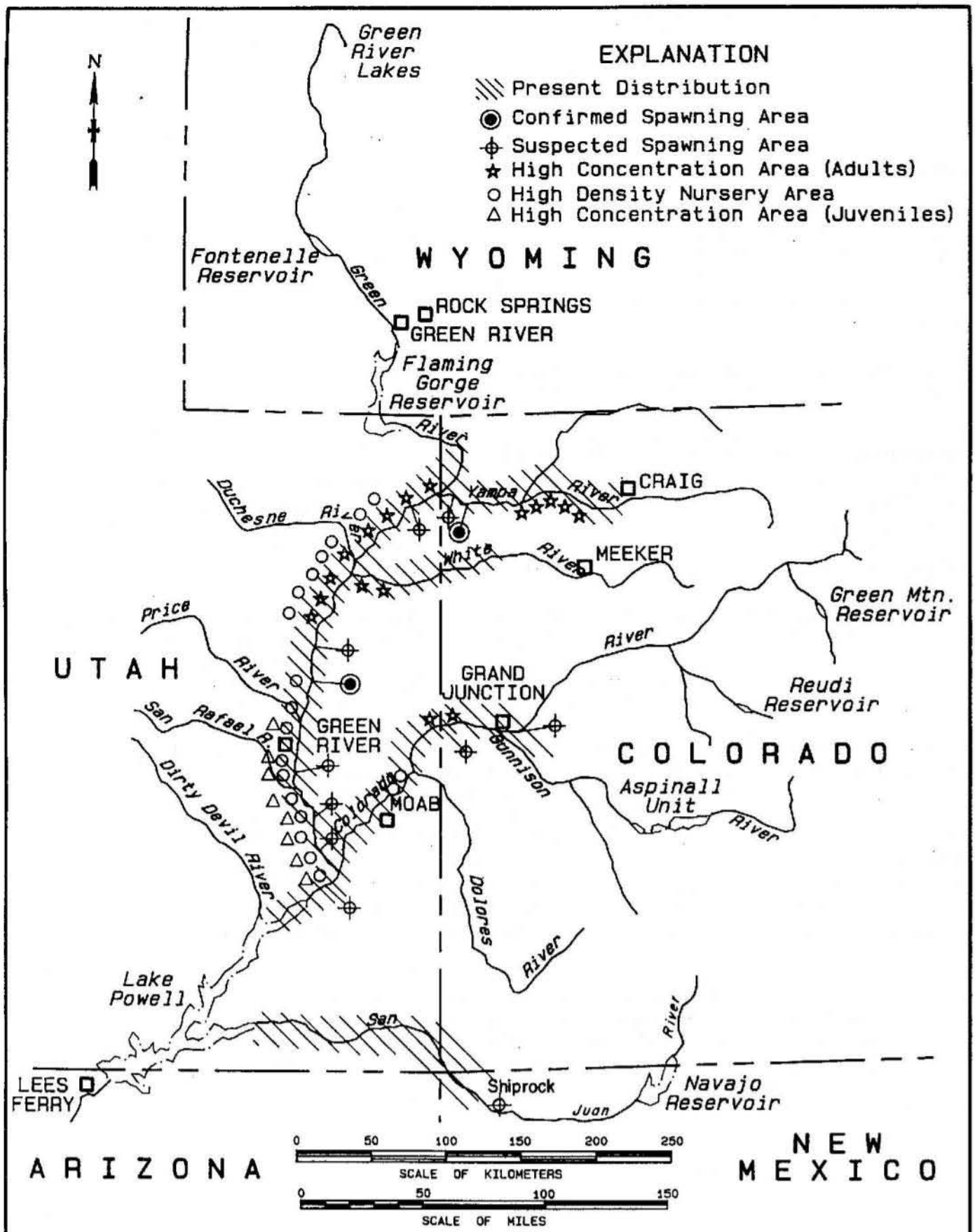


FIGURE 3. Colorado Squawfish sensitive areas identified by the Upper Colorado River Coordinating Committee (1987). (San Juan River information provided by Utah and New Mexico.)