COLORADO SQUAWFISH, *Ptychocheilus lucius*

RECOVERY PLAN

Prepared by the Colorado River Fishes Recovery Team

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All Members Listed in Acknowledgments

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

Approved: ______________________________
Director, U.S. Fish and Wildlife Service

Date: ______________________________

COLORADO SQUAWFISH

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This Colorado Squawfish Recovery Plan has been approved by the U.S. Fish and Wildlife Service. It does not necessarily represent official positions or approvals of cooperating agencies, or views of recovery team members, who contributed to its preparation. This plan is subject to modification as required by new findings, changes in species status and completion of tasks described in the plan. The recovery goals and objectives will be attained and funds expended contingent upon appropriations, priorities, and other constraints.

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PREFACE

The recovery plan was written by the Colorado Fishes Recovery Team composed of representatives from Federal and State agencies with consultants from universities and private enterprise. Funding was furnished by the U.S. Fish and Wildlife Service. The final version of the plan was modified by the U.S. Fish and Wildlife Service to reflect realistic recovery activities that are influenced by constraints of time, money, personnel, and other endangered species priorities in Region 6.

The Colorado Squawfish Recovery Plan summarizes available information on this fish including the description, distribution and abundance, life history and reason for its decline. It also outlines a stepdown recovery plan and narrative of actions believed to be necessary to reduce the threat of extinction.

The implementation schedule includes estimated costs (1987 values) for accomplishing actions described in the recovery plan. The schedule also identifies cooperating agencies and organizations that will conduct studies or recovery activities and the proposed dates for accomplishing these activities.

ACKNOWLEDGEMENTS

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

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Numerous other persons provided information for the preparation and review of this plan.

TABLE OF CONTENTS

INTRODUCTION

Background

The Colorado squawfish (*Ptychocheilus lucius*) is the largest of four living species of this genus. The genus *Ptychocheilus* is known through fossil records to Micene (Minckley et al. 1985). Although the specific name *lucius* means "pike," the Colorado squawfish belongs to the large and diverse minnow family Cyprinidae, and is the largest cyprinid in North America (Miller 1961). It is a voracious predator and the top carnivore of the Colorado River system. Maximum weights exceeding 36 kg, and lengths of nearly 1.8 m have been recorded; however, specimens weighing more than 7 kg have been rare in recent times (Behnke and Benson 1980). Their substantial size and migratory habitats won for them the vernacular name of "white salmon of the Colorado," and they were commonly called "salmon" or "whitefish" in early literature.

Other members of the genus *Ptychocheilus* include P. grandis, of the Sacramento-San Joaguin, Pajaro, Salinas, and Russian Rivers in California, P. *oregonensis,* from the Columbia River basin in Oregon, Washington, Idaho, and Montana, north to the Nass River, British Columbia, and P. *umoaquae,* found in the Umpqua and Suislaw Rivers in Oregon (Lee st al. 1980). The Colorado squawfish has been defamed by association with its abundant and predatory relatives to the point that mention of control efforts have included all species (Everhart and Sedman 1971) even though no control of Colorado squawfish has ever been necessary. Recent information provided by Brown and Moyle (1981) has cast doubts on the need for any control of Ptychocheilus spp., since they found little evidence to indicate strong interaction with salmonids, especially in streams. Brown and Moyle (1981) indicated that squawfish "control" is perhaps detrimental, and that problems causing "unbalanced" fish populations are usually due to man-induced environmental changes and not from squawfish competition or predation.

Evidence that Colorado squawfish migrate only in parts of the range where spawning habitat is limited supports M.L. Smith's (1981) theory that the early evolutionary background of the genus Ptychocheilus allowed P. lucius to adjust its life strategy to accommodate variables in the aquatic environment. Ptychocheilus was adapted to swift water by the mid-Pliocene (Uyeno and Miller 1965), but fossil evidence indicates that it used lakes as well as rivers (Smith 1975, G. Smith 1981, M. Smith 1981). The evolutionary history of Ptychocheilus has been marked by scores of oscillations between pluvial- and aridity-dominated habitats caused by climatic fluctuations during the Pliocene and early Pleistocene (G. Smith 1981). This suggests that Ptychocheilus would have developed the capability to exploit lakes or rivers depending on prevailing climatic conditions (Tyus 1985b). 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).

The Colorado squawfish (*Ptychocheilus lucius*) was listed as endangered by the U. S. Fish and Wildlife Service (FWS) 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 occurred upon its listing in the *Federal Register* (Vol. 39(3):1175) on January 4, 1974.

General Description

The Colorado squawfish is and elongated fish, with a dorsoventrally compressed pike-like body and a long, flattened head. The mouth is large and nearly horizontal, with a pharyngeal tooth formula of 2,5-4,2, and long, slender gill arches and adapted for grasping prey. The dorsal fin has nine rays and lies posteriorly on the body with an origin slightly behind 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 that become lighter along the sides and culminates in a white belly. The young usually have a dark, wedge-shaped spot at the insertion of the caudal fin.

Distribution and Abundance

Historic Distribution

The Colorado squawfish is endemic to the Colorado River basin (Fig. 1). Early records indicate they were abundant throughout the mainstem, most of the major tributaries of the Colorado River and in the Colorado River delta in Mexico. Specific localities included:

1. Colorado - Colorado River and lower reaches of the Gunnison, White, Yampa, Dolores, San Juan, Uncompahgre, and Animas Rivers (Jordan 1891; Ellis 1914; Lemons 1954; Johnson 1976).

2. Utah - Colorado and Green, San Juan, White, Dolores Rivers and probably numerous smaller streams (Holden 1973; Seethaler 1978).

3. New Mexico - San Juan and Animas Rivers (Koster 1957; Conway 1975).

map page

4. Arizona - Gila River and its tributaries, the San Pedro, Salt, and Verde Rivers; throughout the Colorado River mainstem from the Mexican border to Lake Powell (Minckley 1973).

5. Nevada - Only in the Colorado River mainstem (La Rivers 1962).

6. California - Mainstem Colorado River from the U.S.-Mexico border to the Nevada State line, and in the Salton Sea when sporadically filled with Colorado River water (Minckley 1973; Moyle 1976).

7. Mexico - Sonora and Baja del Norte - In the mainstem Colorado River and its distributaries and sloughs from the U.S.-Mexico Boundary to the Gulf of California estuary (Follett 1961; Minckley 1979).

An indication of the prior abundance of Colorado squawfish was their use as animal food and fertilizer when they became stranded in drainage ditches in western and central Arizona (Miller 1961; Minckley 1973), and a widespread and favorable reputation as a food and game fish (Ellis 1914, Dill 1944, Carhart 1950; Rostlund 1952; LaRivers 1962, Sigler and Miller 1963; Minckley 1965, 1973). Testimony of longtime residents from Colorado to Arizona indicates the Colorado squawfish were well known to early settlers.

Present Distribution and Abundance

The present range of the Colorado squawfish is restricted to the upper Colorado River system in Colorado and Utah (Fig. 1). Recent investigators have found adults, juveniles and young in the Green River from the mouth of the Yampa River to its confluence with the Colorado (Holden 1978; Tyus et al. 1982a; Archer et al. 1984, Valdez 1985), and at a spawning site located in Gray Canyon of the Green River in 1982 and 1983. Adults were found in the lower 199 km of the Yampa River and in Lodore Canyon of the Green River (Tyus et al. 1982a), and larvae were identified from the Yampa River in Dinosaur National Monument as far as 30 km above the Yampa-Green River confluence (Wick et al. 1981). Spawning was specifically detected for the first time in nature in the lower 32 km of the Yaw River in 1981 (Miller et al. 1982b, 1983; Tyus et al. 1982b), and was studied at that locale in 1982 (Wick et al. 1983) and 1983 (Archer et al. 1984).

Colorado squawfish also were reported in the White River in Utah and Colorado (Prewitt et al. 1978; Wick et al. 1979, 1981; Lanigan and Berry 1981; Miller st al. 1982b; Radant et al. 1983). A total of 41 Colorado squawfish were captured and an additional 21 specimens were sighted but not captured using electrofishing during pre-and post-impoundment studies (1983-1985) in the 125-mile reach of the White River between Rio Blanco Reservoir and the Colorado-Utah State line (River Kilometers 71.8 to 243.0) (Martinez 1986). Forty-three (69 percent) of the 62 squawfish were observed within the 10 miles below the dam (between Taylor Draw and Rangely. The maximum distance upstream in the

White River that Colorado squawfish have been collected was River Kilometer 243 where two adults were captured in May 1977 (Carlson et al. 1979). Fisherman caught Colorado squawfish in the Duchesne River at the mouth of Uinta River in 1975 (Seethaler 1978), and a specimen implanted with a radio transmitter ascended the Duchesne River in 1980 (Tyus et al. 1981), where several others were observed. An investigation of the Green River in Wyoming above Flaming Gorge Dam and the Little Snake River in 1986 failed to produce any Colorado squawfish. These findings supporting the belief that this species has been extirpated from this reach of Green River (Johnson and Oberholtzen 1987).

In the lower basin, Miller and Lowe (1964), and Minckley and Deacon (1968) considered Colorado squawfish as 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 squawfish have been taken from the Gila River basin since 1950 (Miller 1961); the 1958 record of this species from the Salt River, Arizona (Branson et al. 1966), was based on misidentified roundtail chubs, Gila robusta (R. R. Miller, pers. comm.). The last specimen of adult squawfish from the mainstream Colorado River known to Minckley and Deacon (1968) were taken by a fisherman in 1967.

Adult and young Colorado squawfish still are in Lake Powell (Minckley 1973; Wick et al. 1981; Valdez et al. 1982; Miller et al. 1984). Valdez (1985) reports both adult and juvenile squawfish from Cataract Canyon at the inlet of Lake Powell, indicating that this species is reproducing in that reach. Researchers studying striped bass in 1980 captured adult squawfish in the riverine portion of the reservoir (Persons and Bulkley 1982). A radiotelemetry study, funded by Bureau of Reclamation (BR), is being conducted to investigate the movements of Colorado squawfish in that area. A single young squawfish was also captured in the San Juan River just below the confluence of McElmo Creek near Aneth, Utah, in 1978 (VTN Consolidated, Inc. 1978; Minckley and Carothers 198(J), indicating a possible population in the lowermost San Juan River system.

Li fe Hi story

Several workers have presented information on the biology of the Colorado squawfish: Vanicek and Kramer (1969); Minckley (1973); Stalnaker and Holden (1973; Toney (1974); Holden (1973, 1975, 1978); Joseph et al. (1977); Hamman (1981); Holden and Wick (1982); Seethaler (1978); Wick et al. (1981); Tyus (1983, 1984); Tyus et al. (1981, 1982a,b,c, 1983, 1984); Miller et al. (1982a,b, 1983, 1984); Valdez et al.(1981, 1982). The above references are discussed in detail in the following sections, as appropriate.

Habitat Preferences

Colorado squawfish are adapted to a river known for its variable flow, high silt loads and turbulence. Young-of-the-year (up to 64 mm total length [TL]), juveniles (65-200 mm) and subadults (200-400 mm) live in shallow backwater areas with little or no currents over silt and sand bottoms (Holden 1973, 1975, 1978; Wick et al. 1979, 1981; Holden and Twedt 1980; Miller et al. 1982a,b; Tyus et al. 1982c; Valdez et al. 1982). There is a change in habitat preferences at about 200 mm TL (Miller et al. 1982a), with larger fish selecting deeper water with at least some velocity or flow. It is assumed this is associated with feeding, since Vanicek and Kramer (1969) indicated the Colorado squawfish became piscivores at this size. Adults are large-river fish, found in a variety of depths and velocities over silt, sand, gravel and boulder substrates (Holden 1978; Holden and Wick 1982; Wick et al. 1979, 1981; Holden and Twedt 1980; Miller st al. 1982a,b; Tyus et al 1982a, 1984; Valdez et al. 1982). Young-of-the-year and juvenile Colorado squawfish inhabit backwaters, eddies, or shoreline areas with little water velocity and silt substrates (Holden 1973; Miller et al. 1982C; Tyus, McAda and Burdick 1982).

There may be substantial changes in habitat preferences with changing seasons (Holden and Wick 1982), and radiotelemetry studies (Tyus et al. 1981, 1984; Miller 1983) have provided considerable information on habitat preferences of adults. Adult Colorado squawfish use various habitats that are dependent on season, streamflows, water temperature, and perhaps habitat availability (Tyus and McAda 1984; Wick, Stoneburner, and Hawkins 1983; Wick, Hawkins, and Carlson 1985, 1986). During peak runoff, adult squawfish move into backwater areas or flooded riparian areas where water velocity is lower and water velocity is lower and water temperatures are higher (Wick, Stoneburner, and Hawkins 1983). After runoff subsides, the adult fish move to run--riffle areas--associated with spawning. Following spawning, adults occupy deeper pool reaches where they feed and overwinter.

The best habitat for Colorado squawfish in the Upper Colorado River Basin consists of the Green River below the confluence with the Yampa River, the Yampa River below Craig, Colorado, the White River from Taylor Draw Dam near Rangely downstream to the confluence with the Green River, and mainstem Colorado River downstream to Lake Powell (Archer et al. 1985; Holden and Wick 1982; Tyus et al. 1982; Wick et al. 1985; Wick et al. 1986).

Temperature Preference

Field studies on habitat selection have not established temperature preferences for Colorado squawfish in nature. The fish tends to be displaced by cold tailwaters of dams, as indicated downstream from Flaming Gorge Dam, where colder water temperatures after impoundment were almost certainly the major factor in the loss of native fishes (Vanicek and Kramer 1969). Considering the diversity of habitats formerly occupied by the species, thermal tolerance limits must be quite broad, and perhaps variable throughout the basin. Summer water temperatures in the vicinity of Yuma, Arizona, for example, commonly approach or exceed 35° C, and rarely drop to lower than 10° C in winter (Minckley 1979). In the upper basin, water temperatures may rarely exceed 22° C and freezing conditions are common in winter.

Temperature preferences have been determined in the laboratory for hatchery-reared Colorado squawfish from Willow Beach National Fish Hatchery, Arizona. Juvenile Colorado squawfish acclimated to 20°C preferred a higher temperature (26.6°C) than fish acclimated to either 26°C or 14°C. Fish acclimated at 26°C selected 23.7°C and those acclimated at 14°C selected 21.9°C. Adults selected temperatures ranging from 21.5°to 25.7°C, with best estimate of a final temperature preference of 25.4°C. (Bulkley et al. 1982). Optimum growth of 45-100 mm TL Colorado squawfish occurred at 25°C while growth at 20 and 30°C and was 50 percent of the optimum (Black and Bulkley 1985).

Reproduction and Migration

Wild Colorado squawfish do not mature until they reach 400 mm total length and attain an age of 6 years (Seethaler 1978). Hatchery-reared Colorado squawfish mature at Age V for males and Age VI for females (Haman 1981).

Based on back-calculated ages of squawfish larvae that was correlated with water temperature records, spawning of Colorado squawfish occurs between late June and mid-August when water temperatures are between 18 and 25°C with the peak spawning activity occurring between 22-25°C (Archer et al. 1985; Haynes et al. 1985).

Colorado squawfish gonads mature during the high spring runoff (May-June). Laboratory and field studies indicate that spawning begins when water temperatures reach 21°C (Vanicek and Kramer 1969; Toney 1974; Haman 1981, Miller et al. 1982a). The species was first successfully propagated at Willow Beach National Fish Hatchery in 1974, and progeny have since been obtained from both artificial and natural spawning (Toney 1974; Hamman 1981). Males retained for broodstock from the 1974 year class matured sexually at 5-years of age and females at 6-years of age. Wild Colorado squawfish obtained from the Green and Colorado rivers in autumn 1979 spawned over filter gravel in raceways. Some of these fish matured naturally and some with injection of pituitary extract (Hamman 1981). Wild-caught and hatchery produced broodstock at Dexter National Fish Hatchery spawn in May and June after pituitary injection; production of young is limited only by physical constraints of the facility for holding and growing young to sizes acceptable for stocking or other uses.

Radiotelemetry studies and collections of spawning fish have added to the knowledge of Colorado squawfish spawning activities and seasonal movements (Radant et al. 1983; Wick et al. 1983,; Archer et al. 1984; Miller et al. 1984a). During the spawning season, adult squawfish may migrate up to 320 km, up- or downstream, to reach restricted spawning areas in the Green River basin (Tyus et al. 1982a; Miller et al. 1983). A definite homing behavior has been documented for some Colorado squawfish in the Green and Yampa Rivers (Tyus 1985; Wick, Hawkins, and Carlson 1986; Wick, Stoneburner, and Hawkins 1983). However, the repeated use of the same spawning areas (i.e., homing) by Colorado squawfish may reflect a limited availability of spawning habitats rather than true homing (Archer et al. 1985). In addition, not all adult squawfish exhibit migratory behavior associated with spawning -- perhaps because they are immature (Tyus and McAda 1984; Wick, Stoneburner, and Hawkins 1983) or they do not spawn every year (Wick, Stoneburner, and Hawkins 1984).

Radiotelemetry studies suggest that spawning areas may be limited in the Green River basin, with only two major sites identified: 1) the lower 32 km of Yampa River canyon; and 2) Gray Canyon of Green River. Radiotelemetry, collections of ripe fish and recaptures have confirmed long distance migration to these locales, sometimes of 100 km or more, both up- and downstream. Sixteen adult squawfish were radiotracked in 1981 and 1983 by FWS personnel (Tyus et al. 1982b; Archer et al. 1984) and five were tracked by NPS-CDOW workers in 1982 (Wick et al. 1983). All moved to the lowermost 32 km of the Yampa River in July of each year. Collections made on suspected spawning grounds in 1981 and 1983 produced 51 ripe Colorado squawfish. In 1982, 18 ripe fish were collected from the same localities. Recaptures in 1981 and 1983 included fish originally tagged downstream in the Green River, one of which had traveled more than 100 km upstream. In 1982, a fish tagged in 1981 at RK219 in the White River was recaptured in the Yampa. Recaptured of two fish originally tagged in this reach of the Yampa River in 1981 and 1982 (Tyus 1983), indicate a fidelity to this area. It is likely that this spawning aggregation is historic, since Holden and Stalnaker (1975) 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 by larval Colorado squawfish 9 to 13 mm TL larvae were taken below RK32 on the Yampa in 1980, 1981, and 1982, and below RK40 in 1983 (Haynes 1983); however, none has been collected upstream from these points. Although turbidity precluded direct observation of spawning behavior, radiotracking and collections from the area suggested that is it similar to that of the northern squawfish (Patten and Rodman 1969; Beamesderfer and Cogleton 1981).

Another spawning migration of squawfish to Gray Canyon of the Green River was confirmed in 1983. The area became suspect in 1981 when a squawfish implanted in the White River (Radant et al. 1982) moved to the general locale. In 1982 and 1983, six additional squawfish were tracked to the locality, and 19 ripe fish were collected there.

Studies in 1982-83 in the Colorado River mainstream also indicate movement of adult squawfish between the Black Rocks reach and upstream reaches may be related to spawning. These movement patterns have not, however, been as dramatic as those in the Green River basin with fish generally moving less than 40 miles (Archer et al. 1985).

Two reaches of the Colorado River contained suspected spawning areas; Clifton to Grand Junction RM 180-160; and Loma to Black Rocks RM 145-135 (Archer et al. 1985). Several other sites may be used by Colorado squawfish because aggregations of larval squawfish were found and suitable habitat for spawning was observed immediately upstream from the Dolores River (RM 115-100), Professor Valley (RM 85-75), and near Cataract Canyon (RM202-198) (Archer et al. 1985; Valdez 1985, 1986).

The importance of larval drift in the life cycle of the Colorado squawfish is not clearly understood. Larval Colorado squawfish appear to drift downstream upon hatching in the Green and Yampa Rivers, and rear in different reaches of the rivers from where spawning actually occurs (Haynes et al. 1985; Tyus et al. 1982). However, the similarities between distribution of larval and post-larval squawfish in the Colorado River suggest that little larval drift occurs between spawning and rearing areas (Archer et al. 1985; Valdez 1985).

The most important rearing area for the Colorado squawfish in the Colorado River is between Moab, Utah, and the confluence with the Green River - River Miles 0-60 (Archer et al. 1985). Other nursery areas for the squawfish are located immediately downstream from the Dolores River (RM 70-80), between the confluence with Dolores River upstream to Westwater Canyon (RM 140-150), and immediately downstream from the confluence with the Gunnison River (RM 160-170). Although only 2.6 percent of 1,322 collections from the mainstem Colorado and Yampa Rivers a total of 171 squawfish larvae were collected in the lowermost 31 kn of the Colorado River in Colorado to the Utah State line and in the lowermost 29 km of the Yampa River (Haynes et al. 1984). No larval squawfish were found in either the White or Gunnison Rivers.

More than 96,000 fingerling and 442 larger Colorado squawfish 355-405 mm 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 additional fish of the larger size group were captured about 5 months after stocking. No squawfish were captured on two other sampling trips. The Arizona Game and Fish Department received an unverified report of a single squawfish that was taken by an angler about 3 months after stocking. These preliminary data indicated larger squawfish (greater than 355 mm TL) survived for at least 5 months and may become reestablished if existing riverine conditions and maintained.

Growth

As with most fish species, Colorado squawfish growth rates are variable and dependent upon water temperature, food, water quality, age, and numerous other parameters. Vanicek and Kramer (1969) calculated mean total lengths for 182 Colorado squawfish from the upper Green River, Utah. The fish ranged in estimated age from I to XI, and the mean back-calculated length at annmlus formation was: 1=44 mm, 11=95 mm, 111=162 mm, IV=238 mm, V-320 mm, VI=391 mm, VIII=499 mm, X=600 mm. Seethaler (1978) found similar growth rates in both the Green and Colorado Rivers. At Willow Beach National Fish Hatchery, Colorado squawfish hatched in summer of 1980 doubled their length in 14 days and attained a size of 48-50 mm in 110 days (Haman 1981). Growth of broodstock held Willow Beach National Fish Hatchery in 1973 and 1974 was slow. Seven adult fish gained a total of only 0.64 kg over a 9-month period after having been fed 40.8 kg of live fingerling trout (Toney 1974). Length-weight relationships of these fish was similar to that reported for wild fish by Vanicek and Kramer (1969) and Seethaler (1978).

Colorado squawfish stocked as 50-91 mm TL fingerlings grew to 185-304 mm TL in one grow-out pond along the Colorado River (Osmundson 1986). This same size was attained by wild squawfish in the adjacent river in about 4 years. The difference in growth was attributed to warmer water temperatures in the pond that produced about 1.8 times the degree-days than the river. The growth was less and more variable in other ponds in the same area that was probably due to the variation in limnocharis (e.g., water temperature, food abundance by time, size of the food items, etc.).

Food Habits

The food of young Colorado squawfish consist mainly of zooplankton and insect larvae. Fry at Willow Beach National Fish Hatchery fed on zooplankton in fertilized raceways (Hamman 1981). When Colorado squawfish are about 60 mm long, they begin to feed on fish (Jacobi and Jacobi 1982c); fish comprised nearly 86 percent of the diet of juvenile Colorado squawfish (22 to 59 mm IL) with the major prey being the red shiner, Notropis lutrensis (Jacobi and Jacobi 1982). By 200 cm TL, the diet of Colorado squawfish is almost exclusively fish (Vanicek and Kramer 1969). Adult Colorado squawfish are entirely piscivorous and feed on most native fishes and many introduced fishes present in the river. Nonnative fish have probably entered their diet more frequently as the native fish have declined (Holden and Wick 1982).

Cultural, Economic, and Biological Importance

The Colorado squawfish was an important food source in the past. Indians used them as food along the lower Colorado River and its larger tributaries in Arizona (Rostlund 1952; Miller 1955, 1961; Minckley and Alger 1968, Minckley 1965, 1973, 1976). Jordan (1891) identified Colorado squawfish as the largest and best food fish of the lower Colorado River. Commercial fisherman operated on the lower Salt River from time of settlement until about 1910 and within the Salt River Canyon until the 1930's, at least, and perhaps longer (Chamberlain 1904; Minckley 1965). The species was widely sought by fisherman in the Gila River at Some (Richardson, in Miller 1961), in the Salt River Canyon (Dammann, in Minckley 1965), in the Gila River near Safford (Chamberlain 1904) and in Roosevelt Lake (Frazier, in Miller 1961), prior to its precipitous decline in the period 1930-50. Individuals weighing 2.7 to 15.4 kg were commonly caught along the lower Colorado River prior to 1949 (Moiffett 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 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 and the common name was derived from the size, appearance and palatibility of the species, as well as its tendency to move upstream in spring.

.Wick et al . 1981; Miller (1961) and others (e.g., Behnke 1982; Wydoski 1976) reported that Colorado squawfish may have a substantial sportfishing potential. The Colorado squawfish attains a large size (+36 kg), takes artificial lures readily, and has been reported as "good-eating" in the Cawly literature. The State of Arizona plans to reintroduce and manage Colorado squawfish for sportfishing in the Salt River. When reintroduction is assured and the species is reclassified to threatened, special rules will need to be formulated to allow Colorado squawfish to be taken in accordance with applicable State laws.

The proposed fishery management plan for Kenney Reservoir on the White River in Colorado includes development of a sportfishery for Colorado squawfish (Martinez 1986).

Importance of Tributaries

Tributaries of the Green and Colorado Rivers may be more important to the continued survival of the Colorado squawfish than earlier believed. The section on Distribution and Abundance pointed out records of Colorado squawfish captures in tributaries of the Green and Colorado Rivers including the Yampa, Duchesne, White, Gunnison, and Dolores Rivers. Tagging and telemetry studies indicate the Colorado squawfish may move long distances, between the mainstem Green River to feed and overwinter in the Yampa, White, and Duchesne Rivers (Miller et al. 1982(a,b); 1983; Tyus et al. 1981, 1982(a,b); 1983; Radant et al. 1982).

Work by the FWS indicated that tributary streams may be a sensitive link in Colorado squawfish life history. Miller et al. (1982a) reported a net movement of juveniles from the Green to the White River, while Radant et al. (1983) documented the movement of adult fish between the White and Green Rivers and Green and Yampa Rivers during the spawning season. There is also a downstream movement of larval Colorado squawfish from the Yampa to the Green River (Tyus et al. 1982a; Miller et al. 1982b; Haynes and Muth 1983). Furthermore, a net upstream movement of adult Colorado squawfish from the Green into the Yampa River has been suggested (Miller 1982b).

Colorado squawfish larvae have been collected in Dinosaur National Monument during four successive years, 1980, 1981, 1982, and 1983 (Wick et al. 1981; Miller et al. 1984a). A spawning migration was observed into the lower Yampa in 1981 (Miller et al. 1982b; Tyus 1982a), 1982 (Wick et al. 1983) and 1983, (Archer et al. 1984; Tyus 1983). Holden (1980) stated that flows from the Yampa River were important to Colorado squawfish reproductive success in downstream areas of the Green River. He also noted that during 1977, a year of low flow in the Yampa, young-of-the-year Colorado squawfish were not collected in nursery areas below Jensen, Utah, where they were collected during more "normal" water years (1975, 1976, 1978, 1979). This information suggests that the fate of the Yampa River and other tributaries may determine the fate of the Colorado squawfish in the Green River system. These findings are especially important in light of proposed development on Upper Basin tributaries which could lead to extirpation of Colorado squawfish from these tributaries.

Reasons for Decline

The absolute cause for the decline of Colorado squawfish is unknown, but is probably related to a combination of factors, including: direct loss of habitat, changes in flow regimen, blockage of migration routes, temperature changes, interactions with introduced fish species, and others.

The Colorado squawfish exists today in a basin that has been greatly altered from its historic condition. Historically, the Colorado River was savage and unpredictable (Waters 1946), known simply by its one unchanging color--Rio Colorado, the great Red River of the West. Twenty-seven hundred kilometer (1,700 miles) long, it is cliffbound in canyons nine-tenths of the way. It drops over 3.2 km in its journey to the Gulf of California, creating some of the most turbulent waters found on earth. Its volume is unpredictable. It can crawl past Yuma, Arizona, at a mere 3,000 cfs (5,000 cubic meters per minute) or roar by during spring flood at 380,000 cfs (64,500 cubic meters per minute). Few rivers are so choked with silt. Averaging 0.62 percent silt content by volume, it formerly carried over 100,000 acre-feet 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. In fact, it is so high in salts that it was long questioned whether it could safely be used for drinking water or even irrigation.

The Colorado River was a harsh environment for any living thing, and the fish that evolved in its muddy, turbulent waters are unique. Some formed strangely modified backs, e.g., humpback chub (Gila cypha) and razorback sucker (Xyrauchen texanus); while others developed thin caudal peduncles, tiny scales, and large, falcate fins, e.g., bonytail chub (Gila elegans), all unique adaptations to a demanding environment. At the top of the trophic pyramid, the Colorado squawfish was the top carnivore of the system. Adapted to survive in this strange world of humpbacked fish and dynamic environmental conditions, the Colorado squawfish preyed on these and the other uniquely adapted fish.

The river's character has changed dramatically since the turn of the century. Over 20 dams have been constructed on the mainstem and tributaries since 1913. In the lower basin, these dams now form a series of reservoirs connected by clear, cold-water trout streams. Stable environments created by impoundments create excellent habitat for a variety of introduced game and forage fishes. These nonnative species thrive in reservoirs and some streams, providing biological pressures (i.e., predation and competition) on populations of native fishes already stressed by physical and chemical changes in the environment.

Declines of native fishes below reservoirs clearly is related to alterations in water temperatures. Other, more subtle factors include changes in nutrient relations of the streams, altered seasonal and daily discharge patterns and lowered turbidities. Nutrients that once occurred in the rivers now are tied up in phytoplankton and zooplankton populations of reservoirs and become deposited in quiet depths of reservoirs. Water passing from hypolimnion layers of deep lakes carries far less dissolved materials and fine particulates to fertilize downstream systems. Sediments also are trapped by reservoirs. Erosion of the river channel is enhanced downstream of dams by higher competence of clear water; channel bottoms are changed from shifting sand to armored cobble and boulder. Incision of channels below dams, accompanied by man's channelization activities, reduces the numbers and sizes of backwaters and sloughs used by Colorado squawfish and other native fishes for nursery and resting areas. The natural cycle of flood and drought are thus replaced with stabile discharges and water levels; seasonality of variations has been replaced by periodicity of demands for irrigation water or hydroelectric power. This combination of factors effectively eliminated Colorado squawfish and most other native species in 105 km of the Green River below Flaming Gorge Dam (Stalnaker and Holden 1973; Holden 1980), caused vast faunal modifications in essentially the entire 389-km reach of the Colorado River mainstem in Marble and Grand Canyons below Glen Canyon Dam (Carothers and Minckley 1981) and have excluded most warm-water species of fishes, both native and introduced, from long sections of the Colorado below Davis Dam (Minckley 1979).

Specific streamflows and water temperatures are especially important to survival of Colorado squawfish larvae. During high flow years of 1983 and 1984 in the Green River, squawfish recruitment was negligible (Archer et al. 1985). The Age-0 squawfish only grew to about 25 mm TL by October during those years. The survival of these small fish because of the reduced growth with lower water temperature is probably low (Kaeding, Osmundson, and Berry 1985). However, the high flows were believed to be beneficial to the Colorado squawfish in the Yampa River (Haynes and Muth 1982; Haynes et al. 1984; Wick, Stoneburner, and Hawkins 1983) and detrimental to nonnative fishes. Minckley and Meffe (1987) reported that native fishes in the American Southwest are favored by flooding in streams. In another study, Meffe (1984) reported that periodic, high flows in six unregulated Arizona streams reduced the number of predatory sunfishes and catfishes while native fishes were little affected. Streamflow manipulation will be used to determine the relation between flow and survival of young Colorado squawfish as part of the recovery implementation program for the rare Colorado River fishes (U.S. Fish and Wildlife Service 1986).

Quiet waters of the first few reservoirs constructed in the lower basin were initially inhabited by native fishes, including Colorado squawfish. Substantial catches of squawfish were made from Roosevelt Lake from 1913 through 1937 (Frazier, in Miller 1961), and mainstem reservoirs on the lower Colorado River yielded squawfish of considerable size (Dill 1944; Wallis 1951) until the 1960s (Minckley and Deacon 1968). By the time all but lakes Roosevelt and Meade were filled, however, impounded waters became populated by a variety of introduced species. Top predators such as large- and smallmouth basses (Micropterus salmides, M. dolomieui), bluegill, redear, green and warmouth sunfishes (Lepomis macrochirus, L. microlophus, L. cyanellus, L. gulosus), striped and yellow basses (Morone saxatilis, M. mississippiensis), yellow perch and walleye (Perca flavescens, Stizostedion vitreum), and channel and flathead catfish (Ictalurus punctatus, Pylodictis olivaris), plus potential competitors such as the prolific threadfin shad (Dorosoma petenense), African cichlids (Sarotherodon mossambica, S. aurea, and others) and red and redside shiners (Notropis lutrensis, Richardsonius balteatus) now are abundant in the system. Many populations of these species expanded rapidly as additional reservoirs came online. In the lower basin, about 25 native species in Arizona have been joined by at least 60 introduced fishes since the turn of the century (Minckley 1973). Of 55 fish species in the upper basin, 42 are introduced (Tyus et al. 1982c). Loading of the system with introduced fishes, a large proportion of them predatory, must have subjected Colorado squawfish to biological interactions to which they were poorly adapted due to their long, previous isolation. In this respect, the Colorado squawfish may be similar to some geographically isolated island faunas that were quickly decimated by competition or predation with nonnative species (Molles 1980). Native species that evolved in harsh environment provided by the Rio Colorado appear ill-adapted to these newly created environments, and to interactions with nonnative fish species.

Colorado squawfish have, however, also disappeared in rivers upstream from reservoirs (e.g., Salt River above Roosevelt Lake, Arizona; Green River above Flaming Gorge, Wyoming; San Juan River above Navajo Reservoir, New Mexico), in reaches that appear scarcely changed from predevelopment conditions. Reasons for this are not fully understood. Subtle changes in habitat related to impacts of introduced predatory species is an option now favored by many fisheries biologists. Recent studies cited above may, however, help to clarify relationships between construction of dams and loss of Colorado squawfish from the system by indicating a requirement for large segments of free-flowing river. If such requirements prove true, blockage of long-distance spawning migrations of adults and interruption of downstream drift of larvae could eliminate the species from its remaining natural range.

Below reservoirs, native fish declines are more clearly understood (Vanicek and Kramer 1969; Seethaler 1978). In these areas, streams undergo an altered water temperature regime, a reduction of mean water temperatures, altered seasonal and daily flow patterns, lowered turbidity, and stocking of nonnative fishes. These changes have effectively eliminated Colorado squawfish in (105 km) of the Green River below Flaming Gorge Dam (Holden 1980).

PART II. RECOVERY

Objective - The Colorado squawfish will be considered eligible for reclassification to threatened when naturally self-sustaining populations are maintained in the upper Colorado River basin and further fragmentation of the existing population is prevented. This includes at least the following as primary habitat:

(a) The Green River from its confluence with the Colorado River to Echo Park;

(b) the lower 240 km of the Yampa River;

(c) the lower 240 km of the White River*;

(d) the Colorado River from Palisade to Lake Powell.

The Colorado squawfish will be considered eligible for downlisting in the lower Colorado River basin when criteria are met for downlisting in the upper Colorado River basin.

The Colorado squawfish will be considered eligible for delisting in the upper Colorado River basin when: (a) downlisting criteria have been met, (b) primary essential habitats, migration routes, river flow and water quality parameters are legally protected, and (c) criteria for delisting in the lower Colorado River Basin are met. The Colorado squawfish will be considered eligible for delisting in the lower Colorado River basin when: (a) naturally self-sustaining populations of squawfish are established in three lower basin areas and the habitats in which they are surviving are legally protected, or (b) reintroduction efforts (over a period of 10 years) fail and it is determined that suitable habitat no longer exists in the lower basin (the FWS may then declare the Colorado squawfish extinct in the lower Colorado River basin).

* The White River was recently (1984) impounded by the Taylor Draw Dam above Rangely, Colorado. The Recovery Team still believes that the lower 240 km may be important for recovery of the species. Before the recovery objectives may be amended, (a) upstream and downstream passage by Taylor Draw Dam must be restored and scientific data must be presented to document that the essential habitats in the lower 240 km of the White River are not impaired/modified by the dam, OR (b) scientific data must be presented which documents that the loss of this range (and associated habitats) and population will not impair recovery of the species.

STEP-DOWN OUTLINE

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

    11. Locate and monitor all Colorado squawfish populations.

        111. Compile historical population data.

        112. Survey habitat locations which may potentially support squawfish.

113. Determine population status/dynamics and define a self-sustaining population.

12. Expand on life history information.

121. Define life history/spawning requirements.

122. Describe feeding behavior and food habits.

123. Describe age distribution and growth rates.

124. Delineate migration routes and patterns, and define requirements for fish passage.

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

21. Determine threats to and protect the Colorado squawfish populations and their habitat.

211. Monitor and assess the impact of proposed development projects.

212. Identify and assess the impacts of introduced nonnative species which compete with the Colorado squawfish.

213. Study the nature and extent of parasitism and disease in the Colorado squawfish.

22. Enforce existing laws and regulations protecting the Colorado squawfish.

221. Inform necessary agencies of their enforcement responsibilities.

222. Assure compliance with Section 7 of the ESA by all Federal agencies.

223. Assess effectiveness of current regulations/management and draft additional regulations or increase protection and enforcement as needed.

224. Discontinue or prevent introductions of nonnative fish species which may have a negative impact on the Colorado squawfish.

23. Identify and monitor all essential habitat.

231. Conduct intensive field investigations to locate essential habitat-spawning and rearing areas, etc.

232. Determine critical biological, chemical, and physical components for each essential habitat type.

233. Determine historical habitat characteristics of the Colorado squawfish.

234. Establish criteria to identify suitable habitat.

235. Identify other potential squawfish habitat.

24. Manage and restore primary squawfish habitat.

241. Monitor existing and proposed water development projects.

242. Develop methods to restore use by and movement of Colorado squawfish within its former range where dams now restrict movement.

243. Carry out studies to determine effectiveness of enhancing squawfish spawning and rearing success through habitat improvement.

3. <u>Reintroduce Colorado squawfish into their historic range.</u>

31. Establish hatchery facilities and produce and rear Colorado squawfish.

311. Develop propagation and holding techniques to maximize production.

312. Select and/or construct facilities to produce and rear Colorado squawfish.

313. Maintain a diversified gene pool.

32. Conduct reintroduction program.

321. Inventory and select areas for reintroduction.

322. Restore or prepare stocking sites as needed.

323. Develop a plan for stocking and monitoring reintroduced populations.

3431. Determine stocking rates needed to establish a viable self-sustaining population.

3432. Conduct stocking program in areas of potential habitat.

3433. Monitor reintroduced populations and their habitat.

4. Conduct information and education programs to advise the public of the aesthetic and recreational value of the Colorado squawfish and the efforts needed to preserve its habitat.

41. Conduct nationwide information and education programs.

42. Conduct local information and education programs.

Narrative

Objective - The Colorado squawfish will be considered eligible for reclassification to threatened when naturally self-sustaining populations are maintained in the upper Colorado River basin and further fragmentation of the existing population is prevented. This includes at least the following as primary habitat:

(a) The Green River from its confluence with the Colorado River to Echo Park;

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The Colorado squawfish will be considered eligible for downlisting in the lower Colorado River basin when criteria are met for downlisting in the upper Colorado River basin.

*The White River was recently (1984) impounded by the Taylor Draw Dam above Rangely, Colorado. The Recovery Team still believes that the lower 240 km may be important for recovery of the species. Before the recovery objectives may be amended, (a) upstream and downstream passage by Taylor Draw Dam must be restored and scientific data must be presented to document that the essential habitats in the lower 240 km of the White River are not impaired/modified by the dam, OR (b) scientific data must be presented which documents that the loss of this range (and associated habitats) and population will not impair recovery of the species.

The Colorado squawfish will be considered eligible for delisting when downlisting criteria are met and primary essential habitats, migration routes, river flow and water quality parameters are legally protected. The Colorado squawfish will be considered eligible for delisting in the upper Colorado River basin when: (a) downlisting criteria have been met, (b) primary essential habitats, migration routes, and river flow and water quality parameters are legally protected, and (c) criteria for delisting in the lower Colorado River Basin are met. The Colorado squawfish will be considered eligible for delisting in the lower Colorado River basin when: (a) naturally self-sustaining populations of squawfish are established in three lower basin areas and the habitats in which they are surviving are legally protected, or (b) reintroduction efforts (over a period of 10 years) fail and it is determined that suitable habitat no longer exists in the lower basin (the FWS may then declare the Colorado squawfish extinct in the lower Colorado River basin).

Annual meetings should be conducted to review the overall status of recovery efforts. Each State agency should prepare a report of their recovery efforts for the annual meeting. Additional information is needed before specific quantifiable recovery goals can be established. Thus, interim objectives would.include obtaining and analyzing population data in order to define what constitutes a viable, self-sustaining population and to establish specific quantifiable goals for downlisting to threatened and del isting. If and when these goals are met, the Colorado squawfish will be considered for downlisting, or delisting to a non-endangered status.

1. Determine population status and life history requirements of the Colorado squawfi sh .

11. Locate and monitor all Col orado squawfi sh populations

Intensive field investigations should be conducted to locate Colorado squawfi sh populations. When located, fi sh should be moi tored on a long-term basis.

111. Compile hi storical population data.

Historical aspects of population abundance, distribution, migration and life history, and other general biological information has been synthesized and should be compared with the results of recent and future studies.

112. Survey habitats/locations which may potentially support Colorado squawfish

Potential habitat areas should be surveyed for remnant populations. Potential habitat areas can be identified using information and criteria established under Tasks 232 and 234.

113. Determine populations status/dynamics and define a self-sustaining population.

An intensive monitoring program should be conducted to determine population status through age classes present, hatching and rearing success etc. Criteria for defining what constitutes a self-sustaining population will be obtained from studies on existing populations.

12. Expand on life history information

All aspects of the life history of the Colorado squawfish will be described. During all studies an effort should be made to maximize scientific use of fish. All fish mortalities will be sent to Fort Collins, Colorado for cataloging and storage at the USFWS facility.

121. <u>Define life history/spawning requirements</u>

Requirements of the different age and year classes must be determined. Understanding the spawning requirements of the Colorado squawfish is also vital to achieving recovery of the species. This would include intensive field investigations to locate and describe spawning habitat and collect data on habitat components, hydraulic characteristics, and water temperature regimes as well as data on spawning and rearing success. Studies conducted under field and laboratory conditions would further define: 1. Spawning behavior, a) migration and homing to and from spawning sites, b) pre-spawning behavior and site selection, c) physical and hydrological parameters of spawning sites, d) factors which trigger spawning behavior, e) ratio of males to females, f) movement patterns; 2. egg development a) egg adhesiveness, b) egg predation by non-native species (as part of Task 212), c) hatchability under various temperature regimes, d) effects of siltation and fluctuating water levels; 3. Larval development, a) food availability and preference, b) temperature tolerances, c) habitat preference and availability, d) depredation (Task 212).

122. Describe feeding behavior and food habits

Further investigations on food preference, availability and feeding behavior are essential. This would include investigations on:

a) food preference and availability, b) mechanics and efficiency of feeding, c) ability of squawfish to successfully feed on various spiny-rayed nonnative fishes found in areas outlined in the Objective (ie. catfish), d) the importance of turbidity on squawfish feeding efficiency and ability to compete with other species for food and space, and e) stomach content analysis on any mortalities.

123. Describe age distribution and growth rates

Total length and weight data should be kept by all monitoring agencies. In addition, a reliable aging technique should be developed.

124. Delineate migration routes and patterns, and define requirements for fish passage.

Migration routes and patterns will be determined for existing populations by monitoring tagged individuals. Tests should also be conducted to determine squawfish ability to negotiate various fish passage devices (ladders, elevators) and the feasibility of providing passage around low or moderately high dams.

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

Locations of existing populations and reintroduction sites will be protected using the guidelines under the ESA.

Federal and State agencies will insure that present essential habitat conditions on the upper Colorado River and tributaries utilized by Colorado squawfish are maintained. This includes flow and temperature regimes, water quality and physical characteristics. These primary habitats will be monitored annually until the species is delisted. Monitoring will continue after delisting until it is certain that the habitat remains stable.

21. Determine threats to and protect the Colorado squawfish populations and their habitat.

An assessment of the threats facing the Colorado squawfish and their potential impacts should be made. Once this information is known, management and protective regulations, etc. can be revised or applied as needed.

211. <u>Monitor and assess the impact of proposed development projects.</u>

Ongoing or proposed water development or related projects should be monitored to determine their effects on squawfish populations and their habitat in terms of flow reductions, temperature changes, and water quality (turbidity, salinity, environmental contaminants).

212. <u>Identify and assess the impacts of introduced nonnative species which compete with the squawfish.</u>

Studies should be conducted to determine the impact of competition by nonnative species on the Colorado squawfish and if such competition is a major factor influencing Colorado squawfish distribution.

213. <u>Study the nature and extent of parasitism and disease in the Colorado squawfish.</u>

Although cursory investigations have not indicated that disease or parasitism pose a serious threat to Colorado squawfish populations, additional monitoring of wild populations is needed to provide conclusive evidence.

22. Enforce existing laws and regulations protecting the Colorado squawfish.

The purpose of this task is to maintain Colorado squawfish populations and prevent any degradation of essential habitat.

221. Inform necessary agencies of their enforcement responsibilities.

All agencies should be made aware of their responsibilities regarding the laws protecting listed species and their habitats (Endangered Species Act, Fish and Wildlife Coordination Act, Lacey Act). Agencies should be kept current on all laws and regulations or revisions that would change agency responsibility.

222. Assure compliance with Section 7 of the ESA by all Federal agencies.

Federal agencies should comply with Section 7 of the ESA and should consult with FWS on any project which may affect the Colorado squawfish involving Federal permits, monies, etc. Water quality and flow criteria can then be applied through consultation etc.

223. Assess effectiveness of current regulations/management and draft additional regulations or increase enforcement/protection as needed.

Current management practices, and protection or enforcement activities should be monitored to determine their effectiveness in conserving the species.

224. Discontinue or prevent introductions of nonnative fish species which may have a negative impact on the Colorado squawfish.

Prior to completion of Task 212 and if studies show such introductions will have a negative impact on the Colorado squawfish, stocking of certain nonnative species which are believed to compete with the squawfish should be discontinued.

23. Identify and monitor all essential habitat.

Investigations should be conducted to determine the critical components of essential habitat. State or Federal agencies within the Colorado River basin where Colorado squawfish exist should participate in or supervise habitat monitoring. This would include the FWS, Bureau of Reclamation, the Colorado Division of Wildlife, Utah Division of Wildlife Resources, Arizona Game and Fish Department, and New Mexico Department of Game and Fish.

231. Conduct intensive field investigations to locate essential habitat (i.e. spawning and rearing areas, etc.)

Field investigations must be conducted to locate spawning areas, migration routes, etc. so that information on environmental components can be obtained.

232. Determine critical biological, chemical, and physical components for each essential habitat type.

Conduct studies to determine the various requirements for the different life stages of the Colorado squawfish. This would include data on specific substrate components, hydraulic characteristics, water temperatures, isolating factors, salinity and environmental contaminant levels, and any other essential components of the habitat.

Data on the chemical characteristics of the Green and Colorado Rivers are being collected by the FWS. Included in the data collection are field information and tolerance levels of different life stages of Colorado squawfish determined by laboratory bioassay work. A decision of whether or not more water chemistry information is needed will have to be made at the conclusion of the FWS's investigation. In addition, water chemistry data are being collected from tributaries of the

Green and Colorado Rivers by Colorado Division of Wildlife. This monitoring effort will also determine existing temperature, turbidity, flows, and other physical habitat conditions in the tributaries of the Colorado River. They will then compare the present physical conditions to past conditions to detect possible adverse trends in the physical habitat.

233. **Determine historical habitat characteristics of the Colorado squawfish.**

Data on historical river flows, habitats, etc. in areas where Colorado squawfish were present will be compiled and compared with the results of recent and future studies. Part of this work is being done by the Fish and Wildlife Service and will be included in their study results which will include an instream flow analysis that will recommend flows in the Green and Colorado Rivers. Information will be obtained from past studies, literature reviews, and historical data.

234. **Establish criteria to identify suitable habitat.**

Using information gained through Tasks 231, 232, and 233, develop a set of criteria to use in identifying suitable potential habitat.

235. Identify other potential squawfish habitat

Inventory prospective areas using criteria established under Task 234 to identify all essential or potential habitat sites.

24. Mange and restore primary squawfish habitat.

Techniques for restoring historic migratory and primary habitat must be developed which would include restoration of water flows and physical requirements. Once such restoration methods are established they can be implemented as needed.

241. Monitor existing and proposed water development projects.

Continuous monitoring of ongoing or proposed development projects is essential in order to accurately evaluate cumulative effects and habitat degradation and to apply adequate management.

242. Develop methods to restore use and movement of Colorado squawfish within its former range where dams now restrict movement.

Through the use of radio telemetry and other techniques the migration of the Colorado squawfish and the factors influencing migration will be determined. Studies will then be conducted to determine squawfish ability to negotiate fish passage devices and the feasibility of providing passage around low or moderately high dams.

243. Carry out studies to determine effectiveness of enhancing Colorado squawfish spawning and rearing success through habitat improvement.

Studies need to be conducted to determine if alteration or improvement in water flow, water quality or other physical alterations in habitat will enhance reproduction.

3. Reintroduce Colorado squawfish into their historic range.

Colorado squawfish will be reintroduced into unoccupied historical habitat. Studies on age class, distribution, and creel census will determine success of stocking program. Results of these studies will determine future stocking requirements. Stocking rates will depend on availability of fish.

Follow-up stockings of a reintroduction area should be based on monitoring results to determine carrying capacity and success of the initial stocking.

All fish stocked will be marked before release into the wild. The tagging. should be consistent with the ongoing tagging efforts in the upper Colorado River basin. Restocked areas will be sampled by standard fishery techniques to follow survival, age, growth, etc.

31. Establish hatchery facilities and produce and rear Colorado squawfish.

311. Develop or improve propagation and holding techniques to maximize production.

Additional information on propagation and holding techniques must be developed to maximize production. Methods to induce maturation of gonads have been developed. However, there is a need to determine optimum loading capacities for different sizes.

312. Select and/or construct facilities to produce and rear Colorado squawfish.

The Dexter National Fish Hatchery in New Mexico should be maintained as the holding site for captive broodstocks. The USFWS has begun site studies for a new hatchery facility designed specifically for the propagation of the Colorado squawfish and other Colorado endemic endangered fish species. If feasible, construction could begin by FY-86. Additional ponds may also be required if larger fish (25cm) are proven more desirable for reintroduction.

Management of holding and rearing sites will be the joint responsibility of the USFWS and the States within the Colorado River basin. The California Department of Fish and Game plans to construct ponds at its Imperial Valley Warmwater Hatchery to rear Colorado squawfish and other native Colorado River fish species. Additional ponds including those at Page Springs Hatchery, Arizona, will be needed to obtain maximum utilization of all the endangered fish produced at Dexter and the new FWS facility.

313. Maintain a diversified gene pool.

Hatchery broodstock will be supplemented with wild fish from different rivers in order to maintain genetic diversity. Studies should be undertaken to determine how many brood fish are needed to provide natural genetic diversity for at least 20 generations.

32. Conduct reintroduction program.

321. Inventory and select areas for reintroduction.

An evaluation of each potential reintroduction site will be conducted and its suitability based on information gathered in Tasks 232, 233, 234 and 235.

322. Restore and prepare stocking sites as needed.

Habitat enhancement features will be considered. Improvements could include physical modification of the habitat such as addition of large boulders for cover, the creation of side channels and backwaters, or biological modifications such as moratorium on stocking nonnative species where Colorado squawfish recovery activities will be initiated. Also see Task 243.

323. Develop a plan for stocking and monitoring reintroduced populations.

Specific reintroduction sites will be determined in the future. Follow-up stocking should be based on results of regular monitoring to determine carrying capacity and successfulness of initial stocking.

3231. Determine stocking rates and sizes needed to establish a viable self-sustaining population.

Reintroduction is based on the sites specified in Task 235. Studies on age class, distribution, and creel census will be used to determine success of stocking program. Results of these studies will determine future stocking requirements. Stocking rates will depend on availability of fish.

3232. Conduct stocking program in areas of potential habitat.

See Task 112.

3233. Monitor reintroduced populations and their habitat.

Once reintroductions occur, populations and critical habitat components will be monitored to ensure that stocks of Colorado squawfish are maintained. Monitoring should be conducted in cooperation with State wildlife agencies on an annual basis. Such investigations should be initiated once reintroductions have begun and should continue until viable, self-sustaining populations are established and maintained indefinitely.

4. <u>Conduct information and education programs to advise the public of the aesthetic and recreational value of the Colorado squawfish and the efforts needed to preserve its habitat.</u>

The information and education programs should be implemented on both local and national levels and focus on the value of the Colorado squawfish as an endemic natural resource. An active effort will be made by FWS and the State agencies to inform the public of reintroductions (success of stocking and their sportfishing potential). This should be done in conjunction with changes in fishing regulations and changes in the status of the squawfish once the reintroduction is successful.

41. <u>Conduct nationwide information and education programs.</u>

Conduct an aggressive national campaign to inform the public of impending development of the Colorado River system and likely impacts on the species.

News of restoration efforts should be published in Fish and Wildlife Service's Endangered Species Bulletin. Also, national environmental groups and newspapers could be contacted and asked to write articles on the potential sportfishing.

42. <u>Conduct local information and education programs.</u>

All State wildlife agencies should continue to develop and provide leaflets for local use. Efforts should also be made to contact local newspapers and magazines to carry stories about recent investigations and problems facing the squawfish. The ecological value of the Colorado squawfish as an endemic species should be emphasized as should its potential economic and sports fishing value.

Local chapters of environmental groups, newspapers, and media stations should be informed of efforts being made to recover the species in its former habitat.

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PART III

IMPLEMENTATION SCHEDULE

Definition of Priorities

Priority 1 - All actions that are absolutely essential to prevent the extinction of the species.

Priority 2 - All actions necessary to maintain the species' current population status. status.

Priority 3 - All other actions necessary to provide for full recovery of the species.

Abbreviations Used in Implementation Schedule

AGFD	Arizona Game and Fish Department
BR	Bureau of Reclamation, USDI
CDOW	Colorado Division of Wildlife
FR	Fishery Resources, U.S. Fish and Wildlife Service
LE	Law Enforcement, U.S. Fish and Wildlife Service
NDOW	Nevada Department of Wildlife
NPS	National Park Service, USDI
SE	Endangered Species, U.S. Fish and Wildlife Service
UDWR	Utah Division of Wildlife Resources
compl.	completed-at this time, may be reinitiated
contin.	continuous-task/action will be required over a very long or undetermined pe
on going	Task which is now being implemented

GENERAL CATEGORIES FOR IMPLEMENTATION SCHEDULES

Information Gathering - I or R (research)

1. Population status
2. Habitat status
3. Habitat requirements
4. Management techniques
5. Taxonomic studies
6. Demographic studies
7. Propagation
8. Migration
9. Predation
10. Competition
11. Disease
12. Environmental contaminant
13. Reintroduction
14. Other information

Management - M

1. Propagation
2. Reintroduction
3. Habitat maintenance and manipulation
4. Predator and competitor control
5. Depredation control
6. Disease control
7. Other management

Acquisition - A

1. Lease
2. Easement
3. Management agreement
4. Exchange
5. Withdrawal
6. Fee title
7. Other

Other - O

1. Information and education
2. Law enforcement
3. Regulations
4. Administration