Behnke

ENDANGERED AND THREATENED FISHES OF THE UPPER COLORADO RIVER BASIN

PREFACE

Endangered species often generate controversies, raise emotions and polarize opinions when the preservation of endangered species conflicts with economic development. This is particularly true for the endangered fish species of the Colorado River basin. The water of the Colorado River is in urgent demand for agriculture and energy production. The greatest Major concentrations of oil shale and enormous coal deposits occur within the basin.

All future development will not grind to a halt because of such unusual fish as the squawfish and the humpback chub, as claimed by some alarmists. Some delay, comprimises and modifications in future projects may be necessary, however, in order to maintain certain environmental conditions and avoid the extinction of the rare fishes.

When Congress passed the Endangered Species Act of 1973, it was in response to demands by the American people to reverse the accelerated trend of species extinction. It is often argued that extinction of species is a natural consequence of evolution and man should not interfere with this natural process by preserving ill-adapted species that nature intends to get rid of. After all, the argument goes, there are no longer dinosaurs, pterodactylas, and sabertooth tigers around. Who misses them? What must be recognized here is the difference between slow natural rates of extinction (balanced with the slow evolution of new species) and a highly accelerated rate caused by man's modifications of the earth's environments. During the past century as man's population has increased in geometric proportions, and, with the rise of modern technology, the human species has claimed an ever greater portion of the earth and its resources dramatically changing the original environments on an enormouse scale to provide

food, energy, and the amenities of life to an ever-expanding population. The creation of urban centers for living and business, the conversion of vast land areas to agricultural production, which in turn demands irrigation and dams, and chemical treatment; the pollution of soil, air, and water, are all aspects of the population increase of the human species and resulting in harmful effects to other species with which we share the planet.

It must also be recognized that the accelerated extinction rate caused by man differs from much of natural extinction in that the extinction of a species caused by man's influence, "dead-ends" an evolutionary line. Most extinct species in the fossil record are "extinct" only because of slow, gradual change in the evolutionary line. That is, continual evolutionary change led to new species. The germ plasm or hereditary material has been continuous through time, but gradually changed from an ancestral species into its descendant species. For example, a million years ago or more, the direct ancestor of man is considered to be a different species from modern man, Homo sapiens. If man's ancestral species became extinct by a dead end type of extinction rather than a gradual evolutionary change, we would not be here. This distinction between the two types of extinction -- a dead ending of an evolutionary line, as contrasted to the transformation of one species into another by evolutionary change is critical for the continued maintenance of the diversity of life.

It is often asked, what good is an endangered species? How can they be beneficial to man? Particularly with fishes such as the squawfish, the bonytail and humpback chubs, and the razorback sucker -- species of the

minnow and sucker families that have so long been categorized as "rough" or "trash" fish to be controlled or eliminated for the benefit of game fish. There are no simple answers to these questions. There are standard responses concerning the need to maintain species diversity in nature and to maintain diverse populations within a species to provide the raw material for evolution. It is true that the effects on many animal species from such chemical pollutants as DDT, PCB, mercury, and kepone, provided an early warning system to the dangers these chemicals hold for man. As such, endangered species may act as an indicator or barometer of environmental influences of potential harm to man.

To many, the responsibility of preventing extinction from man's influence, is considered a duty of man's stewardship of the earth, and no more practical reasons are necessary.

The purpose of this bulletin is to provide basic information on the endangered, and threatened, fishes of the upper Colorado River basin, the reasons for their present condition and what is being done and what might be done to enhance their chances for survival. The federal Endangered Species Act is examined and interpreted to explain where potential conflicts may arise due to the occurrence of an endangered species.

It is hoped that this bulletin will stimulate interest and appreciation of some of the unique and unusual fishes of the Colorado River system which are found nowhere else in the world. The continued existence of these rare fishes will require the cooperation of diverse interest groups and improved communication between diverse fields of knowledge and expertise.

Concerned citizens are urged to assist in gathering information on the fishes discussed in this bulletin. The areas involved cover vast expanses of habitat and scientific collecting gear has not been highly

effective in capturing fishes such as the squawfish, razorback sucker, bonytail and humpback chubs. Fishermen catching any of these endangered or threatened species, according to the law, must release them unharmed, but a report of the catch, giving size, location and date, should be made to a local Wildlife Conservation Officer or to the regional office of the state Division of Wildlife. Such information may provide new distribution records for a species or may lead to the discovery of a species such as the bonytail chub -- presently believed extinct in Colorado.

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INTRODUCTION

The Colorado River basin forms its headwaters high in the Rocky Mountains of northcentral Colorado (headwaters of Colorado River) and southwestern Wyoming (headwaters of Green River). Its journey from the source of the Green River to the Gulf of California, extends for more than 1700 miles and a drop in elevation of over two miles. As the ancient river carved its way down, tremendous canyons were formed including the greatest and most magnificent canyon on earth, the Grand Canyon. A view of the Grand Canyon can impart an understanding of the tremendous energy and erosive force of the Colorado River much better than can be conveyed in words.

The official demarcation point for water use which separates the upper Colorado River basin from the lower basin is at Lee's Ferry, Arizona, about 15 miles below Glen Canyon Dam forming Lake Powell. This bulletin concerns the endangered and threatened fishes of the upper Colorado River basin. The demands for water in the lower basin, however, has greatly influenced the environmental changes in the upper basin, namely, the creation of large dams and reservoirs.

Except for the mountainous areas, most of the Colorado River basin is arid and semiarid lands, much of it true desert. Flows fluctu ate wildly during a year and between wet and dry years. Historical flows at Yuma, Arizona, have ranged from lows of a few hundred cubic feet per second (cfs) to almost 400,000 cfs. Erosion is high in the basin and enormous sediment loads are transported in most of the major tributaries to the mainstream of the Colorado. Before major dams tamed this wild river and settled out most of the sediment it has been estimated that more than 100,000 acre feet of sediment was deposited in the Gulf of California each

year (that is, sediment that would cover more than 100,000 acres with an average depth of one foot).

Thus, it can be surmised that fishes living,adapting and evolving in this highly unique environment, characterized by great extremes in flows, turbidity, velocities, and temperatures, would comprise a highly unique group of species. The Colorado River has not had any broad connections with surrounding river basins such as the Missouri and Columbia for millions of years, and this great length of time, isolating the native fishes of the Colorado River basin, promoted the development of unique, often bizarre species specifically adapted to harsh environments. Except for a few headwater species, such as the cutthroat trout, speckled dace, mountain suckers, and sculpins, which have made transfers from other basins in relatively recent geological time (within the last 50,000 years), by headwater stream capture, most of the native fishes of the basin have been so long isolated from their closest relatives and have undergone such a degree of evolutionary change that they are recognized as species endemic to the Colorado River basin -- that is, species that are native only to the Colorado basin and found nowhere else in the world. The Colorado River basin, as a whole, has a higher percentage of endemic species than any river basin in North America.

Among the mainstream fishes specialized for living in the Colorado and Green River and their major tributaries are the squawfish, a predatory, pike-shaped minnow, once attaining a length of 5-6 ft and weights of 60-80 lbs., the largest species of the minnow family in North America; the bonytail chub and humpback chub with their oddly beautiful shapes designed to cope with turbulent flows; and the razorback or humpback sucker, one of the largest species in the sucker family, characterized by a pronounced blade-like body hump with a knife-like edge.

a little extreme or misleading??

It was recognized long ago that much of the arid lands in the basin could be converted to agriculture if irrigated. Beginning with the construction of Hoover Dam, started in 1930, a series of large dams and reservoirs were constructed to insure a reliable supply of irrigation water, for power generation, and for flood control. These dams and reservoirs extend along the mainstream from Imperial Dam, just north of Yuma, Arizona, to Fontenelle Dam which backs up the Green River to near its source in the Wind River Mountain Range of Wyoming. The man-made reservoirs such as Lake Mohave, Lake Havasu, Lake Mead, Lake Powell, and Flaming Gorge Reservoir are completely new aquatic environments unlike any environment that the native fishes evolved in and adapted to. They provide enormous recreational use and sustain attractive sport fisheries, but all of the fishes caught in these reservoirs are nonnative species, introduced by man. The native fishes are essentially gone from the impoundments and from the cold, clear tailwaters below the dams.

It is probable that the native fishes, such as the squawfish, could have flourished in the impoundments if nonnative fishes were not present. The introduction of nonnative fishes began almost 100 years ago when it was recognized that the popular food and sport fishes of the sunfish family (such as the largemouth bass and crappie), the perch family, and catfish family were completely absent from the Colorado River basin. Also, carp, several species of minnows and suckers, rainbow, brown and brook trout have been widely dispersed.

The environmental alterations resulting from large dams, which converted turbulent rivers with great extremes of flow, temperature, and turbidity into a series of great ponds releasing cold, clear water at relatively constant flow and temperature year round, below the dams created conditions that the native fishes are ill-adapted for and placed them at a great

disadvantage in competition with the nonnative fishes.

The large dams and reservoirs, however, cannot be wholly blamed for the present rare status of the native fishes. Man's influence on the land and the watersheds from logging, livestock grazing, agriculture, and irrigation removed the natural vegetation, caused accelerated erosion and greatly increased the amplitudes of flood peaks. This, in turn, caused great changes in the size and shape of river channels and reduced the amount of lagoon or quiet backwater habitat so important as nursery areas for the native fishes. Thus, the squawfish and several other native fish species disappeared from the Gila River of Arizona and were replaced by nonnative fishes long before dams had an influence on them.

The three major factors identified to explain the present status of the native fishes of the Colorado River basin -- reservoirs, land and water use, and nonnative fishes -- are not readily modified.

THE NATIVE FISHES OF THE UPPER COLORADO RIVER BASIN

Because of the long and effective isolation of the Colorado River basin from invasion of fishes from neighboring basins, only 13 species of fishes are native to the upper basin. (That is, they occurred in the basin naturally before man introduced new species.) These include two species of the trout and salmon family -- the cutthroat trout and the Rocky Mountain whitefish; two species of the sculpin family -- the mottled sculpin and the Paiute sculpin; four species of the sucker family consisting of two species of mountain suckers, the flannelmouth sucker, and the razorback or humpback sucker; and five species of the minnow family -- the speckled dace, the roundtail, bonytail, and humpback chubs, and the Colorado River squawfish.

The seven species that occur in headwater streams (cutthroat trout, whitefish, two sculpins, two mountain suckers, and the speckled dace) also are native to other river basins such as the Columbia and Missouri River basins and the Great Basin (several separate basins where the streams never reach the ocean but drain to internal sumps). This distribution indicates that these species have invaded the Colorado River basin (or escaped from it) via headwater stream capture in relatively recent geological times and have not been isolated long enough to evolve into distinctly different species. The remaining six species -- the razorback sucker, flannelmouth sucker, three species of chubs, and the squawfish -- are endemic species. They have been isolated for much greater periods of time, and have evolved into distinctly different species from their nearest relatives in other river basins. Fossils more than three million years old of some of the endemic species have been found. They have been around in the Colorado

River for a very long time. All of the six endemic species also occur (or did until recently) in the lower Colorado River basin. Of the seven native but nonendemic species, only the speckled dace and the bluehead mountain sucker occur in the lower basin.

The native species have different adaptive specializations to live in different environments. They are associated with specific types of habitats and are not randomly distributed throughout the system. For example, the cutthroat trout was originally limited to clear, cold waters at high elevation before it was replaced by nonnative species of trout. The six endemic species, with the exception of the roundtail chub, were largely restricted to the large, main river channels of the Colorado and Green and their major tributaries such as the Yampa, Gunnison, and San Juan rivers below the foothills where the water is warm in the summer months. The roundtail chub's optimum habitat seems to be the intermediate size tributary streams.

The great changes in the original river environments of the Colorado River basin have favored the nonnative fishes. More than 30 species of nonnative fishes have been introduced into the upper basin and now dominate most of the fish communities in the waters of the upper basin. All of the 13 native fishes still occur in the upper basin but all have been depleted in numbers and five species have been reduced to a point that they are listed as endangered or threatened species by the federal government and/or by the State of Colorado.

These five species are discussed in detail in the following sections. The federal list of endangered species also includes a subspecies of the speckled dace, the Kendall Warm Springs dace, which lives only in the outflow

of Kendall Warm Springs in Wyoming. The entire habitat of this peculiar population of speckled dace consists of less than 1000 feet of a small stream before it plunges over a ledge into the Green River. The Kendall Warm Springs dace is classified as endangered because of its restricted habitat and the possibility that the entire population could be wiped out from pollution of the spring.

COLORADO RIVER SQUAWFISH

Status

Endangered on federal and state lists.

Distinguishing Features

This is the largest species of the minnow family native to North America and there are no problems in recognizing larger specimens (18 in. or more) as squawfish by its large mouth, pike-like body shape, and olive-green back with silvery-white belly. With small specimens, however, the squawfish might be confused with the roundtail chub by inexperienced persons. The confusion between squawfish and roundtail chub is promoted by the fact that fishermen in Colorado commonly, but incorrectly, use the name squawfish for the roundtail chub. Among "old timers" who once knew the squawfish, the name "Colorado salmon", "white salmon", or simply "salmon" were frequently used as the common name for the squawfish. The jaw of the squawfish extends beyond the rear margin of the eye, but in roundtail chub, the jaw only reaches to a point beneath the eye. Also in young squawfish (to about 8 in.) a dark blotch is apparent on the base of the tail. This blotch is absent in the roundtail chub.

Life History Notes

The Colorado River squawfish is the largest species of the minnow family native to North America. In recent years, the largest known specimens of squawfish have been no more than 15 lbs. and it appears that the present growth rate is much less than it was under the original, unmodified conditions in the Colorado River basin and before nonnative fishes

became predominant over the native species. The effects of parasites such as the bass tapeworm, probably brought into the basin in nonnative fishes, may also play a role causing reduced growth rates. Unverified weights of 80 to 100 lbs. have been given in the literature. Based on statements in the literature and from the size of squawfish bones found in ancient Indian sites, the length the largest squawfish once attained is on the order of 5 to 6 ft. Plotting a length and weight curve based on squawfish specimens between 1 and 10 lbs. and projecting the curve out to 5 and 6 foot lengths indicates that a squawfish 5 ft. long would weigh nearly 80 lbs. and a 6 ft. specimen about 130 lbs. There is much room for error in such projected calculations but it can be surmised that the largest squawfish once attained a weight of from 60 to 80 lbs. The squawfish is a predator, its food is mainly other fishes. In its first year of life, young squawfish feed on small invertebrate animals in quiet backwater areas and side channels off from the main river. As it grows, fish become more important in its diet. After a size of about 8 in. is reached, fish become the predominant food.

Based on studies in recent years, squawfish mature and spawn at an age of 6 or 7 years and a length of 18 to 20 in. The maximum age of squawfish in recent years is about 10 to 12 years and the maximum size up to about 3 ft. and 15 lbs.

No one has observed the spawning of squawfish so the precise type of habitat selected for spawning is not known. The finding of young squawfish in quiet backwater areas suggests that spawning takes place in river sections near the backwater nursery habitat.

Spawning occurs in the early summer when water temperatures reach about 70° F. It is generally believed that squawfish made major spawning migrations before they were blocked by dams and this is why they were commonly called "salmon". The squawfish and the razorback sucker were the fish most highly valued as food by the early settlers and miners in the Colorado River basin and they were caught and marketed by local commercial fishermen. When formerly abundant, squawfish were frequently caught on bait or lures by anglers.

Adult squawfish favor deep areas of large river channels from which they can move out to adjacent reaches and feed on other fishes.

The nearest living relatives of the Colorado River squawfish are three other species of squawfish native to the Columbia River, Sacramento River, and Oregon coastal rivers. None of the other species of squawfish reach a size comparable to the Colorado River squawfish. The other species of squawfish are not such strict predators and feed more on invertebrate animals and utilize a wider variety of habitats. In contrast to the Colorado River squawfish, the related species are flourishing to such an extent that they are considered as nuisance fish because they compete with game fishes. When reservoirs are constructed in the Columbia River basin, the Columbia squawfish often becomes the dominant species despite efforts to control their numbers. They respond in a most positive manner to man's alteration of the environment and to the presence of nonnative fishes. Although the general appearance of all four species of squawfish is quite similar, there obviously must be large differences in life history and ecology between the Colorado River squawfish and its relatives that have caused the Colorado River squawfish to fare so poorly when subjected to environmental change and nonnative fishes.

Past and Present Distribution

Originally, the squawfish was found throughout the Colorado River basin in the mainstream channels of the Colorado and Green rivers and the large tributaries such as the Gila, San Juan, Gunnison and Yampa. Historically, the distribution of squawfish would begin in the larger, warmer waters at lower elevation at a point where the distribution of trout and whitefish left off. The habitat of the squawfish was shared with the bonytail chub and the razorback sucker.

The squawfish began to disappear from some areas such as the Gila River in Arizona before the impacts of large dams. In the Gila River the replacement of squawfish by nonnative fishes can best be attributed to the great changes in flows and channel structure. The advent of large, mainstream dams, initiated by Hoover Dam in 1930 and proceeding to the completion of Glen Canyon and Flaming Gorge dams in 1963, caused a rapid decline in squawfish abundance and distribution. No squawfish have been found in the entire lower Colorado River basin since 1968.

After the closure of Flaming Gorge Dam and the subsequent cold water releases, squawfish were eliminated from the upper Green River downstream to the section below the confluence with the Yampa River. This ~~section of~~ The lower ~~the Green River, of about 200 miles~~ from the Yampa River to the confluence with the Colorado, is now the greatest stronghold of the squawfish. This is the only area where successful reproduction (finding young fish one or two years of age) has been noted in the past few years. During the past three years (1976-78) several adult squawfish have been found in the Yampa River upstream to a point above Juniper Canyon. In the White River adults were frequently found in the lower reaches in Utah and two were captured

just above Piceance Creek in the White River in Colorado. In the Gunnison River, a few adult squawfish still occur in the lower reaches below Whitewater. A remnant population may occur in the San Juan River between Lake Powell and Navajo Reservoir in Utah and New Mexico. In the Colorado River, squawfish are found sporadically up to Plateau Creek, about 15 miles upstream from Grand Junction. In recent years most captures along the Colorado River have been from gravel excavation ponds connected to the main river such as the Walter Walker Wildlife Pond near Grand Junction. Most captures of razorback suckers in recent years have also been from such ponded areas.

Except for the Green River, there has been no evidence of successful reproduction for the past several years in any of the locations where adult squawfish are found. All specimens have been 6-7 years old or older.

Causes of Decline

The most obvious and clearly identifiable cause and effect relationship contributing to the decline of squawfish are the large dams and reservoirs that converted hundreds of miles of large river habitat into great impoundments. The planning and operation of these projects did not consider the preservation of native fishes. The squawfish and other native fishes do not reproduce successfully in these large reservoirs. The adults present in the river when a dam is constructed may continue to live in a reservoir, thrive and grow but the population consists of fewer, larger and older fish each successive year until they all die of old age. The largest known squawfish caught in relatively recent times was taken in Lake Mead about 30 years ago and weighed 34 lbs. Thus, there is no doubt that squawfish can live in reservoirs but they cannot maintain themselves by natural

reproduction. The reservoirs release water from great depths and this cold water (40^{o} - 50^{o} F) creates trout fisheries for many miles below the large dams, but the cold water is avoided by the squawfish. The coldwater releases from Flaming Gorge Dam effectively eliminated squawfish from 65 miles of the Green River below the dam. Only after the Green River is warmed by the flow from the Yampa River, do temperatures reach 70^{o} F or more in the summer months and reproduction is possible.

The coldwater releases from Glen Canyon Dam apparently eliminated the last squawfish from the Grand Canyon area of the Colorado River.

As mentioned, land use practices, irrigation, and channelization drastically alter flow patterns, river channel characteristics, and eliminate the quiet backwater nursery areas to a point that suitable squawfish habitat is no longer present. Evidently, this was the case in the elimination of squawfish from the Gila River of Arizona. These gradual, cumulative impacts on habitat are much less dramatic and not as obvious as the more sudden changes created by a large dam and reservoir, but the end result can be similar in relation to the continued existence of squawfish.

In other instances, such as the Yampa River, the squawfish has declined in abundance and there has been no sign of successful reproduction for several years. Yet, there are no large dams involved nor has there been any significant changes in the flows, temperatures, or water quality of the Yampa River. That is, no physical or chemical changes can be pointed to suggesting a cause and effect relationship acting against the squawfish. In this case, a biological change must be examined, namely, the nonnative fishes. Because most of the nonnative fishes have lived with the squawfish in the Yampa River for a long time and the squawfish formerly reproduced successfully in the Yampa, the probable cause of lack of successful repro-

If squawfish did migrate from say the Green into the Yampa to spawn, perhaps release from Flaming Gorge creates a thermal block immediately below confluence with the Yampa preventing movement into the Yampa at a critical time.

duction must be looked for in a nonnative species that has become established in the Yampa River in relatively recent times. The obvious culprit here is the redside shiner, a species introduced from the Columbia River basin. The first record of a redside shiner in the Yampa River occurred in 1961. It rapidly proliferated to become a dominant species by the 1970's. The other evidence incriminating the redside shiner as inimical to squawfish is the fact that they prefer waters of low velocity -- the quiet side channels and backwater habitat that is required as a nursery area for newly hatched squawfish. The redside shiner spawns earlier in the year than the squawfish and the young redsides get a head start and quickly saturate the habitat needed by young squawfish. The redside shiner is absent from the Desolation Canyon area of the Green River where the most consistently successful reproduction of squawfish still occurs. It may seem improbable that a small minnow such as the redside shiner could effectively eliminate a large, voracious predator as the squawfish, but the mechanisms of interaction are probably not of direct predation, but rather competition for food and space between the young of each species. The true meaning of "survival of the fittest" in evolutionary terms does not denote success to the biggest and the strongest, but is expressed in the success of reproduction -- those that leave the most offspring.

The evidence of the harmful effects of nonnative species on the squawfish, however, is largely circumstantial and much is yet to be learned on the subject.

Prospects for the Future

When a species is listed as a federally endangered species, a Recovery Team is appointed, made up of state and federal biologists and often biologists from universities to develop a Recovery Plan. The objective of a Recovery Plan is to provide directions and guidelines that can be carried out which, if successful, will lead to the increase in abundance of the species to a point where it is no longer endangered or threatened and can be removed from the list. As might be surmised from what has been discussed previously, a workable Recovery Plan for squawfish is not a simple matter. A Recovery Plan has been written for the squawfish but the only clearly defined area in the plan to increase squawfish abundance concerns the artificial propagation of the species in hatcheries. The complex issue of the interaction of the squawfish with its physical and biological environment and how various factors may be manipulated to the benefit of the squawfish is included under the title of "development of habitat management plans" in the Recovery Plan. The question of how to develop a workable habitat management plan and how to carry it out have not yet been resolved. Toward this goal, the U.S. Fish and Wildlife Service supported by funds from the U.S. Bureau of Reclamation has initiated a large scale study of squawfish and humpback chub. This study is designed to obtain the information needed to develop habitat management plans, to provide the basis for the planning and operation of future water development projects in the upper basin so that harmful effects can be avoided and to seek ways that future environmental modifications could be beneficial to the squawfish.

The U.S. Bureau of Land Management and the Colorado Division of Wildlife have been conducting studies and monitoring programs on the squawfish, and the Division of Wildlife has plans for large scale hatchery propagation of the species. The squawfish can be readily propagated in hatcheries. Hormone injections are necessary to induce spawning. Young squawfish feed on the same food fed to trout and larger squawfish feed on fish. Squawfish have been spawned and raised at the Willow Beach National Hatchery, Nevada, and some are also maintained at the Hotchkiss National Hatchery, Colorado.

Hatchery propagation, however, must be considered only as a stopgap measure in the preservation of squawfish. It is obvious that in areas where the squawfish once occurred but is now gone, the stocking of hatchery reared fish will not result in a self-sustaining population unless the factors causing the elimination of the squawfish in the first place can be reversed or modified. Thus, the abundance of squawfish might be greatly increased by continual stocking of hatchery reared fish into reservoirs and rivers where they do not now occur, but successful reproduction would not be expected and the squawfish would again disappear if the stocking ceases.

If a restoration program for squawfish is to be successful for increasing the abundance and distribution so that the species is no longer considered endangered or threatened, ways must be found to favor successful reproduction. Merely trying to maintain the status quo by strict protection of habitat where squawfish still occur will not do the job of getting the squawfish off of the endangered species list.

The squawfish will play an important role in the planning and operation of any future dams and water development projects in the upper basin.

Flow and temperature releases from dams can be planned to favor squawfish instead of trout. Successful reproduction might be favored by the creation of artificial areas where natural nursery sites no longer exist. Methods of control and replacement of potentially harmful nonnative fishes such as the redside shiner will likely be necessary in areas such as the Yampa River before successful reproduction of squawfish can be established.

The present diagnosis is that the squawfish can probably maintain a healthy and viable population indefinitely in the Green River below the mouth of the Yampa as long as the present environmental conditions are maintained. The probability of increasing the abundance and distribution into other areas where the squawfish has been eliminated or exists in low numbers, depends on the successful application of creative and holistic thinking and work.

Anger and frustration against constraints imposed on future environmental modification which may affect squawfish might well be vented against the squawfish. It must be kept in mind, however, that the squawfish really can't be blamed for its present plight!!!

HUMPBACK CHUB

Status

Endangered on both federal and state lists.

Distinguishing Features

As the name implies, a prominent hump of the body just in back of the head characterizes this species. The hump of the humpback chub differs from the hump of the razorback sucker by being rounded in the chub and not supported by internal bone whereas the razorback sucker has a bony structural support for its hump which is sharp edged rather than rounded. The degree of development of the hump is highly variable and specimens have been identified as hybrids with both the bonytail and roundtail chubs. Thus, positive field identification of humpback chub is not always possible, even for an experienced biologist.

Other distinguishing characters of the humpback chub are the fleshy snout which protrudes over the lower jaw, the large, streamlined fins, and a small eye -- smaller than the eye of roundtail or bonytail chubs of similar size. The caudal peduncle,(the thinnest part of the body just in front of the tail) is thicker in the humpback chub than in the bonytail chub, but thinner than in the roundtail chub.

Life History Notes

The humpback chub is restricted to river sections that include swift, deepwater areas, typically in canyons. Although its original distribution is similar to that of the squawfish, from Wyoming in the upper basin to Arizona and California in the lower basin, it was never a common fish because of its habitat restrictions. The humpback chub was not known to science until 1946 when a specimen from the Grand Canyon was described as a new species.

Because of its rareness, little is known concerning the biology of this species. Apparently it feeds on invertebrate animals and is sometimes caught by fishermen on bait such as grasshoppers or worms. In the Little Colorado River, Arizona, humpback chub have been observed feeding on food scraps thrown into the water by picnickers. The humpback chub may feed on the surface of the water, although the peculiar body shape would suggest it is designed to maintain stability on the bottom in turbulent flow. Its body may be designed to facilitate up and down movements so that it may feed on a variety of foods at different depths from the bottom to the surface. The maximum size attained by humpback chubs is about 16-18 inches. Young humpback chub prefer quiet backwater areas similar to young squawfish. No one has ever observed spawning in this species, but ripe chubs ready to spawn were observed in water of about 65° F., suggesting that they spawn earlier than squawfish. Most of the prime humpback chub habitat in the canyon areas of the basin is now covered by reservoirs. As with the squawfish, adult humpback chub continued to live in reservoirs, but they became older and fewer until they finally disappear from lack of successful reproduction.

Past and Present Distribution

The original distribution of humpback chub is not known but it is assumed to be comparable to that of the squawfish in the main river channels of the Colorado and Green Rivers, except that the chub was restricted to swift, deepwater areas, mainly in canyons and did not occur far up any tributary stream. Presently, the greatest known concentration of this species occurs in the lower few miles of the Little Colorado River in the Grand Canyon area of Arizona. Perhaps the coldwater releases from Lake Powell has forced most of the humpback chub from the main Colorado River in Grand Canyon into the warmer Little Colorado.

In the upper basin, the humpback chub occurs sporadically in the Colorado River up to Palisades, about 10 miles above Grand Junction, but the greatest concentration occurs in the Black Rocks area of Ruby Canyon, about 25 miles below Grand Junction, where turbulent flows create a pool almost 40 feet deep at low water levels. In the Green River, the humpback chub occurs below the mouth of the Yampa, but is concentrated in the Desolation Canyon area. It has been recorded in the lower Yampa River in Dinosaur National Monument.

Causes of Decline

Because the humpback chub had a limited distribution and thus was always relatively rare, there is not much evidence of a decline except where reservoirs were constructed. The deepwater habitat favored by this species is not easily sampled by standard methods of fish collecting. As sampling techniques improve and more is learned about humpback chubs, more populations are likely to be discovered. The most abundant known population, in the Little Colorado River, was not discovered until 1975.

There has been considerable concern that the humpback chub may lose its identity due to hybridization with the bonytail chub and with the roundtail chub. It now seems probable that most of the specimens formerly believed to be hybrids were actually normal variation in the degree of hump developments. A few specimens, however, probably are hybrids. The bonytail chub is now so rare that it can be discounted as a significant source of possible hybridization. The roundtail chub, however, is common in the Colorado River in Colorado and occurs with the humpback chub in Ruby Canyon where some intermediate (hybrid?) specimens have been taken. The roundtail chub is absent or occurs rarely in humpback chub habitat in the Green River and

the Little Colorado River. Thus, overall, the threat to the integrity of the humpback chub species from hybridization is probably not as great as once believed.

The deepwater areas preferred by humpback chub is also a preferred type of habitat for the nonnative channel catfish. Large populations of catfish and carp share the Ruby Canyon habitat with the humpback chub. Because of the different feeding specializations there is probably little direct competition with or predation on the humpback chub from the catfish or carp. It can be assumed, however, that if nonnative fishes were not present, some of the food now consumed by catfish and carp would be eaten by humpback chubs and they would respond by increasing their abundance.

Prospects for the Future

A draft recovery plan has been written for the humpback chub, but, as with the squawfish, the main emphasis is placed on hatchery propagation as the only clearly defined technique to increase abundance. As mentioned, it is likely that additional populations of humpback chub will be found when more of the deepwater canyon areas in the upper basin are more thoroughly sampled. Fishermen can be of assistance in this regard by reporting catches of humpback chub. Good humpback chub habitat is also good channel catfish habitat and the chub can be caught on the same bait often used to catch catfish. Humpback chub, of course, must be released, but the Colorado Division of Wildlife should be notified of the catch, particularly if it is outside of the Ruby Canyon area of the Colorado River. A documented anglers catch (with a photo, if possible) may provide new distribution records and lead to the discovery of new populations of this rare fish.

Humpback chub from the Little Colorado River have been taken to the Willow Beach National Fish Hatchery for an attempt at artificial propagation.

A humpback chub preservation and restoration program is yet to be developed, but it will likely consist of the identification of all areas where populations still occur so that the present environmental conditions in those areas can be maintained. It would be extremely difficult to establish humpback chub where they do not now exist. They may now essentially inhabit all suitable areas where self-sustaining populations can be maintained under present environmental conditions. Thus, the outlook is not encouraging that the distribution and abundance of humpback chub can be expanded by the establishment of new self-sustaining populations where they do not now exist -- their habitat requirements are highly restrictive. Possibilities should be looked for, however, where deep channel areas have been created by bridge or highway construction, forming suitable habitat beyond the present limits of distribution. In such situations, the introduction of humpback chub might result in the successful establishment of a new population. Valuable information could be obtained from experimentation designed to establish new populations. There is little doubt that the humpback chub lost most of its best habitat to reservoirs such as Lake Powell and Flaming Gorge, but the present diagnosis is that this species is not as close to extinction as was commonly believed a few years ago.

BONYTAIL CHUB

Status

Endangered on state list (considered extinct in Colorado), proposed for endangered status on federal list. The results of many recent studies clearly point to the fact that the bonytail chub is the rarest of the Colorado River native fishes and the species nearest extinction.

Distinguishing Features

Large fins, a streamlined body with a very thin caudal peduncle (the thinnest part of the body just in front of the tail) distinguish the bonytail chub. The bonytail chub typically has ~~9~~ 10 rays in both the dorsal fin and the anal fin, whereas the roundtail chub typically has ~~10~~ 9 dorsal and anal rays (the humpback chub most frequently has 9 dorsal rays sometimes 10 and 10 anal rays usually, but is more variable). The bonytail chub might be confused with both roundtail and humpback chubs. The body is more streamlined and the caudal peduncle much thinner in the bonytail chub in comparison to the roundtail chub. Bonytail chub may develop a humping to the back which would cause confusion with the humpback chub. Many unusual specimens were collected in the 1960's which suggested hybridization between the bonytail and humpback chubs. The current consensus of opinion is that although some of these specimens do represent hybrids, most are merely normal variability in the humpback chub.

Considerable confusion surrounds the identification and classification of bonytail chub. The bonytail and roundtail chubs were described as separate species in the nineteenth century but later were considered only as environmental modifications of a single species. That is, it was believed that a roundtail chub, leaving a tributary stream for life in the main river

channel of the Colorado or Green River, would turn into a bonytail chub under the direct influence of a different environment. When it was discovered that both roundtail and bonytail chubs were frequently found living together with both of them maintaining distinctions from each other and not hybridizing, the two chubs were again recognized as separate species.

Confusion also surrounds the common name. In former times, professional biologists typically used the name'bonytail' for both roundtail and true bonytail chubs. Thus, there are many literature references to bonytail chub that, in fact, refer to the roundtail chub.

Life History Notes

Until large dams were constructed, the bonytail chub was probably the most abundant species in the main river channels of the Colorado and Green Rivers and in the lower reaches of the larger tributary rivers. As mentioned, much confusion surrounds the recognition and separation of the three chub species, but a review and synthesis of the literature indicates that the bonytail chub was most common in the open river areas of large river channels. The humpback chub was most common in or near deepwater areas and the roundtail chub was most common in tributary streams. However, where suitably diverse habitat occurred, all three species might be found together.

The bonytail chub is a relatively long lived species, not spawning until it reaches an age of 5-7 years. Similar to the other chub species, the bonytail spawns when the water reaches about 65^{o} F. Little is known about the life history of bonytail chub because they rapidly disappeared before intensive studies were made. The bonytail feeds on insects, often terrestrial

insects taken on the surface of the water. Various debris and algae fragments in their stomachs suggest that the bonytail may feed intensively after a sudden storm would cause floodwaters to wash food out of tributaries into the main river channels.

The optimum habitat of bonytails, based on former collections when they were abundant, appears to be the open river areas of relatively uniform depth and current velocity. This type of habitat consists of a shifting sand bottom, water depths of 3-4 feet, and a relatively constant moderately swift current. The streamlined body and large fins of the bonytail seem well adapted to live in this type of habitat. The maximum size attained by bonytails is, in general, 16-18 inches. A small number of bonytail chub have continued to exist in the lower basin reservoirs, Lake Mohave and Lake Havasu. These are large, old fish. A specimen of about 3 feet and weighing 8 lbs. was reported caught by an angler in 1975 from Lake Mohave.

Present and Past Distribution

The original distribution included the large river environments of the entire basin from Mexico to Wyoming. Bonytail chub were last recorded from the Gila River, Arizona, in 1926. They rapidly declined in the lower basin, after the construction of Lake Mead, Lake Havasu and Lake Mohave. Bonytail persisted in large numbers in these reservoirs for several years and large numbers were observed spawning in Lake Mohave in 1954, but their numbers continued to decline due to lack of reproductive success. The bonytail was still abundant in the Green River until after the completion of Lake Powell and Flaming Gorge Reservoir in 1963. By the late 1960's bonytail became very rare. Except for the few specimens that may yet persist in Lake Havasu and Lake Mohave, the only bonytail chub recorded

in the last three years, has been from the Green River in the Desolation Canyon area.

Similar to the demise of the Passenger Pigeon, it seems unbelievable that a species once so abundant could so rapidly vanish.

Causes of Decline

The lack of successful reproduction in reservoirs explains the disappearance of bonytail chub from the segments of their former range that were converted into impoundments. Their absence in the Colorado River of Colorado and Utah and from most of the Green River where apparently suitable habitat still exists is not so easily explained. The open river or "run" type of habitat does not seem to be extensively used by nonnative fishes, thus the "bonytail niche" would be expected to be lesser impaired than the niches of some other native fishes. Yet the bonytail has suffered greater declines than any other native species and is now the rarest member of the original fish fauna.

The flow releases from Flaming Gorge Dam has eliminated the great seasonal peaks of high and low flows of the original Green River regime and also causes daily fluctuations due to power generation. These changes in the flow regime undoubtedly have influenced subtle changes in channel configuration and altered optimum bonytail chub habitat. However, similar influences from upstream impoundments cannot be invoked to explain the apparent disappearance of the bonytail from the Colorado River in Colorado and Utah. There is little in the way of documented evidence concerning the occurrence or abundance of bonytail chub in the Colorado River in Colorado and Utah, but it is assumed that they were common here because of the large river environment.

The loss of great numbers of bonytail chub from the areas inhabited by squawfish must have severely depleted the potential food supply of squawfish and suggests a major cause of the reduced growth rates of squawfish in recent times.

Prospects for the Future

Realistically, the prospects for restoring the abundance of bonytail chub to a semblance of their former numbers in any part of the original range, must be viewed as dim. The bonytail is now the rarest of the native fishes and the species in most imminent danger of extinction. Biologists have been attempting to obtain live specimens from Lake Mohave and Lake Havasu to hold in a hatchery for artificial propagation. Captive propagation may prove to be the only way this species can be maintained. Unless the factors causing the elimination of bonytail chub are understood and some action could be taken to modify or eliminate these factors, the restoration of bonytail chub in its historic range cannot be expected from stocking hatchery reared fish. Even if the factors causing elimination from a river section became clearly understood, it is not likely that remedial action would be possible. For example, the dismantling of Flaming Gorge Dam to restore the original flow and temperature regime of the Green River must be considered beyond the realm of possibility.

If bonytail chub occurs in an area, it is likely that an occasional bonytail would be caught by fishermen fishing for catfish. If fishermen become familiar with the appearance of bonytail chub and if a suspected specimen of bonytail is caught, it should be photographed before release and reported to the Colorado Division of Wildlife. There have been no verified records of this species for many years in Colorado. The discovery of a population would be a significant event and brighten the prospects for survival of the species.

RAZORBACK SUCKER

Status

Threatened on state list, proposed for threatened status on federal list.

Distinguishing Features

The abrupt, sharp edged hump on the back immediately posterior to the head identifies the razorback sucker from all other suckers and from all other fishes. The hump of the humpback chub is rounded and lacks the sharp leading edge. Although the common name humpback sucker is the name recognized for this species by the American Fisheries Society, the name razorback sucker is more descriptive of the species and avoids confusion with the humpback chub.

The size and development of the hump is related to size and age. Young razorback suckers of less than 6 to 8 inches have only a slight development of the hump and might be confused with the flannelmouth sucker. Hybrids between razorback and flannelmouth suckers are common in some areas. The razorback sucker typically has 14 to 15 dorsal fin rays vs. typically 12 in the flannelmouth. The razorback sucker has more gillrakers (small protuberances on the upper surface of the gill arches). Typically 45 or more gillrakers are found on the first gill arch of razorback suckers and about 35 in flannelmouth suckers. Hybrid specimens are intermediate in the size of the hump and in other characters.

Life History Notes

The peculiar body shape would suggest a design for stability on the bottom in turbulent flow. This may be true when razorback suckers might migrate during high flows, but virtually all captures of razorback suckers

are from essentially still water areas, particularly off channel ponds created from gravel excavation or for irrigation storage.

As is typical of species in the sucker family, the razorback sucker has large, fleshy lips with which it can suck up small invertebrate animals and organic debris from the bottom. The food material is sifted by the gillrakers and funneled into the throat where it is finely ground by rows of teeth (pharyngeal teeth). The razorback sucker attains an old age (probably more than 20 years) and can reach a large size (to over 10 lbs.). When formerly abundant, the razorback sucker and the squawfish were the most common and desirable food fish and they supported local commercial fisheries in the Colorado River basin.

Although the razorback sucker is well adapted to thrive in reservoirs, reproduction has not been sufficiently successful to maintain their numbers. When impoundments were created in the lower basin, razorback suckers soon established large populations but the populations declined as the fish became fewer and older each succeeding year. Razorback suckers have been observed spawning along the shores in the lower basin reservoirs, but young individuals have not been found. With a long evolutionary background in a river environment, young razorback suckers may lack the instincts necessary to avoid predation in a lake environment. Thus, predators such as the largemouth bass and crappie may soon eliminate the newly hatched razorback suckers.

All actual observations of spawning have been from reservoirs. Spawning is reported to occur at temperatures from 54° F to 68° F. in water 1 to 20 feet deep. In river environments, the razorback sucker probably spawns in side channels or backwater areas with slow current or still water. Finding ripe and spawned out fish in off channel ponded areas indicates that spawning

also occurs in such habitats. Along the Colorado River in Colorado, razorback suckers are most frequently found in ponds created by gravel excavation adjacent to and connected to the river such as the Walter Walker Wildlife Pond near Grand Junction.

Past and Present Distribution

The original range of the razorback sucker was approximately that of the squawfish and bonytail chub, in the large river environments from Mexico to Wyoming. Historically, it was more common in the lower Colorado River basin than in the upper basin. In the lower basin initially large populations built up in the artificial impoundments in the early years but they have gradually declined and now largely consist of old (20 years and more), large, fish.

In the upper basin razorback suckers disappeared from the Green River above the mouth of the Yampa River after the completion of Flaming Gorge Dam and the release of cold water. Some razorback suckers persist in the Green River below the mouth of the Yampa and are occasionally found in the lowermost reaches of the Yampa River. In the Colorado River in Colorado, razorback suckers occur upstream to De Beque, about 30 miles above Grand Junction. In 1977, an estimated 250 razorback suckers were found stranded when a small irrigation reservoir, connected to the San Juan River near Bluff, Utah, was drawn down.

Causes of Decline

The dams and impoundments can be pointed to as the major cause of razorback sucker decline, as is the case with the other species discussed. Land and water use practices, changing flow regimes and river channel characteristics which eliminated the lagoon or backwater type habitat can

also be blamed. This seems evident from the intensive utilization of artificially created off channel ponded habitat by razorback suckers. Nonnative fishes such as largemouth bass and green sunfish also typically thrive in these ponded areas and they may effectively suppress successful reproduction of razorback suckers by predation on the young in such habitat.

As the razorback sucker became rarer, the incidence of hybridization with flannelmouth suckers has apparently increased. About 50% of the specimens captured, mainly in the Green River, from 1967 to 1973 were identified as hybrids. However, specimens taken from the Colorado River in recent years rarely indicate a hybrid influence.

Prospects for the Future

Because of its more widespread distribution, greater abundance and its utilization of artificially created habitat, the razorback sucker seems to have a more hopeful future than do the three species previously discussed. The problem of successful reproduction must be solved before the continued existence can be assured and increased abundance can be effected. Adult razorback suckers flourish in reservoirs and pond type environments but young of the species have not been found in such environments. It would be most important to know what are the optimum spawning conditions in regards to depth, velocity and substrate and what associated nonnative fishes are least harmful and what species are most harmful to successful reproduction.

Artificial propagation of razorback suckers has been carried on for several years at the Willow Beach Federal Hatchery, Nevada. Populations could be maintained in reservoirs by stocking fish reared in a hatchery but if reproduction is not successful in a reservoir or a section of a

river, reproduction by stocked razorbacks cannot be expected.

Because the razorback sucker and the bonytail chub have not yet been listed as federal endangered or threatened species, they have not been eligible for federally funded projects on endangered species and have received much less attention than have the squawfish and humpback chub. It would be useful for a better understanding of the species to document their occurrence in all off channel ponded habitat, correlating the abundance of razorback suckers with habitat characteristics such as size, shape, depths, and associated fish species, and try to find the common denominators in the factors that favor the success of the species. If this were done, future man made modifications might be designed to benefit the razorback sucker and perhaps the squawfish, also.

COLORADO RIVER CUTTHROAT TROUT

Status

Threatened on state list. Rare throughout its original range.

Distinguishing Features

The cutthroat trout native to the upper Colorado River basin can be distinguished from nonnative trout by its red or orange slash marks beneath the lower jaws and by the spotting pattern. Relatively large spots, rounded in outline and typically concentrated on the posterior part of the body characterize the native cutthroat trout. The native trout has the hereditary basis to develop brilliant coloration, but the color pigments must be derived from its food. Thus, a native trout living in a lake with crustaceans (water fleas, "shrimps", etc.) when sexually mature will express bright red, orange and golden-yellow coloration, but the same fish living in a small stream with only insects in its diet will be more dull colored.

The cutthroat trout species is made up of about 15 subspecies or geographical races distributed widely throughout the western United States and western Canada. The Colorado River cutthroat is a geographical race which has been isolated in the upper Colorado River basin.

It is closely related to the greenback cutthroat trout native to the headwaters of the South Platte and Arkansas River basins and to the Rio Grande cutthroat trout. There are no consistent differences that can separate all Colorado River cutthroat trout from all greenback cutthroat trout except for the geographical distribution -- one is native to the Colorado River basin, the other to the South Platte and Arkansas.

Hybrid populations between the native trout and rainbow trout and with nonnative subspecies of cutthroat trout are much more common than

are pure populations of native trout and greatly confound the problem of native trout identification.

Life History Notes

There are no obvious ecological differences between the Colorado River cutthroat trout and other trout species in regards to feeding, spawning, optimum habitat, etc. In general, however, the cutthroat trout is like the canary in the mine in respect to tolerance of environmental disturbance -- it is usually the first species to go.

Spawning occurs in the spring when water temperatures reach about 45° F. The female digs out a nest in gravel in flowing water. After fertilization, the eggs are covered with gravel and left to hatch out later in the summer. As with most trout species, the cutthroat is opportunistic in its feeding. A wide range of invertebrate animals are eaten and larger cutthroat trout will prey on fish if they are available.

Originally the Colorado River cutthroat trout inhabited all of the colder lakes and streams in the upper basin that it had access to. The largest size attained by this subspecies is not known but was probably about 15 lbs. In small streams, however, few cutthroat trout will ever exceed 10 inches.

Past and Present Distribution

One hundred years ago the cutthroat trout inhabited all of the colder waters of the upper basin from the headwaters of the Green and Colorado Rivers to the San Juan River system on the east and the Dirty Devil River drainage on the west. The Green River below the town of Green River, Wyoming, and the Colorado River below Glenwood Springs, Colorado, were too warm for cutthroat trout and the main distribution was in the colder

tributary systems at higher elevations. The distribution of cutthroat trout would begin above a point where the distribution of the warmwater species such as the squawfish left off.

The early settlers found the native cutthroat trout in great numbers in all of the suitable trout waters of the basin. After the introduction of nonnative trouts, the native cutthroat rapidly declined. Presently, only a few pure populations found in small, isolated headwaters in Wyoming and Colorado, are known to exist.

In Trappers Lake, Colorado, a native cutthroat trout population still exists. The Trappers Lake cutthroat has been exposed to hybridization from the Yellowstone Lake subspecies of cutthroat trout and from rainbow trout and they cannot be strictly regarded as a "pure" population, but the effects of past hybridization is not evident. The present Trappers Lake cutthroat trout are wholly typical of the native subspecies and are correctly classified as the Colorado River cutthroat trout.

Trappers Lake cutthroat are propagated and stocked each year into high elevation lakes in the northwest region of Colorado, thus, besides those caught in Trappers Lake itself, fishermen have the opportunity to catch the native trout from numerous lakes because of the stocking program. Most of the cutthroat trout presently occurring in the Rocky Mountain region, are found in high elevation lakes. Because of this, most fishermen assume that this is their native habitat. Almost all of the high mountain lakes in Colorado are isolated by formidable waterfalls and no fish occurred in them naturally. Most of these lakes lack suitable tributary spawning streams and the cutthroat trout populations are maintained by regular stocking.

Causes of Decline

Virtually all of the subspecies of cutthroat trout native to the interior regions of western North America have suffered the same fate as has the Colorado River cutthroat trout. One hundred years ago, in all of the famous western trout streams such as the Gunnison, Roaring Fork, Arkansas, South Platte, the upper Yampa and the upper Colorado rivers in Colorado, the cutthroat trout was the only trout that occurred. After stocking of nonnative fishes, brown trout and rainbow trout replaced the cutthroat at lower elevations in the larger streams and brook trout replaced the cutthroat trout in the higher elevation small streams. Hybridization between native cutthroat trout and nonnative rainbow trout was initiated on a massive scale in all waters where rainbows became established. Unlike most hybrids between animal species, the cutthroat x rainbow hybrid is fertile and can reproduce. Thus, once hybridization was started it rapidly spread. Nonnative subspecies of cutthroat trout, mainly from Yellowstone Lake, Wyoming, were stocked into Colorado waters by the millions to hybridize with the native cutthroat trout. Early fish cultural practices commonly mixed native and nonnative trout indiscriminantly. The introduction of nonnative trouts was the major cause of the virtual elimination of pure populations of Colorado River Cutthroat trout.

Prospects for the Future

Fortunately for the native trout, its highly generalized ecology allows it to flourish in a variety of habitats, including very small headwater streams. Thus, a restoration program for native trout is relatively simple in comparison to the problems faced in attempts to restore the previously discussed species. If all nonnative trout can be eliminated by poisoning the water in

a small watershed above a barrier (so they cannot reinvade from downstream), then native cutthroat trout from a known pure population can be transplanted and a new population established. This method of restoration has been used to establish several new populations of the greenback cutthroat trout in the South Platte River basin. In 1979, the elimination of nonnative trout is planned for a small lake and stream in the Colorado River drainage of Rocky Mountain National Park. If complete removal of the nonnative fish is achieved, pure Colorado River cutthroat trout will be introduced and they should multiply to thousands of fish in a few years.

The cutthroat trout is more easily caught by fishermen than other trout species. Because of this, the cutthroat trout is the only trout that consistently responds to restrictive fishing regulations by increasing its numbers. Regulations designed to recycle all or most of the catch by releasing all fish or all fish within certain size limits, have worked very well with cutthroat trout. The use of special regulations that allow the catching of native cutthroat trout but severely restricts the kill, will likely become an important part of the management of the several subspecies of cutthroat trout native to the Rocky Mountain West.

THE ENDANGERED SPECIES ACT

In the 1960's the environmental movement gathered momentum and increasing concern was expressed over accelerated extinction rates of life on earth. Congress passed an endangered species act in 1966, but this act was more of an expression of concern and awareness and it lacked enforcement provisions to protect endangered species where conflicts might arise. The U.S. Fish and Wildlife Service created an Office of Endangered Species and prepared the first list of endangered species in 1964. The Colorado River squawfish and the humpback chub were included on the first list.

In December 1973, Congress passed new endangered species legislation, P.L. 93-205, known as the Endangered Species Act of 1973. The 1973 Act contains strong provisions to protect species on the list when they or their environment are in conflict with any federal action or project which might have negative impacts. These provisions are spelled out in Section 7 of the Act which states that all federal agencies are to use their authority in furtherance of the Act by carrying out conservation programs for endangered and threatened species. Federal agencies are directed to ... "insure that actions authorized, funded, or carried out by them do not jeopardize the continued existence of endangered and threatened species or result in the destruction or modification of these species habitat that is determined to be critical by the Secretary of Interior after consultation with the affected states."

It was Section 7 of the Endangered Species Act which has prevented the completion of the Tellico Dam in Tennessee because this project was deemed to jeopardize the continued existence of the snail darter, an endangered species, and would modify the snail darter's critical habitat.

For a clearer understanding of the ramifications of the Endangered Species Act, two aspects must be differentiated -- that of private vs. federal jurisdiction and that of the endangered species and its critical habitat. The Endangered Species Act does not apply to private property or actions unless some federal agency or federal funding is involved. If private funds construct a dam for electrical generation on private property, there would be the matter of permits from the Corps of Engineers and licensing by the Federal Energy Regulatory Commission, which would then subject the private project to the provisions of the Endangered Species Act. Irrigation projects of the Bureau of Reclamation and land modifications funded by the Soil Conservation Service are subjected to the provisions of the Endangered Species Act.

There has been considerable confusion over the term "critical habitat". The legal ramifications of critical habitat apply only to those endangered and threatened species that have had critical habitat designated by the Secretary of Interior.

In an attempt to allay fears and to more clearly explain the meaning of "critical habitat", Mr. Keith M. Schreiner, former Director of the Endangered Species Office, published the following statement in the August, 1976, issue of the Endangered Species Technical Bulletin (published by the Office of Endangered Species):

> "The most important point I can make about critical habitat is that in no way does it place an iron curtain around a particular area; that is, it does not create a wilderness area, inviolable sanctuary, or sealed-off refuge. Furthermore, I would stress that it does not give the Fish and Wildlife Service or any other government agency an easement on private property nor will it affect the ultimate jurisdiction regarding any public lands.
>
> Critical habitat is provided for by section 7 of the Endangered Species Act of 1973, which charges Federal agencies -- and <u>only</u> Federal agencies -- with the responsibility for ensuring actions authorized, funded, or carried out by them do not either

1) jeopardize the continued existence of Endangered or Threatened Species or 2) result in destruction or adverse modification of the habitats of these species. (State and private actions that do not involve Federal money or approval do not come under the terms of the Act.)

Simply stated, critical habitat is the area of land, water, and airspace required for the normal needs and survival of a species. As published in the Federal Register on April 22, 1975, the Service has defined these needs as space for growth, movements, and behavior; food and water; sites for breeding and rearing of offspring; cover or shelter; and other biological and physical requirements. Determination of a critical habitat may include consideration of certain biological, physical, or human elements of a species' environment, if -- but only if -- the element is required for the continued survival or reasonable recovery of the species.

We are taking special pains to make sure that every shred of biological data is obtained and analyzed before any critical habitat is determined. Federal and State agencies are being contacted in writing prior to publication of a proposal. Once the proposal has been published, written comments on its biological adequacy are actively sought from all interested parties. In some cases, if the situation warrants, public hearings are being held in the affected States to seek the views of local residents. It is only after all of this biological information has been collected and carefully analyzed that a final determination is made.

Once the final determination has been published, its only effect is to cause Federal agencies managing lands or administering programs within the area to examine their actions in light of section 7.

The actions of private individuals (farmers, ranchers, trappers, etc.), firms, and State agencies are not affected unless funding or approval from a Federal agency is involved.

If an action does require Federal funds or approval, then the particular Federal agency having jurisdiction must decide whether or not the action would "jeopardize the continued existence of the species or result in destruction or modification" of its critical habitat.

There is no way to predict how Federal agencies will decide about particular actions in particular areas. The agencies simply consider them on a case-by-case basis as they arise. Nevertheless, I should emphasize that there are many types of existing land uses that are compatible with the continued survival of species and maintenance of the quality of their habitats. In addition the Service is prepared to provide assistance and consultation on the biological impacts of proposed activities whenever such consultation is needed. However, the final decisions will be made by the appropriate Federal agencies.

> In short, the determination of critical habitat is a means of helping all Federal agencies meet their responsibilities under the Endangered Species Act of 1973. It is a tool to help save and restore species, not a weapon to hinder economic or social progress.

Amendments were made to the Endangered Species Act in 1978. One of the amendments calls for an economic analysis to be prepared before any critical habitat is designated. This amendment is designed to reveal any negative economic impacts from the designation of critical habitat that might retard or block future development. Critical habitat had been proposed for the squawfish but has been withdrawn until an economic analysis can be prepared. Thus, the squawfish and humpback chub are endangered species, but neither has "critical habitat" in the legal sense of the term. Any future development project or environmental modification in the upper Colorado River basin, to be compatible with the Endangered Species Act would be subjected to the provision that its construction and operation do not "jeopardize the continued existence" of the squawfish or humpback chub, but would not be subjected to the critical habitat provision until such critical habitat is defined and designated by the Secretary of Interior.

Another 1978 amendment states that, in the future, any species proposed for the federal list of endangered or threatened species, must have the critical habitat designated at the time it is listed. This stipulation will probably cause considerable delay in the listing of the bonytail chub and the razorback sucker. The effects of the listing of a species as endangered or threatened by the Colorado Wildlife Commission, consist mainly of the recognition of the plight of a species, the ordering of priorities for funding, study and restoration. There are no provisions in the state law which might conflict with the activities of state or federal agencies or private individuals, except that endangered species cannot be killed, transported, or sold. The three subspecies of native cutthroat trout in Colorado (Colorado

River, greenback, and Rio Grande cutthroat trout) are all listed as threatened by the state, but they are covered by game fish regulations. It is not illegal to fish for, catch and eat the native cutthroat trout except in those waters where all angling has been prohibited such as where greenback cutthroat trout occur in Rocky Mountain National Park. Some streams have been set aside for catch-and-release angling for the Rio Grande cutthroat trout and more of these special regulation trout fisheries are likely to be established as part of restoration programs.

The federal Endangered Species Act defines an endangered species as any species that is in danger of extinction throughout all or a significant portion of its range. A "species" is defined to include subspecies and smaller units of a species. Thus, the Kendall Warm Springs dace subspecies and several subspecies of cutthroat trout, including the greenback cutthroat in Colorado, have been listed as endangered species on the federal list even though the species as a whole was not endangered. The greenback cutthroat has been changed from an endangered status to a threatened status. A "threatened species" is defined as any species that is likely to become an endangered species in the foreseeable future. As far as the Endangered Species Act is concerned, there is little difference in the legal protection between the endangered and the threatened status. A threatened species, however, may be the object of a sport fishery if properly regulated.

When a potential conflict arises with the occurrence of an endangered species in an area where a federal project or action is deemed to pose a threat to the species, a consultation process with the U.S. Fish and Wildlife Service is initiated. The consultation process is an attempt to find ways

that would allow the planning, construction, and operation of a proposed project to be compatible with the Endangered Species Act.

Fair and equitable administration of the Endangered Species Act to protect a species and at the same time allow new development projects to proceed is most difficult. It is generally realized that an uncompromising, ultra protectionist stance should not be taken with endangered species to block future economic development. Such action would create a backlash in public opinion concerning the need to preserve endangered species. The official view of the Endangered Species Office was presented by the former director, Mr. Schreiner, to the 1977 annual meeting of Western State Game and Fish Commissioners where Mr. Schreiner said:

> "We must stop our traditional adversary role in water development, power developments, agricultural expansion, energy production, etc., and start trying to help the developers locate the site, design the structure, and develop the operational regime that will do the least harm to wild plant and animal species and their habitats. It is likely that we can enhance the habitat and ultimately the species if we accept the fact that development must and will continue.
>
> So I repeat, realistic endangered species administration means all of us helping developers to locate, design and operate their projects in a manner that is least harmful to species and their habitats."

Almost all conflicts between development and endangered species have been resolved to date by the consultation process.

In a situation where a conflict cannot be resolved (such as was the case with Tellico Dam and the snail darter), the 1978 amendments to the Endangered Species Act, provides for a high level Review Board, appointed by the President. The Review Board makes a decision to abide by the provisions of the Endangered Species Act or to exempt the project from the Act. If the Review Board votes against exempting a project then only special legislation passed by Congress can create an exemption to the Endangered Species Act.

There is no doubt that there are great potential areas for conflict in the upper Colorado River basin in relation to future water and energy projects as they may modify the environment and impact the squawfish and the humpback chub. Although each project must be examined individually, a holistic view of the future is necessary to predict their combined effects if all were to be constructed. The ultimate objectives are to guide and direct future environmental modifications so that changes in flow regime, temperature, and water quality will have a beneficial impact on the endangered species. The present research of the Fish and Wildlife Service on the life history ecology and habitat preference of squawfish and humpback chub are designed to provide the bases for resolving conflicts between the endangered species and future development in the basin.

There are likely to be delays, compromises, and increased costs associated with some new projects in the upper Colorado River basin that would influence the environment of the squawfish and humpback chub. To avoid violation of the Endangered Species Act, any new environmental change should not be harmful and, hopefully, can be designed to be beneficial to the endangered species.

APPENDIX

Common and Scientific Names of the Native Fishes of the Upper Colorado River Basin.

Family Salmonidae: Trout and salmon family	
Colorado River cutthroat trout	*Salmo clarki pleuriticus*
Mountain whitefish	*Prosopium williamsoni*
Family Cyprinidae: Minnow family	
Colorado River Squawfish	*Ptychocheilus lucius*
Humpback chub	*Gila cypha*
Bonytail chub	*Gila elegans*
Roundtail chub	*Gila robusta*
Speckled dace	*Rhinichthys osculus yarrowi*
Kendall Warm Springs dace	*Rhinichthys osculus thermalis*
Family Catostomidae: Sucker family	
Razorback sucker	*Xyrauchen texanus*
Flannelmouth sucker	*Catostomus latipinnis*
Bluehead mountain sucker	*Catostomus discobolus*
Mountain sucker	*Catostomus platyrhynchus*
Family Cottidae: Scuplin family	
Mottled sculpin	*Cottus bairdi*
Paiute sculpin	*Cottus beldingi*

[1980]

ENDANGERED AND THREATENED FISHES OF THE UPPER COLORADO RIVER BASIN

Robert J. Behnke

Delwin Benson

PREFACE

Endangered species often generate controversies, raise emotions and polarize opinions when the preservation of endangered species conflicts with economic development. This is particularly true for the endangered fish species of the Colorado River basin. The water of the Colorado River is in urgent demand for agriculture and energy production. The greatest concentrations of oil shale and enormous coal deposits occur within the basin. Presently, two species, the Colorado River squawfish and the humpback chub, are listed as endangered under the federal endangered species act. Two additional species, the razorback sucker and the bonytail chub have been proposed for listing. The Colorado state list of endangered and threatened species includes all of the four above mentioned fishes plus the Colorado River cutthroat trout.

It is often asked, what good is an endangered species? How can they be beneficial to man? Fishes such as the squawfish, the bonytail and humpback chubs, and the razorback sucker -- species of the minnow and sucker families that have so long been categorized as "rough" or "trash" fish to be controlled or eliminated for the benefit of game fish. There are no simple answers to these questions. There are standard responses concerning the need to maintain species diversity in nature and to maintain diverse populations within a species to provide the raw material for evolution. It is true that the effects on many animal species from such chemical pollutants as DDT, PCB, mercury, and kepone, provided an early warning system to the dangers these chemicals hold for man. As such, endangered species may act as an indicator or barometer of environmental influences of potential harm to man. To many, the responsibility of preventing extinction from man's influence, is

considered a duty of man's stewardship of the earth, and more practical reasons are not necessary.

When Congress passed the Endangered Species Act of 1973, it was in response to demands by the American people to reverse the accelerated trend of species extinction. It often is argued that extinction of species is a natural consequence of evolution and man should not interfere with this natural process by preserving ill-adapted species that nature intends to get rid of. After all, the argument goes, there are no longer dinosaurs, pterodactylas, and sabertooth tigers around. Who misses them? What must be recognized here is the difference between slow natural rates of extinction (balanced with the slow evolution of new species) and a highly accelerated rate caused b- man's modifications of the earth's environments.

During the past century as the human population has increased in geometric proportions and with the rise of modern technology, the human species has claimed an ever greater portion of the earth and its resources. Man has dramatically changed the original environments on an enormous scale to provide food, energy, and the amenities of life to an ever-expanding population. The creation of urban centers for living and business, the conversion of vast land areas to agricultural production, which in turn demands irrigation and dams, and chemical treatment; the pollution of soil, air, and water, are all aspects of the population increase of the human species resulting in harmful effects to other species with which we share the planet.

It must also be recognized that the accelerated extinction rate caused by man differs from much of natural extinction in that the extinction of a species caused by man's influence, "dead-ends" an evolutionary line. Most extinct species in the fossil record are "extinct" only because of slow,

gradual change in the evolutionary line. That is, continual evolutionary change led to new species. The germ plasm or hereditary material has been continuous through time, but gradually changed from an ancestral species into its descendant species. For example, a million years ago or more, the direct ancestor of man is considered to be a different species from modern man, Homo sapiens. If man's ancestral species became extinct by a dead end type of extinction rather than a gradual evolutionary change, we would not be here. This distinction between the two types of extinction -- a dead ending of an evolutionary line, as contrasted to the transformation of one species into another by evolutionary change is critical for the continued maintenance of the diversity of life.

The purpose of this bulletin is to provide basic information on the endangered, and threatened, fishes of the upper Colorado River basin, the reasons for their present condition and what is being done and what might be done to enhance their chances for survival. The federal Endangered Species Act is examined and interpreted to explain where potential conflicts may arise due to the occurrence of an endangered species.

It is hoped that this bulletin will stimulate interest and appreciation of some of the unique and unusual fishes of the Colorado River which are found nowhere else in the world. The continued existence of these rare fishes will require the cooperation of diverse interest groups and improved communication between diverse fields of knowledge and expertise.

All future development will not grind to a halt because of such unusual fish as the squawfish and the humpback chub, as claimed by some alarmists. Some delay, compromises and modifications in future projects may be necessary, however, in order to maintain certain environmental conditions and avoid the extinction of the rare fishes.

Concerned citizens are urged to assist in gathering information on the fishes discussed in this bulletin. The areas involved cover vast expanses of habitat. Scientific collecting gear has not been highly effective in capturing fishes such as squawfish, razorback sucker, bonytail and humpback chubs. Fishermen catching any of these endangered or threatened species, according to the law, must release them unharmed, but a report of the catch, giving size, location and date, should be made to a local District Wildlife Manager or to the regional office of the State Division of Wildlife. Squawfish and humpback chub are being tagged as part of current research projects. If a tagged fish is caught, the tag number should be recorded along with the other information and sent to the Colorado Division of Wildlife. Such information may provide new distribution records for a species or may lead to the discovery of a species such as the bonytail chub -- presently believed extinct in Colorado.

The native fishes of the Colorado River basin received little attention until recent times. The area involved is large and the physical, chemical, and biological interactions affecting the well-being of the native fishes are complex. Thus, detailed data and documentation on cause and effect relationships to explain the decline of rare fishes are largely lacking. The assessments made are made on the basis of available information but must be considered in the realm of speculation.

Much of the information used in writing this bulletin is not available in most libraries. For those interested, however, a list of references is provided.

INTRODUCTION

The Colorado River basin forms its headwaters high in the Rocky Mountains of northcentral Colorado (headwaters of Colorado River) and southwestern Wyoming (headwaters of Green River). Its journey from the source of the Green River to the Gulf of California, extends for more than 1700 miles and a drop in elevation of over two miles. The ancient river carved tremendous canyons by its erosive energy including the Grand Canyon.

The official demarcation point for water use which separates the upper Colorado River basin from the lower basin is at Lee's Ferry, Arizona, about 15 miles below Glen Canyon Dam forming Lake Powell. This bulletin contains information on the endangered and threatened fishes of the upper Colorado River basin. The demands for water in the lower basin, however, have greatly influenced the environmental changes in the upper basin, namely, the creation of large dams and reservoirs.

Except for the mountainous areas, most of the Colorado River basin is arid and semiarid lands, much of it is true desert. Flows fluctuate wildly during a year and between wet and dry years. Historical flows at Yuma, Arizona, have ranged from lows of a few hundred cubic feet per second (cfs) to almost 400,000 cfs. Erosion is high in the basin and enormous sediment loads are transported in most of the major tributaries to the mainstream of the Colorado. Before major dams tamed this wild river and settled out most of the sediment it has been estimated that more than 100,000 acre feet of sediment was deposited in the Gulf of California each year.

Thus, it can be surmised that fishes living, adapting and evolving in this harch environment, characterized by great extremes in flows, turbidity, velocities, and temperatures, would consist of a highly unique group of species.

The Colorado River has not had any broad connections with surrounding river basins such as the Missouri and Columbia for millions of years. This great time of isolation promoted the development of unique, often bizarre fishes specifically adapted to harsh environments. Most of the native fishes of the basin have been long isolated from their closest relatives and have undergone sufficient evolutionary change that they are recognized as species endemic to the Colorado River basin -- that is, species that are native only to the Colorado basin and found nowhere else in the world. The Colorado River basin, as a whole, has the highest percentage of endemic species of any river basin in North America.

Among the unusual mainstream fishes specialized for living in the Colorado and Green River and their major tributaries are the squawfish, the bonytail and humpback chubs, and the razorback sucker. The squawfish is a predatory, pike-shaped minnow, reputedly reaching lengths of 5-6 ft and weights of 60-80 pounds. The bonytail chub and humpback chub with their oddly streamlined shapes are designed to cope with turbulent flows. The razorback or humpback sucker, one of the largest species in the sucker family is characterized by a pronounced boyd hump with a knife-like edge.

It was recognized long ago that much of the arid lands in the basin could be converted to agriculture if irrigated. Beginning with the construction of Hoover Dam, starting in 1930, a series of large dams and reservoirs were constructed to insure a reliable supply of irrigation water and for power generation and flood control. These dams and reservoirs extend along the mainstream from Imperial Dam, just north of Yuma, Arizona, to Fontenelle Dam which backs up the Green River to near its source in the Wind River Mountain Range of Wyoming. The man-made reservoirs such as Lake Mohave, Lake Havasu, Lake Mead, Lake Powell, and Flaming Gorge Reservoir are completely new aquatic

environments unlike any environment that the native fishes evolved in or adapted to. These reservoirs provide enormous recreational use and sustain attractive sport fishing for nonnative species, introduced by man. Native fishes are essentially gone from the impoundments and from the cold, clear tailwaters below the dams.

It is probable that native fishes, such as squawfish, could have persisted in the impoundments if nonnative fishes were not present. The introduction of nonnative fishes began almost 100 years ago when it was recognized that the popular food and sport fishes of the sunfish family (such as the largemouth bass and crappie), the perch family, and catfish family were completely absent from the Colorado River basin. Also, carp, several species of minnows and suckers, rainbow, brown and brook trout have been widely introduced.

The environmental alterations resulting from large dams converted a turbulent river of great extremes of flow, temperature, and turbidity into a series of great ponds with cold, clear water released at a relatively constant flow and temperature year round below the dams. The native fishes are ill-adapted for these new conditions and they were placed at a great disadvantage in competition with the nonnative fishes.

The large dams and reservoirs, however, cannot be wholly blamed for the present rare status of the native fishes. Man's influence on the land and the watersheds from logging, livestock grazing, agriculture, and irrigation removed the natural vegetation, caused accelerated erosion and greatly increased the amplitudes of flood peaks. This, in turn, caused great changes in the size and shape of river channels and reduced the amount of lagoon or quiet backwater habitat so important as nursery areas for the native fishes. Thus, squawfish and several other native fish species disappeared from the Gila River of Arizona and were replaced by nonnative fishes long before dams had an

influence on them. The three major factors identified to explain the present status of the native fishes of the Colorado River basin -- reservoirs, land and water use, and nonnative fishes -- are not readily modified.

THE NATIVE FISHES OF THE UPPER COLORADO RIVER BASIN

Because of the long and effective isolation of the Colorado River basin from invasion of fishes from neighboring basins, only 13 species of fishes are native to the upper basin (that is, they occurred in the basin naturally before man introduced new species). Appendix II lists the common and scientific names of the native fishes. These include two species of the trout and salmon family -- the cutthroat trout and the Rocky Mountain whitefish; two species of the sculpin family -- the mottled sculpin and the Paiute sculpin; four species of the sucker family -- two species of mountain suckers, the flannelmouth sucker, and the razorback or humpback sucker; and five species of the minnow family -- the speckled dace, the roundtail, bonytail, and humpback chubs, and the Colorado River squawfish.

The seven species that occur in headwater streams (cutthroat trout, whitefish, two sculpins, two mountain suckers, and the speckled dace) also are native to other river basins such as the Columbia and Missouri River basins and the Great Basin (several separate basins where the streams never reach the ocean but drain to internal sumps). This distribution indicates that these species have invaded the Colorado River basin (or escaped from it) in relatively recent geological times and have not been isolated long enough to evolve into distinctly different species. The remaining six species -- the raxorback sucker, flannelmouth sucker, three species of chubs, and the squawfish -- are endemic species. They have been isolated for much greater periods of time, and have evolved into distinctly different species from their nearest relatives in other river basins. Fossils of some endemic species more than three million years old have been found. All of the six endemic species also occur (or did until recently) in the lower Colorado River basin. Of the seven

native but nonendemic species, only the speckled dace and the bluehead mountain sucker occur in the lower basin.

The native species have adaptive specializations to live in different environments. They are associated with specific types of habitats and are not randomly distributed throughout the system. For example, the cutthroat trout originally was limited to clear, cold waters at high elevation before it was replaced by nonnative species of trout. The six endemic species, with the exception of the roundtail chub, were largely restricted to the large, main river channels of the Colorado and Green and their major tributaries such as the Yampa, Gunnison, and San Juan rivers below the foothills where the water is warm in the summer months. The roundtail chub's optimum habitat seems to be the intermediate size tributary streams.

Great changes in the original river environments of the Colorado River basin have favored the nonnative fishes. More than 30 species of nonnative fishes have been introduced into the upper basin and now dominate most of the fish communities in the waters of the upper basin. All of the 13 native fishes still occur in the upper basin but all have been depleted in numbers. Five species have been reduced to a point that they are listed as endangered or threatened in Colorado. The squawfish and the humpback chub are also on the federal list of endangered species. These five species are discussed in detail in the following sections.

The federal list of endangered species also includes the Kendall Warm Springs dace, a subspecies of speckled dace. The Kendall dace lives only in the outflow of Kendall Warm Springs in Wyoming. The entire habitat of this peculiar population of speckled dace consists of less than 1000 feet of a small stream before it plunges over a ledge into the Green River. The Kendall Warm

Springs dace is classified as endangered because of its restricted habitat and the possibility that the entire population could be wiped out from pollution of the spring.

COLORADO RIVER SQUAWFISH

Ptychocheilus lucius

Status

Endangered on federal and state lists.

Distinguishing Features

This is the largest species of the minnow family native to North America. Specimens of 18 inches or more in length are easily identified by their large mouth, pike-like body shape, and olive-green back with silvery-white belly. Small specimens might be confused with the roundtail chub by inexperienced persons. Confusion is promoted because fishermen in Colorado commonly, but incorrectly, use the name squawfish for the roundtail chub. Among "old timers" who once knew the squawfish, the name "Colorado salmon", "white salmon", or simply "salmon" were frequently used as the common name for the squawfish. The jaw of the squawfish extends to or beyond the middle of the eye, but in roundtail chub, the jaw only reaches to a point in front of the eye. Also in young squawfish up to a size of about 8 to 10 inches) a dark blotch occurs on the base of the tail. This blotch is absent in the roundtail chub. Appendix I illustrates the characters useful to distinguish squawfish from roundtail chub.

Life History Notes

In recent years, the largest known specimens of squawfish have been about 3 feet long and about 15 pounds in weight. It appears that the present growth rate is much less than it was under the original, unmodified conditions in the Colorado River basin and before nonnative fishes became predominant over the native species. The effects of parasites such as the bass tapeworm, probably

probably brought into the basin in nonnative fishes, may also play a role causing reduced growth rates. Unverified weights of 80 to 100 pounds have been given in the literature. Based on statements in the literature and from the size of squawfish bones found in ancient Indian sites, the length the largest squawfish once attained is on the order of 5 to 6 feet. Plotting a length and weight curve based on squawfish specimens between 1 and 10 pounds and projecting the curve out to 5 and 6 foot lengths indicates that a squawfish 5 ft. long would weigh nearly 80 pounds and a 6 ft. specimen about 130 pounds. There is much room for error in such projected calculations but it can be surmised that the largest squawfish once attained a weight of from 60 to 80 pounds.

The squawfish is a predator, its food is mainly other fishes. In its first year of life, young squawfish feed on small invertebrate animals in quiet backwater areas and side channels off from the main river. As it grows, fish become more important in its diet. After a size of about 8 inches is reached, fish become the predominant food.

The maximum age of squawfish in recent years is about 10 to 12 years. They mature and spawn at an age of 6 or 7 years and a length of 18 to 20 inches. No one has observed the spawning of squawfish so the precise type of habitat selected for spawning is not known. The finding of young squawfish in quiet backwater areas suggests that spawning takes place in river sections near the backwater nursery habitat. Spawning occurs in early or mid summer when water temperatures reach about 70^{o} F. It generally is believed that squawfish made major spawning migrations before they were blocked by dams and this is why they were commonly called "salmon". Adult squawfish favor deep areas of large river channels from which they can move out to adjacent reaches and feed on other fishes. Squawfish and razorback sucker were the fish most highly valued as food by the early settlers and miners in the Colorado River basin. They were

caught and marketed by local commercial fishermen. When formerly abundant, squawfish were frequently caught on bait or lures by anglers.

The nearest living relatives of the Colorado River squawfish are three other species of squawfish native to the Columbia River, Sacramento River, and Oregon coastal rivers. None of the other species of squawfish reach a size comparable to the Colorado River squawfish. The other species of squawfish are not such strict predators and feed more on invertebrate animals and utilize a wider variety of habitats. In contrast to the Colorado River squawfish, the related species are flourishing to such an extent that they are considered a nuisance because they compete with game fishes. When reservoirs are constructed in the Columbia River basin, the Columbia squawfish often becomes the dominant species despite efforts to control their numbers. They respond in a most positive manner to man's alteration of the environment and to the presence of nonnative fishes. Although the general appearance of all four species of squawfish is quite similar, there obviously must be large differences in life history and ecology between the Colorado River squawfish and its relatives that have caused the Colorado River squawfish to fare so poorly when subjected to environmental change and nonnative fishes.

Past and Present Distribution

Originally, the squawfish was found throughout the Colorado River basin in the mainstream channels of the Colorado and Green rivers and the large tributaries such as the Gila, San Juan, Gunnison and Yampa. Historically, the distribution of squawfish would begin in the larger, warmer waters at lower elevation where the distribution of trout and whitefish left off. The habitat of the squawfish was originally hsared with the bonytail chub, the flannelmouth sucker and the razorback sucker. Squawfish began ti disappear from some areas

such as the Gila River in Arizona before the impacts of large dams. In the Gila River the replacement of squawfish by nonnative fishes can best be attributed to the great changes in flows and channel structure.

The advent of large, mainstream dams, initiated by Hoover Dam in 1930 and proceeding to the completion of Glen Canyon and Flaming Gorge dams in 1963, caused a rapid decline in squawfish abundance and distribution. No squawfish have been found in the entire lower Colorado River basin since 1968. After the closure of Flaming Gorge Dam and the subsequent cold water releases, squawfish were eliminated from the upper Green River downstream to a point below the confluence with the Yampa River. This section of the Green River from the Yampa River to the confluence with the Colorado is about 200 miles in length and is now the greatest stronghold of the squawfish. This is the only area where successful reproduction (finding young fish one or two years of age) has been consistently found in the past few years. From 1975 through 1979 several adult squawfish have been found in the Yampa River upstream to above Juniper Canyon. In the White River, adults were frequently found in the lower reaches in Utah and two were captured just above Piceance Creek in Colorado. In the Gunnison River, a few adult squawfish still occur in the lower reaches below Whitewater. A remnant population may occur in the San Juan River between Lake Powell and Navajo Reservoir in Utah and New Mexico. Squawfish are found sporadically in the Colorado River up to Plateau Creek, about 15 miles above Grand Junction. In recent years many captures along the Colorado River have been from gravel excavation ponds connected to the main river.

Except for the Green River below Jensen, Utah, and the Colorado River below Westwater Canyon, Utah, there has been little evidence of successful reproduction for the past several years in any of the locations where adult squawfish are found. Most specimens have been at least six years old or older.

Causes of Decline

The most obvious and clearly identifiable cause and effect relationship contributing to the decline of squawfish are the large dams and reservoirs that converted hundreds of miles of large river habitat into great impoundments. The planning and operation of these projects did not consider the preservation of native fishes. Squawfish and other native fishes do not reproduce successfully in large reservoirs. The adults present in the river when a dam is constructed may continue to live in a reservoir. They may thrive and grow, but the population consists of fewer, larger and older fish each successive year until they all die of old age. The largest known squawfish caught in relatively recent times was taken in Lake Mead about 35 years ago and weighed 34 pounds. Thus, there is no doubt that squawfish can live in reservoirs but they have not maintained themselved by natural reproduction.

Reservoirs release cold (40^{o} - 50^{o}) water from great depths. These cold tailwaters below dams create trout fisheries but they are avoided by squawfish. Coldwater releases from Flaming Gorge Dam effectively eliminated squawfish from 65 miles of the Green River below the dam. Only after the Green River is warmed by the flow from the Yampa River, do temperatures reach 70^{o} F or more in the summer months and reproduction is possible. Coldwater releases from Glen Canyon Dam apparently eliminated the last squawfish from the Grand Canyon area of the Colorado River.

Land use practices, irrigation, and channelization drastically alter flow patterns, river channel characteristics, and eliminate the quiet backwater nursery areas to a point that suitable squawfish habitat is no longer present. Evidently, this was the case in the elimination of squawfish from the Gila River of Arizona. These gradual, cumulative impacts on habitat are much less

dramatic and not as obvious as the more sudden changes created by a large dam and reservoir, but the end result can be similar in relation to the continued existence of squawfish.

In other instances, such as in the Yampa River, squawfish have declined in abundance and virtually no young squawfish have been found for several years. Yet, there are no large dams involved nor has there been any great changes in the flows, temperatures, or water quality of the Yampa River. That is, no physical or chemical changes can be pointed to suggesting a cause and effect relationship acting against the squawfish. In this case, a biological change must be examined, namely, the influence of nonnative fishes. Most nonnative fishes have lived with the squawfish in the Yampa River for a long time and the squawfish formerly reproduced successfully in the Yampa. The probable cause of reproductive failure in recent years is most likely attributed to a nonnative species that has become established in the Yampa River in relatively recent times. The probable culprit here is the redside shiner, a species introduced from the Columbia River basin. The first record of a redside shiner in the Yampa River occurred in 1961. It rapidly proliferated to become a dominant species by the 1970's. The redside shiner prefers waters of low velocity -- the quiet side channels and backwater habitat that is required as a nursery area for newly hatched squawfish. The redside shiner spawns earlier in the year than the squawfish. Thus, the young redsides get a head start and quickly saturate the habitat needed by young squawfish. The redside shiner is absent from the Desolation Canyon area of the Green River where the most consistently successful reproduction of squawfish still occurs. The negative cuase and effect relationship of redside shiner on squawfish is actually not so clear-cut as it might appear. Squawfish reproduction has been

severely limited in the Colorado River above and below Grand Junction for several years; yet the redside shiner does not occur in the Colorado River. The evidence of harmful effects of nonnative species on the squawfish is largely circumstantial and much is yet to be learned on the subject.

Prospects for the Future

When a species is listed federally endangered, a Recovery Team is usually appointed, made up of state and federal biologists and often biologists from universities to develop a Recovery Plan. The objective of a Recovery Plan is to provide directions and guidelines for management. If successful, the abundance of the species will increase to a point where it is no longer endangered or threatened and can be removed from the list. A workable Recovery Plan for squawfish is not a simple matter. A Recovery Plan has been written for the squawfish but the only clearly defined program in the plan to increase squawfish abundance is artificial propagation in hatcheries. The complex issue of interaction of the squawfish with its physical and biological environment and how various factors may be manipulated to the benefit of the squawfish is included under the title of "development of habitat management plans" in the Recovery Plan. The problem of a workable habitat management plan and how to implement it have not yet been resolved. Toward this goal, the U.S. Fish and Wildlife Service supported by funds from the U.S. Bureau of Reclamation has initiated a large scale study of squawfish and humpback chub. This study is designed to obtain the information needed to develop habitat management plans, to provide the basis for the planning and operation of future water development projects in the upper basin, and to seek ways that future environmental modifications might be beneficial to the squawfish. The U.S. Bureau of Land Management and the Colorado Division of Wildlife have also been conducting studies and monitoring programs on the squawfish.

Squawfish can be readily propagated in hatcheries. Hormone injections are necessary to induce spawning. Young squawfish feed on the same food fed to trout and larger squawfish feed on fish. Squawfish have been spawned and raised at the Willow Beach National Hatchery, Arizona, and some are also

maintained at the Hotchkiss National Hatchery, Colorado. Hatchery propagation, however, must be considered only as a stopgap measure in the preservation of squawfish. It is obvious that in areas where the squawfish once occurred but is now gone, the stocking of hatchery reared fish will not result in a self-sustaining population unless the factors causing the elimination of the squawfish in the first place can be reversed or modified. Ways must be found to favor successful reproduction of squawfish in natural environments. Merely trying to maintain the status quo by strict protection of habitat where squawfish still occur will not do the job of getting the squawfish off the endangered species list.

Squawfish will play an important role in the planning and operation of any future dams and water development projects in the upper basin. Flow and temperature releases from dams can be planned to favor squawfish instead of trout. Successful reproduction might be favored by the creation of artificial areas where natural nursery sites no longer exist. Methods of control and replacement of potentially harmful nonnative fishes, such as the redside shiner, will likely be necessary in areas such as the Yampa River, before successful reproduction of squawfish can be established.

The present diagnosis is that the squawfish can probably maintain a healthy and viable population indefinitely in the Green River below the mouth of the Yampa as long as the present environmental conditions are maintained. The probability of increasing the abundance and distribution into other areas where the squawfish has been eliminated or exists in low numbers, depends on the successful application of creative and holistic thinking and work.

HUMPBACK CHUB

Gila cypha

Status

Endangered on both federal and state lists.

Distinguishing Features

As the name implies, a prominent hump on the body just in back of the head characterizes this species. The hump of the humpback chub differs from the hump of the razorback sucker by being rounded in the chub and not supported by internal bone whereas the razorback sucker has a bony structural support for its hump which is sharp edged rather than rounded. The degree of development of the hump is highly variable. The humpback chub has a fleshy snout which protrudes over the lower jaw; large, streamlined fins, and a small eye -- smaller than the eye of roundtail or bonytail chubs of similar size. The caudal peduncle (the thinnest part of the body just in front of the tail) is thicker in the humpback chub than in the bonytail chub, but thinner than in the roundtail chub. Hybridization between the humpback chub and the bonytail chub have been reported. Thus, positive field identification of humpback chub is not always possible, even for an experienced biologist.

The humpback chub was not known to science until 1946 when a specimen from the Grand Canyon was described as a new species. It never was a common fish because of its habitat restrictions. Humpback chub occur in river sections that contain swift, deepwater areas, typically in canyons. Because of its rareness, little is known concerning the biology of this species. Apparently it feeds on invertebrate animals and is sometimes caught by fishermen on bait such as grasshoppers or worms. In the Little Colorado River of Arizona,

humpback chub have been observed feeding on food scraps thrown into the water by picnickers. The humpback chub may feed on the surface of the water, although the peculiar body shape would suggest it is designed to maintain stability on the bottom in turbulent flow. Its body may be designed to facilitate up and down movements so that it may feed on a variety of foods at different depths from the bottom to the surface.

The maximum size attained by humpback chubs is about 16 to 18 inches. Young humpback chub prefer quiet backwater areas similar to young squawfish. No one has yet observed this species spawn, but chubs ready to spawn were observed in water of about 65^{o} F., suggesting that they spawn slightly earlier than squawfish. Most of the prime humpback chub habitat in the canyon areas of the basin is now covered by reservoirs. As with the squawfish, adult humpback chub continued to live in reservoirs, but they became older and fewer until they finally disappeared from lack of successful reproduction.

Past and Present Distribution

The original distribution of humpback chub is not known with certainty but it is assumed to be comparable to that of the squawfish in the main river channels of the Colorado and Green Rivers. Chubs were restricted to swift, deepwater areas, mainly in canyons and did not occur far up any tributary stream. Presently, the greatest known concentration of this species occurs in the lower few miles of the Little Colorado River in the Grand Canyon area of Arizona. Perhaps the coldwater releases from Lake Powell have forced most of the humpback chub from the main Colorado River in Grand Canyon into the warmer Little Colorado.

In the upper basin, humpback chub occur sporadically in the Colorado River up to Palisades, Colorado, about 10 miles above Grand Junction. The

greatest concentration occurs in the Black Rocks area of Ruby Canyon, about 25 miles below Grand Junction, where turbulent flows create a pool almost 40 feet deep at low water levels. In the Green River, the humpback chub occurs below the mouth of the Yampa, and is concentrated in the Desolation Canyon area. It has been recorded from the lower Yampa River in Dinosaur National Monument.

Causes of Decline

Because the humpback chub had a restricted distribution and thus was always relatively rare, there is not much evidence of a decline except where reservoirs were constructed. The deepwater habitat favored by this species is not easily sampled by standard methods of fish collecting. As sampling techniques improve and more is learned about humpback chubs, more populations are likely to be discovered. The most abundant known population, in the Little Colorado River, was not discovered until 1975.

There has been considerable concern that the humpback chub may lose its identity due to hybridization with bonytail and roundtail chub. It now seems probable that most of the specimens formerly believed to be hybrids were actually normal variation in the degree of hump development. Some specimens, however, probably are hybrids. The bonytail chub now is so rare that it can be discounted as a significant source of possible hybridization. The roundtail chub, however, is common in the Colorado River in Colorado and occurs with the humpback chub in Ruby Canyon where some intermediate (hybrid?) specimens have been taken. The roundtail chub is absent or occurs rarely in humpback chub habitat in the Green River or in the Little Colorado River. Thus, overall, the threat to the integrity of the humpback chub species from hybridization is probably not as great as once believed.

The deepwater areas preferred by humpback chub are also a preferred habitat for nonnative channel catfish. Large populations of catfish and carp share the Ruby Canyon habitat with the humpback chub. Because of the different feeding specializations there is probably little direct competition with or predation on humpback chub from the catfish or carp. It might be assumed, however, that if nonnative fishes were not present, some of the food now consumed by catfish and carp would be eaten by humpback chubs and they would respond by increasing their abundance.

Prospects for the Future

A draft recovery plan has been written for the humpback chub, but, as with the squawfish, the main emphasis was placed on hatchery propagation as the only clearly defined technique to increase abundance. Humpback chub have been transported to the Willow Beach National Fish Hatchery, Arizona, for an attempt at artificial propagation. It is likely that additional populations will be found when more of the deepwater canyon areas in the upper basin are more thoroughly sampled. Fishermen can be of assistance in this regard by reporting catches of humpback chub. Good humpback chub habitat is also good channel catfish habitat and the chub can be caught on the same bait often used to catch catfish. Humpback chub, of course, must be released, but the Colorado Division of Wildlife should be notified of the catch, particularly if it is outside of the Ruby Canyon area of the Colorado River. A documented anglers catch (with a photo, if possible) may provide new distribution records and lead to the discovery of new populations of this rare fish.

A humpback chub preservation and restoration program is yet to be developed, but it will likely consist of the identification of all areas where populations still occur so that the present environmental conditions in those

areas can be maintained. It would be extremely difficult to establish humpback chub where they do not now exist. They may now inhabit all suitable areas wh-re self-sustaining populations can be maintained under present environmental conditions. The outlook is not encouraging for expanding the distribution and abundance of humpback chub by establishing new self-sustaining populations. Their habitat requirements are highly restrictive. Possibilities should be looked for, however, where deep channel areas have been created by bridge or highway construction, forming suitable habitat beyond the present limits of distribution. In such situations, the introduction of humpback chub might result in the successful establishment of a new population. Valuable information could be obtained from experimentation designed to establish new populations. There is little doubt that the humpback chub lost most of its best habitat to reservoirs such as Lake Powell and Flaming Gorge, but the present diagnosis is that this species is not as close to extinction as was commonly believed a few years ago.

BONYTAIL CHUB

Status

Many recent studies clearly point to the fact that the bonytail chub is the rarest of the Colorado River native fishes and the species nearest extinction.

Distinguishing Features

Large fins, a streamlined body with a very thin caudal peduncle (the thinnest part of the body just in front of the tail) distinguish the bonytail chub. The bonytail chub might be confused with both roundtail and humpback chubs. The body is more streamlined and the caudal peduncle much thinner in the bonytail chub in comparison to the roundtail chub. Bonytail chub may develop a slight hump on the back which would cause confusion with the humpback chub. The bonytail chub typically has 10 fin rays in both the dorsal fin and the anal fin, whereas the roundtail chub typically has dorsal and anal rays; the humpback chub most frequently has 9 dorsal rays and 10 anal rays, but is more variable. Many unusual specimens were collected in the 1960's which suggested hybridization between the bonytail and humpback chubs. The current consensus of opinion is that although some of these specimens do

represent hybrids, most are merely normal variability in the humpback chub.

Considerable confusion surrounds the identification and classification of bonytail chub. The bonytail and roundtail chubs were described as separate species in the nineteenth century but later were considered only as environmental modifications of a single species. That is, it was believed that a roundtail chub, leaving a tributary stream for life in the main river channel of the Colorado or Green River, would turn into a bonytail chub under the direct influence of a different environment. When it was discovered that both roundtail and bonytail chubs were frequently found living together with both of them maintaining distinctions from each other and not hybridizing, the two chubs were again recognized as separate species.

Confusion also surrounds the common name. In former times, professional biologists typically used the name 'bonytail' for both roundtail and true bonytail chubs. Thus, there are many literature references to bonytail chub that, in fact, refer to the roundtail chub.

Life History Notes

Until large dams were constructed, the bonytail chub was probably the most abundant species in the main river channels of the Colorado and Green Rivers and in the lower reaches of the larger tributary rivers. The bonytail chub was most common in the open river areas of large river channels. The humpback chub was most common in or near deepwater areas and the roundtail chub was most common in tributary streams. However, where suitably diverse habitat occurred, all three species might be found together.

The optimum habitat of bonytails, based on former collections when they were abundant, appears to be the open river areas of relatively uniform depth

and current velocity. This type of habitat typically consists of a shifting sand bottom, water depths of 3-4 feet, and a relatively constant, moderately swift current. The streamlined body and large fins of the bonytail seem well adapted to live in this type of habitat.

The bonytail chub is a relatively long lived species, not spawning until it reaches an age of 5-7 years. Similar to the other chub species, the bonytail spawns when the water reaches about 65° F. Little is known about the life history of bonytail chub because they rapidly disappeared before intensive studies were made. The bonytail feeds on insects, often terrestrial insects taken on the surface of the water. Various debris and algae fragments in their stomachs suggest that the bonytail may feed intensively after a sudden storm would cause floodwaters to wash food out of tributaries into the main river channels. The maximum size attained by the bonytails is, in general, 16 to 18 inches. However, small numbers of bonytail chub have continued to exist in the lower basin reservoirs, Lake Mohave and Lake Havasu where they may attain a great size. A specimen of about 3 feet and weighing 8 pounds was reported caught by an angler in 1975 from Lake Mohave.

Present and Past Distribution

The original distribution included the large river environments of the entire basin from Mexico to Wyoming. Bonytail chub were last recorded from the Gila River, Arizona, in 1926. They declined in the lower basin after the construction of Lake Mead, Lake Havasu and Lake Mohave. Bonytail persisted in large numbers in these reservoirs for several years and large numbers were observed spawning in Lake Mohave in 1954, but their numbers continued to decline due to poor reproductive success. The bonytail was still abundant in the Green River until after the completion of Lake Powell and Flaming Gorge Reservoir in 1963. By the late 1960's bonytail became very rare.

Except for the few specimens that may yet persist in Lake Havasu and Lake Mohave, the only bonytail chub recorded in the last three years, has been from the Green River in the Desolation Canyon area. Similar to the demise of the Passenger Pigeon, it seems unbelievable that a species once so abundant could so rapidly vanish.

Causes of Decline

The lack of successful reproduction in reservoirs explains the disappearance of bonytail chub from the segments of their former range that were converted into impoundments. Their absence in the Colorado River of Colorado and Utah and from most of the Green River where apparently suitable habitat still exists is not so easily explained. There is little in the way of documented evidence concerning the occurrence or abundance of bonytail chub in the Colorado River in Colorado and Utah, but it is assumed that they were common here because of the large river environment. The open river or "run" type of habitat does not seem to be extensively used by nonnative fishes. Thus, the "bonytail niche" would be expected to be lesser impaired than the niches of some other native fishes. Yet, the bonytail has suffered greater declines than any other native species and is now the rarest member of the original fish fauna.

Controlled water releases from Flaming Gorge Dam eliminated the great seasonal peaks of high and low flows of the original Green River regime and also causes daily fluctuations due to power generation. These changes in the flow regime undoubtedly have influenced subtle changes in channel configuration and altered optimum bonytail chub habitat. Although there are no large dams on the Colorado River above Lake Powell (except for headwaters), tributary reservoirs such as the Curecanti Project on the Gunnison, Reudi Reservoir on the Frying Pan River, Dillon and Green Mountain Reservoirs on the Blue River,

alter the historical flow regime in the Colorado by reducing the peak spring flows. Large amounts of water are diverted for irrigation with diminished return flows of altered water quality. Such changes in the flow regime and water quality exert influences downstream on channel structure and fish habitat. The loss of great numbers of bonytail chub from the areas inhabited by squawfish must have severely depleted the potential food supply of squawfish and may be a major cause of the reduced growth rates of squawfish in recent times.

Prospects for the Future

Realistically, the prospects for restoring the abundance of bonytail chub to a semblance of their former numbers in any part of the original range, must be viewed as dim. The bonytail is now the rarest of the native fishes and the species in most imminent danger of extinction. Biologists have been attempting to obtain live specimens from Lake Mohave and Lake Havasu to hold in a hatchery for artificial propagation. Captive propagation may prove to be the only way this species can be maintained. Unless the factors causing the elimination of bonytail chub are understood and some action taken to modify or eliminate these factors, the restoration of bonytail chub in its historic range cannot be expected from stocking hatchery reared fish. Even if the factors causing elimination from a river section became clearly understood, it is not likely that remedial action would be possible. For example, the dismantling of Flaming Gorge Dam to restore the original flow and temperature regime of the Green River must be considered beyond the realm of possibility.

If bonytail chubs occur in an area, it is likely that an occasional bonytail would be caught by fishermen fishing for catfish. If fishermen become

familiar with the appearance of bonytail chub and if a suspected specimen of bonytail is caught, it should be photographed before release and reported to the Colorado Division of Wildlife. There have been no verified records of this species for many years in Colorado. The discovery of a population would be a significant event.

RAZORBACK SUCKER

Xyrauchen texanus

Status

The razorback sucker is listed as threatened on the Colorado state list and has been proposed for threatened status on the federal list.

Distinguishing Features

The abrupt, sharp-edged hump on the back immediately posterior to the head identifies the razorback sucker from all other suckers and from all other fishes. The hump of the humpback chub is rounded and lacks the sharp leading edge. Although the common name "humpback sucker" is the name recognized for this species by the American Fisheries Society, the name razorback sucker is more descriptive of the species and avoids confusion with the humpback chub.

The size and development of the hump is related to size and age. Young razorback suckers of less than 6 to 8 inches have only a slight hump and might be confused with the flannelmouth sucker. Hybrids between razorback and flannelmouth suckers are common in some areas. The razorback sucker typically has 14 of 15 dorsal fin rays vs. typically 12 or 13 in the flannelmouth sucker. The razorback sucker has more gillrakers (small protuberances on the upper surface of the gill arches). Typically 45 or more gillrakers are found on the first gill arch of razorback suckers and about 35 in flannelmouth suckers. Hybrid specimens are intermediate in the size of the hump and in other characters.

Life History Notes

The peculiar body shape would suggest a design for stability on the bottom in burbulent flow. This may be true when they migrate during high flows,

but virtually all captures of razorback suckers have been from essentially still water, particularly off channel ponds created from gravel excavation or for irrigation storage.

As is typical of species in the sucker family, the razorback sucker has fleshy lips with which it can suck up small invertebrate animals and organic debris from the bottom. The numerous gillrakers makes the razorback sucker well adapted for straining small animals (zooplankton) from the water passed over the gills for respiration. The food material is sifted by the gillrakers and funneled into the throat where it is finely ground by rows of teeth (pharyngeal teeth). The razorback sucker attains an old age (probably more than 20 years) and can reach a large size (more than 10 pounds). When formerly abundant, the razorback sucker and the squawfish were the most common and desirable food fish of the Colorado River basin and they supported local commercial fisheries.

Although the razorback sucker is well adapted to thrive in reservoirs, reproduction has not been sufficiently successful to maintain their numbers. When impoundments were created in the lower basin, razorback suckers soon established large populations but the populations declined as the fish became fewer and older each succeeding year. Razorback suckers have been observed spawning along the shores in the lower basin reservoirs, but young individuals have not been found. With a long evolutionary background in a river environment, young razorback suckers may lack the instincts necessary to avoid predation in a lake environment. Thus, predators such as the largemouth bass and crappie may soon eliminate the newly hatched razorback suckers. Also, schools of large carp occur in the lower basin reservoirs and their bottom feeding may consume most razorback sucker eggs.

Most actual observations of spawning have been in reservoirs. Spawning is reported to occur at temperatures from 54° F. to 68° F. in water 1 to 20 feet deep. In river environments, groups of spawning razorback suckers have been observed on gravel bars in the Colorado River and lower Yampa River when the water temperature reached about 62° F. Ripe and spawned out fish found in off-channel ponds, which suggests that spawning also occurs in such habitats. Along the Colorado River in Colorado, razorback suckers are most frequently found in ponds created by gravel excavation adjacent to and connected with the river.

Past and Present Distribution

The original range of the razorback sucker was approximately that of the squawfish and bonytail chub, in the large river environments from Mexico to Syoming. Historically, it was more common in the lower Colorado River basin than in the upper basin. In the lower basin large populations built up in the artificial impoundments during early years but they gradually declined and now largely consist mainly of old (20 years and more), large, fish.

In the upper basin, razorback suckers disappeared from the Green River above the mouth of the Yampa River after the completion of Flaming Gorge Dam and the release of cold water. Some razorback suckers persist in the Green River below the mouth of the Yampa and are occasionally found in the lowermost reaches of the Yampa River. In the Colorado River in Colorado, razorback suckers occur upstream to De Beque, about 30 miles above Grand Junction. In 1977, an estimated 250 razorback suckers were found stranded when a small irrigation reservoir, connected to the San Juan River near Bluff, Utah, was drawn down.

Causes of Decline

Dams and [illegible] can be pointed to as the major cause of razorback sucker decline, as is the case with the other species discussed. Land and water use practices altering flow regimes and river channel characteristics which eliminate the [illegible] or backwater type habitat can also be blamed. This seems evident from the intensive utilization of artificially created, off-channel ponds by razorback suckers. Nonnative fishes such as carp, largemouth bass and the sunfish also typically thrive in these pond areas and they may effectively suppress successful reproduction of razorback suckers by predation on the [illegible] young in such habitat.

In seeking [illegible] the reasons for the decline of the razorback sucker, and interpretations from an evolutionary perspective can be made. It is known that before environmental changes occurred and before nonnative fishes became widely established in the Colorado River basin, two species of large suckers, the razorback and the flannelmouth, were both abundant. This means that the razorback sucker and flannelmouth sucker must have different niches. That is, the two species avoided direct competition with each other by differences in their life histories and ecologies so that they divided the food and space resources of their environment in such a way that both maintained abundant populations.

The ecological distinctions between flannelmouth and razorback suckers can be interpreted from differences in the way the two species are put together -- the differences in body shape, lip structure, and gillrakers. These distinctions in body parts are a reflection of the different evolutionary pathways followed by the two species to make maximum utilization of a certain part of their environment and avoid direct competition when they live together.

The flannelmouth sucker still maintains abundant populations under the present altered environmental regime, but the razorback sucker is rare. Obviously, then, the evolutionary specializations adopted by the razorback sucker to best utilize its historical niche, have placed the species at a severe disadvantage in the modified environment of the Colorado River basin. What factors in the original environment characterized optimum habitat for razorback suckers? How have these factors been lost, impaired, or modified?

As the razorback sucker became rarer, the incidence of hybridization with flannelmouth suckers has apparently increased. Almost half of the specimens captured, mainly in the Green River, from 1967 to 1973 were identified as hybrids. The proportion of hybrid specimens taken from the Colorado River in recent years varies from site to site. Some populations seem to be pure, but others contain a high percentage of hybrids.

Prospects for the Future

Because of its more widespread distribution, greater abundance and its utilization of artificially created habitat, the razorback sucker seems to have a more hopeful future than do the three species previously discussed. The problem of successful reproduction must be solved before the continued existence can be assured and increased abundance can be effected. Adult razorback suckers flourish in reservoirs and pond type environments but young of the species have not been found in such environments. It would be most important to know what are the optimum spawning conditions in regards to depth, velocity and substrate. It will also be important to learn what associated nonnative fishes are least harmful and what species are most harmful to successful reproduction.

Artificial propagation of razorback suckers has been conducted for several years at the Willow Beach Federal Hatchery, Arizona. Populations could be maintained in reservoirs by stocking fish reared in a hatchery but if reproduction is not successful in a reservoir or a section of a river, reproduction by stocked razorbacks cannot be expected.

Because the razorback sucker and the bonytail chub have not yet been listed as federal endangered or threatened species, they have not been eligible for federally funded projects on endangered species and have received much less attention than have the squawfish and humpback chub. It would be useful, for a better understanding of the species, to document their occurrence in all off-channel, pond habitats, correlating the abundance of razorback suckers with habitat characteristics such as size, shape, depths, and associated fish species. An analysis of the common denominators of the factors that favor the success of the species could then be made. If this were done, future man-made modifications might be designed to benefit the razorback sucker and perhaps the squawfish, also.

COLORADO RIVER CUTTHROAT TROUT

Salmo clarki pleuriticus

Status

Threatened on Colorado state list. Rare throughout its original range.

Distinguishing Features

The cutthroat trout that is native to the upper Colorado River basin can be distinguished from nonnative trout by its red or orange slash marks beneath the lower jaws and by the spotting pattern. Relatively large spots, rounded in outline and typically concentrated on the posterior part of the body characterize the native cutthroat trout. The native trout has the hereditary basis to develop brilliant coloration, but the color pigments must be derived from its food. Thus, a native trout living in a lake with crustaceans (water fleas, "shrimps", etc.) will express bright red, orange and golden-yellow coloration when sexually mature, but the same fish living in a small stream with only insects in its diet will be more dull colored.

The cutthroat trout species is made up of about 15 subspecies or geographical races distributed widely throughout the western United States and western Canada. The Colorado River cutthroat is a geographical race which has been isolated in the upper Colorado River basin.

It is closely related to the greenback cutthroat trout native to the headwaters of the South Platte and Arkansas River basins and to the Rio Grande cutthroat trout. There are no consistent differences that can separate all Colorado River cutthroat trout from all greenback cutthroat trout except for geographical distribution -- one is native to the Colorado River basin, the other to the South Platte and Arkansas basins.

Hybrid populations between the native trout, rainbow trout and nonnative subspecies of cutthroat trout are much more common than are pure populations of native trout.

Life History Notes

There are no obvious ecological differences between the Colorado River cutthroat trout and other trout species in regards to feeding, spawning, optimum habitat, etc. The cutthroat trout is like the canary in the mine in respect to tolerance of environmental disturbance -- it is usually the first species to go.

Spawning occurs in the spring when water temperatures reach about 45^{o} F. The female digs out a nest in gravel in flowing water. After fertilization, the eggs are covered with gravel and left to hatch later in the summer. As with most trout species, the cutthroat is opportunistic in its feeding. A wide range of invertebrate animals are eaten and larger cutthroat trout will prey on fish if they are available. The largest size attained by this subspecies is not known but probably was about 15 pounds. In small streams, however, few cutthroat trout will ever exceed 10 inches.

Past and Present Distribution

One hundred years ago the cutthroat trout inhabited all of the colder waters of the upper basin from the headwaters of the Green and Colorado Rivers to the San Juan River system on the east and the Dirty Devil River drainage on the west. The Green River below the town of Green River, Wyoming, and the Colorado River below Glenwood Springs, Colorado, were too warm in the summer for cutthroat trout. The main distribution was in the colder tributary systems at higher elevations. The distribution of cutthroat trout would begin above a point where the distribution of the warmwater species such as the squawfish left off.

The early settlers found the native cutthroat trout in great numbers in all of the suitable trout waters of the basin. After the introduction of non-native trouts, the native cutthroat rapidly declined. Presently, only a few pure populations are found in small, isolated headwaters in Wyoming and Colorado.

In Trappers Lake, Colorado, a native cutthroat trout population still occurs. The Trappers Lake cutthroat has been exposed to hybridization from the Yellowstone Lake subspecies of cutthroat trout and from rainbow trout and they cannot be strictly regarded as a "pure" population, but the effect of past hybridization is not evident. The present Trappers Lake cutthroat trout are quite typical of the native subspecies and are correctly classified as the Colorado River cutthroat trout. Trappers Lake cutthroat are propagated and stocked each year into high elevation lakes in the northwest region of Colorado, thus, besides those caught in Trappers Lake itself, fishermen have the opportunity to catch the native trout from numerous lakes because of the stocking program. Most of the cutthroat trout presently occurring in the Rocky Mountain region, are found in high elevation lakes. Because of this, many fishermen assume that this is their native habitat. Almost all of the high mountain lakes in Colorado are isolated by formidable waterfalls and no fish occurred in them naturally. Most of these lakes lack suitable tributary spawning streams and the cutthroat trout populations are maintained by regular stocking.

Causes of Decline

Virtually all of the subspecies of cutthroat trout native to the interior regions of western North America have suffered the same fate as the Colorado River cutthroat trout. One hundred years ago, the cutthroat trout was the only

trout that occurred in all of the famous Colorado trout streams such as the Gunnison, Roaring Fork, Arkansas, South Platte, the upper Yampa and the upper Colorado River. After stocking of nonnative fishes, the cutthroat trout was replaced by brown trout and rainbow trout in the larter streams and by brook trout in the higher elevation small streams. Hybridization between native cutthroat trout and nonnative rainbow trout was initiated on a massive scale in all waters where rainbows became established. Unlike most hybrids between animal species, the cutthroat x rainbow hybrid is fertile and can reproduce. Thus, once hybridization was started it rapidly spread. Nonnative subspecies of cutthroat trout, mainly from Yellowstone Lake, Wyoming, were stocked into Colorado waters by the millions to hybridize with the native cutthroat trout. Early fish cultural practices commonly mixed native and nonnative trout indiscriminantly. The introduction of nonnative trouts was the major cause of the virtual elimination of pure populations of Colorado River Cutthroat trout.

Prospects for the Future

Fortunately for the native trout, its highly generalized ecology allows it to flourish in a variety of habitats, including very small headwater streams. Thus, a restoration program for native trout is relatively simple in comparison to the problems faced in attempts to restore the previously discussed species. If all nonnative trout can be eliminated from a lake or an isolated stream section by chemical treatment, then native cutthroat trout from a known pure population can be transplanted and a new population established. This method of restoration has been used to establish several new populations of the greenback cutthroat trout in the South Platte River b-sin. In 1979, the elimination of nonnative trout is planned for a small lake and stream in the Colorado River drainage of Rocky Mountain National Park. If complete

removal of the nonnative fish is achieved, pure Colorado River cutthroat trout will be introduced and they should multiply rapidly in a few years.

The cutthroat trout is more easily caught by fishermen than other trout species. Because of this, the cutthroat trout is the only trout that consistently responds to restrictive fishing regulations by increasing its numbers. Regulations designed to recycle all or most of the catch by releasing all fish or all fish within certain size limits, have worked very well with cutthroat trout. The use of special regulations allowing the catching of native cutthroat trout but restricting the kill, will likely become an important part of the management of the several subspecies of cutthroat trout native to the Rocky Mountain West.

THE ENDANGERED SPECIES ACT

In the 1960's the environmental movement gathered momentum from increasing concern over accelerated extinction rates of life on earth. The U.S. Fish and Wildlife Service created an Office of Endangered Species and prepared the first list of endangered species in 1964. The Colorado River squawfish and the humpback chub were included on the first list. Congress passed an endangered species preservation act in 1966, as an expression of concern and awareness but it lacked enforcement provisions to protect endangered species where conflicts might arise. In December 1973, Congress passed new endangered species legislation, P.L. 93-205, known as the Endangered Species Act of 1973. The 1973 Act contains strong provisions to protect species on the list when they or their environment are in conflict with any federal action or project which might have negative impacts. These provisions are spelled out in Section 7 of the Act which states that all federal agencies are to use their authority in furtherance of the Act by carrying out conservation programs for endangered and threatened species. Federal agencies are directed to ... "insure that actions authorized, funded, or carried out by them do not jeopardize the continued existence of endangered and threatened species or result in the destruction or modification of these species habitat that is determined to be critical by the Secretary of Interior after consultation with the affected states."

It was Section 7 of the Endangered Species Act which caused the conflict between the snail darter and Tellico Dam in Tennessee. This project was deemed to jeopardize the continued existence of the snail darter, an endangered species, because the dam would modify the snail darter's critical habitat.

For a clearer understanding of the ramifications of the Endangered Species Act, two aspects must be differentiated -- that of private vs. federal

jurisdiction and that of the endangered species and its critical habitat. The Endangered Species Act does not apply to private property or actions unless some federal agency or federal funding is involved. If private funds construct a dam for electrical generation on private property, there would be the matter of permits from the Corps of Engineers and licensing by the Federal Energy Regulatory Commission, which would then subject the private project to the provisions of the Endangered Species Act. Irrigation projects of the Bureau of Reclamation and land modifications funded by the Soil Conservation Service are subjected to the provisions of the Endangered Species Act.

There has been considerable confusion over the term "critical habitat". The legal ramifications of critical habitat apply only to those endangered and threatened species that have had critical habitat designated by the Secretary of Interior. In an attempt to allay fears and to more clearly explain the meaning of "critical habitat", Mr. Keith M. Schreiner, former Director of the Endangered Species Office, published the following statement in the August, 1976, issue of the Endangered Species Technical Bulletin (published by the Office of Endangered Species):

> "The most important point I can make about critical habitat is that in no way does it place an iron curtain around a particular area; that is, it does not create a wilderness area, inviolable sanctuary, or sealed-off refuge. Furthermore, I would stress that it does not give the Fish and Wildlife Service or any other government agency an easement on private property nor will it affect the ultimate jurisdiction regarding any public lands.
>
> Critical habitat is provided for by Section 7 of the Endangered Species Act of 1973, which charges Federal agencies -- and only Federal agencies -- with the responsibility for ensuring actions authorized, funded, or carried out by them do not either 1) jeopardize the continued existence of Endangered or Threatened Species or 2) result in destruction or adverse modification of the habitats of these species. (State and private actions that do not involve Federal money or approval do not come under the terms of the Act.)

Simply stated, critical habitat is the area of land, water, and airspace required for the normal needs and survival of a species. As published in the Federal Register on April 22, 1975, the Service has defined these needs as space for growth, movements, and behavior; food and water; sites for breeding and rearing of offspring; cover or shelter; and other biological and physical requirements. Determination of a critical habitat may include consideration of certain biological, physical, or human elements of a species' environment, if -- but only if -- the element is required for the continued survival or reasonable recovery of the species.

We are taking special pains to make sure that every shred of biological data is obtained and analyzed before any critical habitat is determined. Federal and State agencies are being contacted in writing prior to publication of a proposal. Once the proposal has been published, written comments on its biological adequacy are actively sought from all interested parties. In some cases, if the situation warrants, public hearings are being held in the affected States to seek the views of local residents. It is only after all of this biological information has been collected and carefully analyzed that a final determination is made.

Once the final determination has been published, its only effect is to cause Federal agencies managing lands or administering programs within the area to examine their actions in light of section 7.

The actions of private individuals (farmers, ranchers, trappers, etc.), firms, and State agencies are not affected unless funding or approval from a Federal agency is involved.

If an action does require Federal funds or approval, then the particular Federal agency having jurisdiction must decide whether or not the action would "jeopardize the continued existence of the species or result in destruction or modification" of its critical habitat.

There is no way to predict how Federal agencies will decide about particular actions in particular areas. The agencies simply consider them on a case-by-case basis as they arise. Nevertheless, I should emphasize that there are many types of existing land uses that are compatible with the continued survival of species and maintenance of the quality of their habitats. In addition the Service is prepared to provide assistance and consultation on the biological impacts of proposed activities whenever such consultation is needed. However, the final decisions will be made by the appropriate Federal agencies.

In short, the determination of critical habitat is a means of helping all Federal agencies meet their responsibilities under the Endangered Species Act of 1973. It is a tool to help save and restore species, not a weapon to hinder economic or social progress.

Amendments were made to the Endangered Species Act in 1978. One of the amendments calls for an economic analysis to be prepared before any critical habitat is designated. This amendment is designed to reveal negative economic impacts from the designation of critical habitat that might retard or block future development. Critical habitat had been proposed for the squawfish but has been withdrawn until an economic analysis can be prepared. Thus, the squawfish and humpback chub are endangered species, but neither has "critical habitat" in the legal sense of the term. Any future development project or environmental modification in the upper Colorado River basin, to be compatible with the Endangered Species Act would be subjected to the provision that its construction and operation do not "jeopardize the continued existence" of the squawfish or humpback chub, but would not be subjected to the critical habitat provision until such critical habitat is defined and designated by the Secretary of Interior. Another 1978 amendment stipulates that, in the future, any species proposed for the federal list of endangered or threatened species must have the critical habitat designated at the time it is listed. This stipulation will probably cause considerable delay in the listing of the bo-ytail chub and the razorback sucker.

The effects of the listing of a species as endangered or threatened by the Colorado Wildlife Commission, consist mainly of the recognition of the plight of a species and the ordering of priorities for funding, study and restoration. There are no provisions in the state law which might conflict with the activities of state or federal agencies or private individuals, except that endangered species cannot be killed, transported, or sold. The three subspecies of native cutthroat trout in Colorado (Colorado River, greenback, and Rio Grande cutthroat trout) are all listed as threatened by the

state, but they are covered by game fish regulations. It is not illegal to fish for, catch and eat the native cutthroat trout except in those waters where all angling has been prohibited such as where greenback cutthroat trout occur in Rocky Mountain National Park. Some streams have been set aside for catch-and-release angling for the Rio Grande cutthroat trout and more of these special regulation trout fisheries are likely to be established as part of restoration programs.

The federal Endangered Species Act defines an endangered species as any species that is in danger of extinction throughout all or a significant portion of its range. A "species" is defined to include subspecies and smaller units of a species. Thus, the Kendall Warm Springs dace subspecies and several subspecies of cutthroat trout, including the greenback cutthroat in Colorado, have been listed as endangered or threatened species on the federal list even though the species as a whole was not endangered. A "threatened species" is defined as any species that is likely to become an endangered species in the foreseeable future. As far as the Endangered Species Act is concerned, there is little difference in the legal protection between the endangered and the threatened status. A threatened species, however, may be the object of a sport fishery if properly regulated.

When a potential conflict arises with the occurrence of an endangered species in an area where a federal project or action is deemed to pose a threat to the species, a consultation process with the U.S. Fish and Wildlife Service is initiated. The consultation process is an attempt to find ways that would allow the planning, construction, and operation of a proposed project to be compatible with the Endangered Species Act.

Fair and equitable administration of the Endangered Species Act to protect a species and at the same time allow new development projects to proceed

is not a simple matter. It is generally realized that an uncompromising, ultra-protectionist stance should not be taken with endangered species to block future economic development. Such action would create a backlash in public opinion concerning the need to preserve endangered species. The official view of the Endangered Species Office was presented by the former director, Mr. Schreiner, to the 1977 annual meeting of Western State Game and Fish Commissioners:

> "We must stop our traditional adversary role in water development, power developments, agricultural expansion, energy production, etc., and start trying to help the developers locate the site, design the structure and develop the operational regime that will do the least harm to wild plant and animal species and their habitats. It is likely that we can enhance the habitat and ultimately the species if we accept the fact that development must and will continue.
>
> So I repeat, realistic endangered species administration means all of us helping developers to locate, design and operate their projects in a manner that is least harmful to species and their habitats."

Almost all conflicts between development and endangered species have been resolved to date by the consultation process. In a situation where a conflict cannot be resolved (such as was the case with Tellico Dam and the snail darter), a 1978 amendment to the Endangered Species Act provides for an exemption process. A Review Board consisting of persons appointed by the Secretary of the Interior and by the President, with a third member represented by a judge appointed by the Civil Service Commission, decides if an irresolvable conflict does exist. If the Review Board decides that an irresolvable conflict exists, then the exemption application is considered by a seven member Endangered Species Committee made up of the Secretary of Agriculture, the Secretary of the Army, the Secretary of the Interior, the Chairman of the Council of Economic Advisors, the Administrator of the Environmental Protection Agency,

the Administrator of the National Oceanic and Atmospheric Administration, and a person appointed by the President after consultation with the Governor of the concerned state. An exemption to the Endangered Species Act can be granted if five of the seven members of the Committee agree to exempt the project. In their judgement, the Committee considers if there are reasonable alternatives to the project, if the benefits of exemption clearly outweigh the values of endangered species protection, and the overall significance of the project to the region and to the nation. The final decision is subject to a review by the U.S. Court of Appeals. Any person is entitled to bring action to obtain this judicial review. If the Committee votes against exemption and the decision is upheld by the court, only special legislation passed by Congress can create an exemption.

There is no doubt that there are many situations of potential conflict in the upper Colorado River basin in relation to future water and energy projects as they may modify the environment and impact the squawfish and the humpback chub. Although each project must be examined individually, a holistic view of the future is necessary to predict combined effects if all projects were to be constructed. The ultimate objectives are to guide and direct future environmental modifications so that changes in flow regime, temperature, and water quality will have a beneficial impact on the endangered species. The present research efforts of the U.S. Fish and Wildlife Service and the Colorado Division of Wildlife on the life history, ecology, and habitat preference of squawfish and humpback chub are designed to provide the bases for resolving conflicts between the endangered species and future development in the basin.

There are likely to be delays, compromises, and increased costs associated with some new projects in the upper Colorado River basin. To avoid conflict

with the Endangered Species Act, any future environmental modification should not be harmful and, hopefully, can be designed to be beneficial for endangered species.

Comprehensive bibliographies on the upper Colorado River basin were compiled by Wydoski, et al. 1976 and by Joseph, et al. 1977. Most of the pertinent literature pertaining to the current status of the rare native fishes of the upper Colorado River basin is in the form of theses and agency reports that are not generally available in libraries. The following list of references include those that have appeared since the above-mentioned bibliographies were completed and some of the significant older publications that are in journals or serials available in the larger academic libraries.

Behnke, R. J. and M. Zarn. 1976. Biology and management of threatened and endangered western trouts. USDA Forest Service, Rocky Mtn. For., Rng. Exp. Sta., Gen. Tech. Rep. RM-28:45p.

Carlson, C. A., C. G. Prewitt, D. E. Snyder, and E. J. Wick. 1979. Fishes and macroinvertebrates of the White and Yampa Rivers, Colorado. Final Report Baseline Survey for U.S. Bureau Land Management, Denver, Co.:276p.

Deacon, J. E., G. Kobetich, J. D. Williams, and S. Contreras. 1979. Fishes of North America endangered, threatened, or of special concern:1979. Fisheries (Bull. of Am. Fish. Soc.) 4(2):29-44.

Ehrenfeld, D. W. 1976. The conservation of non-resources. Am. Sci. 64:648-656.

Evermann, B. W. and C. Rutter. 1895. Fishes of the Colorado basin. U.S. Fish Comm. Bull. 14:473-486.

Holden, P. B. 1977a. A study of the habitat use and movement of the rare fishes in the Green River from Jensen to Green River Utah, August and September, 1977. U.S. Fish and Wildlife Ser., West. Energy, Land Use Team, Fort Collins, Co., Final Rep. PR-13-1:65p.

_____. 1977b. Habitat requirements of juvenile Colorado River squawfish. U.S. Fish and Wildlife Ser., Biol. Ser. Program, FWS/OBS-77/65:71p.

_____. 1979. (in press). Ecology of riverine fishes in regulated stream systems with emphasis on the Colorado River. In: J. V. Ward and J. A. Stanford (eds.). The ecology of regulated streams. Plenum Publ. Corp., N.Y., N.Y.

_____ and L. W. Crist. 1979. Documentation of changes in the macroinvertebrate and fish populations in the Green River due to inlet modification of Flaming Gorge Dam. U.S. Fish and Wildlife Ser., Biol. Ser. Program, Fort Collins, Co., PR-16-2:112p.

_____ and D. A. Selby. 1978. A study to determine spawning requirements of Colorado squawfish. Ibid. PR-17-1:29p.

_____ and C. B. Stalnaker. 1975a. Distribution and abundance of mainstream fishes of the middle and upper Colorado River basin, 1967-1973. Trans. Am. Fish. Soc. 104(2):217-231.

_____ and _____. 1975b. Distribution of fishes in the Dolores and Yampa river systems of the upper Colorado basin. Southwest. Nat. 19(4): 403-412.

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

Joseph, T. W., J. A. Sinning, R. J. Behnke, and P. B. Holden. 1977a. An indexed, annotated bibliography of the endangered and threatened fishes of the upper Colorado River system. U.S. Fish and Wildlife Ser., Office of Biol. Ser., Fort Collins, Co., FWS/OBS Rep. 24, part 1:168p.

_____, _____, _____, and _____. 1977b. An evaluation of the status, life history, and habitat requirements of endangered and threatened fishes of the upper Colorado River system. Ibid., part 2:183p.

Langlois, D. 1977. Status of the razorback sucker and bonytail chub in western Colorado. Colorado Div. Wildlife (mimeo):12p.

Lanigan, S. H., C. R. Berry, and D. Robinson. 1979. Distribution and abundance of fishes in the White River, Utah. U.S. Bur. Land Mgt., Utah St. Office, interim rep.:72p.

McAda, C. W. and R. S. Wydoski. 1979. The razorback sucker. *Xyrauchen texanus*, in the upper Colorado River basin. Ms. submitted to U.S. Fish and Wildlife Service for publication.

_____, C. R. Berry, and R. S. Wydoski. 1977. A survey of endangered, threatened, and unique fish in southeastern Utah streams within the coal planning area. p. 1-265 in: T. C. Bonner, W. A. Heggen, C. McAda, C. Phillips, C. R. Berry, and R. S. Wydoski. A survey of endangered, threatened, and unique terrestrial and aquatic wildlife in Utah's coal planning area. Utah Dept. Nat. Resources, Div. Wildlife, Salt Lake City.

Miller, R. R. 1961. Man and the changing fish fauna of the American Southwest. Mich. Acad. Sci. Arts, Lett. 46:365-404.

_____. 1963. Is our native underwater life worth saving? Nat. Parks Mag. 37(188):4-9.

Minckley, W. L. and J. E. Deacon. 1968. Southwest fishes and the enigma of "endangered species". Science 159 (3822):1424-1432.

Myers, N. 1977. Garden of Eden to weed patch: the earth's vanishing genetic heritage. Nat. Resour. Defense Counc. Newsletter 6(1):1-15.

Pister, E. P. 1976. A rationale for the management of nongame fish and wildlife. Fisheries (Bull. Am. Fish. Soc.) 1(1):11-14.

Seethaeler, K. 1978. Life history and ecology of the Colorado squawfish (*Ptychocheilus lucius*) in the upper Colorado River basin. M.S. thesis, Utah St. Univ., Logan, Utah:155p.

Suttkus, R. D. and G. H. Clemmer. 1977. The humpback chub, *Gila cypha*, in the Grand Canyon area of the Colorado River. Occ. Pap. Tulane Univ. Mus. Nat. Hist. 1:30p.

Vanicek, C. D. and R. H. Kramer. 1969. Life history of the Colorado squawfish, *Ptychocheilus lucius*, and the Colorado chub, *Gila robusta*, in the Green River in Dinosaur National Monument, 1964-1966. Trans. Am. Fish. Soc. 98(2):193-208.

_____, _____ and D. R. Franklin. 1970. Distribution of Green River fishes in Utah and Colorado following closure of Flaming Gorge Dam. Southwest. Nat. 14(3):297-315.

Williams, J. D. and D. K. Finnley. 1977. Our vanishing fishes, can they be saved? Frontiers, Summer, 1977:12p.

Wiltzius, W. J. 1978. Some factors historically affecting the distribution and abundance of fishes in the Gunnison River. Final Rep. to U.S. Bur. Reclamatkon, Fish. Invest. Power Gunnison R. drainage:215p.

Wydoski, R. S., K. Gilbert, K. Seethaeler, and C. W. McAda. 1976. Annotated bibliography for aquatic resource management of the upper Colorado River ecosystem. Utah Coop. Fish. Res. Unit, Utah St. Univ., Logan, Utah: 204p.