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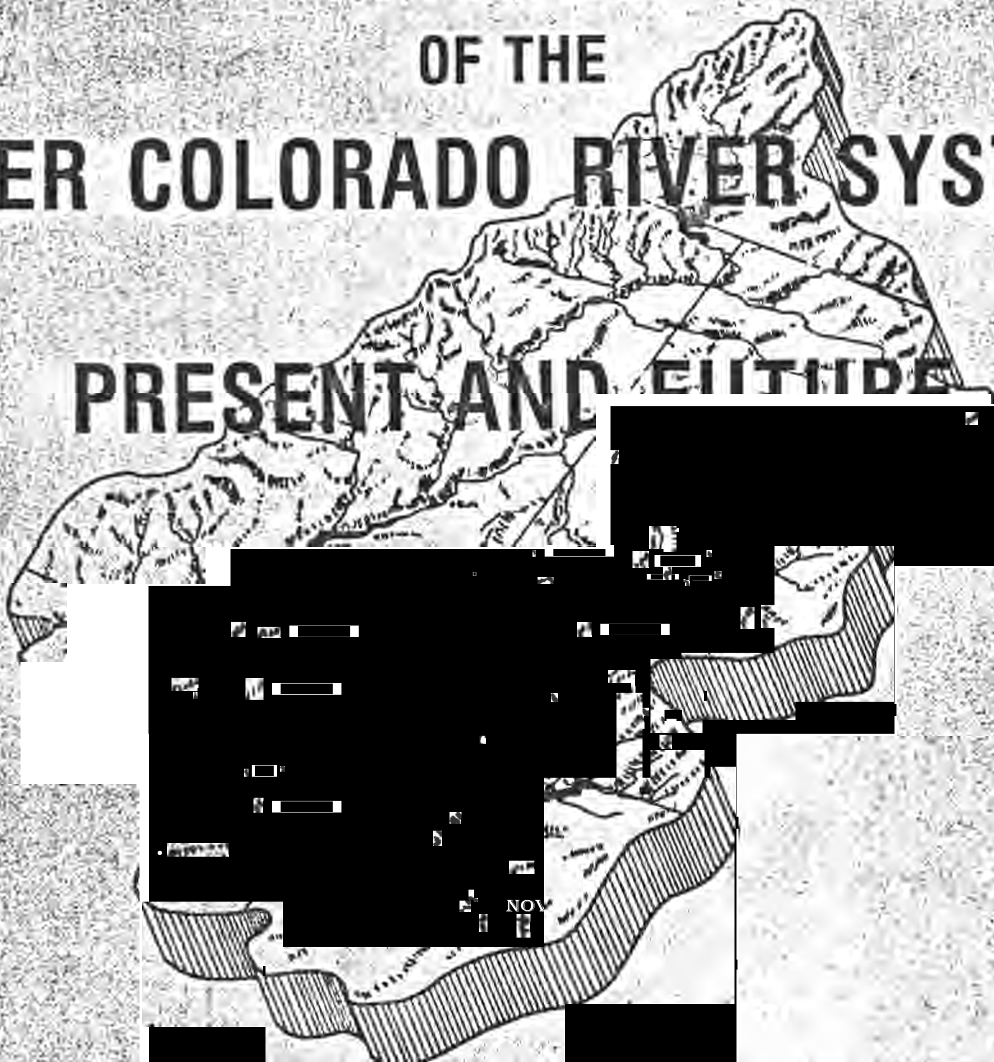
FISHES OF THE UPPER COLORADO RIVER SYSTEM: PRESENT AND [redacted]



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EDITORIAL NOTES

The editors express thanks to the contributors for their cooperation and to the reviewers for their efforts. We are especially grateful to Oliver B. Cope for his editorial assistance in final preparation of these proceedings. In cases where no abstracts were provided by the authors, the editors prepared indicative abstracts, which are identified. In some cases we also provided up-to-date (1982) citations for authors who cited draft or unpublished material. The editors accept responsibility for errors or misquotes resulting from our misinterpretation or editing.

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FOREWORD

Clarence A. Carlson

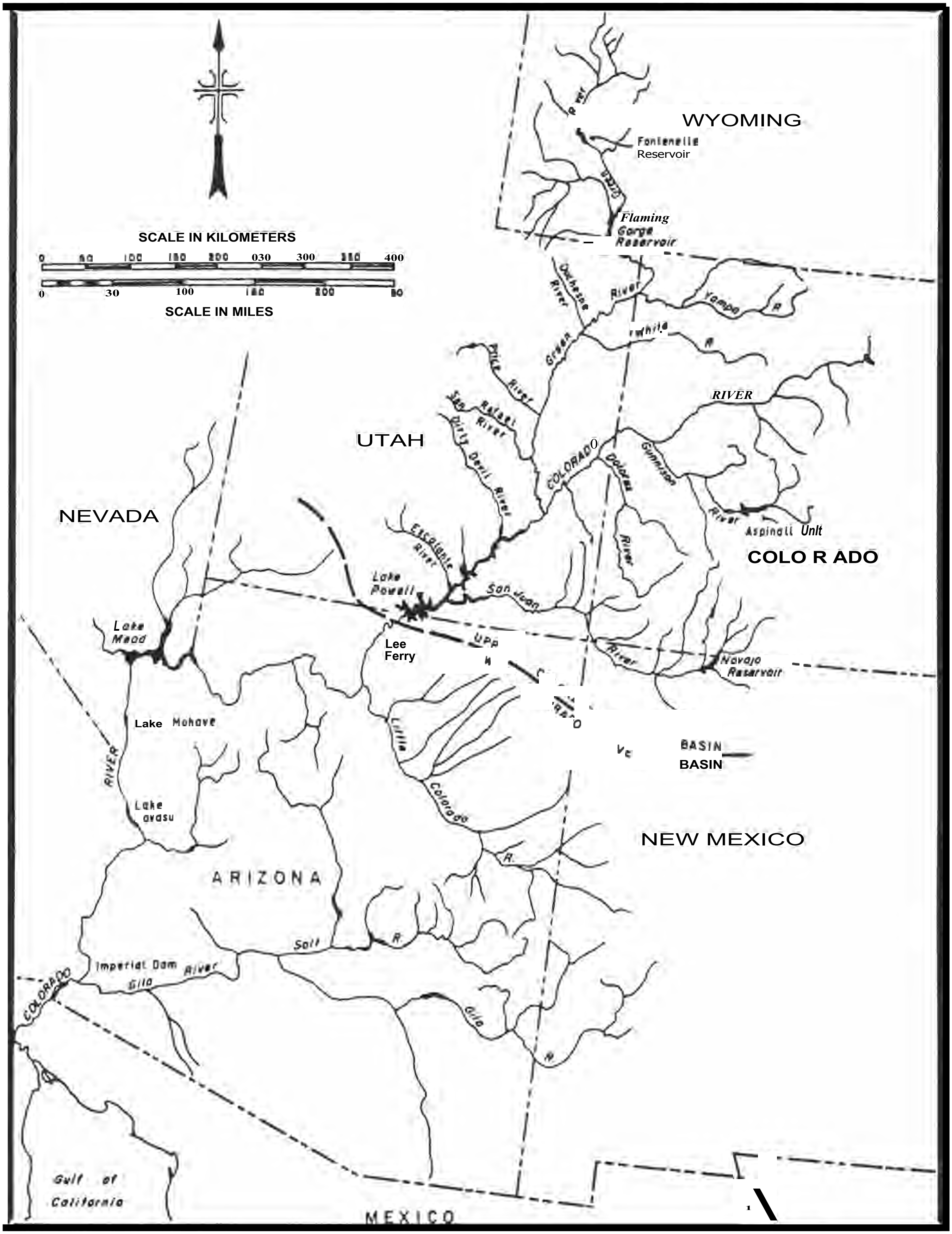
The rare native fishes of the Upper Colorado River System have been the subject of considerable interest and contention for decades, but research on them intensified in the 1970's and early 1980's. Because many research efforts had recently culminated or were nearing completion, a committee consisting of Bill Miller, Darrel Snyder, Ed Wick, and I began early last year to arrange a series of papers on these fishes for presentation at the 1981 meeting of the American Fisheries Society. Our intent was to focus attention on a subject of major interest to western fishery biologists, concentrating on research conducted after 1975 on fishes of the intermediate and lower (large-river) habitat zones in the Upper Colorado River Basin. Our objectives were to: (1) present basic information about these fishes, (2) identify critical needs for recovery or continued existence of rare fishes, (3) emphasize life history and status of rare and endangered fishes, and (4) consider impacts on fishes of past human actions and anticipate future impacts as water use increases. A secondary goal was to provide a basis and opportunity for discussion regarding what can be done to preserve the native fishes of the Upper Colorado River System in light of human needs, legal constraints, and political realities.

Participation of a diverse group of experts was obtained, and written versions of their presentations comprise these proceedings. Eileen Carlson and I have provided background and introduced the Upper Colorado River System and its fishes through a brief literature review. Bob Shields presented a summary of biological and political problems encountered by resource agencies responsible for water management and endangered species in the Upper Basin. He introduced the Colorado River Fishery Project and the Conservation Plan approach to resolving conflicts. Harold Tyus spearheaded a cooperative effort to summarize current data on fish species in the Upper Colorado River System, including a breakdown on numbers of native, introduced, endemic, and rare fishes. Tyus and his co-authors also charted fish distribution, relative abundance, and preferred habitats in rivers and their incidence in reservoirs.

Bob Jacobsen discussed energy and mineral development, water development, and transportation expansion in the Upper Basin. These activities, associated with massing of people, are expected to result in fish and wildlife habitat losses and other adverse effects, which will require cooperative efforts to minimize their impacts. Mike Prewitt and Clair Stalnaker suggested establishment of habitat and population-enhancement programs based on modeling of flow regimes. Ron Lambertson stated that mitigation tradeoffs are not acceptable for endangered species under Section 7 of the Endangered Species Act, but a comprehensive effort by resource agencies should allow protection of natural ecosystems (and listed fishes) while responsible economic growth and development proceed. Reed Harris and his co-authors discussed natural flows in Upper Basin streams, the extent of present water use, and legal constraints on use of Upper Basin water. Some rather surprising estimates of future flows as a percentage of natural flows were presented. Flexibility in methods of using water will decrease with water supply, and more compromises will be necessary. Bob Behnke fully recognizes the inevitability of compromise and doubts that endangered fishes will be protected at the expense of economic "benefit". He concluded his presentation by proposing creation of an independent agency to study and monitor effects of habitat alterations. This agency would be funded by taxes on benefits from human activities that alter the environment.

Kent Miller described the Colorado River Fishes Recovery Team and summarized its philosophy, activities, and methods of accomplishing recovery plan goals. Paul Holden, Rich Valdez, Ed Wick and their co-authors emphasized new data on the life histories of the rarest endemic fishes of the system and discussed reasons for declines and prospects for saving these fishes from extinction. Little optimism was expressed about the future of the Colorado squawfish, razorback sucker, humpback chub, and, especially, the bonytail chub in the Upper Colorado River Basin.

A panel consisting of Bob Behnke, Paul Holden, Ron Lambertson, Bill Miller, Phil Sharpe, and Clair Stalnaker presented additional information and addressed audience concerns. The discussion was ably led and summarized by Dick Wydoski. Bill Miller's closing remarks concluded the symposium.



Frontispiece — The Colorodo River Basin, showing Upper and Lower sections.

REVIEW OF SELECTED LITERATURE ON THE UPPER COLORADO RIVER SYSTEM AND ITS FISHES

Clarence A. Carlson and Eileen M. Carlson

ABSTRACT

A review of selected literature provides the foundation for this symposium and a background for those unfamiliar with the Colorado River. The Upper Colorado River System is discussed and its fishes are introduced by reviewing easily accessible reports. Readers are referred to the bibliographies of Ecology Consultants, Inc. (1977) and Wydoski *et al.* (1980) as guides to other literature.

The Colorado River arises at the headwaters of the Green River in the Wind River Range in western Wyoming and among the peaks of the Rocky Mountains in north-central Colorado. It flows through or adjacent to seven states and 145 km of Mexico to the Gulf of California (Frontis.), receiving major tributaries and losing its waters to major diversions. Including the Green, the river is about 2,735 km long; it flows over 1,609 km through deep canyons, including the Grand Canyon in Arizona. Its basin contains 1/12 of the land area of the United States (Bishop and Porcella 1980). The Colorado River supplies more water for consumptive use than any other in the United States but is not on the U.S. Geological Survey list of 33 rivers with highest discharge (Pillsbury 1981).

The Colorado River Compact approved by Congress in 1928 divided the basin into approximately equal upper and lower segments for water-management purposes. "Lee Ferry," Arizona, defined as "a point 1 mile downstream from the mouth of the Paria River," was selected as the dividing point between the upper and lower basins. Other laws regulating use of Colorado River water are reviewed in this symposium by Harris *et al.*

THE UPPER COLORADO RIVER BASIN

The Upper Colorado River Basin extends about 885 km from north to south, is about 563 km from east to west, and comprises about 283,600 km^2 of western Colorado, southwestern Wyoming, eastern Utah, northwestern New Mexico, and northeastern Arizona (Iorns *et al.* 1965). Rimmed by some of the highest mountains in America, it includes the Colorado Plateau region and portions of the Middle and Southern Rocky Mountain and Wyoming Basin regions described by Hunt (1974). Hunt (1956,1969,1974) described the geologic history of the basin and the development of the Colorado River. The Upper Colorado River Basin has been sub-divided by several authors into the Green, Upper Main-stem Colorado (or Grand), and San Juan (or San Juan-Colorado) hydrologic sub-basins. The main-stem Colorado River above the confluence with the Green was known as the Grand River prior to 1921. Much of the following descriptive information on the sub-basins is based on the works of LaRue (1916) and Iorns *et al.* (1965).

The Green Sub-basin

The Green Sub-basin has a drainage area of 115,773 km^2 in Wyoming, Colorado, and Utah. It extends from the source of the Colorado's largest tributary, the Green River, to the confluence of the Green with the Colorado.

The headwaters of the 805-km-long Green River are on the western slopes of the Wind River Range in western Wyoming at an altitude of almost 4,270 m (Frontis.). The Green River has been impounded by Fontenelle Dam in Wyoming and Flaming Gorge Dam in Utah; both impoundments are participating projects of the Colorado River Storage Project, built and operated by the U.S. Bureau of Reclamation. Principal tributaries of the Green River include the Yampa River, the Duchesne River, the White River, the Price River, and the San Rafael River.

The Upper Main-stem Colorado Sub-basin

This sub-basin consists of 68,625 km^2 in Colorado and Utah; it contains the Colorado River above its confluence with the Green. The Colorado River arises near the eastern slope of Mount Richthofen on the Continental Divide and flows generally southwestward for about 480 km to its confluence with the Green River (Frontis.). Fradkin (1981) stated that seepage from the Grand Ditch, the first major conveyor of water from the basin, now is the source of the Upper Main-stem Colorado River.

Diversion of water out of the Upper Main-stem Colorado River Sub-basin began in 1880, when Eagle River headwaters were diverted to the Arkansas River Basin for placer mining. The Colorado-Big Thompson Reclamation Project, virtually completed in 1956, exports water from the Colorado River headwaters to the South Platte drainage in eastern Colorado (Pennak 1963). Water is stored in Willow Creek Reservoir, Lake Granby, Shadow Mountain Lake, and Grand Lake and is delivered to the eastern slope through the 21-km Adams Tunnel for flood control, irrigation, municipal supplies, hydroelectric power, and recreational facilities.

The Roaring Fork River joins the Colorado River at Glenwood Springs, Colorado. The largest tributary of the Upper Main-stem Colorado, the Gunnison River, enters the Colorado at Grand Junction, Colorado. In Utah, the Dolores River enters the Colorado; it is the last major tributary upstream of the Colorado-Green River confluence.

The San Juan Sub-basin

The San Juan Sub-basin is the drainage between the junction of the Green and Colorado rivers and the Lower Colorado River Basin. Its 99,200 km^2 area is in Colorado, Utah, New Mexico, and Arizona.

The Colorado River below the mouth of the Green River passes through Cataract Canyon and remains entrenched in a deep canyon as it flows about 200 km southwestward to Lee Ferry (Frontis.). Much of the stretch of river below Cataract Canyon is now part of Lake Powell. Glen Canyon Dam and Reservoir (Lake Powell) were authorized by the Colorado River Storage Project Act in 1956; the dam, a few miles below the Utah-Arizona line, was completed in 1964 (Upper Colorado River Commission 1980).

Principal Colorado River tributaries which now enter Lake Powell are the Dirty Devil, Escalante, and San Juan rivers.

The San Juan River arises on the southern slopes of the San Juan Mountains in southwestern Colorado, flows southwestward into New Mexico, and then turns back into the southwestern corner of Colorado before entering Utah. It flows through a deep canyon before entering Lake Powell. The Navajo Storage Unit of the Colorado River Storage Project was completed in 1963 to regulate San Juan River flows for irrigation and municipal purposes (Upper Colorado River Commission 1980).

The Paria River joins the Colorado River about 25 km below Glen Canyon Dam and 1.6 km north of Lee Ferry.

Dams, Reservoirs, and Water Diversions

We have not attempted to mention all dams, reservoirs, and water diversions in the Upper Colorado River Basin. Spofford (1980) referred to nine principal federal reservoirs in the basin. A complete list of the 21 participating projects of the Colorado River Storage Project authorized by Congress appeared in the Thirtieth Annual Report of the Upper Colorado River Commission (1978). Some of these are still in planning phases or under construction. Other, non-federal, projects such as the Moffat and Roberts tunnels of the Denver Water Board also exist. A complete list of existing and planned projects is very difficult to develop and keep up-to-date.

Many diversions, like the Colorado-Big Thompson Project, result in export of water from the Colorado River Basin. Water diverted from the Upper Colorado River Basin is used in the Arkansas River, Platte River, and Rio Grande River basins and in the Great Basin. Martin (1981) reported, for example, that 27% of Colorado's legal share of Colorado River water is diverted to eastern-slope cities from Fort Collins south to Pueblo and that water needs of these cities are expected to increase by at least 200% in the next 30 years. Schad (1980) noted the irony in the Colorado River Basin, which drains some of the nation's more arid lands and has the lowest run-off per square mile of any major river basin, being the source of such a large number of interbasin transfers.

Conditions in the Basin

Iorns *et al.* (1965), Joseph *et al.* (1977), and Bishop and Porcella (1980) summarized conditions in the Upper Colorado River Basin. A broad range of climatic and streamflow conditions exist in the basin; annual precipitation varies from over 127 cm in mountains to under 15 cm in desert areas.

Seasonal streamflow is derived primarily from snowmelt in mountainous areas, and historic unit discharge rates decrease rapidly as tributary streams flow from their headwaters into less humid areas (Bishop and Porcella 1980). Significant variations in annual discharge have occurred from year to year and over periods of years (due to long-term climatic trends). Progressive 10-year running averages of estimated "virgin flow" (if the stream were in its natural state and unaffected by the activities of man) at Lee Ferry have ranged from 16.0 to 17.8 billion m^3 since 1970, and the 1896-1980 long-term annual average virgin flow at Lee Ferry is about 18.3 billion m^3 (Upper Colorado River Commission 1980). The Upper Main-stem Colorado Sub-basin contributes the greatest volume of water and the San Juan Sub-basin the least. Joseph *et al.* (1977) and Spofford (1980) summarized flow data from selected U.S. Geological Survey gaging stations in the Upper Colorado River Basin.

Joseph *et al.* (1977) recognized three distinct stream zones in the Upper Colorado River System. Their upper (headwater) zone was characterized by cold, clear water, high gradient, and rocky or gravelly substrate and was regarded as ideal habitat for cold-water fishes. In this zone primary production (mainly by "periphytic" algae) was considered "significant" and benthic invertebrate production "substantial". An intermediate zone occurs as streams flow from the upper zone; there, water warms, discharge increases, waters are turbid during spring runoff and after heavy rains, and substrates are generally rocky with occasional expanses of sand. Benthic invertebrates are generally abundant only where substrates are rocky, and primary production is higher than in other zones. Salmonid fishes are less common than in the upper zone, and cyprinids and catostomids are predominant. The lower (large-river) zone has warm, turbid water and can be subdivided into two distinct subunits — canyon areas of steep gradient and meandering sections with low gradient in flat terrain. Substrates in high-gradient canyons are of sand, gravel, and rubble; in low-gradient canyons or on flats, sand substrates predominate. Primary production is virtually absent in this zone, and production of benthic invertebrates depends on the availability of gravel-rubble substrate. Allochthonous materials are the basic energy source for this zone's aquatic communities. The fish components of large-river communities are cyprinids and catostomids, and the relative abundance of various species differs considerably in the two subdivisions of the zone.

Bishop and Porcella (1980) identified water-quality problems in the Upper Colorado River System by determining where federal or state water-quality standards were exceeded. Problems were considered primarily local and included acid mine drainage and heavy metals pollution, energy impact, reservoir eutrophication and sedimentation, biochemical oxygen and dissolved oxygen interactions below treatment facilities, and potential health problems associated with municipal sewage discharge. The most serious water-quality problem, in a general sense, is increasing salinity (total dissolved solids). Salinity increases downstream because of concentration of salt in subsurface waters by range and forest tracts and evapotranspiration by phreatophytes and marshy areas along the river. Man's activities have also contributed salts, and salts have been concentrated by irrigation of crops, reservoir evaporation, water diversions, and municipal and industrial water uses. In 1974, at the behest of the Environmental Protection Agency, the seven states of the Colorado River Basin agreed to maintain salinity in the Lower Basin at or below levels measured in 1972. The U.S. also agreed in 1974 to deliver Colorado River water to Mexico at Morales Dam in an amount that does not exceed the average salinity at Imperial Dam (north of Yuma, Arizona) by more than 115 (± 30) mg/liter.

Total sediment load has decreased substantially since construction of Colorado River Storage Project dams on the Upper Colorado River; Lake Powell and Navajo, Fontenelle, Flaming Gorge, Blue Mesa, and Morrow Point reservoirs trap about 75-80% of the sediment that normally flowed into Lake Mead on the lower Colorado (Joseph *et aL* 1977). These and other reservoirs have also significantly altered stream temperatures and discharge in the Upper Colorado River Basin. Joseph *et aL* (1977) discussed temperature, pH, and dissolved oxygen and summarized voluminous U.S. Geological Survey records on carbonates, calcium, chloride, conductivity, magnesium, phosphate, potassium, silica, sodium, sulfate, and turbidity in the Upper Colorado River Basin.

STUDIES OF FISHES OF THE UPPER COLORADO RIVER SYSTEM

The present Colorado River drainage has existed since the Pliocene and has had no broad connections with surrounding river basins for millions of years (Behnke 1980). This long period of isolation has led to a high degree of endemism in the fish fauna of the river (Behnke 1980; Behnke and Benson 1980). Miller (1959) stated that the Colorado River drainage system was second of seven centers of endemism studied in degree of endemism of fish species. It ranked highest (87%) in endemism of primary (strictly freshwater) fishes. Miller listed 35 species, 22 genera, and 11 families of native fishes for the Colorado River System. Hubbard (1980) reported 30 species, 18 genera, and 6 families of native freshwater fishes in the Colorado River Basin, with 73% of the species and 39% of the genera being endemic.

Some disagreement regarding numbers of native and introduced fishes in the Upper Colorado River System is reflected in recent reports. Wydoski (1980) referred to an unpublished 1976 Colorado Wildlife Council list of 50 species and 4 subspecies of fish in the Upper Colorado River. Twenty species and 4 subspecies were said to be native to one or more states in the Upper Basin. Raleigh (1980) cited a 1975 unpublished report of the Utah Water Research Laboratory listing 13 native and 31 introduced fish species in the Upper Colorado River drainage system. Joseph *et aL* (1977) and Behnke and Benson (1980) listed 13 species of fishes native to the Upper Basin. The report by Tyus *et aL* in this symposium contains the most recent and authoritative data on this subject.

Fishes of the Green Sub-basin

Fontenelle and Flaming Gorge reservoirs have had a profound effect on flow and water quality in the Green River; lower summer water temperatures have resulted, and spawning of native fishes in these areas has virtually ceased. The changed habitat immediately downstream favors introduced salmonids which compete with native species (Joseph *et aL* 1977). Generally, introduced fishes appear to be thriving in the Upper Colorado River Basin.

Banks (1974) discussed the fishery resource of the Green River in the Fontenelle tailwater (between the Fontenelle and Flaming Gorge impoundments), where a very productive trout fishery competes with industry, agriculture, and municipal interests for river water. The impact of reduced flows on fish and wildlife was evaluated, and flows to meet most production and survival needs for all sizes of trout and to ensure winter survival were recommended. Wiley and Mullan (1975) evaluated consequences of four flow regimes to help the public allocate their basic water supply. When discharges released from Fontenelle Reservoir resulted in excessive water velocities in relation to available shelter, low use, low yield, and modest standing crop of trout were realized (Mullan *et aL* 1976). Wiley and Dufek (1980) discussed standing stocks and mortality rates of rainbow and brown trout in the Fontenelle tailwater; growth was excellent because of the productive environment. The main factor limiting standing stock was lack of instream cover. Early data collected after some instream cover (large boulders) was provided suggested increased stock in the improved areas.

Gaufin *et aL* (1960) conducted an aquatic survey of the Green River and its tributaries in the Flaming Gorge Reservoir Basin. A checklist of native and introduced fishes was included in their report.

In early September 1962, prior to the closure of Flaming Gorge Dam, the Green River and its tributaries for 362 km above the damsite were treated with rotenone to cause a large-scale reduction of "coarse" fish populations and allow reservoirs and rivers to realize their full potential as trout fisheries (Dexter 1965). The result of introduction of rotenone into the complex river ecosystem was a biological catastrophe. However, Dexter reported a gradual increase in river biota, aided by the stocking of "desired" fish species, by the time his paper was written. Binns (1967) substantiated Dexter's report and discussed devastation of the invertebrate community and its subsequent inability to recover.

Vanicek *et aL* (1970) analyzed the effect on the Green River in Utah of the closure in November 1962 of Flaming Gorge Dam. They studied changes in the river environment; determined species composition, distribution, and abundance of fishes; and compared 1963-1966 distribution of fishes with preimpoundment collections. Seasonal flows changed from high spring and low winter flows to a relatively stabilized seasonal flow pattern, and temperatures and temperature fluctuations decreased. Native fish populations were replaced by rainbow trout in a 42-km section below the damsite. Stalnaker and Holden (1973) stated that no native species were reproducing in the 105-km area from the dam to the mouth of the Yampa River and that trout had replaced native species to the confluence of the Yampa. Four native species (humpback chub, Colorado squawfish, bonytail chub, and razorback sucker) were considered rare. These authors suggested that the Yampa River, the Green and Colorado rivers in the Canyonlands section of southeastern Utah, and Desolation Canyon on the middle Green River appeared to be the only areas in this sub-basin ecologically suitable for maintaining reproducing populations of the large-river endemic fishes.

The tailwater fishery of Flaming Gorge Reservoir had discharge and shelter components that resulted in an exceptional trout yield prior to dysfunction by lowered water temperatures (Mullan *et* aL 1976). In 1978, the U.S. Bureau of Reclamation installed an inlet modification to aid the failing tailwater trout fishery. Warmer water drawn from higher reservoir levels to enhance trout production has elevated stream temperatures and may restore successful reproduction of Colorado squawfish below the dam (Holden 1979).

Miller (1965) discussed the fishes of Dinosaur National Monument and reviewed changes resulting from the closure of Flaming Gorge Dam. Seethaler *et* aL (1979) reviewed earlier work and emphasized the importance of waters in Dinosaur National Monument for the continued existence of endemic fishes. They listed stream alteration (due to dams, irrigation, dewatering, channelization, and unstable banks), increases in competition and predation (due to introduction of non-native fishes), pollution, eutrophication, and other factors as possible causes of declines of endangered and threatened endemic fishes.

Three sampling areas of Holden and Stalnaker (1975a) were on the Green River below its confluence with the Yampa. Flannelmouth and bluehead suckers were predominant in this area.

Joseph et aL (1977) stressed the importance of the Yampa River for maintenance of Green River spawning temperatures; recent evidence demonstrates that the Yampa itself provides spawning habitat for rare native fishes. An extensive review of the literature on fishes of the Yampa was done by Carlson *et aL* (1979). Holden and Stalnaker (1975b) concluded that the Yampa River was of extreme importance to the preservation of rare and endangered fishes in the Colorado River Basin; all of the rare forms were then present in the Yampa, and some were apparently reproducing. Carlson *et* aL (1979) presented data on fishes collected in the Yampa River from 1975 to 1978 between Lily Park Pool near Cross Mountain and Hayden, Colorado. Fish distribution, relative abundance, reproduction, growth, food, and habitat were discussed. In 1981, Tyus *et aL* (1982) discovered the first spawning ground of Colorado squawfish in lower Yampa Canyon. Radiotelemetered fish moved into this location from the upper Yampa and middle Green rivers. This discovery links the decline of the Colorado squawfish with blockage of spawning migrations.

Joseph *et* aL (1977) reviewed the history of the White River Basin and stated that changes in the White River due to potential oil shale development will significantly affect the Green River. Carlson *et aL* (1979) provided an extensive literature review on the White River fishes and a report on fishes collected in Colorado from 1975 to 1978. Lanigan and Berry (1979) provided an in-depth report on the endemic fishes of the White River in Utah.

Fishes of the San Rafael River system were discussed by McAda *et al.* (1980). Native fishes were dominant in the tributary streams and middle section of the San Rafael River, while introduced fishes were dominant near the mouth of the river.

Fishes of the Upper Main-stem Colorado Sub-basin

Joseph *et al.* (1977) considered native and introduced fishes of the Upper Main-stem Colorado and factors affecting area streams. Introduction of non-native fishes and waterflow reductions were the main factors involved in declines of native species, and oil shale development will surely add another major obstacle to their survival.

The Gunnison River at one time contained all threatened or endangered fishes of the Upper Colorado System except the Kendall Warm Springs dace and the humpback chub. With the introduction of non-native fishes, the abundance and distribution of these native fishes was drastically curtailed (Joseph *et al.* 1977). Part of the Gunnison River was once a world-famous trout fishery. Wiltzius (1978) reviewed many studies done on the Gunnison after 1927 and discussed the quality and quantity of the trout fisheries since the 1880's. Introduction of several species, together with continued stocking and other factors, played a role in changing the fish fauna. Wiltzius also considered the effects of Blue Mesa and Morrow Point reservoirs on the fishery of the Gunnison. The fisheries in the tailwaters of dams forming these and other major reservoirs in the Upper Basin were discussed by Mullan *et al.* (1976).

Holden and Stalnaker (1975b) discussed the native and introduced fishes of the Dolores, including their abundance and distribution. The Dolores River System appeared to have little importance regarding preservation of rare and endangered fish species and was far from its natural state due to irrigation and severe pollution.

General notes on fishes of the Upper Main-stem Colorado near Moab, Utah, were provided by Taba et *al.* (1965). Holden and Stalnaker (1975a) collected near Moab, at three other sites on the Upper Main-stem Colorado, and at one station on the Gunnison River.

Fishes of the San Juan Sub-basin

Joseph *et al.* (1977) stated that many of the native large-river endemics of the San Juan River were much reduced in distribution and abundance and that some were probably extirpated. Navajo Dam construction appeared to exert the major impact, and competition from introduced species was another significant factor. Koster (1960) and Minckley and Carothers (1979) reported Colorado squawfish captures from the San Juan River.

Fish encountered in the Glen Canyon area on the Colorado River before construction of Glen Canyon Dam included 17 species; only six were native (Woodbury 1959). Major faunal collections came from the tributaries as the river at this point was rapid, showing much scouring and providing little habitat for flora and fauna.

Water impoundment behind Glen Canyon Dam began in January 1963. Largemouth bass were stocked in the resultant Lake Powell in 1963 and 1964, and abundant stocks have been maintained by natural reproduction (Miller and Kramer 1971). Rainbow trout were also introduced in 1963; yearly stocking continued but in later years was restricted to the lower reservoir (May 1973). Introduction of other fishes occurred in part to provide an abundant, vulnerable food source for the four major centrarchids (largemouth bass, black crappie, bluegill, and green sunfish) in the reservoir (May and Thompson 1974; May *et al.* 1975). All resident species experienced changes in their food habits as feeding on introduced threadfin shad increased. Introductions of striped bass in 1974 and 1975 have provided another species to the fishery. May and Gloss (1979) studied depth distribution of major gamefishes in Lake Powell in relation to oxygen and temperature profiles. They referred to earlier, largely-unpublished research on physical, chemical, and biological characteristics of the reservoir. Diversity of habitat in Lake Powell and of its community of endemic and introduced fishes was emphasized. Potter (1980) provided an ecological description of Lake Powell, stressing management of the resource.

Holden and Stalnaker (1975a) collected just below Glen Canyon Dam and reported on fishes of that area. Minckley and Carothers (1979) reported collection of razorback suckers near the mouth of the Paria River.

ACKNOWLEDGEMENTS

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FISHES OF THE UPPER COLORADO RIVER SYSTEM: POLITICAL AND RESOURCE CONSIDERATIONS

Robert H. Shields

ABSTRACT

Preservation of rare fishes in the Upper Colorado River Basin conflicts with water-development projects. Responsibilities of federal agencies under the Endangered Species Act of 1973 are discussed and the concept of a Conservation Plan, being prepared by the U.S. Fish and Wildlife Service, is offered as a means to resolve conflicts. The plan will be funded by developers whose projects adversely affect fish habitats. Editors' abstract)

This paper summarizes biological and political problems faced by the U.S. Fish and Wildlife Service FWS and other agencies in dealing with four imperiled fishes of the Upper Colorado River Basin. The Colorado squawfish, Ptychocheilus lucius, and humpback chub, *Gila* cypha, were formally listed on 11 March 1967 as threatened with extinction. The bonytail chub, *Gila* elegans, was listed as endangered on 23 April 1980. Not currently listed but imperiled is the razorback sucker, Xyrauchen tex*anus.* These fishes are considered jeopardized because of man's changes in their environment.

The Endangered Species Act of 1966 ESA and subsequent Acts and amendments provide for a comprehensive program for the conservation, restoration, and propagation of fish and wildlife species that are threatened with extinction in the United States. Federal agencies shall not take actions that are likely to jeopardize the continued existence of any endangered or threatened species. Virtually all water projects involve federal action, whether they are state-sponsored or private developments. Right-of-ways are required to cross or utilize federal lands, licenses must be obtained from the Federal Energy and Regulatory Commission, and permits obtained from the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act.

"Guidelines To Assist Federal Agencies In Complying With Section 7 of The Endangered Species Act of 1973" were issued in April 1976 to pertinent agencies; regulations followed in January 1978. The Upper Colorado River office of the U.S. Bureau of Reclamation BR in Salt Lake City, Utah was concerned that water projects being developed under the Colorado River Storage Project Act CRSP would need to be analyzed for impacts under the ESA. Consequently, FWS's Area Office in Salt Lake City was asked to provide input into BR's water-development planning. FWS foresaw numerous conflicts between preserving the Colorado River endangered fishes and the development of planned or potential water projects. A dearth of background knowledge regarding life history, distribution, abundance, and other information on the endangered fishes compounded the issue. Of special concern were: 1 what magnitude of water depletion from the drainage would jeopardize the continued existence of the fishes, and 2 what reasonable and prudent alternatives could be offered?

In 1977, the Salt Lake City Area Office of FWS became acutely aware of pending bio-political conflicts. Consequently, Dr. William Miller, a fishery biologist, was hired to give full-time attention to the problem, and a catalog of existing, planned, or potentially-associated water projects in the drainage was compiled. Between 1906 and 1978, more than 226 projects were delineated, and these projects had the potential to deplete up to 2.9 million acre-feet of water annually from the Upper Colorado River drainage. Predevelopment flows were estimated at 12.2 million acre-feet annually.

When the headgates of the Tellico Dam were closed in the face of potential extinction of the snail darter, it became apparent that more than the ESA would be required to ensure survival of the Colorado River endangered fishes. The Tellico project cost approximately $125 million to build. Cost of the Central Utah Project CUP alone, part of the CRSP, has been estimated to exceed $1 billion at completion, and total development of all CRSP and other projects in the basin should cost far more than $2 billion. Compounding the Colorado River problem is the water demand for energy development, domestic and industrial needs, and irrigation.

Biological conflicts also exist. Outflows from Flaming Gorge Dam have created favorable habitat for coldwater species at the expense of endemic fishes. Also, a similar potential conflict exists in respect to BR's proposed Dominquez Project. Simply put, FWS and associated federal agencies face a major undertaking to gather biological data and develop acceptable solutions to some difficult biological and political problems. To ignore the issue is to encourage another snail darter solution.

The 1978 amendments to the ESA require the provision of reasonable and prudent alternatives if jeopardy opinions are to be issued. Subsequently, BR requested formal consultation under the ESA on the proposed Upalco Unit of the CUP, which would annually deplete the lower Duchesne River by about 10,000 acre-feet. The FWS requested a 2-year extension from BR for providing a biological opinion in order that results of ongoing studies could be utilized. BR declined; consequently, an opinion provided in June 1979 with subsequent amendments addressed the cumulative impact of the Upalco Unit and other projects and dealt with other issues such as changes in water quality. This opinion, however, identified modifying the operation of Flaming Gorge Dam as an acceptable alternative — to make releases up to the 10,000 acre-foot depletion at such times and in such volumes to meet the needs of the fishes. Thus, the status quo could be maintained. This approach was subsequently used on other projects, but BR cannot continue indefinitely to write "blank checks" on the use of Flaming Gorge water.

The 1978 amendments to the ESA require federal agencies to submit biological assessments to FWS for use in determining effects of their proposals on listed and proposed endangered species. The BR began arranging for FWS to conduct detailed investigations on the fishes, with initial concern for the Green and Colorado rivers. Subsequently, a contract was negotiated, and studies began in the spring of 1979. Dr. Miller leads the investigation, which is identified as the Colorado River Fishery Project (CRFP). Three teams consisting of four FWS biologists and several temporary personnel were assigned to the mainstem Colorado and Green rivers. An additional team has since been assigned to investigate the humpback chub in the Little Colorado River in Arizona. During the spring of 1981, four additional fishery crews were assigned to study the Yampa and White rivers in Colorado and Utah and the Dolores and Gunnison rivers in Colorado. Biological assistance has been provided by the Utah Division of Wildlife Resources and the Colorado Division of Wildlife. Personnel from the National Park Service's Dinosaur National Monument and the Bureau of Land Management's (BLM) Vernal District have also contributed to the work. To date, BR has invested approximately $1.4 million in the studies. Over $300,000 has been provided by BLM, over $200,000 by FWS, and a lesser amount by the National Park Service. The U.S. Congress earmarked $100,000 for specific studies on the Yampa River.

When the CRFP was initiated, it was fully recognized that a crash program would be necessary to obtain data in time to respond to major biopolitical problems. Field investigations began in the spring of 1979 and terminated in July 1981; a final report is due to BR by October 1981. FWS believes that important, needed, and new knowledge on the fishes has been gained.

In addition, numerous other major developments are awaiting biological recommendations. For example, the State of Utah has proposed a dam on the White River which would basically supply water for energy-related projects. FWS must provide a biological opinion by January 1982 to BLM, which is responsible for rights-of-way issuance for the project.

In mid-1980, FWS recognized that other approaches were needed to adequately address so many projects. The idea of a "Conservation Plan" began to emerge, and it was discussed at a Salt Lake City workshop on 7 August 1980. Leading experts from FWS and other federal and state agencies, along with private, academic, and water resource personnel there attempted to resolve conflicts between the fishes and the proposed White River Dam and other projects. At that time, as now, FWS recognized that acceptable solutions must be forthcoming to avoid special legislation proposals, litigations, and appeals for exemption from the ESA. The "Conservation Plan" may, in part, hold the solution.

In this case, the Conservation Plan should be construed as a document which more precisely defines actions and recommendations found in the Colorado River Fishes Recovery Plans. Additionally, the Conservation Plan would dwell on actions which are politically realistic and, therefore, more likely to be implemented. Recovery Plans address species throughout their entire range. The Conservation Plan considers only the Upper Colorado River Basin.

The Colorado River endangered fishes will not recover to occupy their former range by merely stopping further water depletions, since they have been extirpated from extensive areas in the Lower Colorado River Basin. CRFP investigators also recognize that the fishes will not be safeguarded by merely providing needed flow regimes at key areas in their habitats under existing conditions. Additionally, there is a point at which additional flow depletions will cause extinction of the endangered fishes; this may have already occurred for the bonytail chub. Furthermore, habitat improvements and artificial propagation/reintroduction, along with maintenance of adequate water flows, may be necessary to prevent extinction and ultimately to lead to downlisting of the species.

The Colorado River Fishes Recovery Team and consultants met in late 1980. At that time, the recovery team was asked to revise the old recovery plans for the Colorado squawfish and humpback chub. They also agreed to provide an initial plan for the bonytail chub. Team members were informed at that time about the need for a Conservation Plan and that information contained in this plan would emanate in large part from their recovery plan input. Recovery team members performed admirably; their three draft documents contained up-to-date biological recommendations. Consequently, in July 1981, FWS fishery biologist Don Archer, formally assigned to CRFP, was designated as the lead individual in FWS to develop the Conservation Plan according to these recovery plans. Much effort will be expended to seek comprehensive and workable solutions. The draft Conservation Plan should be completed by mid-1982.

The Conservation Plan may include such management practices as:

1. Habitat manipulation, including construction of streamside nursery areas, instream spawning grounds, and fish ladders;
2. Purchase of water rights to replace depletions;
3. Supplemental stocking programs, including the development of fish-cultural facilities necessary

to supply required numbers and sizes of fish; and
4. Investigations to monitor species populations and species reactions to the management efforts.

Some rudimentary aspects of the Conservation Plan have already been informally approved by high-level Interior Department officials. Ultimately, approval from the Secretary of the Interior and/or the U.S. Congress will be required. The plan will address strategies for the preservation, recovery, and maintenance of the fishes in the Upper Basin. Funding to carry out the plan will come primarily from those water users and/or developers whose projects are responsible for adverse impacts on fish habitats. Assessments against water developers will consider whether their projects will appreciably reduce the likelihood of the survival or recovery of the species. Those projects complicating the *survival* of species, such as impeding migration passages, may not be amenable to a monetary assessment. On the other hand, projects which may reduce the likelihood of species *recovery* may be assessed for funds to offset harmful effects. The assessment formula is somewhat complex and dynamic. Basically, sponsors are assessed against the amount of water flows their projects will deplete. To date, some monetary assessments have already been made against water project sponsors to provide for Conservation Plan fulfillment.

The compensation approach emanated after numerous face-to-face discussions with personnel from BR, FWS, and the Northern Colorado Water Conservancy District (NCWCD). The NCWCD is a sponsor of the Windy Gap Project which provides municipal water to Longmont, Colorado. The assessment to ensure recovery of the fishes in this case was set at $550,000. Other assessments are pending against the Moon Lake Irrigation Project in Utah ($500,000) and Phase II of the Cheyenne Water Project (not to exceed $180,000). Ongoing projects will receive similar scrutiny for assessments. Again, I should stress that these projects will produce impacts serious enough to effect recovery of the fishes but not so severe as to jeopardize their survival.

In summary, I believe many of you will recognize that FWS and conservation agencies have serious conflicts in addressing preservation of these fishes. We believe that the Conservation Plan approach has merit in that it provides for payment by those doing the damage. Additionally, implementation of a management program as envisioned in the plan has a much greater chance of ensuring that the four imperiled fishes continue to survive in unison with our nation's energy demands and today's political climate.

FISHES OF THE UPPER COLORADO RIVER BASIN: DISTRIBUTION, ABUNDANCE, AND STATUS

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C.M. Haynes, T.A. Lytle, and C.R. Berry

ABSTRACT

The distribution and relative abundance of fishes from the Upper Colorado River Basin are presented, by major tributary and reservoir. A total of 55 fishes are reported, of which 49 are primarily restricted to riverine habitat. Although 42 fishes are reported from reservoirs, only 6 species are primarily restricted to them. There are 42 exotic, 13 native, 8 endemic,1 threatened, and 5 endangered fishes in the Upper Basin. Abundant species include 3 exotic and 3 native fishes; common species included 4 exotic and 3 native fishes. Exotic species also include 24 classified as incidental.

Remnant populations of four threatened and endangered fishes are found in main-stem rivers of the Upper Colorado River Basin: Colorado squawfish *(Ptychocheilus lucius)*, bonytail chub *(Gila elegans)*, humpback chub *(Gila cypha)*, and razorback sucker *(Xyrauchen texanus)*. Two other native fishes (subspecies) also exist in headwaters—the endangered Kendall Warm Springs dace *(Rhinichthys osculus thermalis)* and the threatened Colorado River cutthroat *(Salmo* darki *pleuriticus)*. The threatened greenback cutthroat trout *(Salmo clarki stomias)* was designated as an exotic fish in the Upper Colorado River Basin.

The federally protected endangered species appear to be further declining and there is no indication that known sub-populations are increasing. The razorback sucker should be brought under federal protection as a threatened, or possibly an endangered, species.

INTRODUCTION

The Colorado River Basin (Frontis.) is predominantly arid to semiarid and is therefore limited in water resources. Water development has resulted in a significant demand for available water, and this demand is increasing with the need for more energy. Environmental alterations, including changing land and water use and the introduction of exotic species, have degraded the native fish fauna of the once-mighty Colorado River. Endemic fishes, uniquely adapted to the hostile river system in its unaltered form, are now exposed to new stress which threatens them with extinction. Although mainstem rivers are still occupied by endemic fishes, historic ranges have been markedly reduced.

This paper discusses distribution, abundance, and the present status of fishes of the Upper Colorado River Basin. It provides a base for documenting past and future changes of this highly variable river system.

METHODS

The Colorado River Basin is divided into Lower and Upper Basins near Lee Ferry, Arizona (Frontis). The Upper Basin is further divided into three major systems, or hydrologic sub-basins: Green, Upper Main-stem and San Juan-Colorado (Fig. 1). Each major tributary consists of three aquatic zones (Joseph *et al.* 1977) — headwaters (upper zone), intermediate zone, and large river channels (lower zone). Fish distribution was mapped for the lower and intermediate zones. Smaller coldwater tributaries of the upper zone were deleted from the base map throughout most of the basin because endemic fishes (with some exceptions) are absent in them. Reservoirs greater than 1,200 surface hectares are included. Also, hybrid fishes are listed but not included in distribution mapping.

Every attempt has been made to obtain and present information acquired since 1977, although limited use was made of some 1975 data. Maps present current fish distribution, much of which is unpublished.

The relative abundance of native and exotic fishes is presented as:

A = abundant — a species or subspecies occurring in large numbers and consistently collected in a designated area;

C = common — a species or subspecies occurring in moderate numbers, and frequently collected in a designated area;

R = rare — a species or subspecies occurring in low numbers either in a restricted area or having sporadic distribution over a larger area; or

I = incidental — an exotic species or subspecies occurring in very low numbers and known from only a few point collections.

A combination of shading, triangles, and circles was selected for distribution mapping. Circles are used only when more than one species is placed on one map. A series of triangles (or circles), closely spaced, indicates that a fish is rare. A single triangle

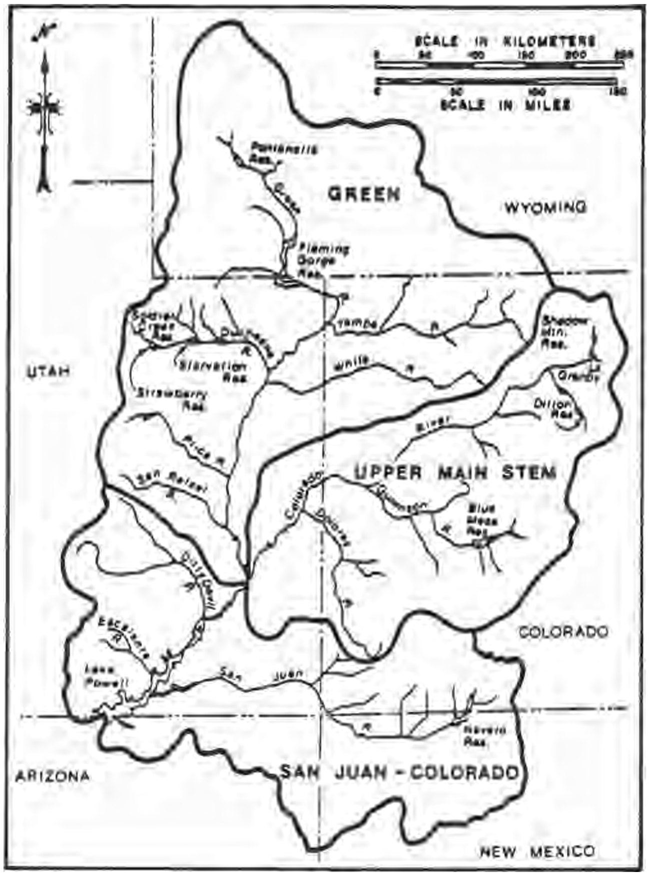

Figure 1. The hydrologic subregions of the Upper Colorado River Basin. (After Joseph *et al.* 1977)

(or circle) indicates point collections and suggests the species is incidental or extremely rare. Species that were locally abundant in a small tributary but rare elsewhere would appear so on the maps but might be classified in tables as rare for a sub-basin.

The status of fishes is designated as:

EN = endemic — a species or subspecies found only in the Colorado River Basin;

NA = native — a species or subspecies recent to the Colorado River Basin but occurring there before introductions by man;

EX = exotic — a species or subspecies newly introduced into the Colorado River Basin (non-native);

TH = threatened — a species or subspecies which may become endangered in the near future; or

ED = endangered — a species or subspecies in danger of extinction.

The separation between native and endemic fishes is presented according to Behnke and Benson (1980), whose treatment varied significantly from that of others (Kirch 1977). All endemic fishes are native; however, native fishes also include those species which have invaded the Upper Colorado River Basin naturally and were not introduced by man.

Fishes are classified as threatened or endangered according to designations by the U.S. Fish and Wildlife Service (1973, 1974, 1980a, 1980b) or the State of Colorado (1980). Where these do not agree, the most restrictive classification is given.

Information on distribution and abundance of fishes was obtained primarily from recent studies by the Colorado Division of Wildlife and the U.S. Fish and Wildlife Service. The New Mexico Department of Game and Fish, the Utah Division of Wildlife Resources, and the Wyoming Game and Fish Department also furnished information. Other published sources were sought where recent collections were unavailable. All such sources of information are referenced by sub-basin, tributary, or reservoir.

Scientific and common names of fishes were obtained from Robins *et al.* (1980) except for the bonytail, which we refer to as bonytail chub. Distribution maps contain both scientific and common names in the order presented by Robins *et al.* (1980), except when the distribution of two species are combined on one map.

Because source material (Table 1) varied widely in sampling design and effort, it was necessary to use judgement in many cases for designating relative abundance. Some incidental species may have been overlooked or unpublished collections not obtained.

RESULTS

General

A total of 55 fishes (52 species and 3 subspecies) presently exist in the Upper Colorado River Basin (Table 2). Relative abundance of fishes found in riverine habitat is provided according to major tributary (Table 3). A list of species found in major reservoirs (Table 4) and graphic displays of distribution and specific locations for abundance (Figs. 2-46) are provided.

Abundance designations for some species were difficult, and judgement was required in those instances. An example of this is the fathead minnow, a widely distributed species that is abundant in backwater habitat throughout the system. Because this species was restricted largely to one habitat, it was designated as common. Other species, for example the red shiner, were also widely distributed but occurred abundantly in a wide variety of habitats (backwaters, shorelines, eddies, riffles). The red shiner was designated as abundant.

Although reservoir fishes were not a primary objective of this study, 42 species occurred in reservoirs, with 7 species primarily restricted to them. Reservoirs in the Upper Colorado River Basin are managed primarily for exotic sport fishes; salmonids are in the upper zone, and primarily centrarchid and percid fishes are in the lower zone.

Table 5 presents status for 42 exotic, 13 native, 8 endemic, 1 threatened, and 5 endangered fishes of

TABLE 1. Source material for distribution mapping (Figs. 2-46), relative abundance (Table 3), and occurrence of fishes in reservoirs (Table 4) for the Upper Colorado River Basin

Hydrologic subregion Tributaries and reservoirs	Source reference
Upper Main-stem	
Colorado River (Green River confluence upriver)	4, 5, 11, 13, 21, 22, 34, 35, 37
Gunnison River	34, 35, 37, 40
Dolores River	34, 35
Lake Granby	20
Dillon Reservoir	20
Blue Mesa Reservoir	20, 34
Green	
Green River	1, 2, 3, 7, 13, 14, 15, 19, 21, 32, 41
Yampa River	2, 6, 13, 24, 32, 37
White River	2, 6, 7, 10, 18, 20, 23, 28, 32, 37, 38, 39
Duchesne River	25, 33
Price River	33
San Rafael River	33
Fontenelle Reservoir	41
Flaming Gorge Reservoir	29, 33
Soldier Creek/Strawberry Reservoir	31, 33
Starvation Reservoir	33
San Juan-Colorado	
Colorado River (Green River confluence to Lake Powell)	13, 21, 26, 27, 33, 34, 35
San Juan River	8, 12, 16, 17, 21, 30, 36
Dirty Devil River	33
Escalante River	33
Lake Powell	26, 33, 34
Navajo Reservoir	8, 12, 30, 36

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18. Lanigan and Berry 1981.
19. Larsen, E., Utah Division of Wildlife Resources, Dutch John, Utah, 1981 pers. comm.
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31. Thompson, C., Utah Division of Wildlife Resources, Springville, Utah, 1981 pers. comm.
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36. VTN Consolidated Inc. and Museum of Northern Arizona 1978.
37. Wick, E.J., Colorado Division of Wildlife, Fort Collins, Colorado, 1981 pers. comm.
38. Wick et al. 1981.
39. Wiltzius 1978.
40. White, J.R., Wyoming Game and Fish Department, Cheyenne, Wyoming, 1981 pers. comm.

the Upper Colorado River Basin (one additional threatened species is exotic to the basin). Joseph *et al.* (1977) listed 27 exotic, 14 native, 8 endemic, 4 threatened, and 2 endangered fishes. The largest discrepancy in these two treatments is in the number of exotic, threatened, and endangered fishes. Some recently-discovered exotics have been included in this paper, but the greatest difference probably occurs because of inclusion of reservoir fishes. Differences in numbers of threatened and endangered fishes have resulted from changes in federal and state listings.

A total of 10 hybrid fishes have been reported in recent years from the Upper Colorado River Basin (Table 6). No effort was made to validate the identification of these fishes.

Exotic Fishes

Fifteen exotic fishes were probably introduced into the Upper Colorado River Basin through pond and reservoir stocking. Seven of these are restricted to reservoirs (Figs. 2, 3, 4, 11-0, 32, 36, 43-0). Nine are common to abundant in reservoirs (Figs. 2, 4, 32, 36, 37, 38, 40, 42, 45). The remainder (Figs. 3, 11-A, 36-0, 41) are found in varying distribution patterns throughout the major tributaries.

TABLE 2. Zoological and common names of fishes in the Upper Colorado River Basin

Species	Common Name	Species	Common Name	Species	Common Name
Dorosoma petenense	Threadfin shad	*Hybognathus placitus*	Plains minnow	*Ictalurus natalis*	Yellow bullhead
Oncorhynchus kisutch	Coho salmon	*Notropis lutrensis*	Red shiner	*Ictalurus punctatus*	Channel catfish
Oncorhynchus nerka	Kokanee	*Notropis stramineus*	Sand shiner	*Fundulus zebrinus*	Rio Grande killifish
Prosopium williamsoni	Mountain whitefish	*Pimephales promelas*	Fathead minnow	*Fundulus sciadicus*	Plains topminnow
Salmo clarki	Cutthroat trout	*Ptychocheilus lucius*	Colorado squawfish	*Gambusia affinis*	Mosquitofish
Salmo clarki pleuriticus	Colo. cutthroat trout	*Rhinichthys cataractae*	Longnose dace	*Morone chrysops*	White bass
Salmo clarki stomias	Greenback cutthroat trout	*Rhinichthys osculus*	Speckled dace	*Morone saxatilis*	Striped bass
Salmo gairdneri	Rainbow trout	*Rhinichthys osculus thermalis*	Kendall Warm Springs dace	*Lepomis cyanellus*	Green sunfish
Salmo trutta	Brown trout	*Richardsonius balteatus*	Redside shiner	*Lepomis macrochirus*	Bluegill
Salvelinus fontinalis	Brook trout	*Semotilus atromaculatus*	Creek chub	*Micropterus dolomieui*	Smallmouth bass
Salvelinus namaycush	Lake trout	*Catostomus ardens*	Utah sucker	*Micropterus salmoides*	Largemouth bass
Esox lucius	Northern pike	*Catostomus catostomus*	Longnose sucker	*Pomoxis annularis*	White crappie
Cyprinus carpio	Carp	*Catostomus commersoni*	White sucker	*Pomoxis nigromaculatus*	Black crappie
Gila atraria	Utah chub	*Catostomus discobolus*	Bluehead sucker	*Etheostoma exile*	Iowa darter
Gila copei	Leatherside chub	*Catostomus latipinnis*	Flannelmouth sucker	*Etheostoma nigrum*	Johnny darter
Gila cypha	Humpback chub	*Catostomus platyrhynchus*	Mountain sucker	*Perca flavescens*	Yellow perch
Gila elegans	Bonytail chub	*Xyrauchen texanus*	Razorback sucker	*Stizostedion vitreum*	Walleye
Gila robusta	Roundtail chub	*Ictalurus melas*	Black bullhead	*Cottus bairdi*	Mottled sculpin
Hybognathus hankinsoni	Brassy minnow				

TABLE 3 (concluded)

Family and species	Hydrologic subregion and river						
	Usper Main-stem			Green			San Juan-Colorado
	Colorado	Gunnison	Dolores	Green	Yampa	White	San Juan
Catostomidae							
Catostomus ardens				R			R
Catostomus catostomus		R					
Catostomus commersoni	R	C	I	I	R		I
Catostomus discobolus	C	C	C	C	C	R	C
Catostomus latipinnis	A	C	C	A	A	A	A
Catostomus platyrhynchus				R	R	R	R
Xyrauchen texanus	R	R		R	R		R
Ictaluridae							
Ictalurus melas	R			R	I	I	R
Ictalurus natalis[b]							
Ictalurus punctatus	C	I	C	A	C	R	C
Cyprinodontidae							
Fundulus sciadicus						I	
Fundulus zebrinus	I				I		R
Poeciliidae							
Gambusia affinis							
Percichthyidae							
Morone chrysops[b]							
Morone saxatilis[b]							
Centrarchidae							
Lepomis cyanellus	R	I	I	R	I	I	R
Lepomis macrochirus	I			I		I	R
Micropterus dolomieui	I	I		R	I		I
Micropterus salmoides	R	I	I		I		I
Pomoxis annularis							I
Pomoxis nigromaculatus	R	R	R				R
Percidae							
Etheostoma exile							
Etheostoma nigrumb							
Perca flavescens							
Stizostedion vitreum							
Cottidae							
Cottus bairdi							

[a] A=Abundant; C=Common; R=Rare; I=Incidental
[b] Restricted to reservoirs

TABLE 4. **Fishes in major reservoirs (larger than 1,200 hectares) in the Upper Colorado River Basin**

Family and species	Hydrologic subregion and reservoir								
	Upper Main-stem			Green				San Juan-Colorado	
	Dillon (1,335)	Granby (2,938)	Blue Mesa (3,175)	Fontenelle (3,261)	Flaming Gorge (17,005)	Soldier Creek[b] (17,163)	Starvation (1,340)	Lake Powell (65,314)	Navajo (6,317)
Clupeidae									
Dorosoma petenense								X	
Salmonidae									
Oncorhynchus kisutch			X						X
Oncorhynchus nerka	X	X	X		X				X
Prosopium williamsoni		X[c]		X	X		X		
Salmo clarki		X	X		X	X	X		
Salmo gairdneri	X	X	X	X	X	X	X	X	X
Salmo trutta	X	X	X	X	X	X	X	X	X
Salvelinus fontinalis	X		X	X	X	X			X
Salvelinus namaycush		X	X	X	X				
Esocidae									
Esox lucius								X	
Cyprinidae									
Cyprinu				X	X		X	X	
Gila atraria				X	X	X	X	X	
Gila cope									
Cyprinidae									
Gila cypha								X	
Gila robusta				X	X				X
Notropis lutrensis				X	X			X	
imep a es prome as				X	X			X	
Ptychocheilus lucius								X	
Rhinichthys cataractae				X	X				
Rhinichthys osculus		X	X	X	X	X			
Richardsonius balteatus				X	X	X		X	
Catostomidae									
Catostomus ardens				X					
Catostomus catostomus		X	X						
Catostomus commersoni		X	X	X	X				X
Catostomus discobolus	X		X					X	X
Catostomus latipinnis			X	X	X		X	X	X
Catostomus platyrhynchus		X		X	X	X	X		
Xyrauchen texanus								X	
Ictaluridae									
Ictalurus melas							X[c]		X
Icta urus natalis								X	
Icta urus punctatus								X	X
Percichthyidae									
Morone saxatilis								X	
Centrarchidae									
Lepomis cyanellus								X	
Lepomis macrochirus								X	X
Micropterus dolomieui					X				X
Micropterus salmoides					X			X	X
Pomoxis annularis									X
Pomoxis nigromaculatus								X	X
Percidae									
Etheostoma exile		X							
Etheostoma nigrum		X							
Stizostedion vitreum							X	X	
Cottidae									
Cottus bairdi		X	X	X	X		X		

Maximum surface area (ha)
Surface area includes Strawberry Reservoir
Indicates presence only

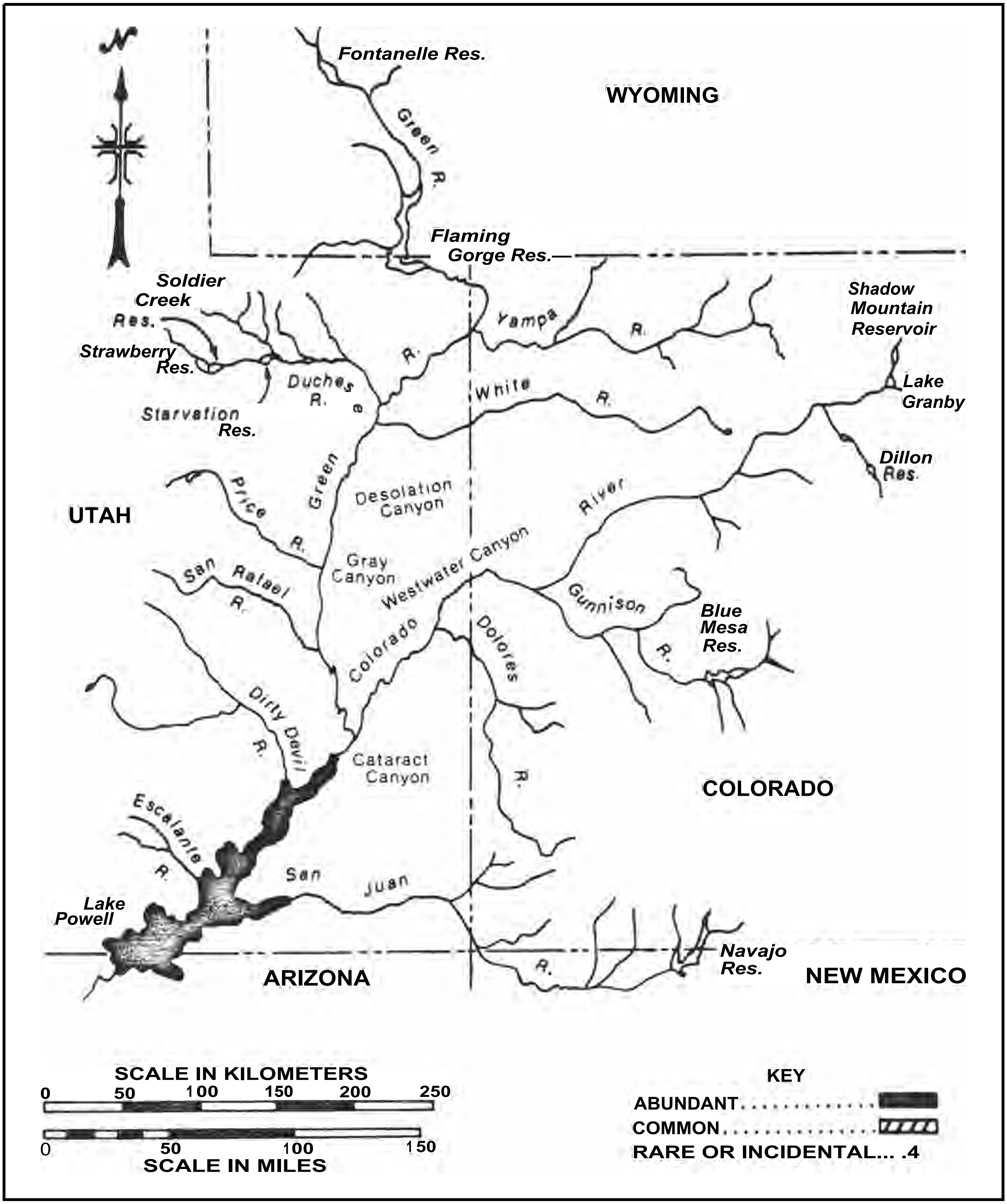

Figure 2. Distribution and relative abundance of threadfin shod, *Dorosoma petenense,* in the Upper Colorado Basin.

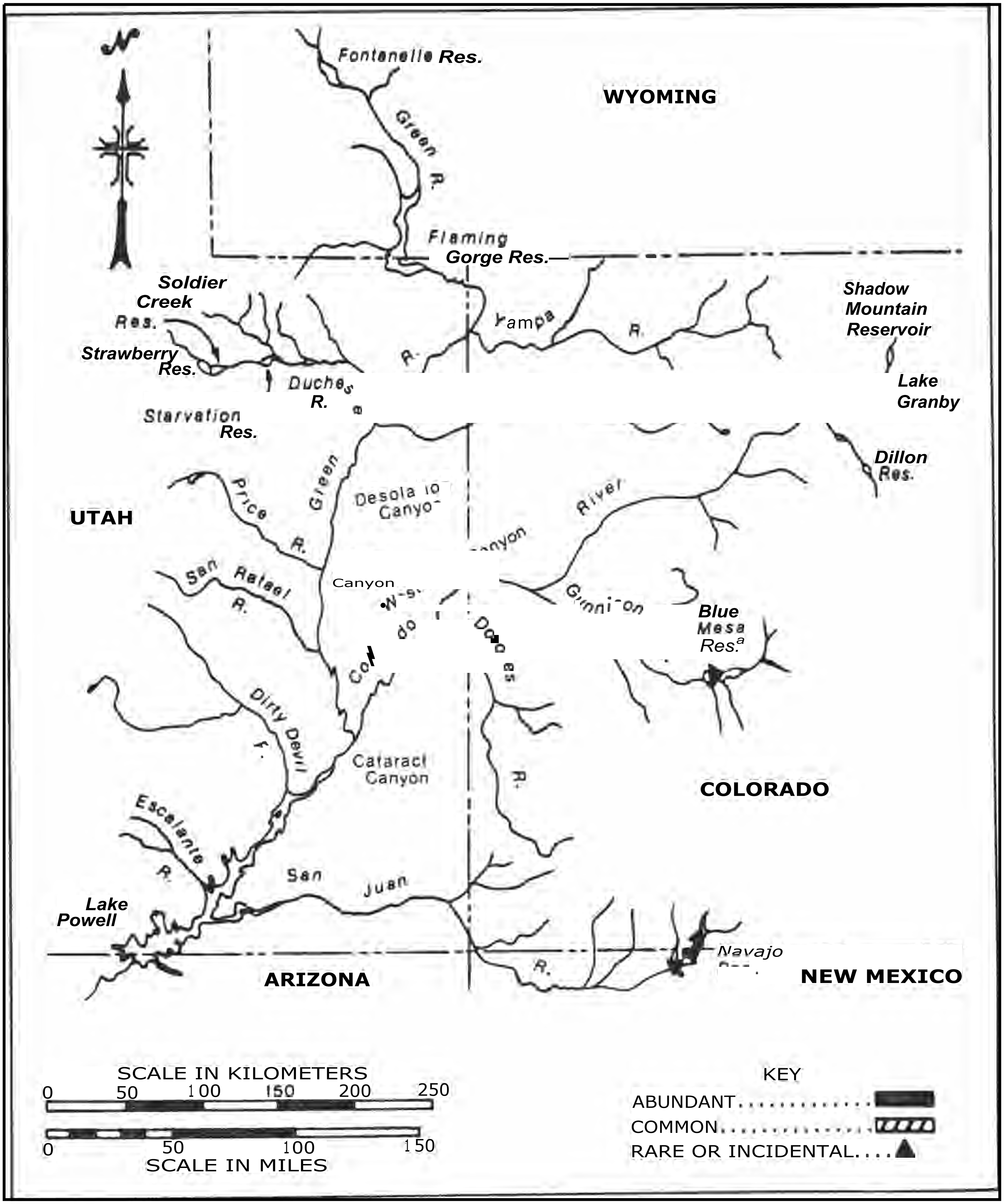

Figure 3. Distribution and relative abundance of coho salmon, *Oncorhynchus* kisutch, in the Upper Colorado Basin.

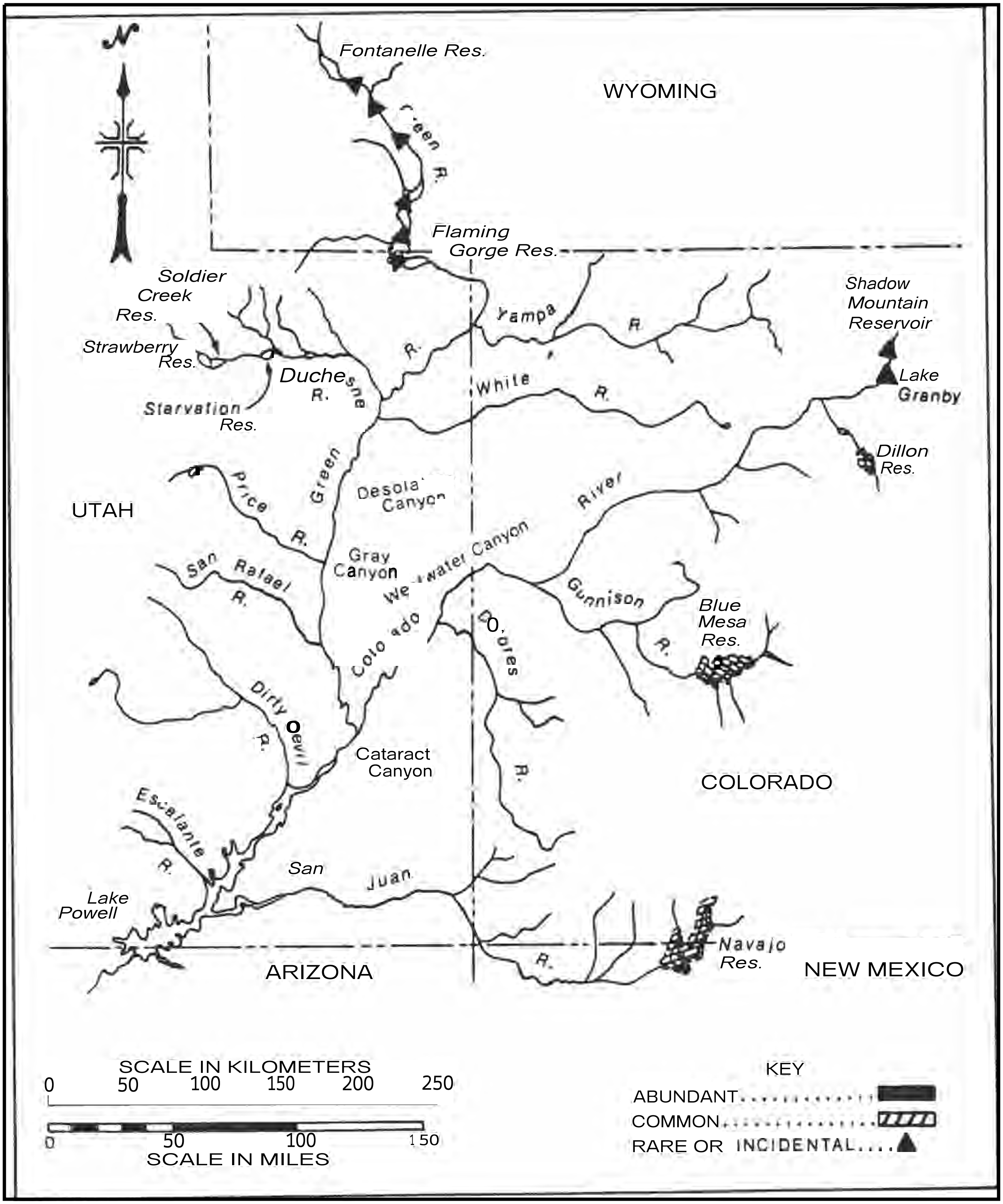

Figure 4. Distribution and relative abundance of kokanee, Oncorhynchus nerka, in the Upper Colorado Basin.

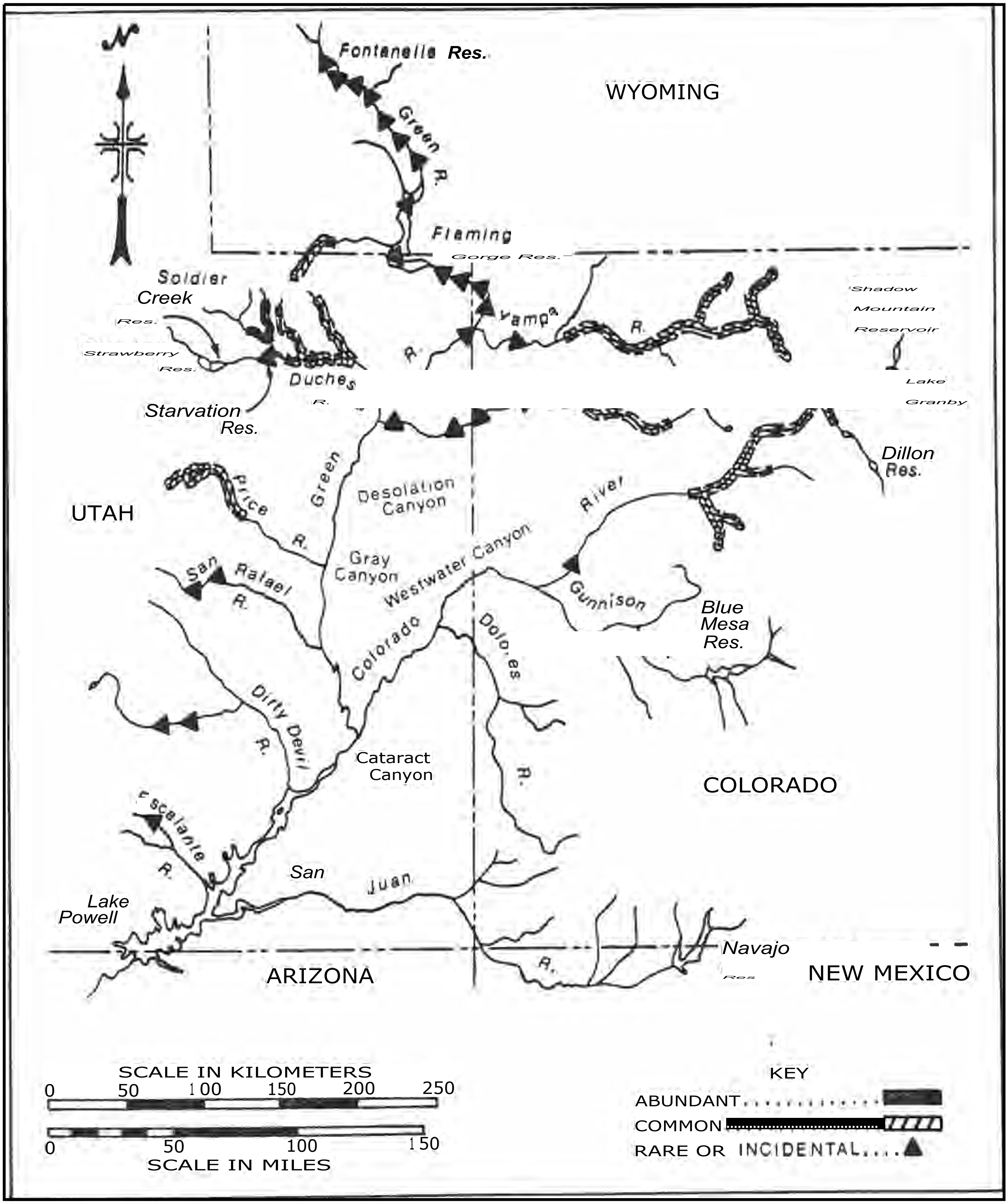

Figure 5. Distribution and relative abundance of mountain whitefish, *Prosopium williamsoni*, in the Upper Colorado Basin.

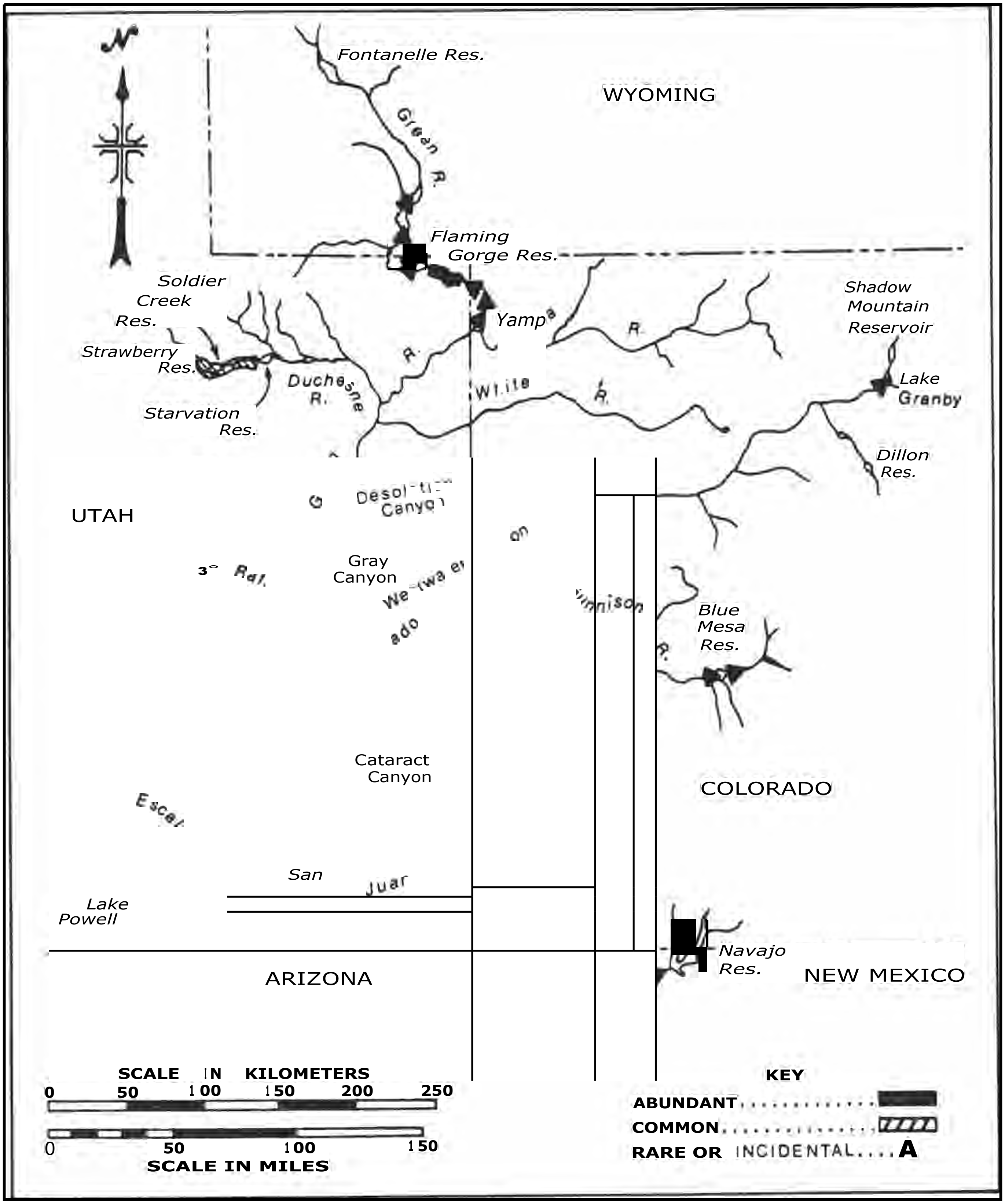

Figure 6. Distribution and relative abundance of cutthroat trout, *Salmo clarki*, in the Upper Colorado Basin.

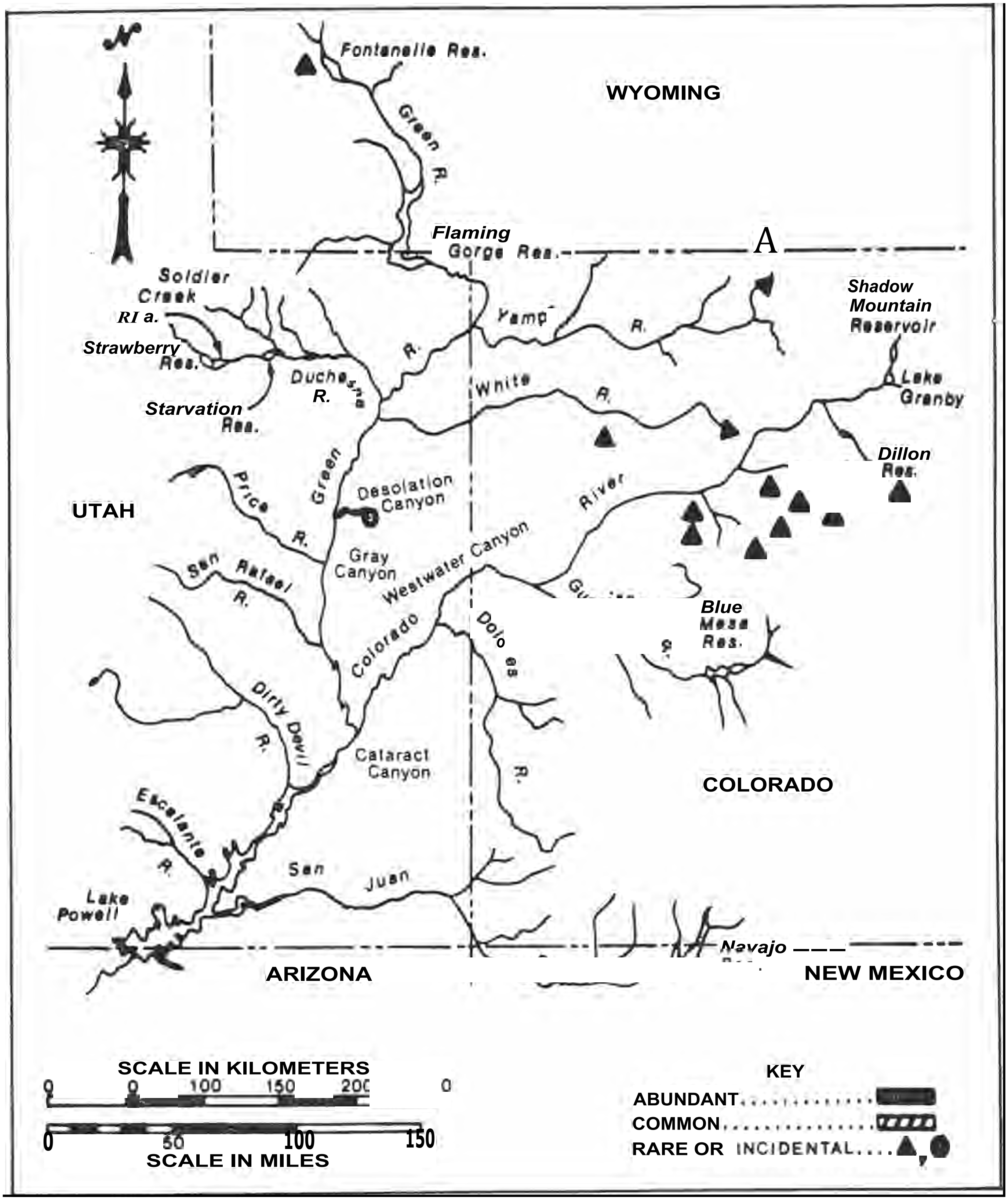

Figure 7. Distribution and relative abundance of Colorado River cutthroat trout, Salmo clarki pleuriticus (▲), ond greenback cutthroat trout, Salmo clarki stomias (0), in the Upper Colorado Basin.

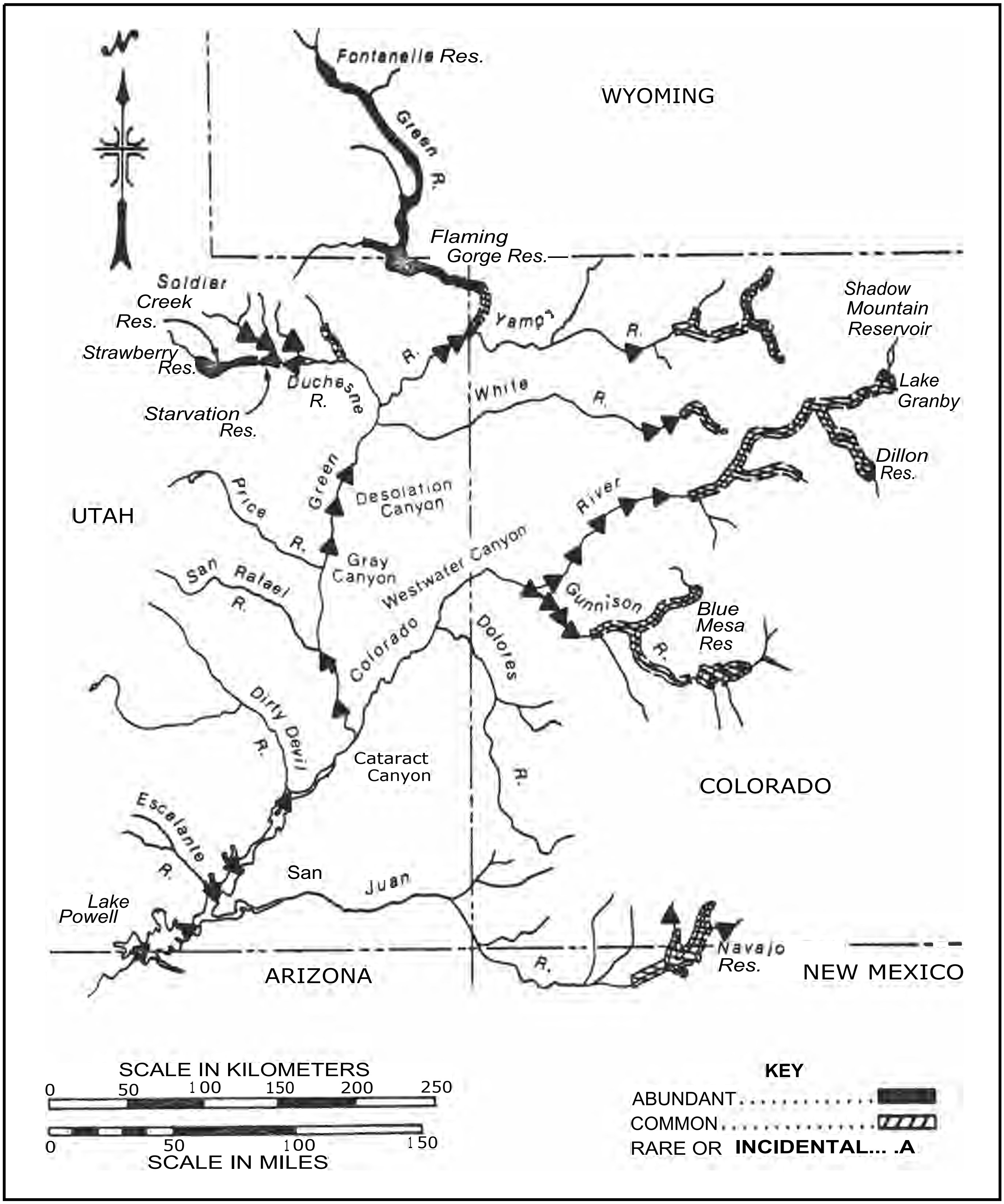

Figure 8. Distribution and relotive abundance of rainbow trout, Solmo gairdneri, in the Upper Colorado Basin.

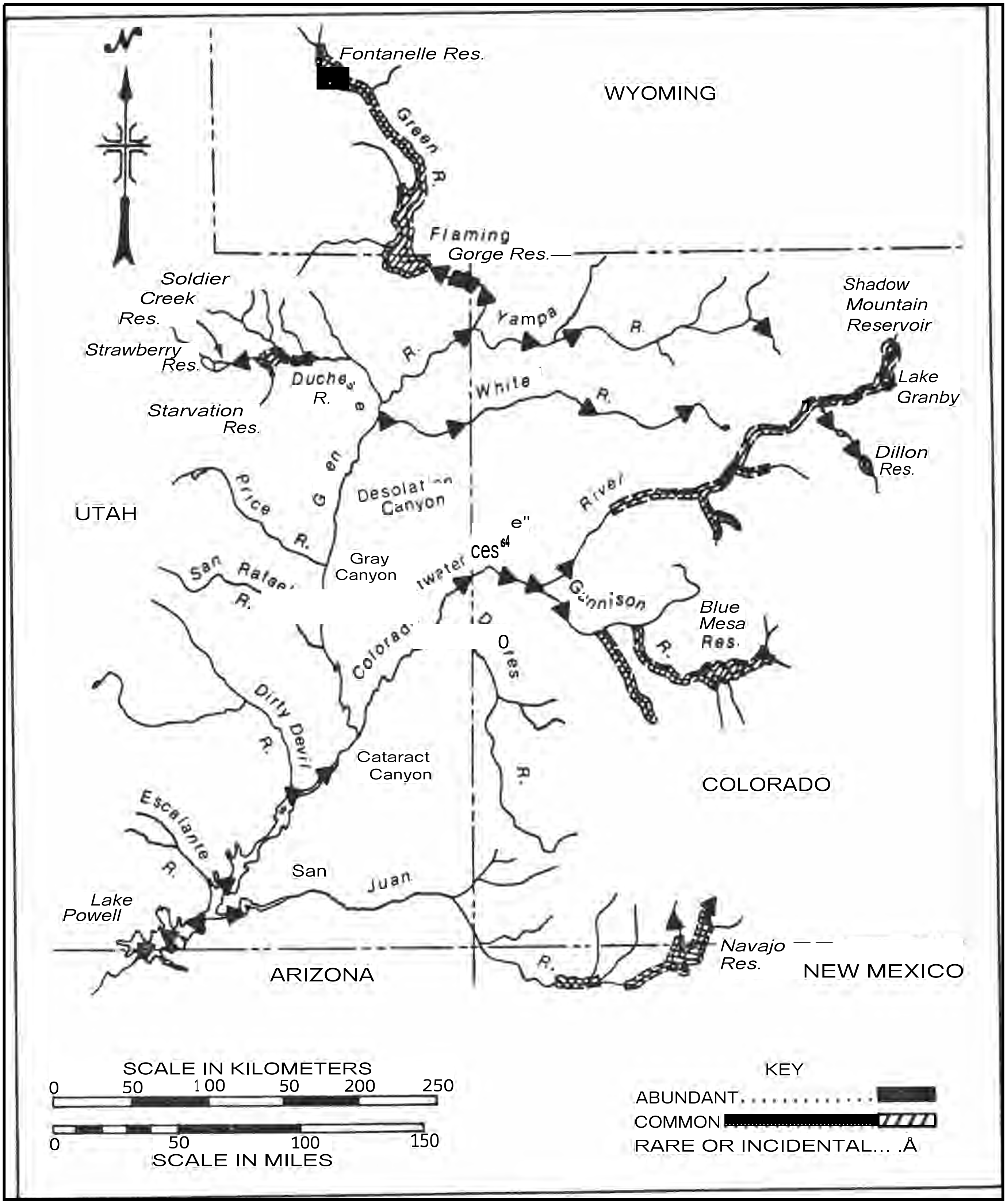

Figure 9. Distribution and relative abundance of brown trout, *Solmo trutta*, in the Upper Colorado Basin.

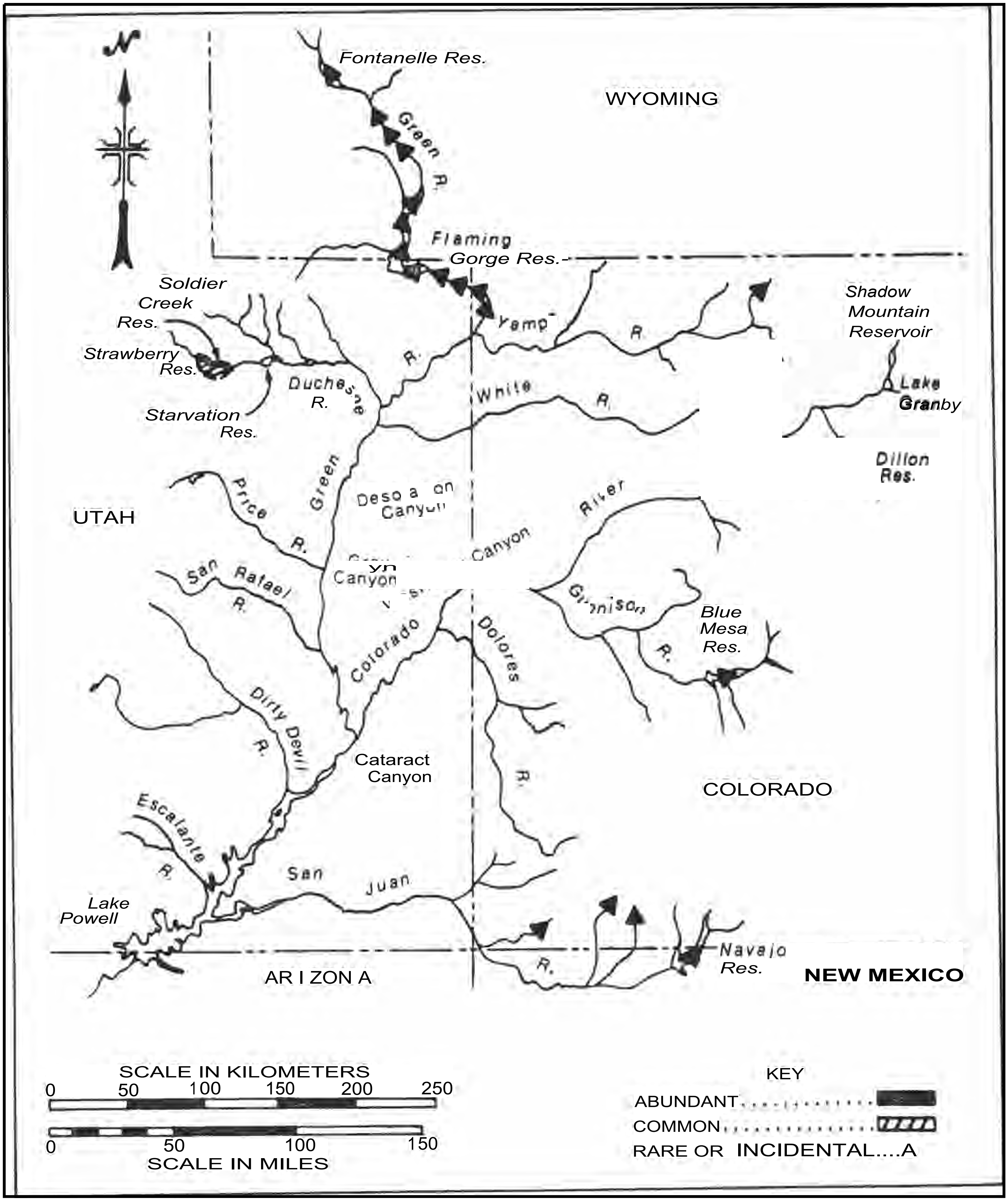

Figure 10. Distribution and relative abundance of brook trout, *Solvelinus fontinalis*, in the Upper Colorado Basin.

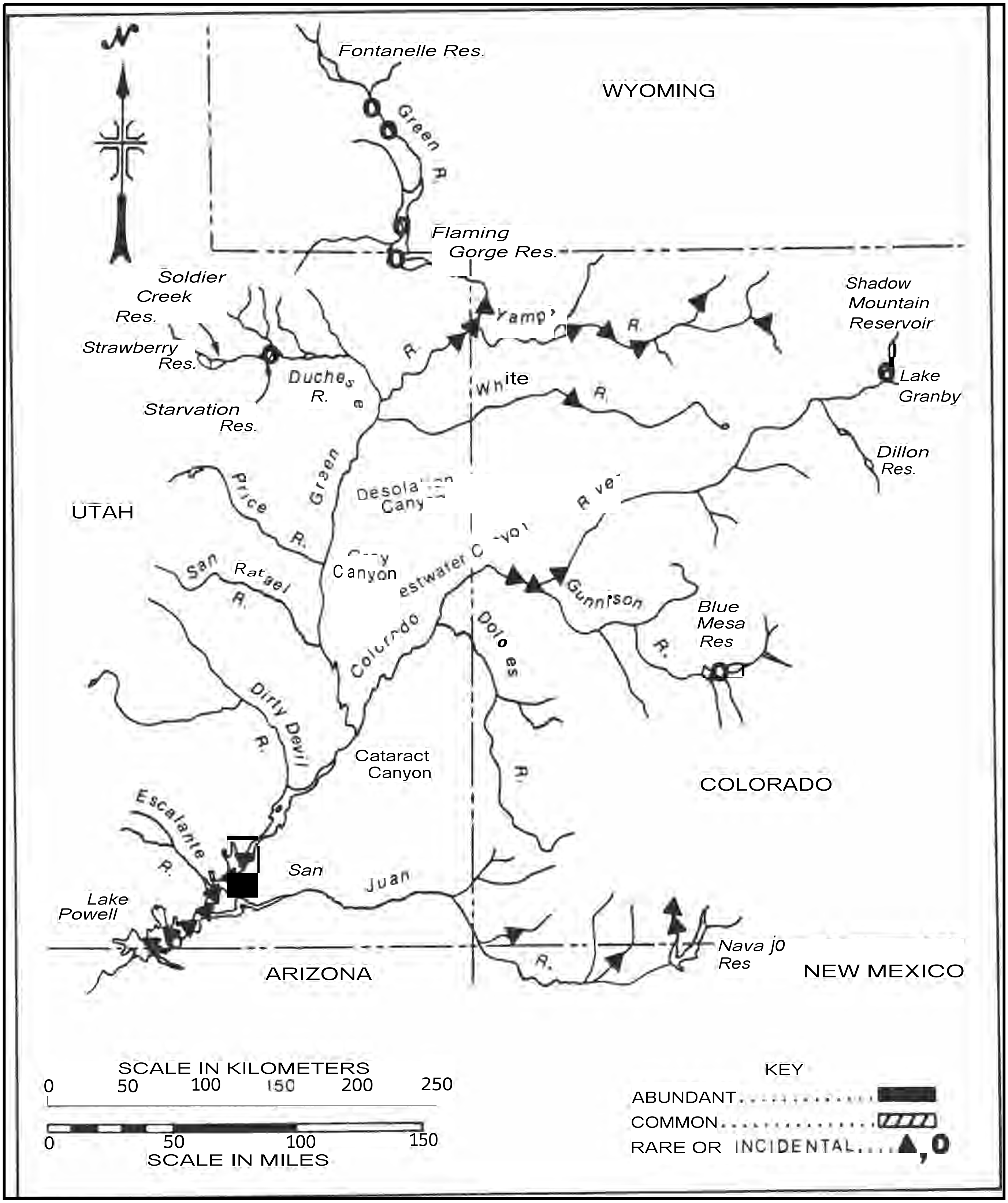

Figure 11. Distribution and relative abundance of lake trout, *Salvelinus namaycush* (0), and northern pike, ***Esox lucius*** (▲), in the Upper Colorado Basin.

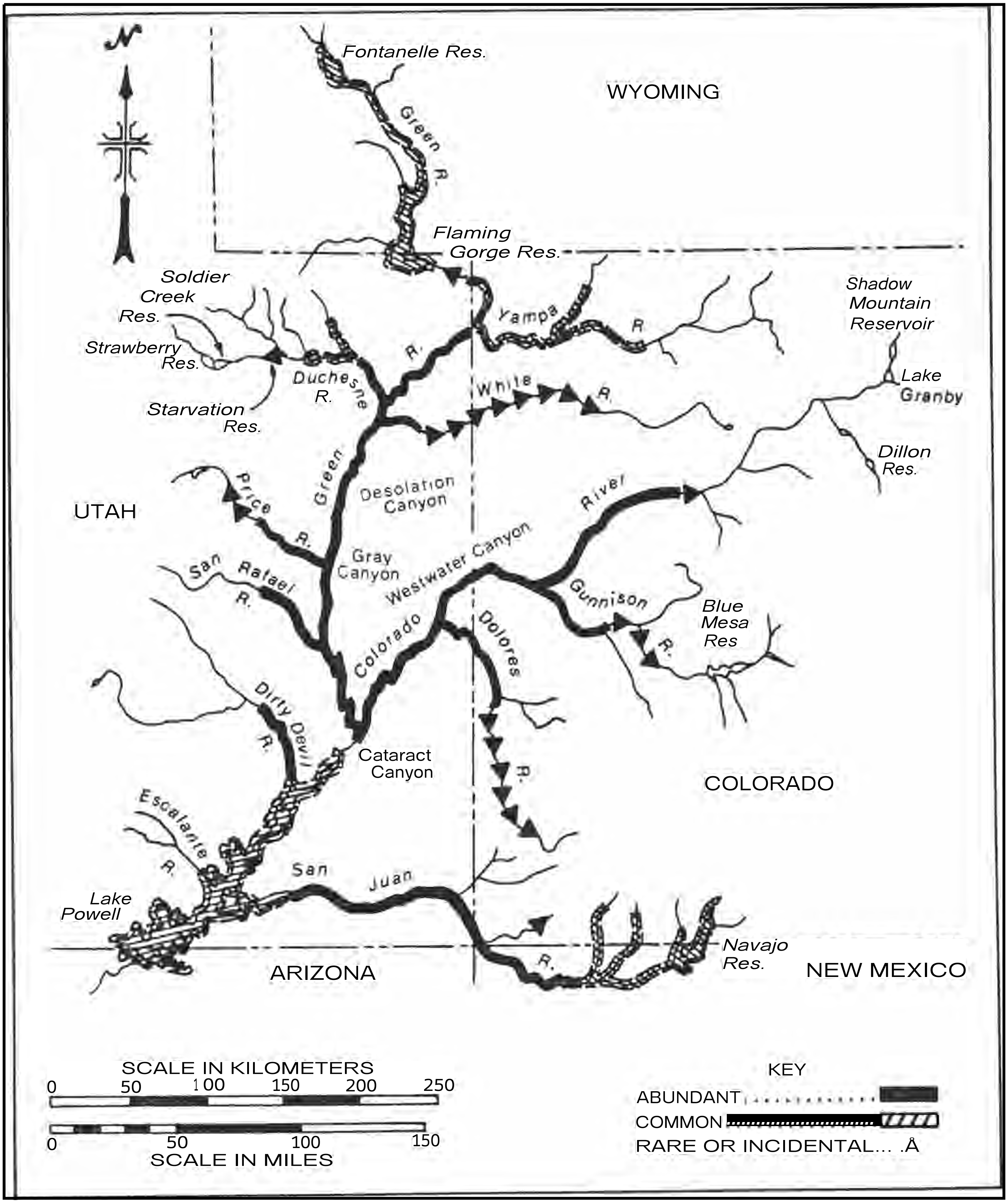

Figure 12. Distribution and relative abundance of carp, Cyprinus carpio, in the Upper Colorado Basin.

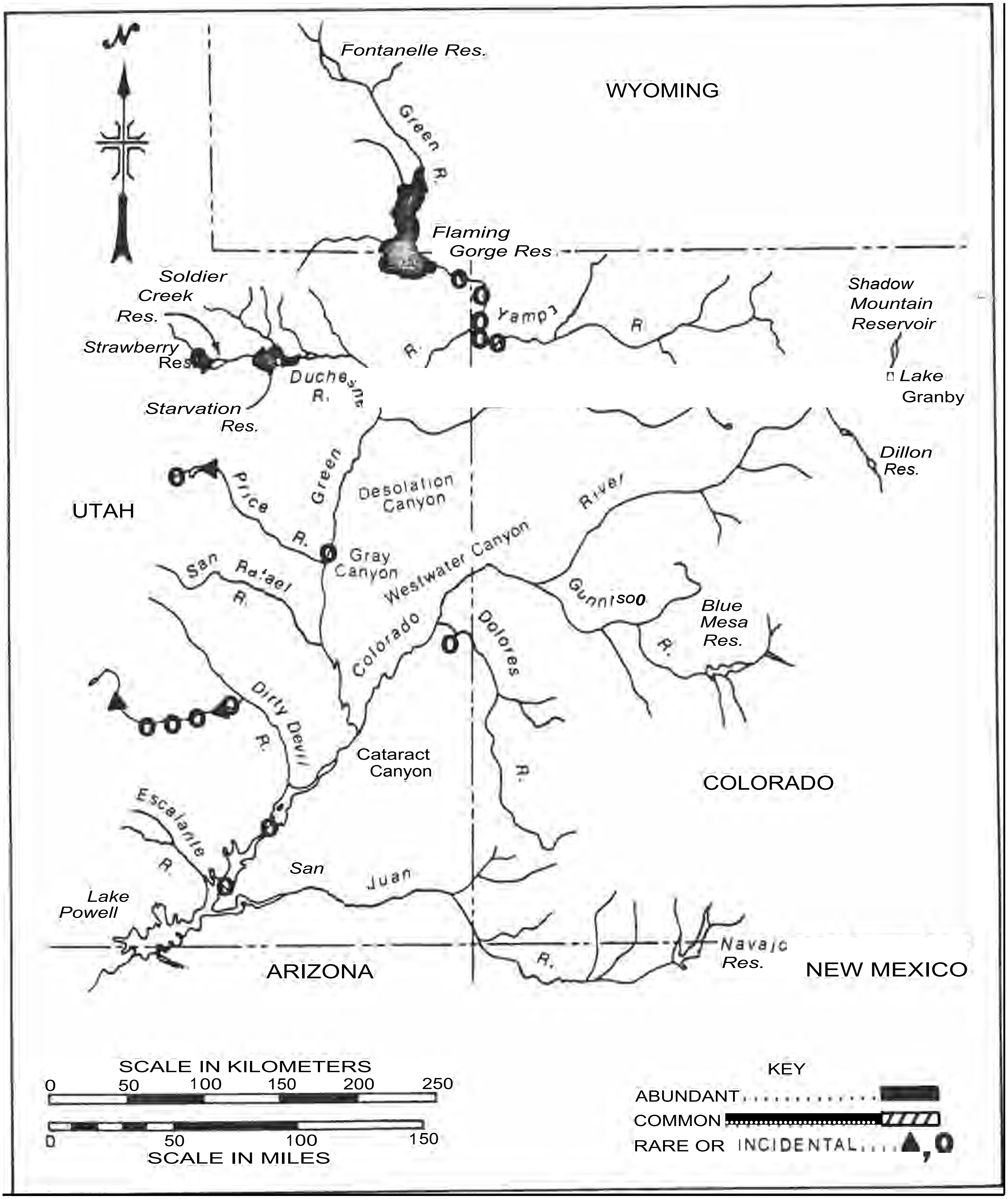

Figure 13. Distribution and relative abundance of Utah chub, Gila atraria (0) and leatherside chub, *Gila* copei (▲), in the Upper Colorado Basin. "Abundant" symbol refers to Utah chub.

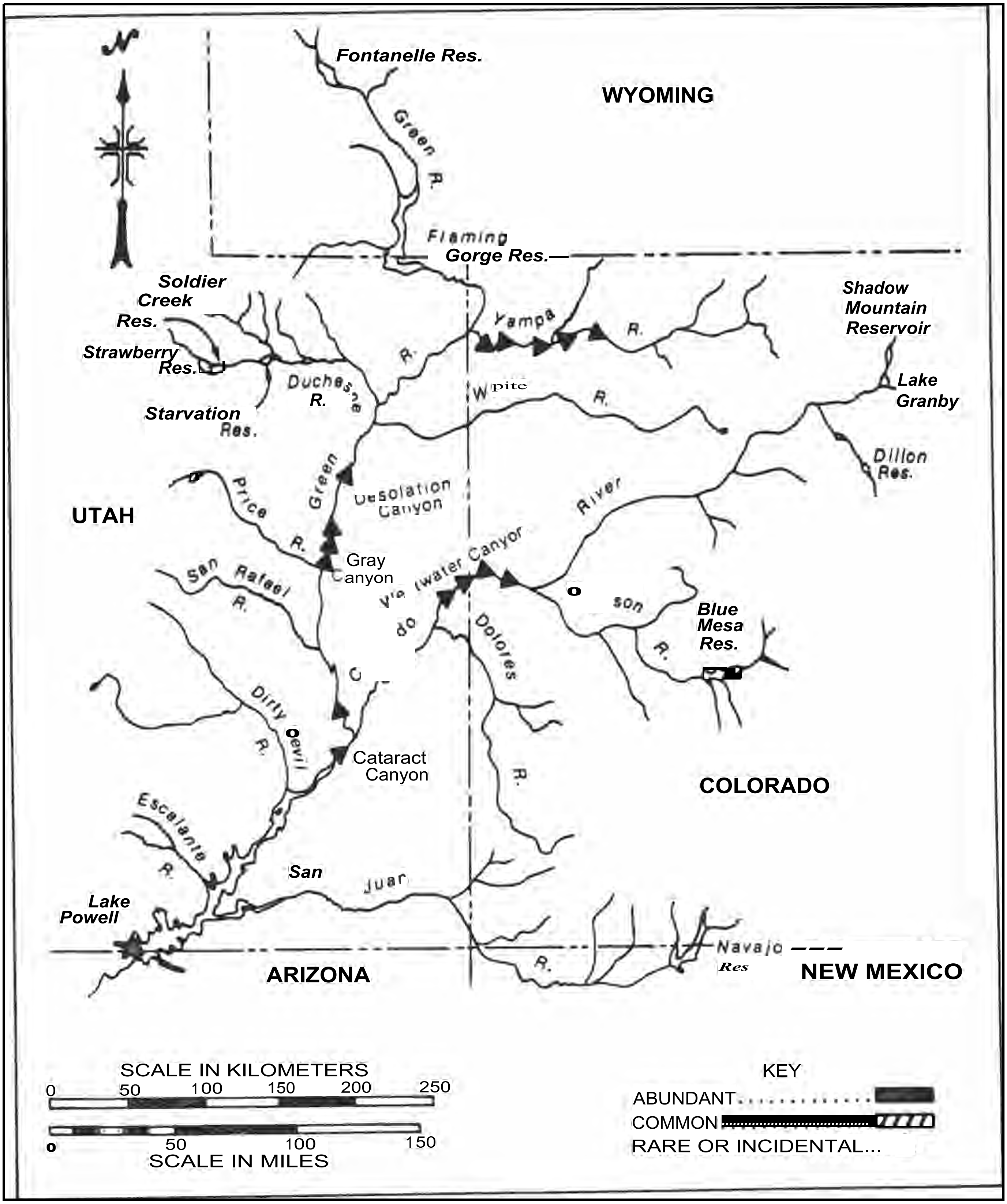

Figure 14. Distribution and relative abundance of humpback chub, Gila cypha, in the Upper Colorado Basin.

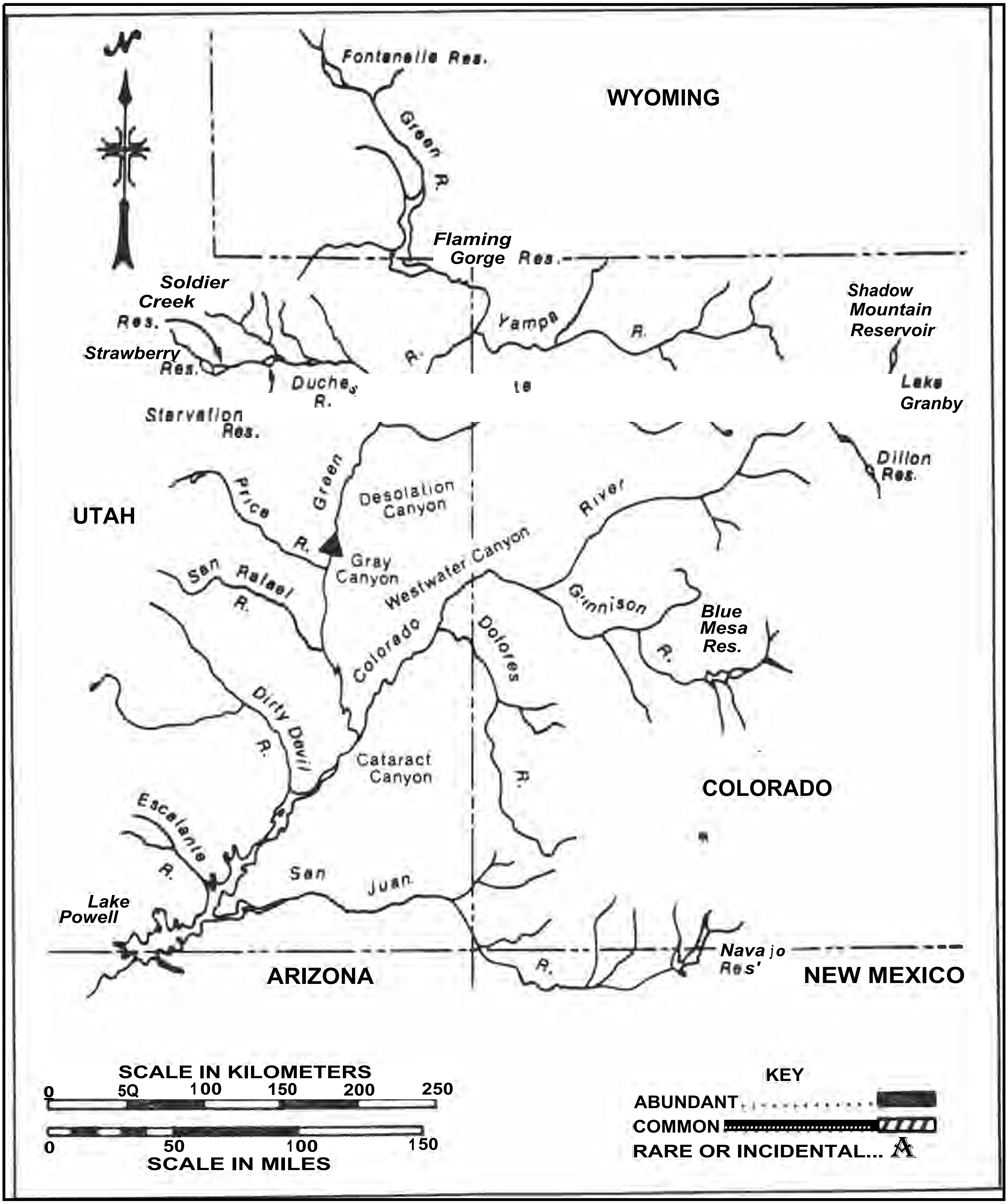

Figure 15. Distribution and relative abundance of bonytoil chub, Gilo elegons, in the Upper Colorado Basin.

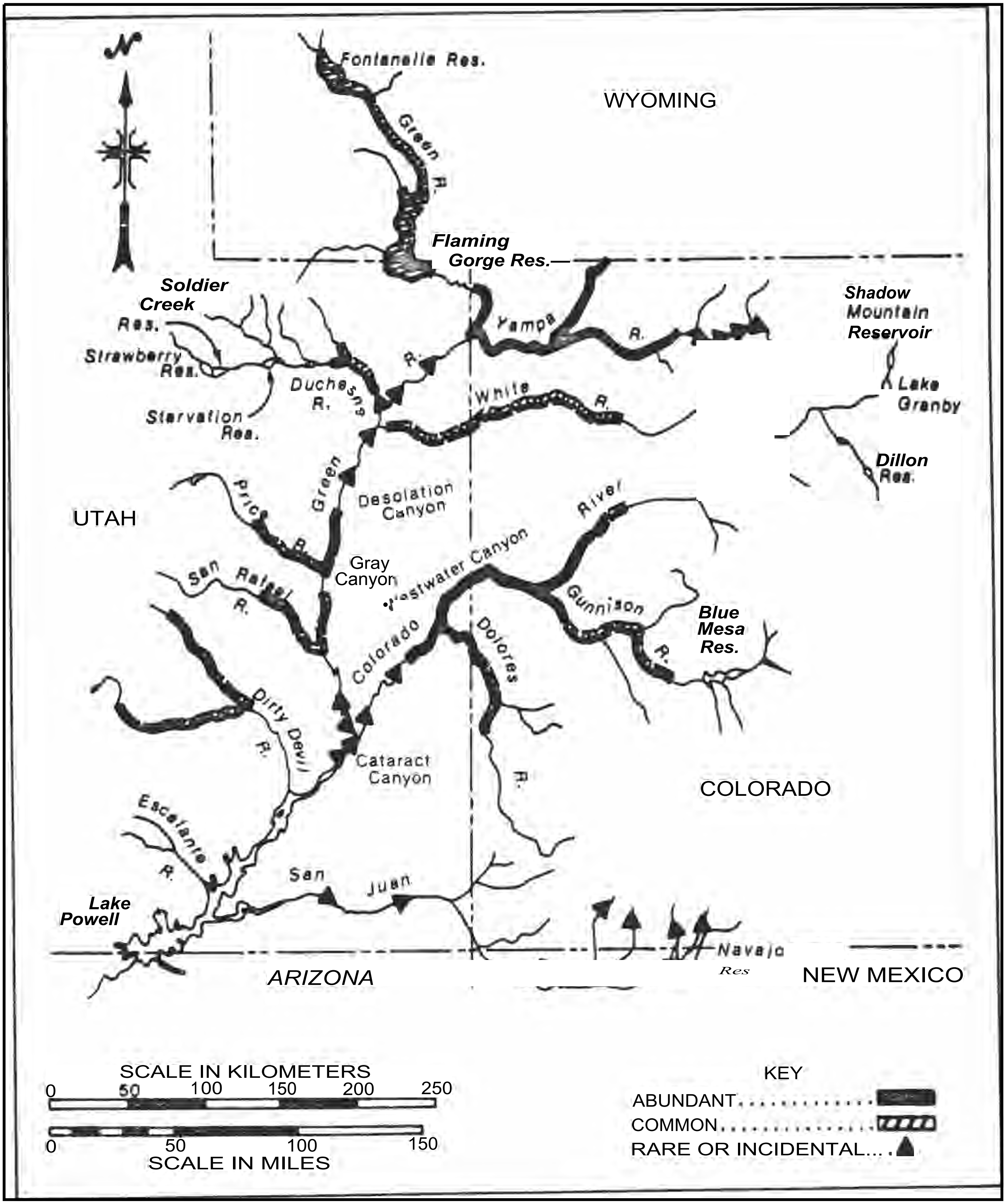

Figure 16. Distribution and relative abundance of roundtail chub, *Gila robusto,* in the Upper Colorado Basin.

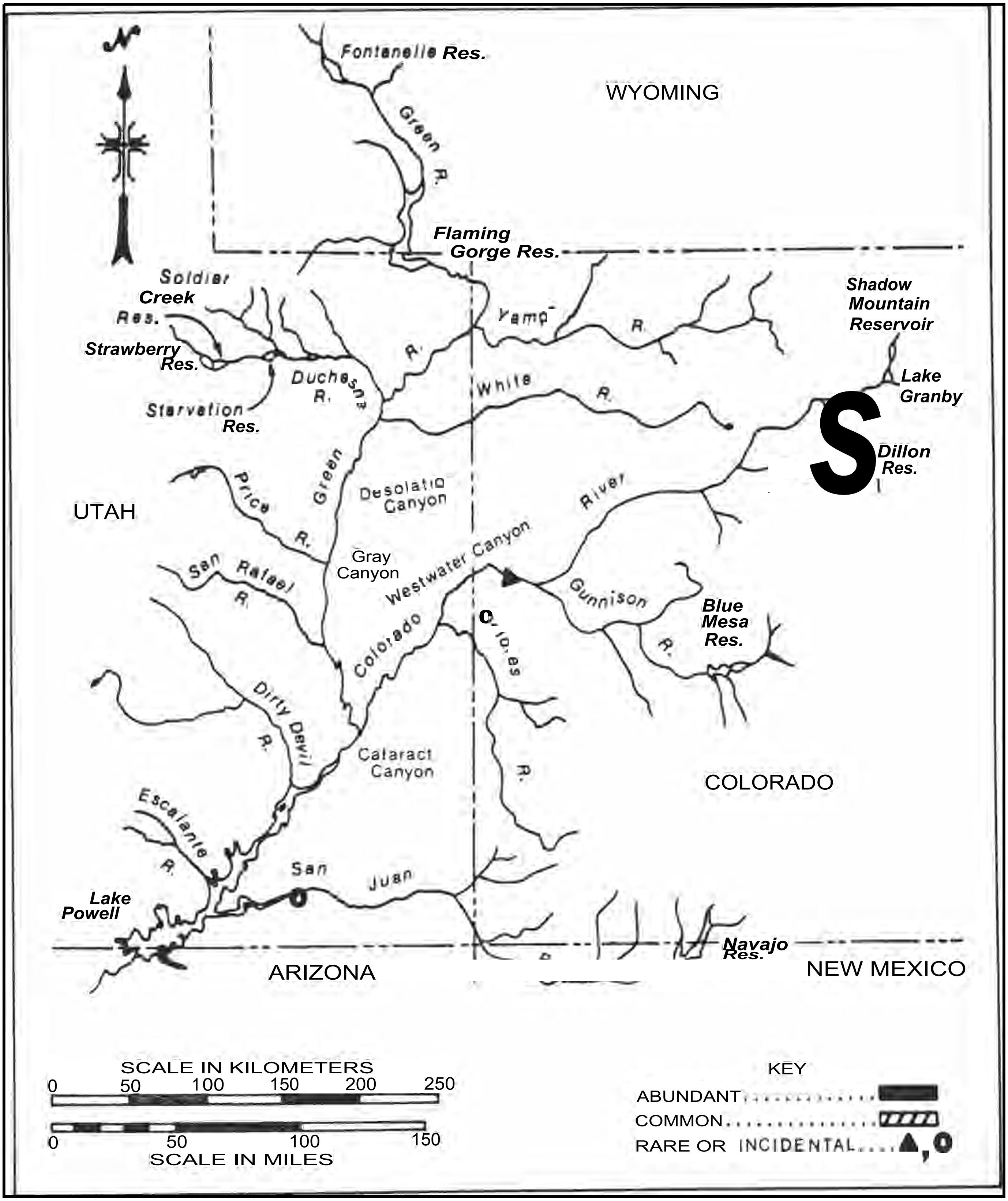

Figure 17. Distribution and relative abundance of brassy minnow, Hybognothus honkinsoni (▲), and plains minnow, *Hybognothus plocitus* (0), in the Upper Colorado Basin.

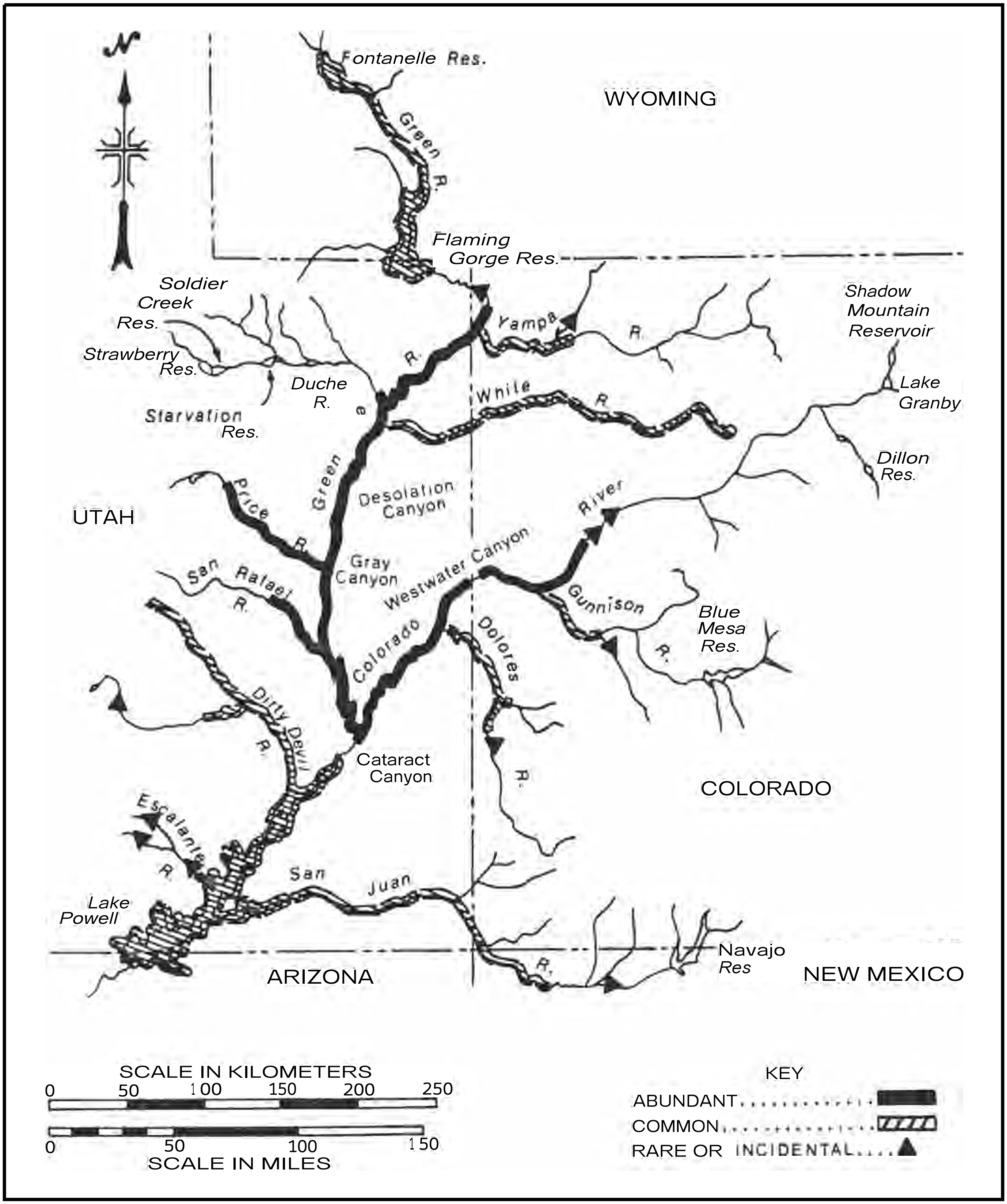

Figure 18. Distribution and relative abundance of red shiner, *Notropis lutrensis*, in the Upper Colorado Basin.

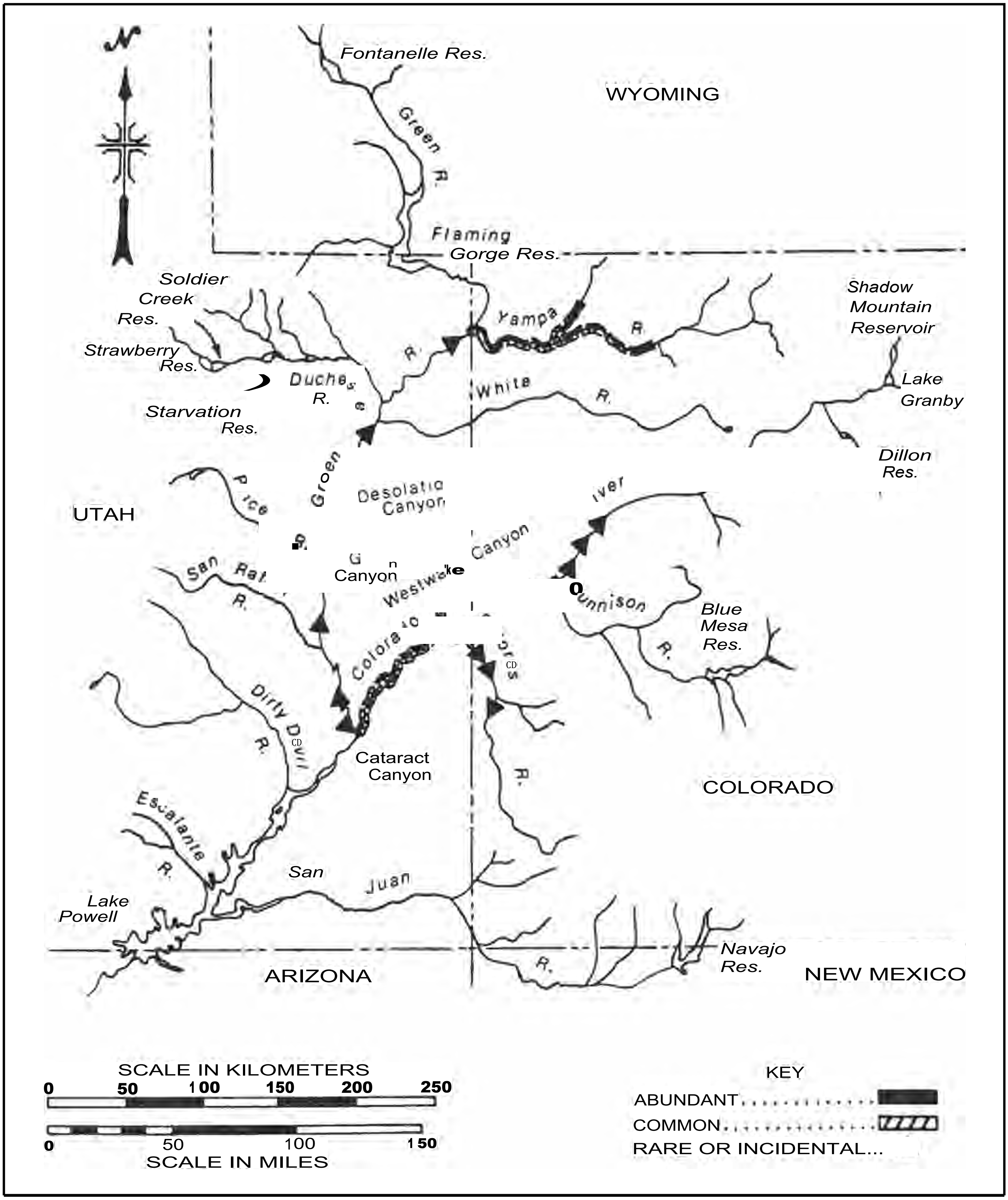

Figure 19. Distribution and relative abundance of sand shiner, *Notropis stromineus,* in the Upper Colorado Basin.

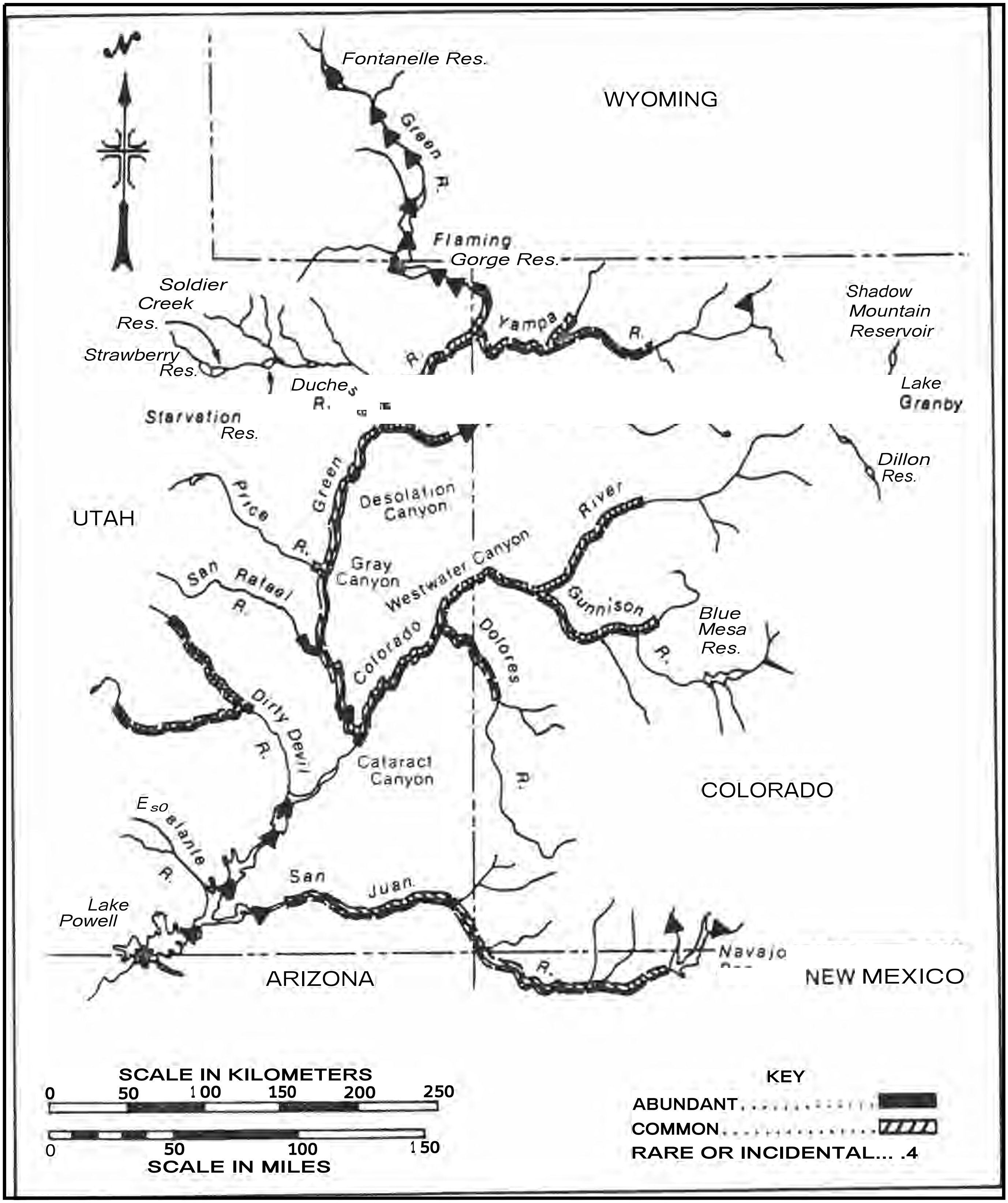

Figure 20. Distribution and relative abundance of fathead minnow, Pimepholes promelas, in the Upper Colorado Basin.

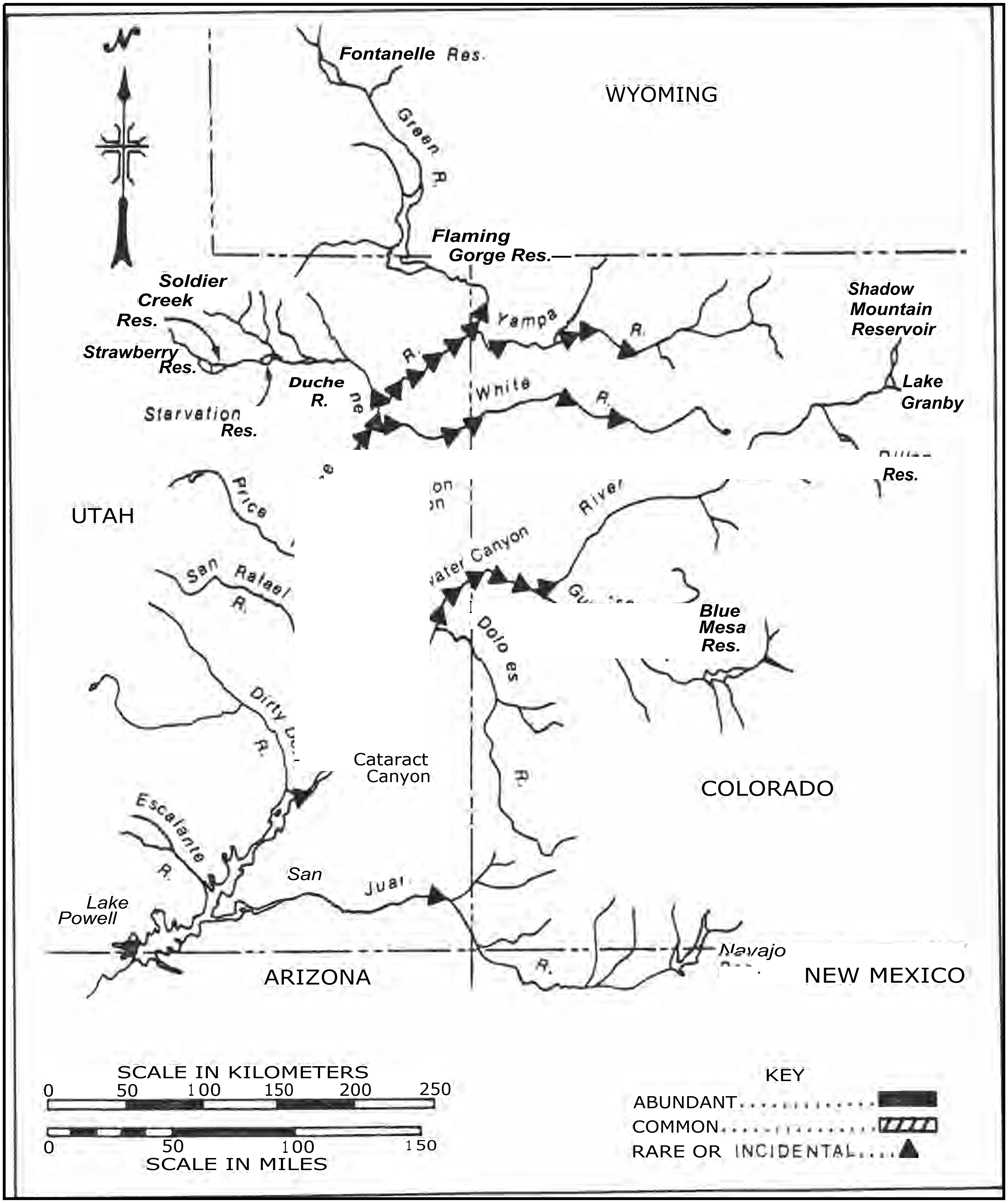

Figure 21. Distribution and relative abundance of Colorado squawfish, *Ptychocheilus lucius*, in the Upper Colorado Basin.

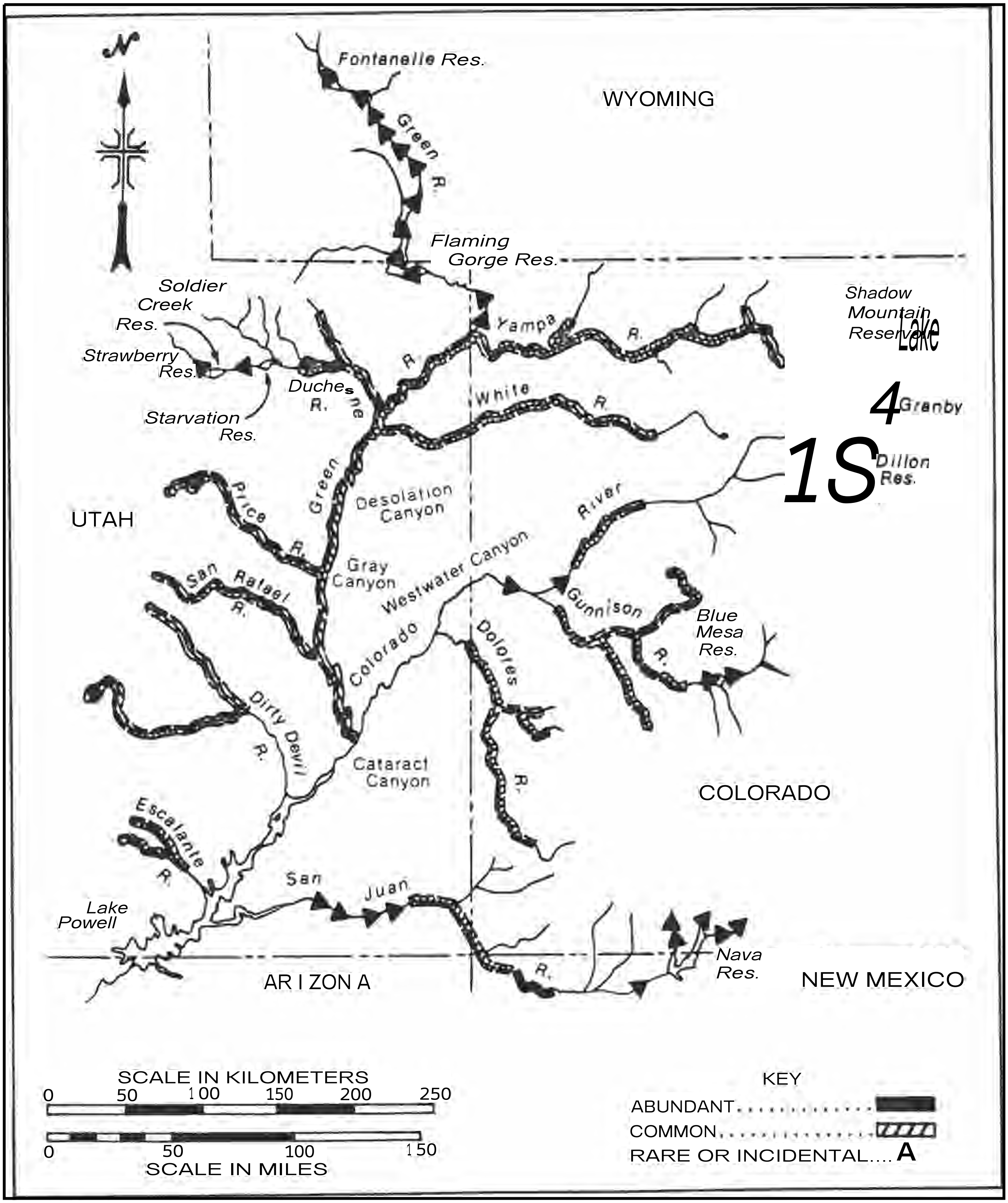

Figure 22. Distribution and relative abundance of speckled dace, *Rhinichthys osculus*, in the Upper Colorado Basin.

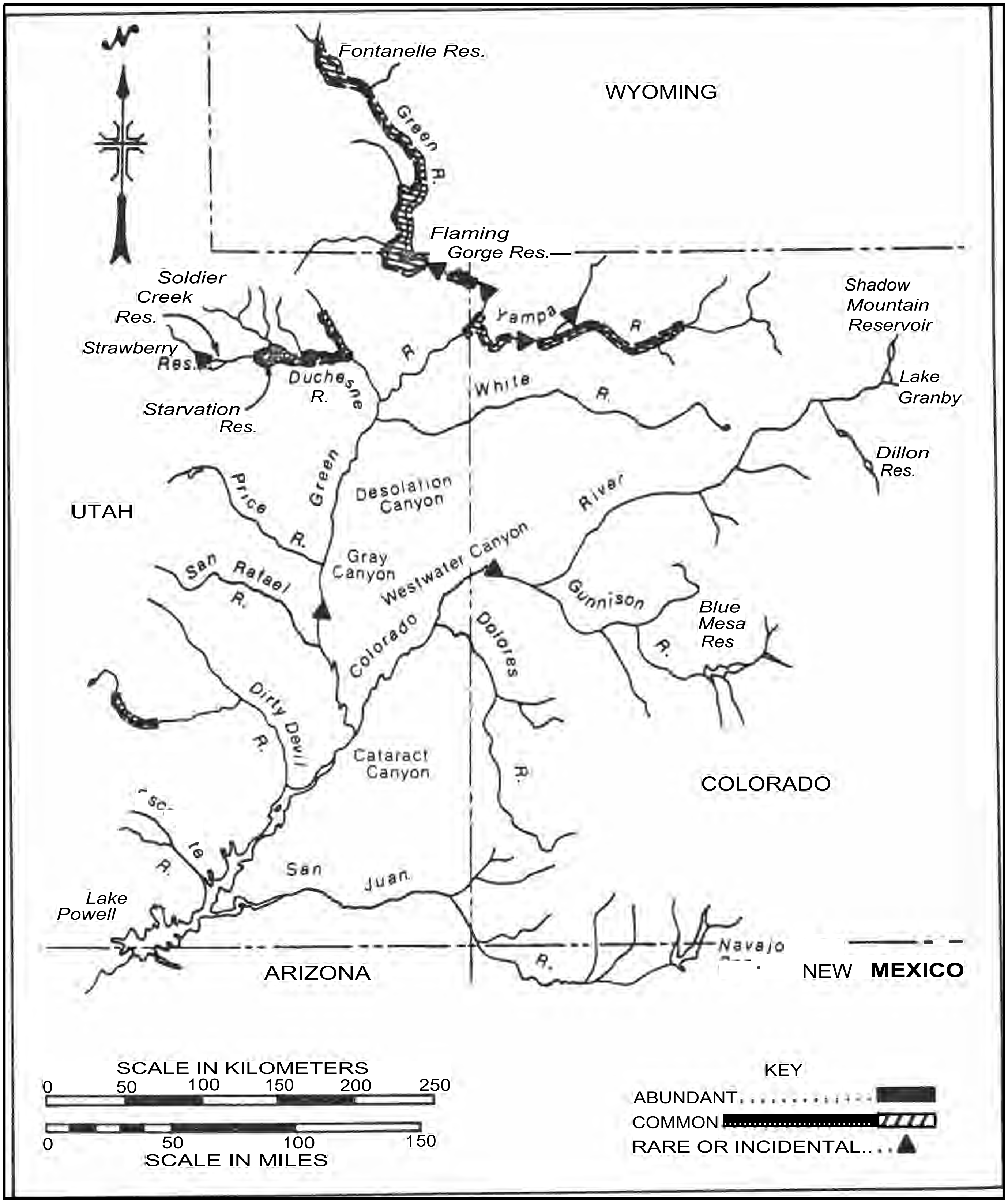

Figure 23. Distribution and relative abundance of redside shiner, *Richardsonius balteatus*, in the Upper Colorado Basin.

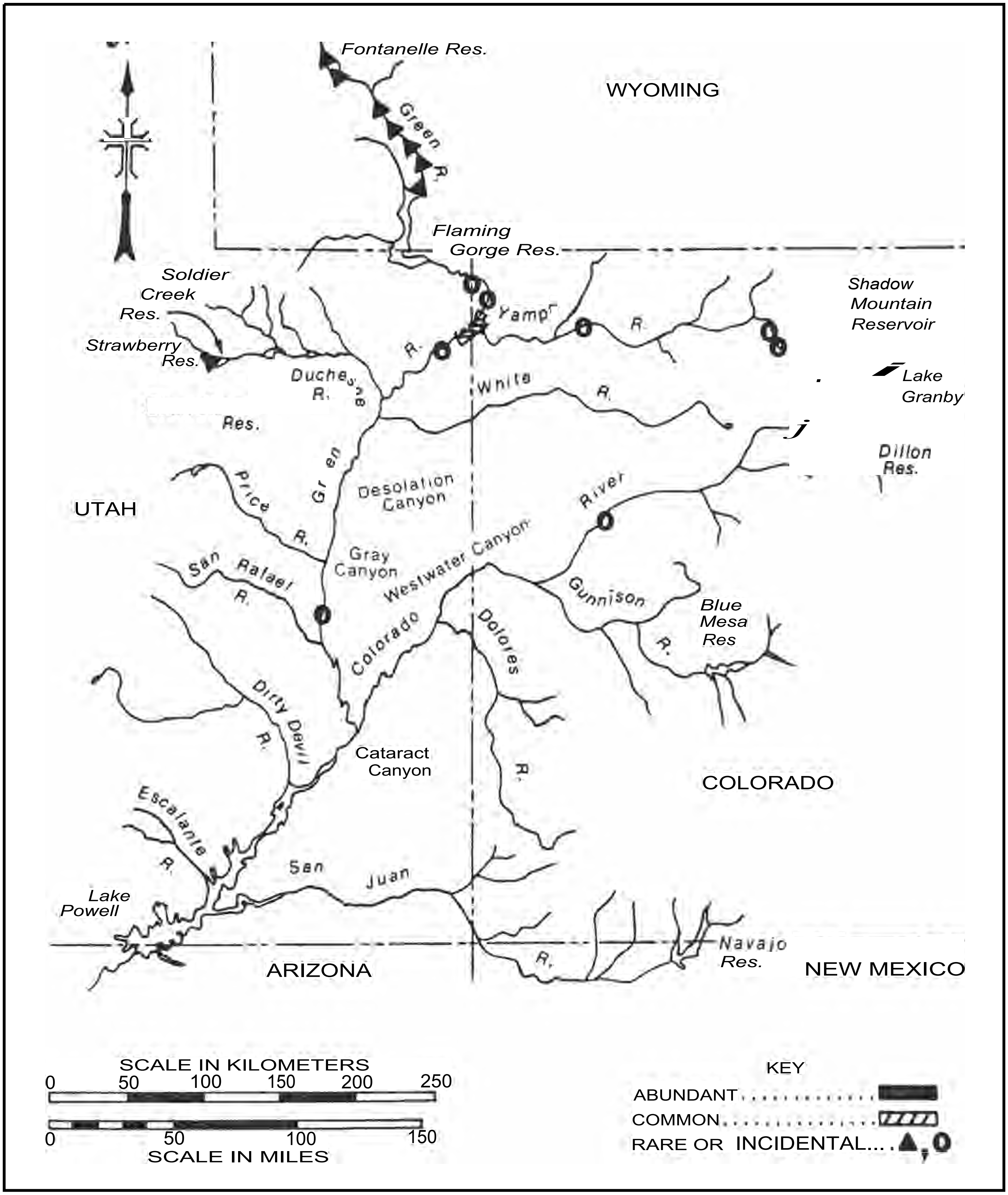

Figure 24. Distribution and relative abundance of creek chub, *Semotilus atromaculatus* (O) and longnose dace, Rhinichthys *cataractae* (▲), in the Upper Colorado Basin. "Common" symbol refers to creek chub.

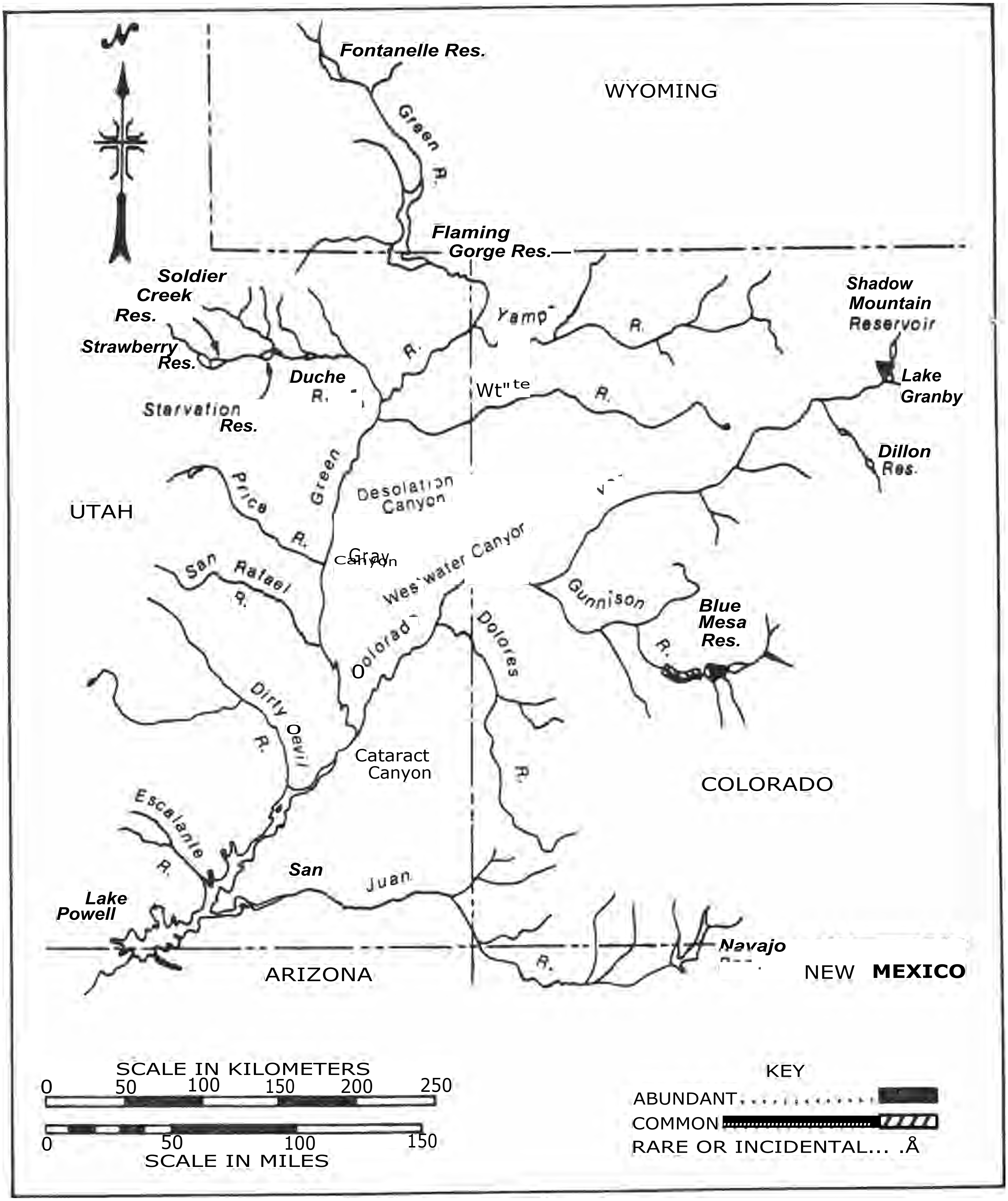

Figure 25. Distribution and relative abundance of longnose sucker, Catostomus catostomus , in **the Upper Colorado Basin.**

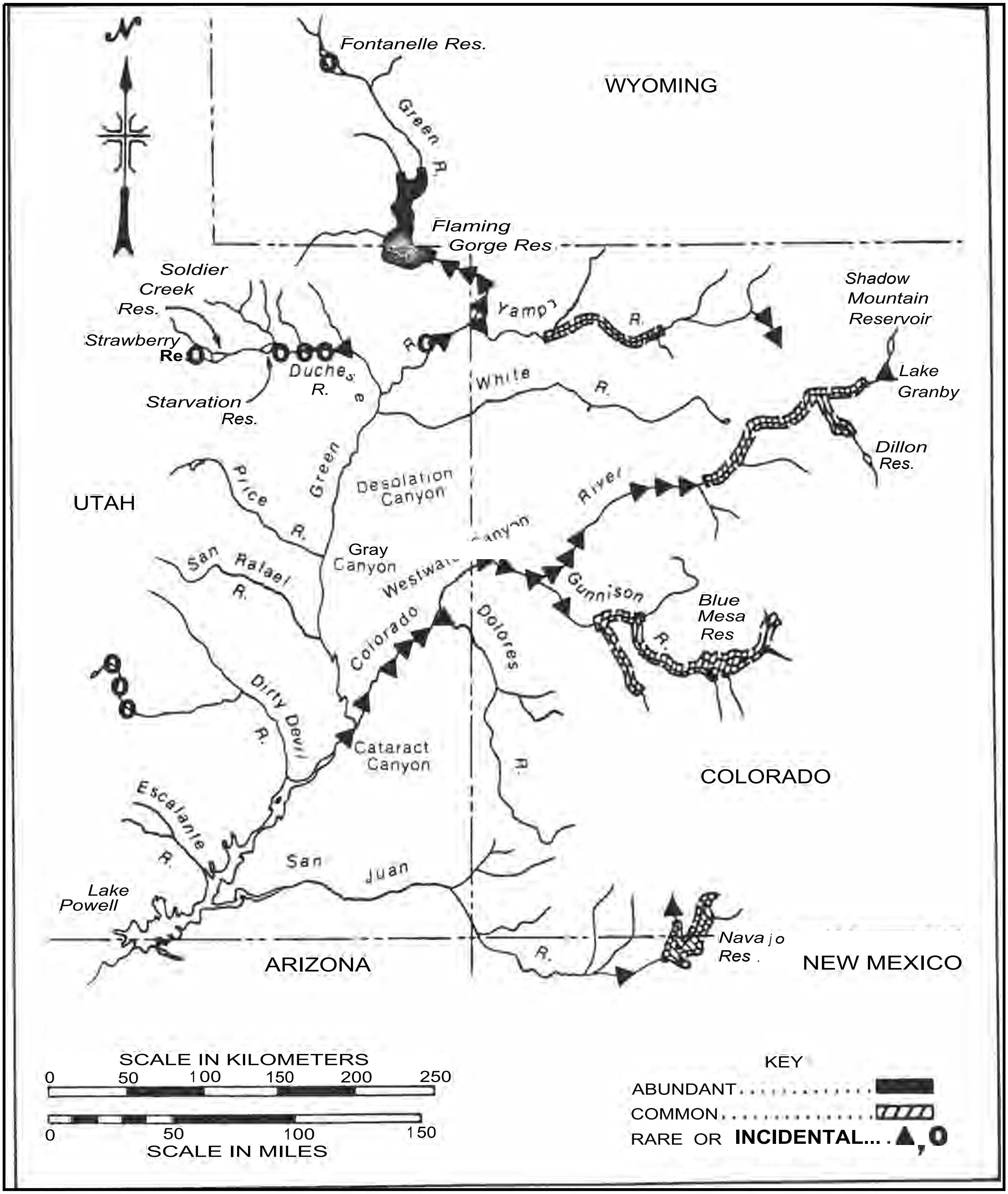

Figure 26. Distribution and relative abundance of Utah sucker, Catostomus ardens (0), and white sucker, *Catostomus commersoni* (▲), in the Upper Colorado Basin. Abundant and common occurrence refers to white sucker.

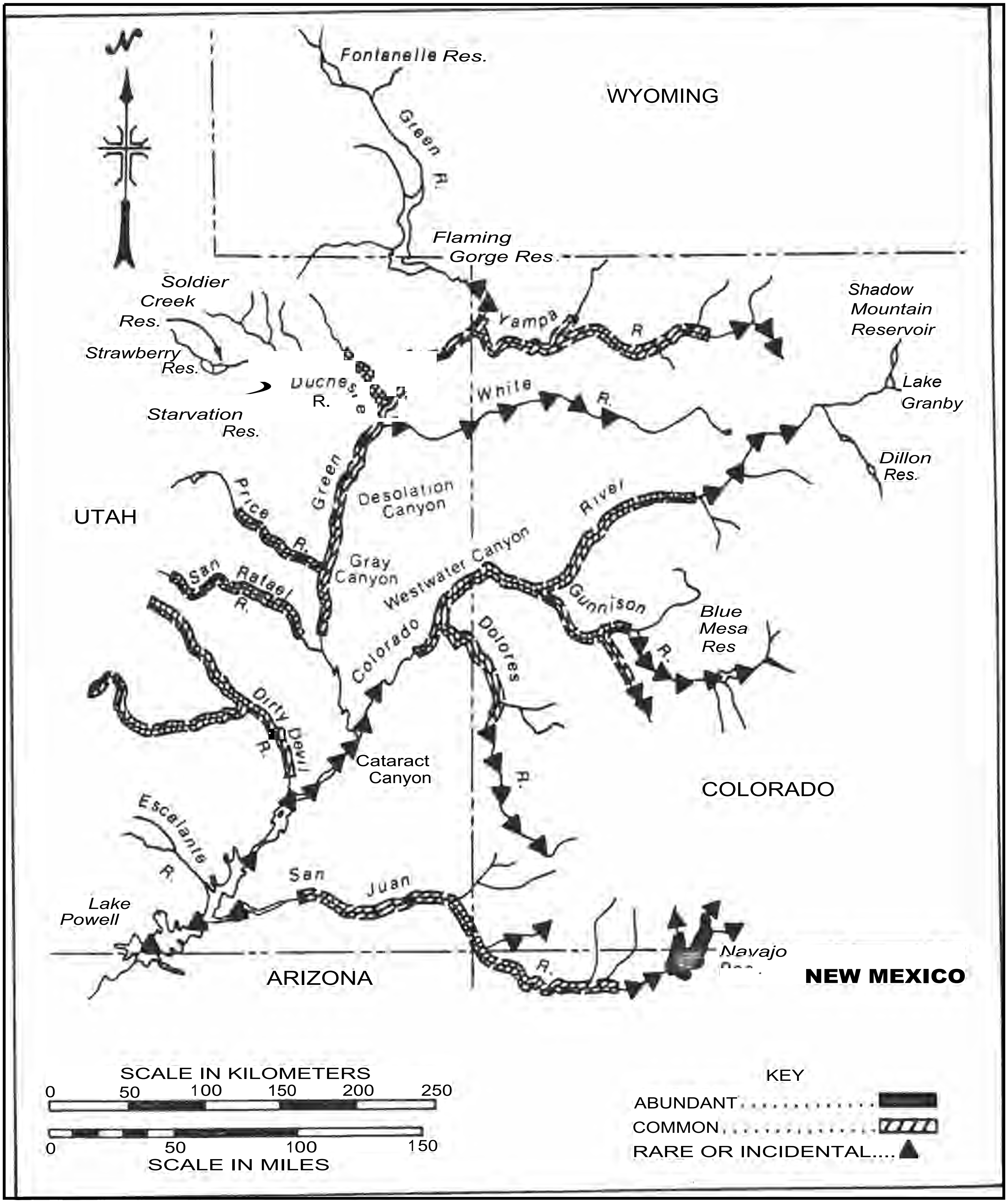

Figure 27. Distribution and relative abundance of bluehead sucker, *Catostomus discobolus,* in the Upper Colorado Basin.

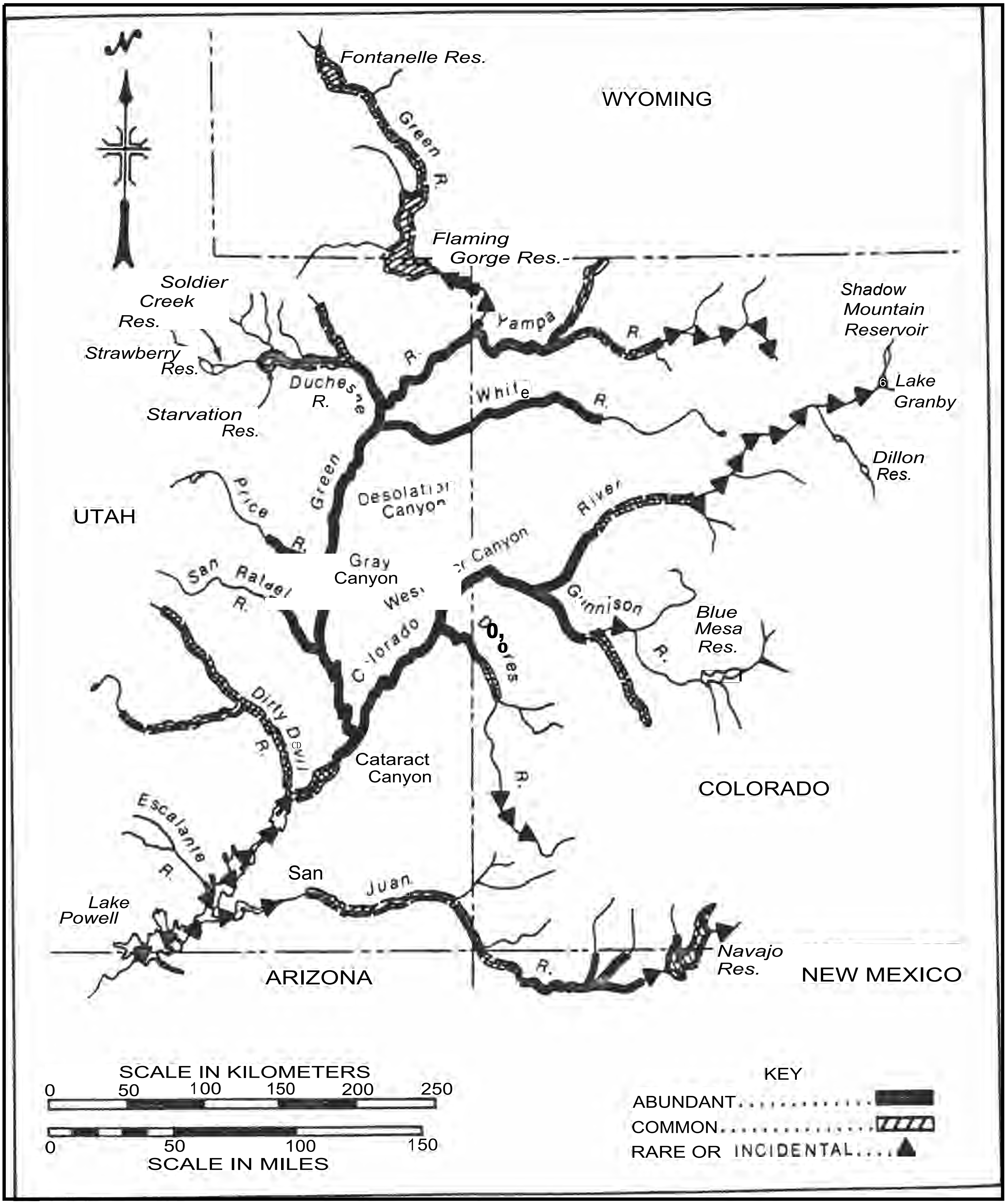

Figure 28. Distribution and relative abundance of flannelmouth sucker, *Cotostomus latipinnis*, in the Upper Colorado Basin.

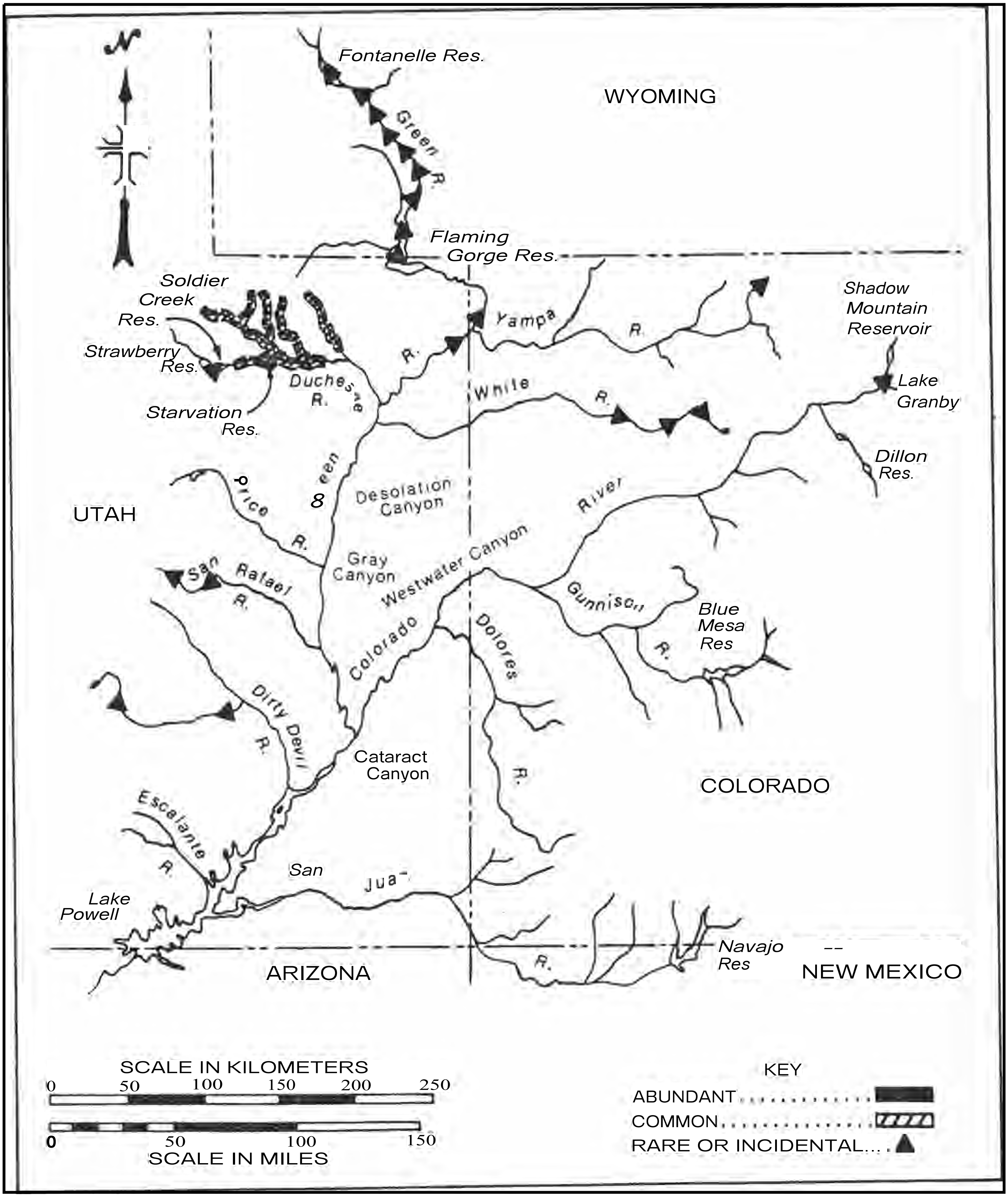

Figure 29. Distribution and relative abundance of mountain sucker, *Catostomus platyrhynchus*, in the Upper Colorado Basin.

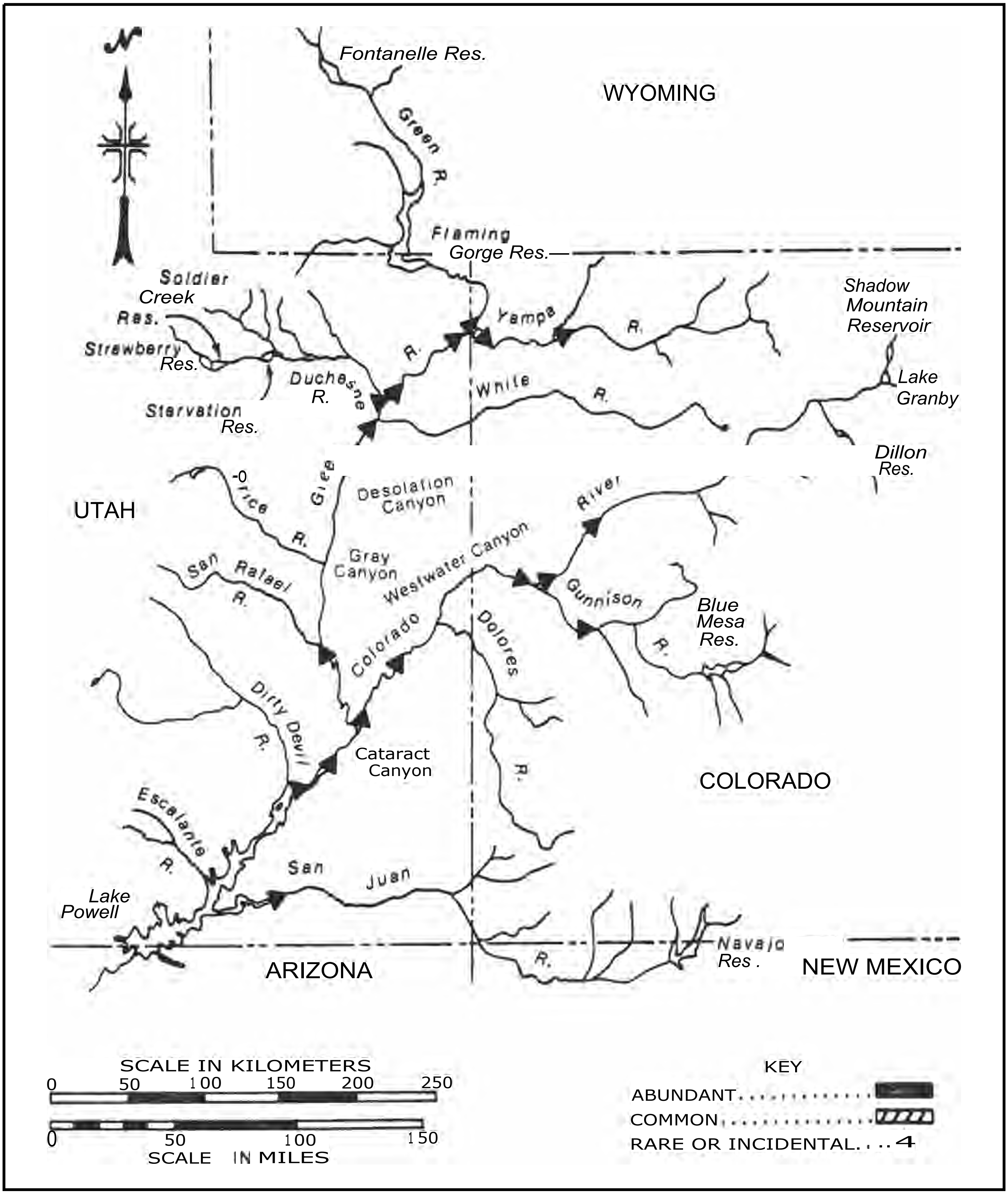

Figure 30. Distribution and relative abundance of razorback sucker, *Xyrauchen texanus*, in the Upper Colorado Basin.

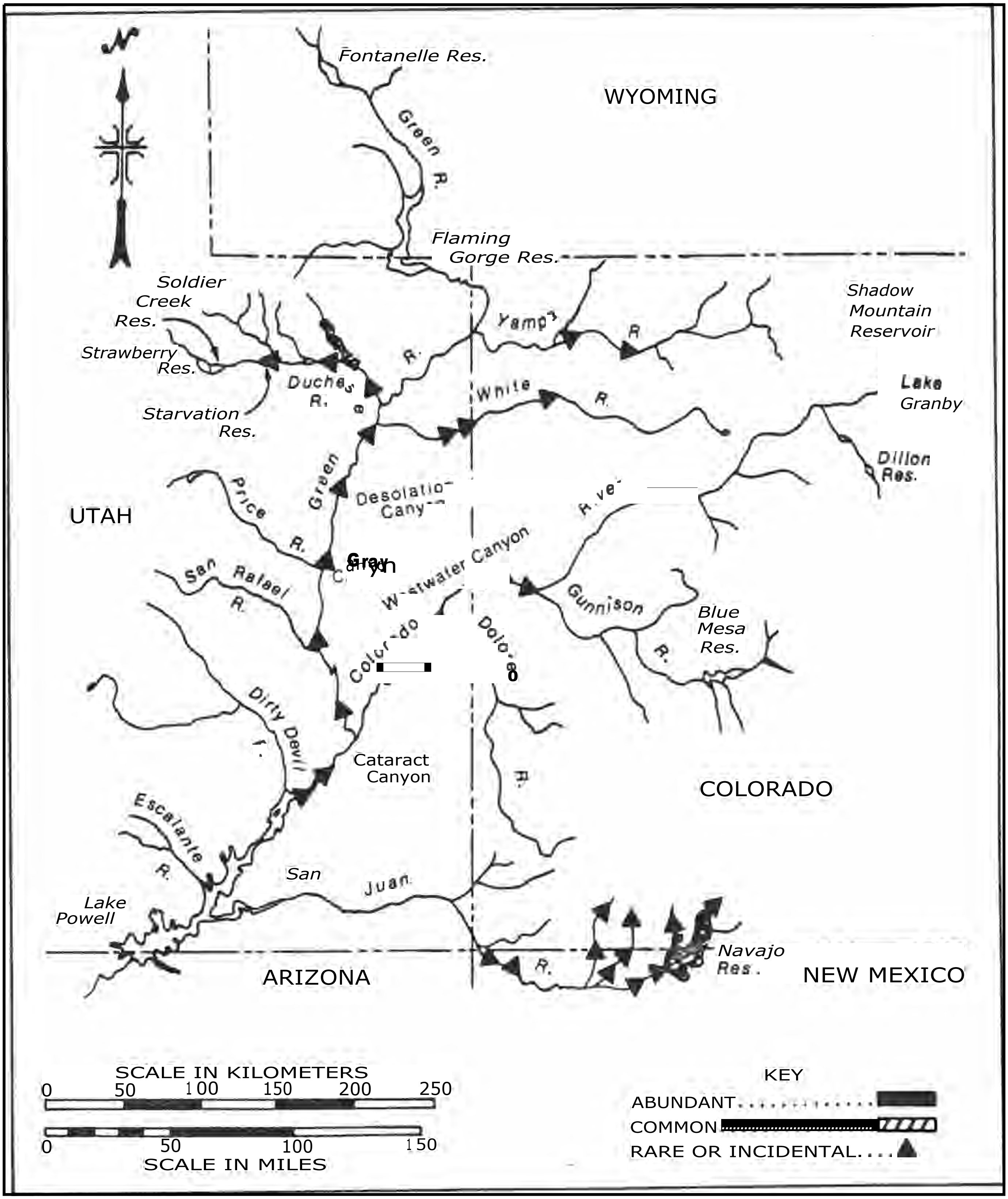

Figure 31. Distribution and relative abundance of black bullhead, *Ictalurus melas*, in the Upper Colorado Basin.

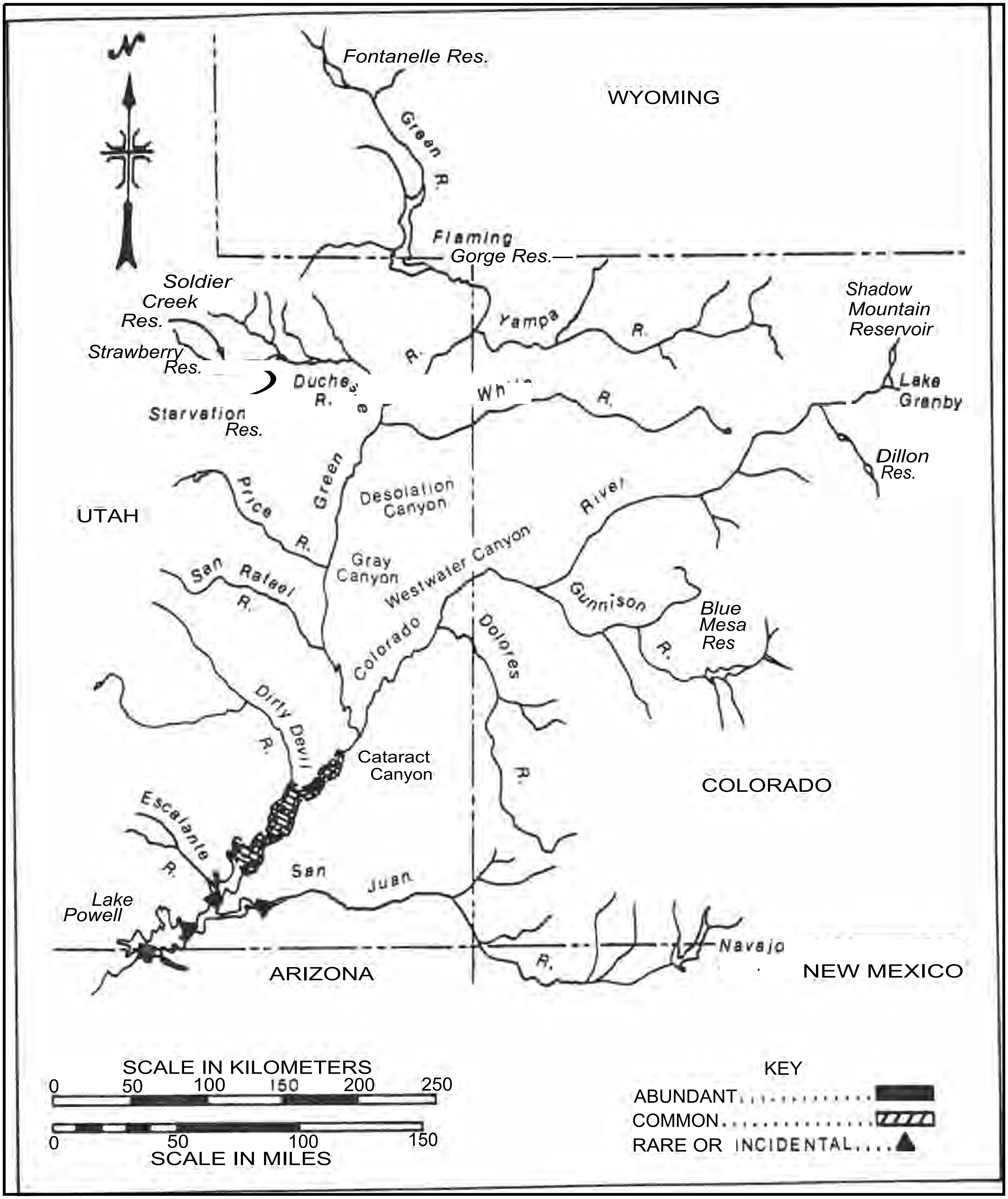

Figure 32. Distribution ond relative abundance of yellow bullhead, *Ictolurus nafalis*, in the Upper Colorado Basin.

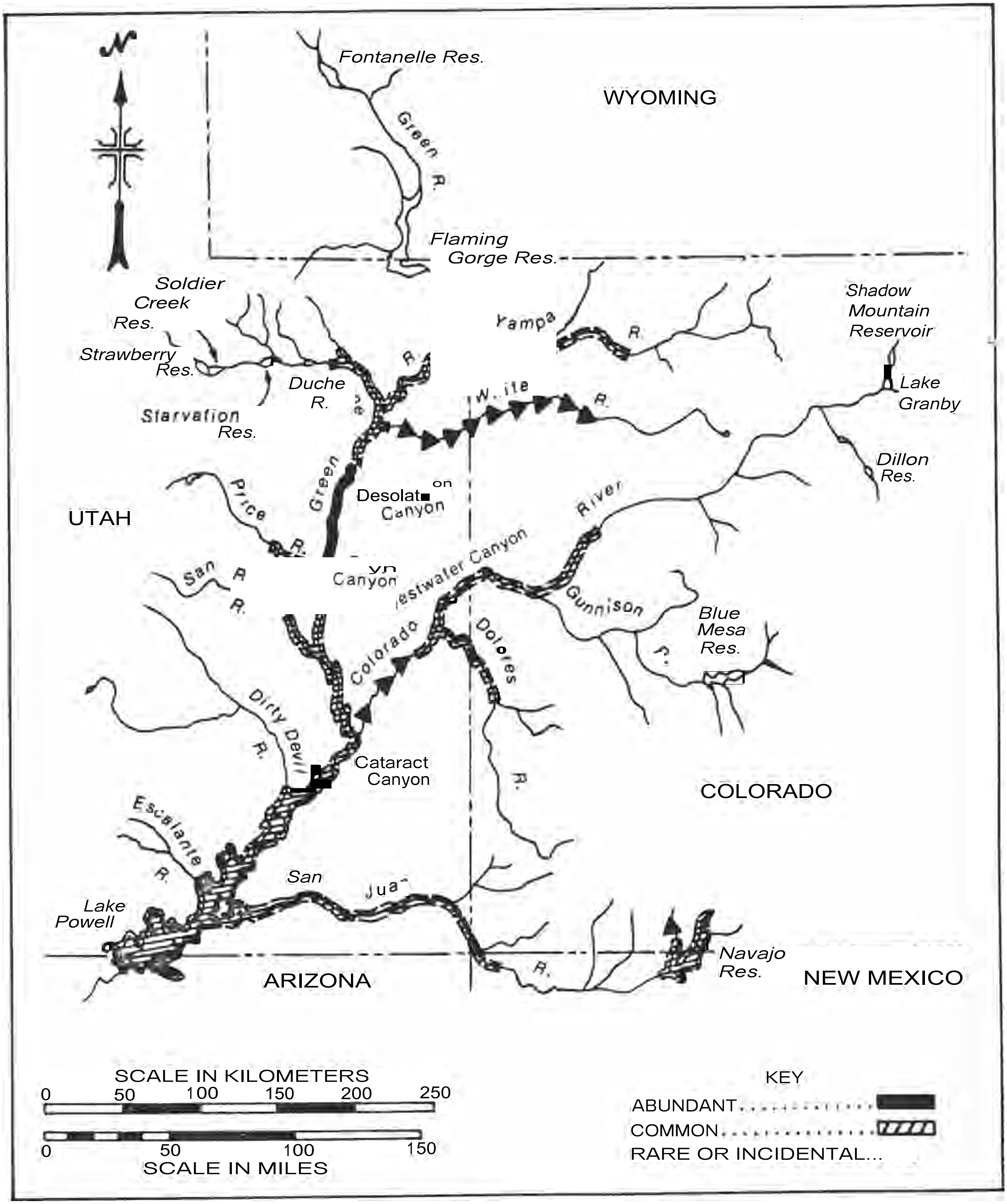

Figure 33. Distribution and relative abundance of channel catfish, *Ictalurus punctatus*, in the Upper Colorado Basin.

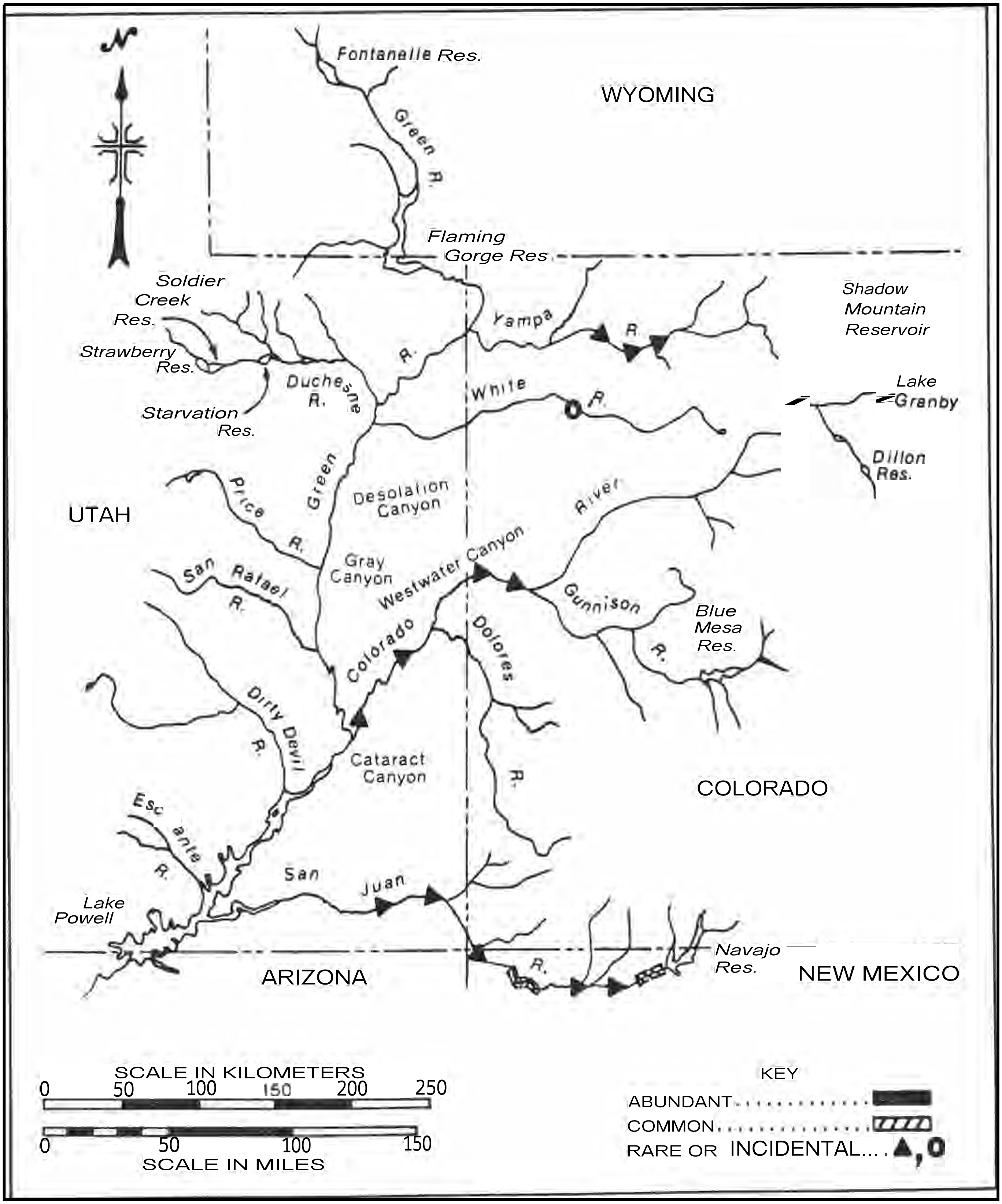

Figure 34. Distribution and relative abundance of Rio Grande killifish, *Fundulus zebrinus* (▲), and plains topminnow, *Fundulus sciadicus* (O), in the Upper Colorado Basin. Common occurrence refers to the Rio Grande killifish.

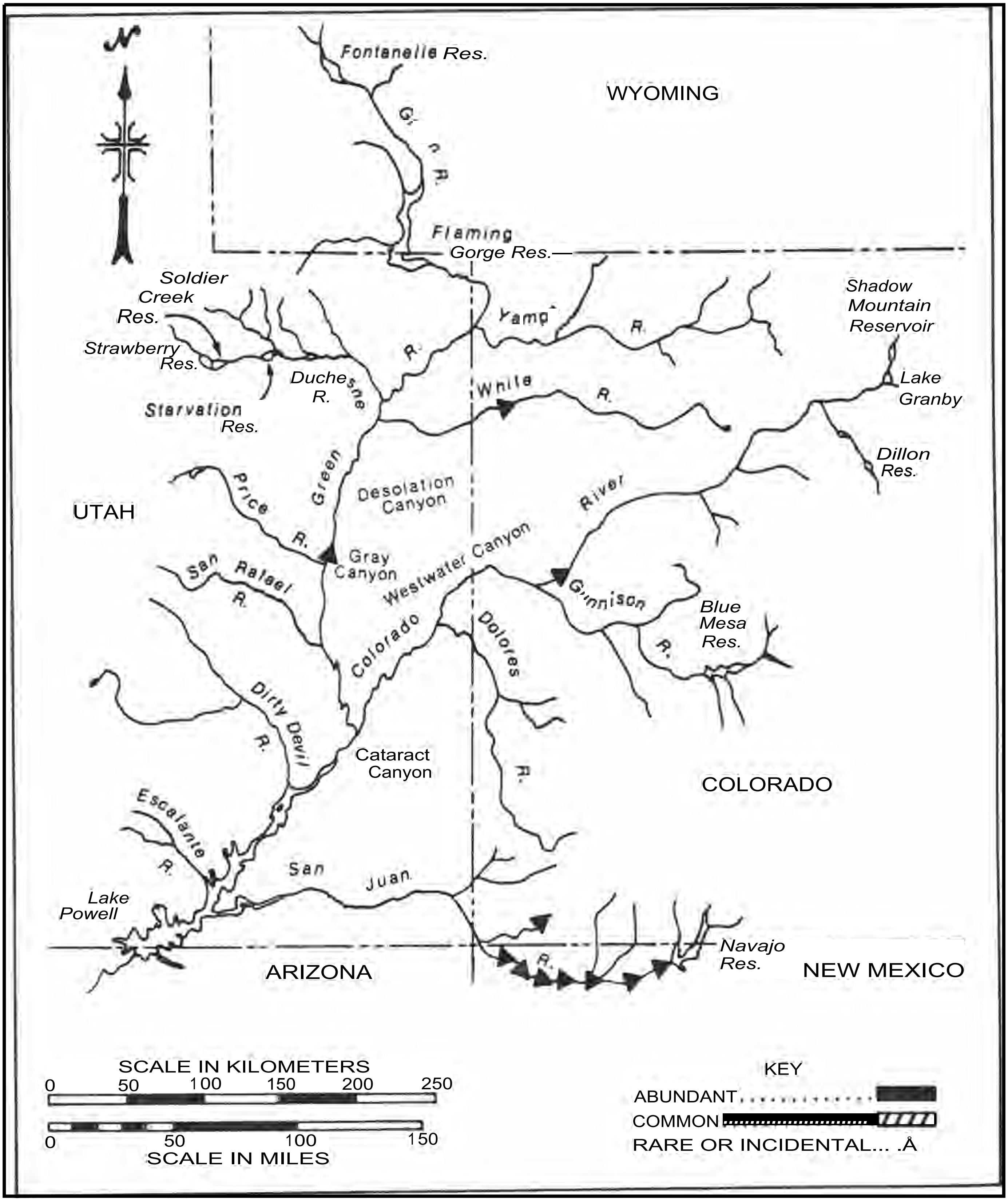

Figure 35. Distribution and relative abundance of mosquitofish, *Gambusia* offinis, in the Upper Colorado Basin.

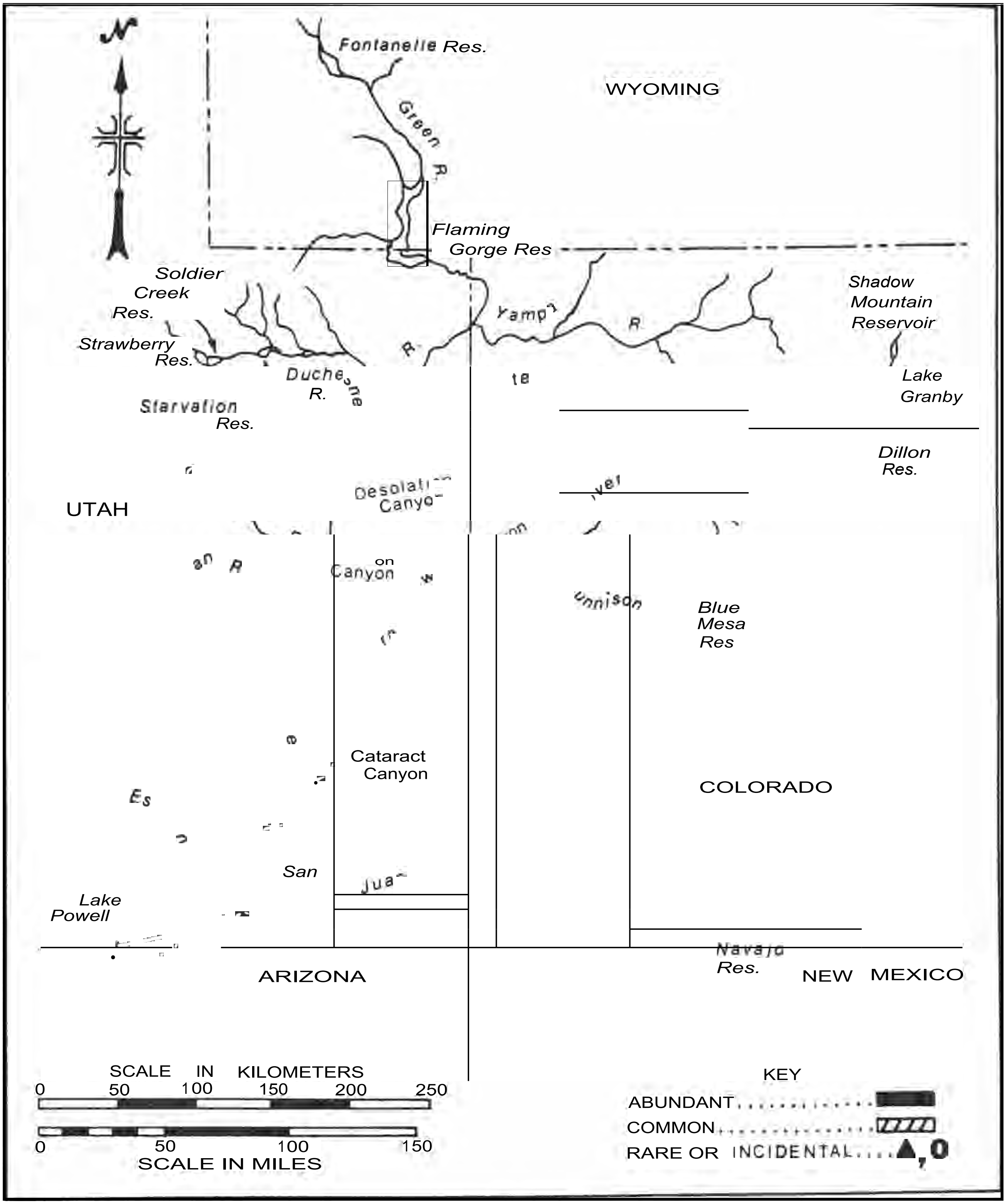

Figure 36. Distribution and relative abundance of white boss, Morone chrssops (0), and striped boss, Morone *saxatilis*, in the Upper Colorado Basin. Common occurrence refers to striped bass.

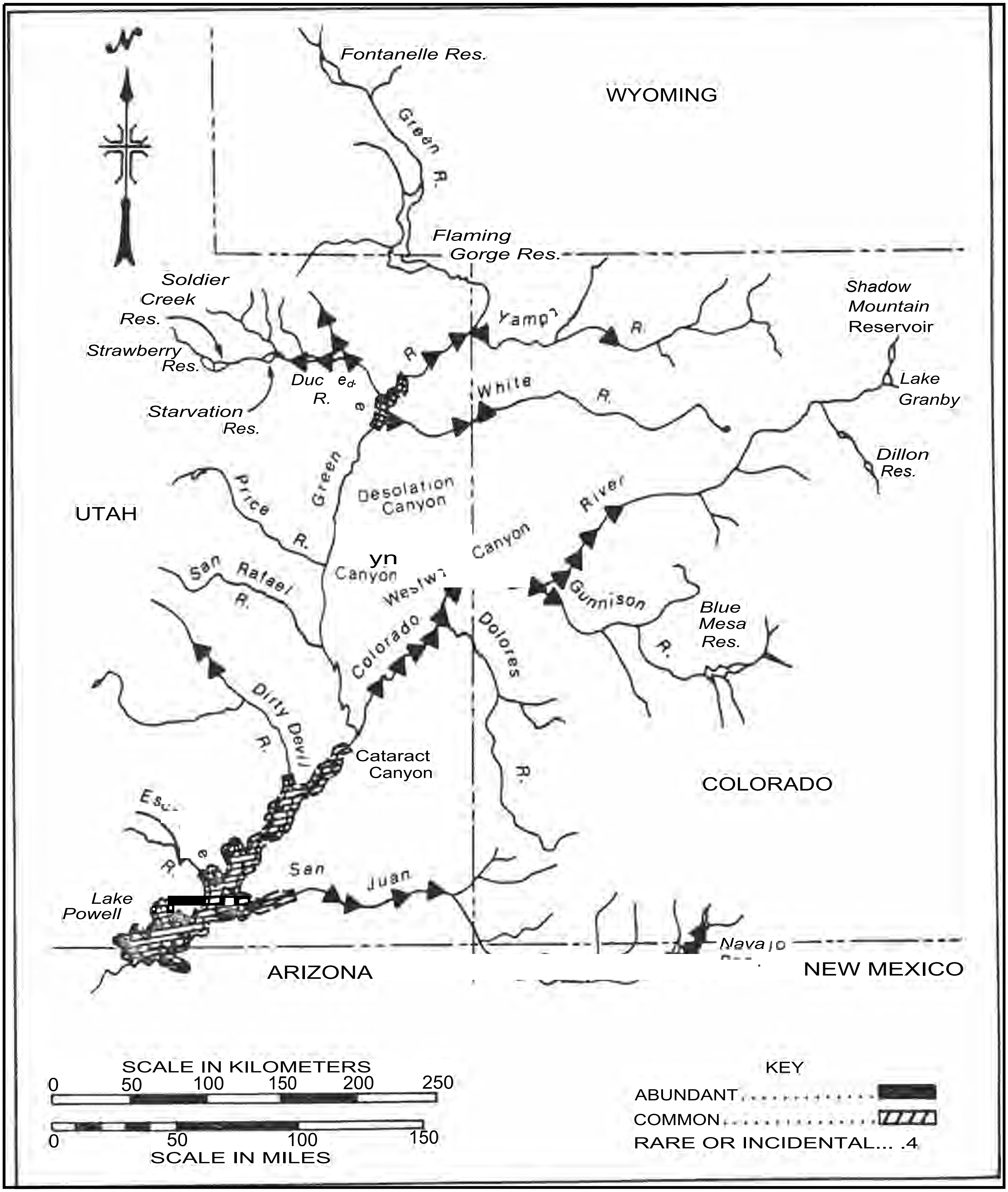

Figure 37. Distribution and relative abundance of green sunfish, *Lepomis cyanellus*, in the Upper Colorado Basin.

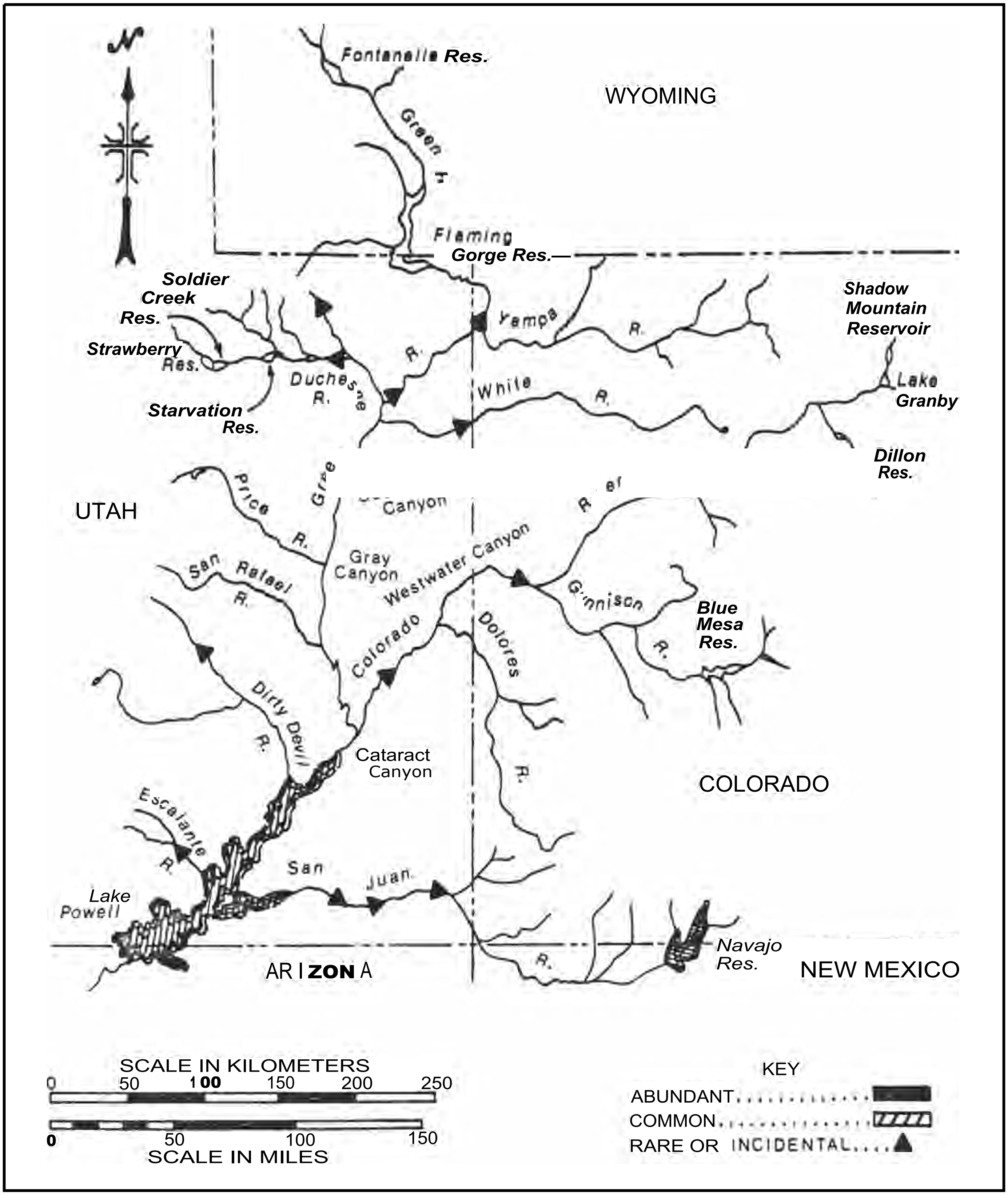

Figure 38. Distribution and relative abundance of bluegill, Lepomis macrochirus, in the Upper Colorado Basin.

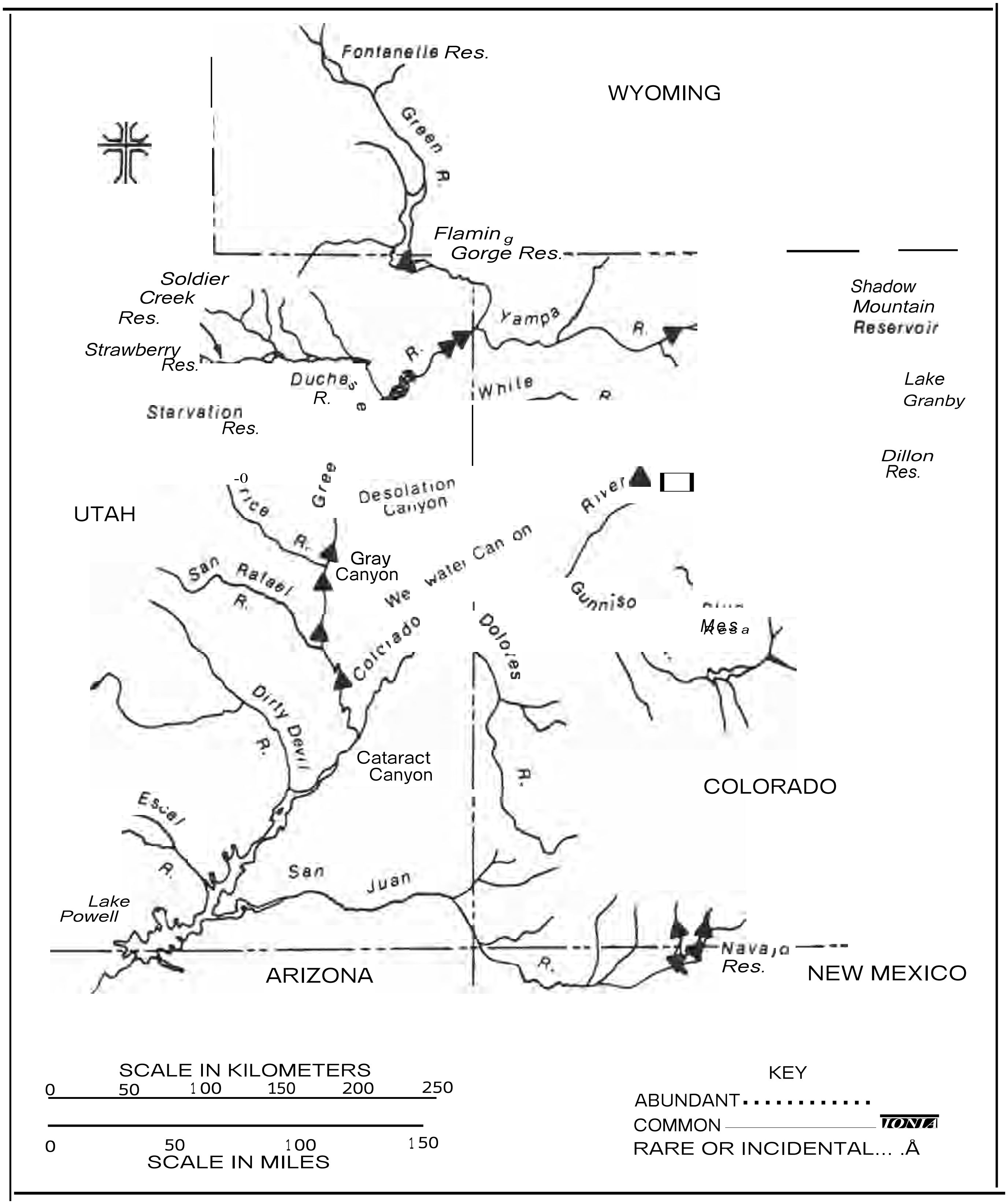

Figure 39. Distribution and relative abundance of smollmouth boss, Micropterus dolomieui, in the Upper Colorado Basin.

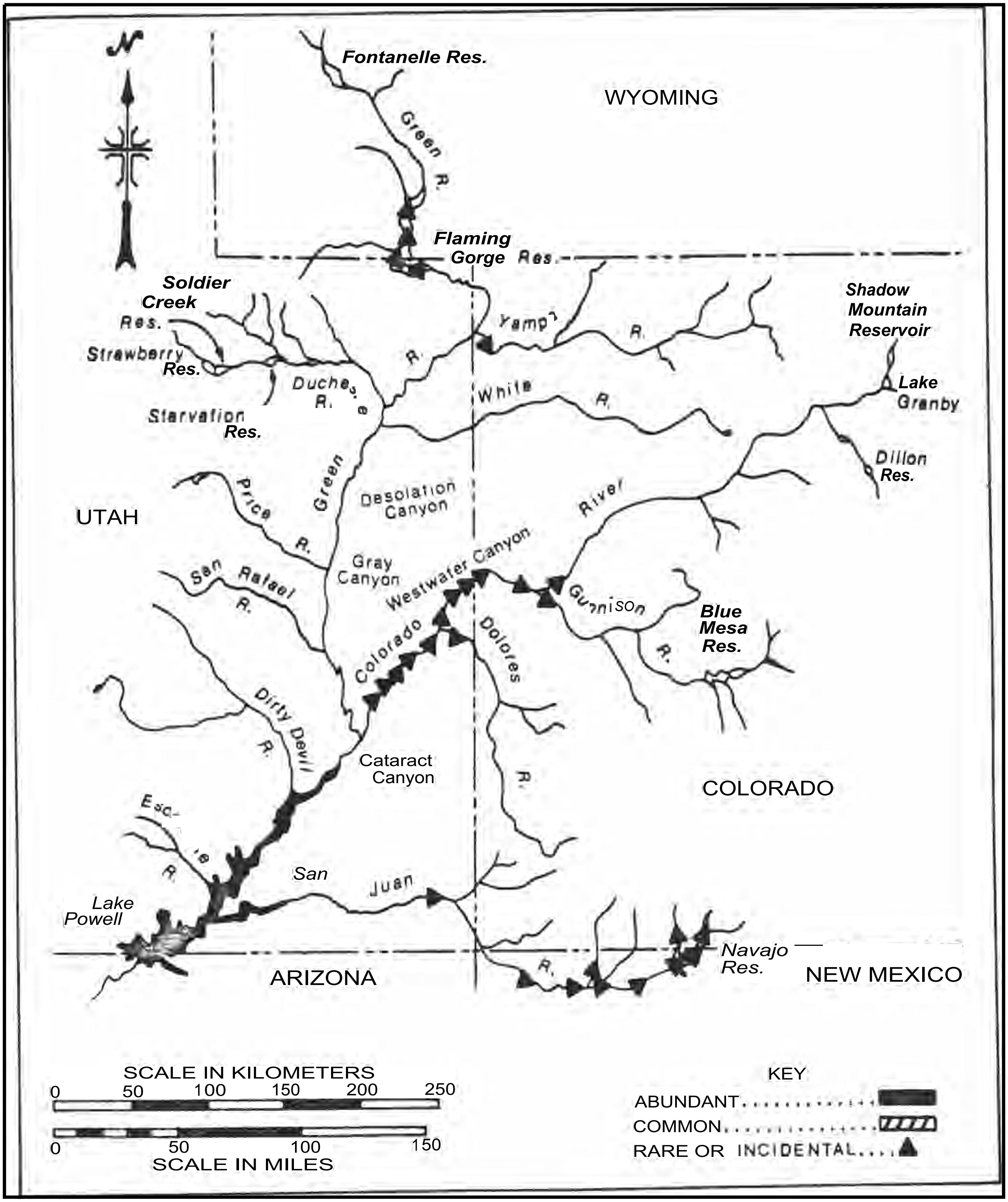

Figure 40. Distribution and relative abundance of largemouth bass, Micropterus solmoides, in the Upper Colorado Basin.

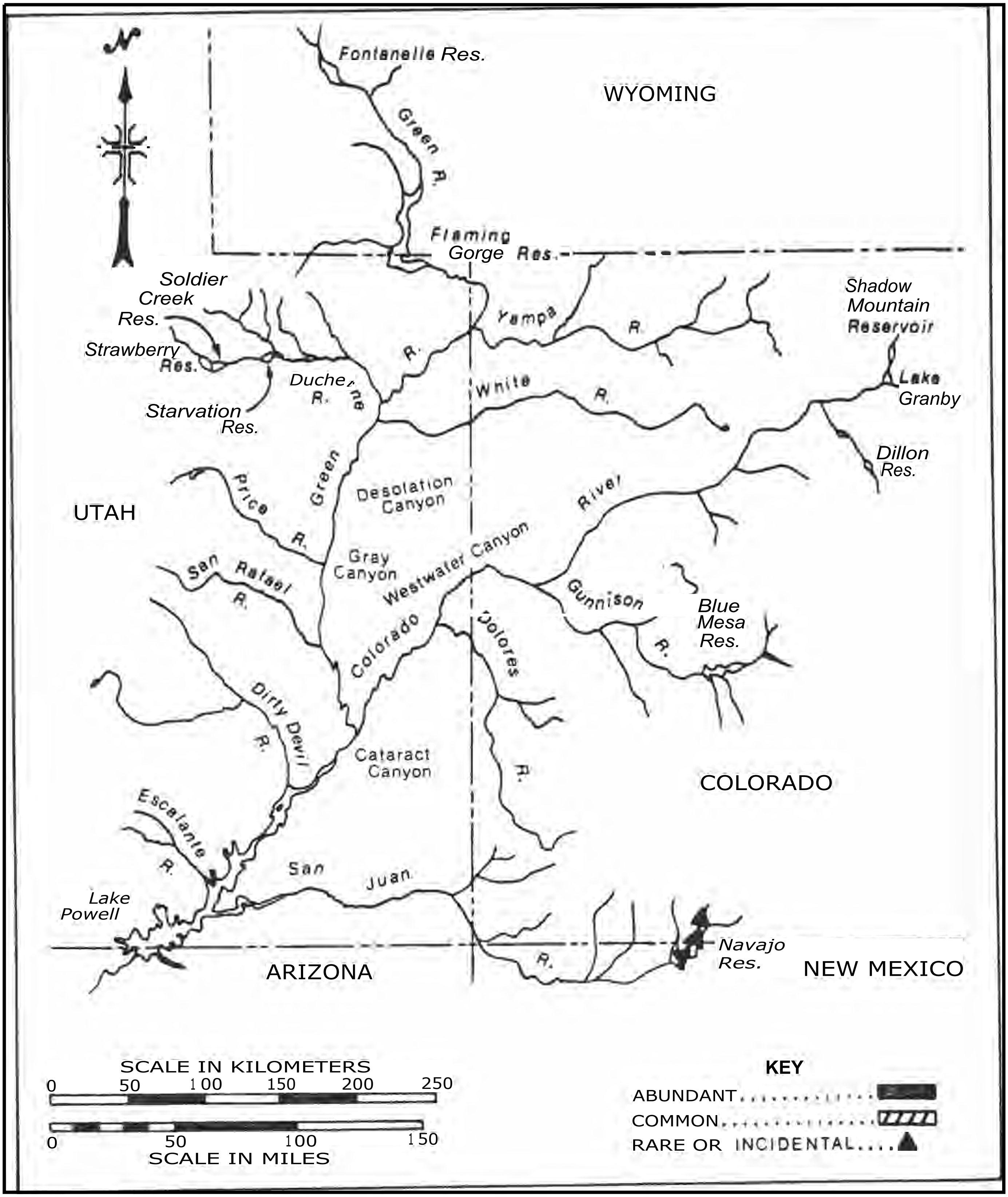

Figure 41. Distribution and relative abundance of white crappie, *Pomoxis annularis*, in the Upper Colorado Basin.

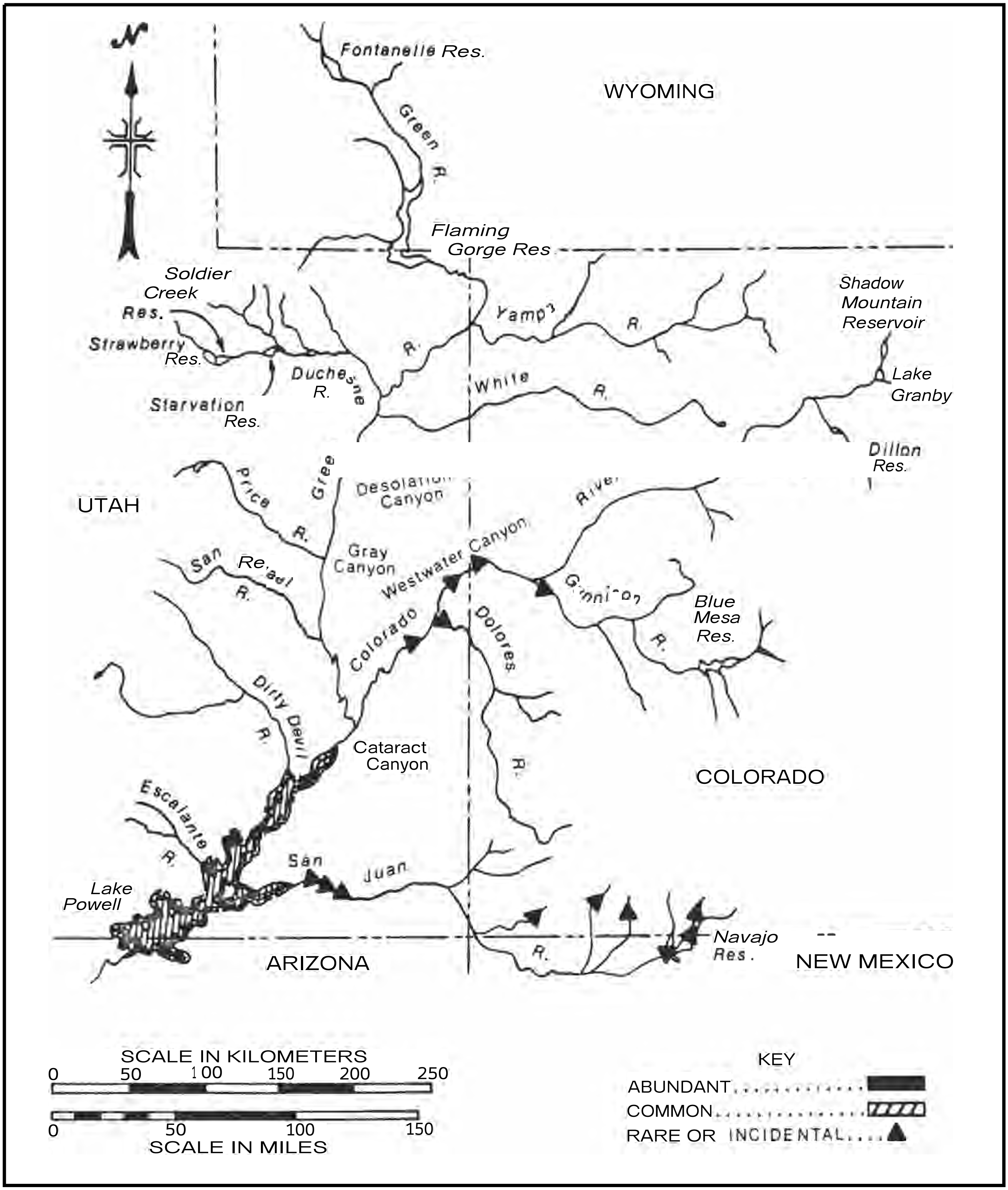

Figure 42. Distribution and relative abundance of black crappie, *Pomoxis nigromaculatus*, in the Upper Colorado Basin.

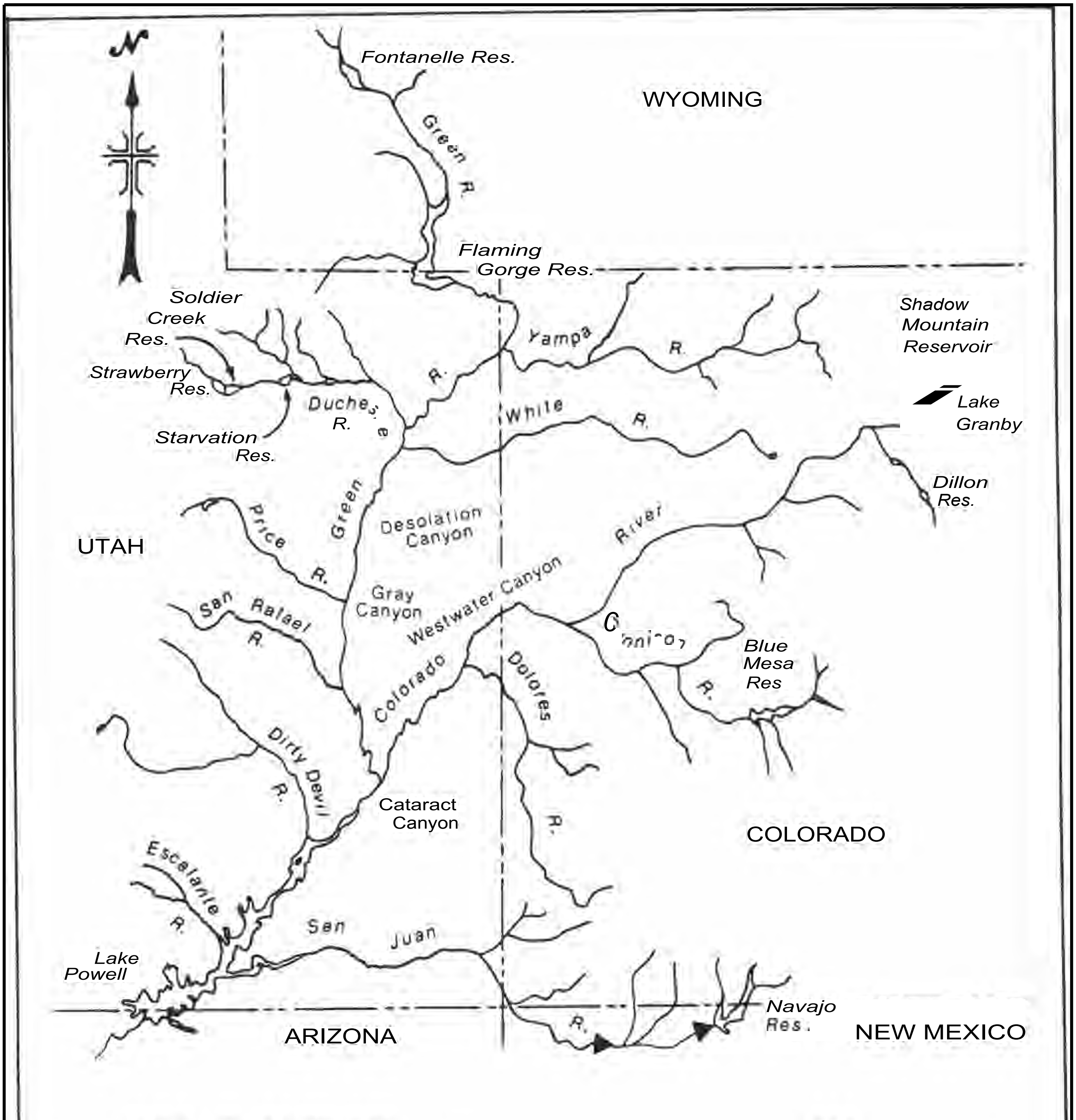

Figure 43 Distribution and relative abundance of Iowa darter, Etheostomo *exile* (▲), and johnny darter, *Etheostoma* nigrum (0), in the Upper Colorado Basin.

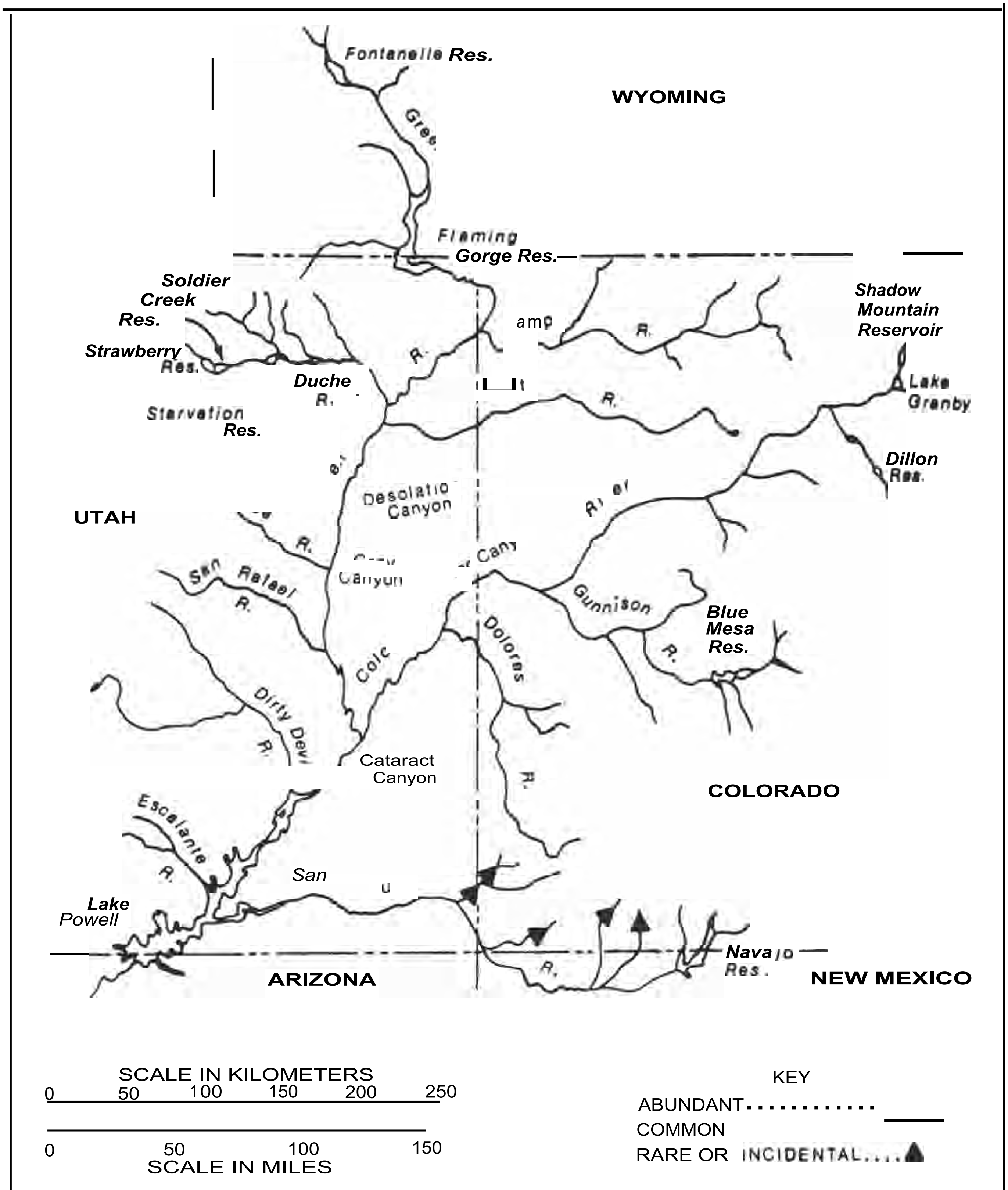

Figure 44. Distribution and relative abundance of yellow perch, *Perca flavescens*, in the Upper Colorado Basin.

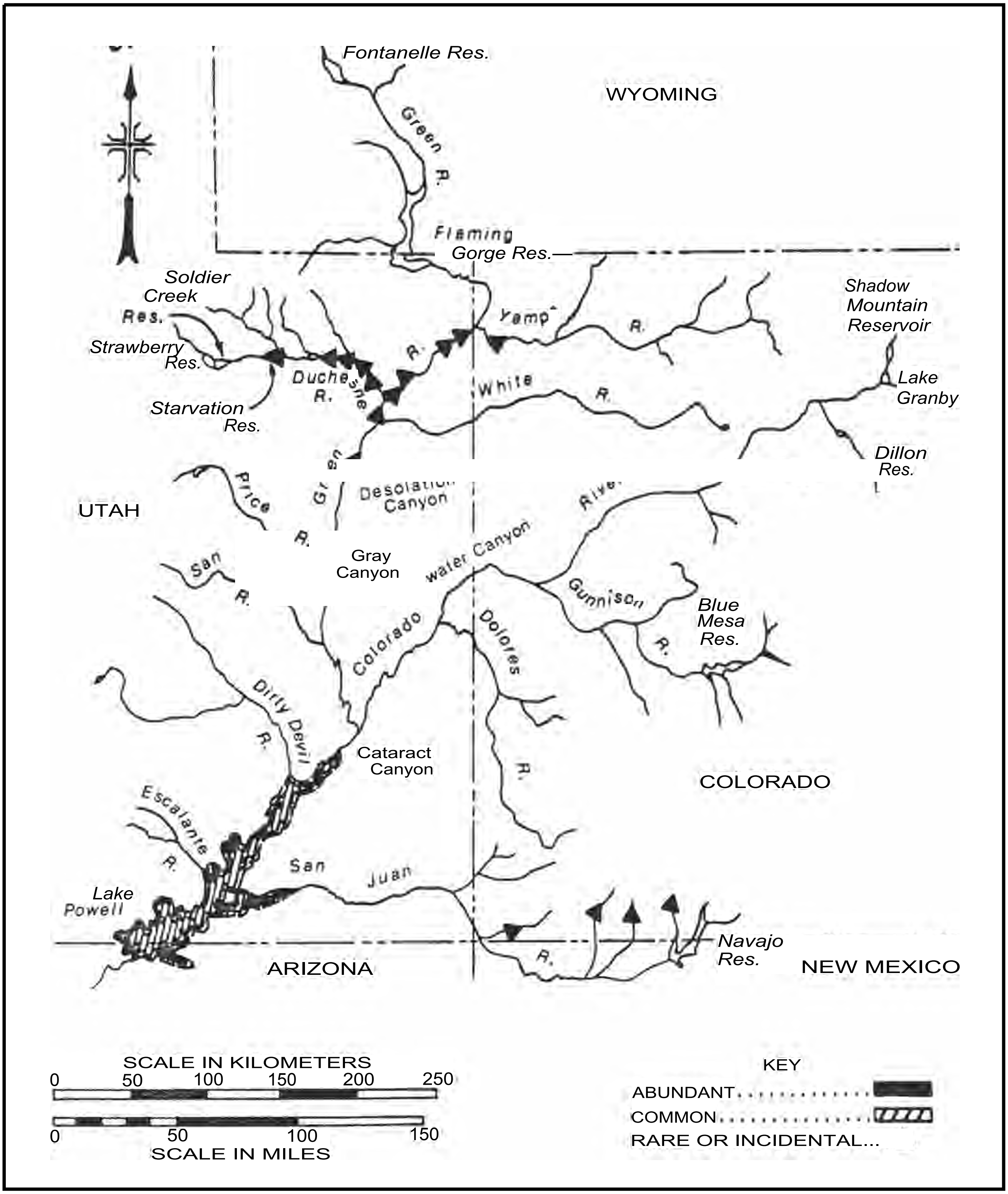

Figure 45 Distribution and relative abundance of walleye, Stizostedion vitreum, in the Upper Colorado Basin.

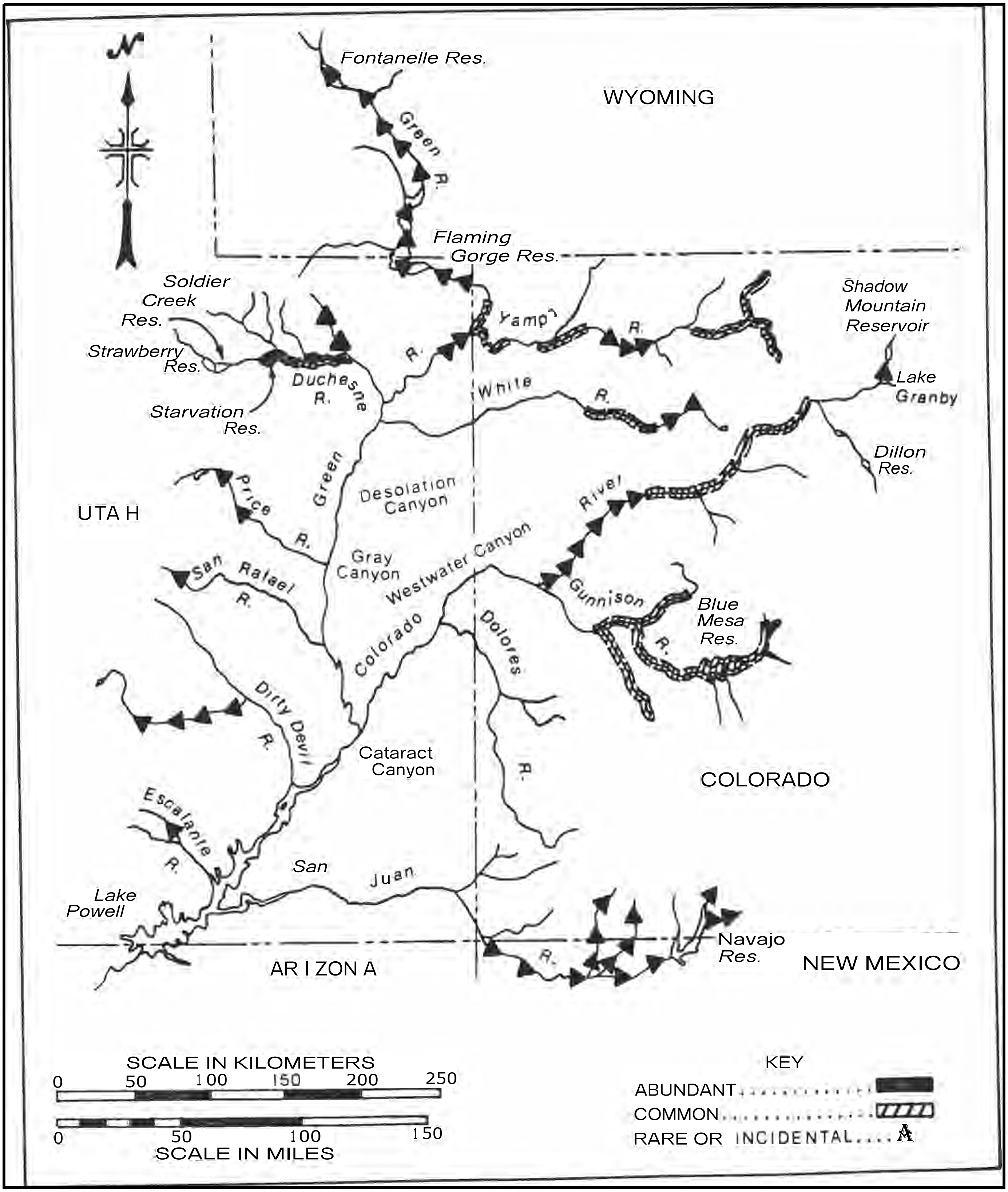

Figure 46. Distribution and relative abundance of mottled sculpin, Cottus *bairdi*, in the Upper Colorado Basin.

TABLE 5. Status and habitat preference of fishes in the Upper Colorado River Basin and species associations of native fishes

Family and species	Status	Preferred habitat	Associated species
Clupeidae			
Dorosoma petenense	EX	Pelagic zones of reservoirs	
Salmonidae			
Oncorhynchus kisutch	EX	Pelagic zones of reservoirs	
Oncorhynchus nerka	EX	Pelagic zones of reservoirs	
Prosopium williamsoni	NA	Swift deep runs over gravel/rubble substrate	S. clarki, S. gairdneri, R. osculus, C. bairdi, C. platyrhynchus
Salmo clarki	EX	Gravel, bedrock, deep mountain lakes and mountain streams	
Salmo clarki Teuriticus	EN, %A, TH	Cold, clear headwater streams and lakes	P. williamsoni, S. clarki, S. gairdneri, S. fontinalis, C. bairdi, C. platyrhynchus
Salmo clarki stomias	EX, TH	Cold, clear headwater streams	P. williamsoni, S. clarki, S. gairdneri, S. fontinalis, C. bairdi, C. platyrhynchus
Salmo gairdneri	EX	Pools, eddies, runs, riffles of mountain streams and lakes with gravel/cobble substrates	
Salmo trutta	EX	Deep pools, riffles, runs over sand/cobble substrate w/moderate to fast current	
Salvelinus fontinalis	EX	Clear headwater ponds and spring-fed streams w/gravel substrate	
Salvelinus namaycush	EX	Cold water in deep reservoirs	
Esocidae			
Esox lucius	EX	Pools in dam tailraces, riverine pools and inundated gravel pits over silt/gravel, rubble/sand substrate; shallow vegetated areas of lakes	
Cyprinidae			
Cyprinus carpio	EX	Runs, eddies, gravel pits and backwaters in moderate to deep water of low velocity w/silt/sand/boulder substrate; irrigation flow returns	
Gila at ia	EX	Littoral and pelagic zones of reservoirs	
Gila co	EX	Cool to cold creeks and rivers in pools or riffles of moderate current	
Gila cypha	EN, NA, ED	Eddy/run interfaces in deep, swift canyon areas w/steep indented walls; boulder/rubble substrate	G. robusta, P. lucius, C. discobolus, C. latipinnis, I. punctatus
Gila elegans	EN, NA, ED	Eddy/runs in swift canyon areas w/steep walls; boulder/rubble substrate	G. cypha, G. robusta, P. lucius, C. discobolus, C. latipinnis, I. punctatus
Gila robusta	EN, NA	Large river channels in association with boulders or overhanging cliffs; riffles, shallow runs, eddy/run interfaces	G. cypha, P. lucius, N. lutrensis, N. stramineus, P. promelas, C. discobolus, C. latipinnis, I. punctatus
Cyprinidae			
Hybognathus hankinsoni	EX	Small, sluggish, weedy creeks or streams with sand, gravel or mud bottom overlain by organic sediment	
Hybognathus placitus	EX	Open, shallow river channels w/sand bottom	
Notropis lutrensis	EX	Backwaters, side channels, inundated gravel pits w/silt/sand/gravel substrates; shorelines with emergent vegetation	
Notropis stramineus	EX	Shallow runs and backwaters w/silt/sand substrate	
Pimephales promelas	EX	Backwaters and pools w/ silt/sand substrate	

ED=endangered; EN=endemic; EX=exotic; NA= native; TH= threatened.

TABLE 5 (continued)

Family and species	Status[a]	Preferred habitat	Associated species
Ptychocheilus lucius	EN, NA, ED	Adults: deep runs, eddies and large backwaters w/silt/boulder substrate. Juvenile and YOY: backwaters w/silt/sand substrate	C. carpio, G. cypha, G. robusta, N. stramineus, P. promelas, C. discobolus, C. latipinnis, X. texanus, I. punctatus
Rhinichthys cataractae	EX	Swift streams; stream riffles and reservoir littoral zones	
Rhinichthys osculus	NA	Shallow, swift runs and riffles w/gravel substrate	P. williamsoni, S. gairdneri, S. clarki, G. robusta, C. discobolus, C. bairdi, C. platyrhynchus
Rhinichthys osculus thermalis	EN, NA, ED	Only in Kendall Warm Springs; mainstream eddies and pools w/pockets of aquatic vegetation	
Richardsonius balteatus	EX	Backwaters and pools w/slow current; reservoir littoral zones	
Semotilus atromaculatus	EX	Riffles, runs, pools w/rubble/cobble substrate	
Catostomidae			
Catostomus ardens	EX	Reservoirs, streams w/slow to rapid current	
Catostoffus catostomus	EX	Clear, cold waters of reservoirs	
Catostomus commersoni	EX	Deep riffles and runs over gravel/cobble substrate	
Catostomus discobolus	NA	Deep riffles and shallow runs over gravel/cobble substrate	G. robusta, R. osculus, C. latipinnis
Catosto latipinnis	EN, NA	Runs, shorelines, eddies of mainstream rivers	G. robusta, N. lutrensis, P. promelas, C. discobolus
Catostomus platyrhynchus	NA	Cool, clear streams w/gravel/cobble substrate	P. williamsoni, C. bairdi, S. clarki, S. gairdneri, R. osculus
Xyrauchen texanus	EN, NA, ED	Backwater, quiet eddies and deep runs of large river channels	C. carpio, N. lutrensis, T. promelas, P. lucius, C. latipinnis
Ictaluridae			
Ictaluras melas	EX	Backwaters, inundated gravel pits w/silt/gravel substrates	
Ictaluras natalis	EX	Clear water of slower streams, ponds and lakes w/ abundant vegetation	
Ictaluridae			
Ictaluras punctatus	EX	Deep pools, eddies, shorelines and runs over silt/gravel/boulder substrate; backwaters w/silt/sand substrate	
Cyprinodontidae			
Fundulus sciadicus	EX	Small to medium-sized clear, sandy/rocky streams w/moderate to rapid current; quiet pools and backwaters	
Fundulus zebrinus	EX	Shallow backwaters w/silt/sand substrate	
Poeciliidae			
Gambusia affinis	EX	Vegetated ponds, drainage ditches and backwaters and oxbows w/little or no current	
Percichthyidae			
Morone chrysops	EX	Clear lakes and streams	
Morone saxatilis	EX	Estuaries; large rivers; reservoir zones (landlocked race developed)	

[a] ED=endangered; EN=endemic; EX=exotic; NA= native; TH=threatened.

TABLE 5 (concluded)

Family and species	Status[a]	Preferred habitat	Associated species
Centrarchidae			
Lepomis cyanellus	EX	Slow-moving streams; weed beds of warm-water lakes and reservoirs	
Lepomis macrochirus	EX	Shallow warm lakes, ponds and slow-flowing streams .'/abundant aquatic vegetation	
Micropterus dolomieui	EX	Clear, fast-flowing streams and flowing pools w/gravel/rubble substrate	
Micropterus salmoides	EX	Clear, quiet waters w/aquatic macrophytes; reservoir littoral zones	
Pomoxis annularis	EX	Streams, lakes, ponds, slow-moving areas of large rivers	
Pomoxis nigromaculatus	EX	Clear, deep, cool waters of lakes, reservoirs w/abundant aquatic vegetation	
Percidae			
Etheostoma exile	EX	Clear, cool lakes and slow-moving rivers w/submerged aquatic vegetation and substrate of sand, peat, and/or organic debris	
Etheostoma nigrum	EX	Moderate to quiet streams w/sand/gravel and sand/silt substrate; vegetated areas and riffles	
Perca flavescens	EX	Clear, open water with moderate aquatic vegetation	
Stizostedion vitreum	EX	Large streams, rivers and lakes in moderately deep water	
Cottidae			
Cottus bairdi	NA	Riffles and deep runs w/gravel/rubble/boulder substrate	P. williamsoni, S. clarki, S. gairdneri, S. fontinalis, R. osculus, C. beldingi, C. platyrhynchus

[a] ED=endangered; EN=endemic; EX=exotic; NA=native; TH=threatened.

TABLE 6. Hybrid fishes of the Upper Colorado River Basin

Family and species
Salmonidae
Salmo gairdneri x Salmo clarki
Salvelinus fontinalis x Salvelinus namaycush
Cyprinidae
Rhinichthys osculus x Richardsonius balteatus
Gila cypha x Gila robusta
Gila robusta x Gila elegans
Gila elegans x Gila cypha
Catostomidae
Catostomus latipinnis x Xyrauchen texanus
Catostomus discobolus x Catostomus commersoni
Catostomus latipinnis x Catostomus commersoni
Catostomus discobolus x Catostomus latipinnis

Only three exotic fishes *(C. carpio, N. lutrensis,* and *I. punctatus)* (Figs. 12, 18, 33) were classified as abundant in the Upper Colorado River Basin, and four exotics *(N. stramineus,* ***P.*** *promelas,* ***R.*** *balteatus,* and *C. commersoni)* (Figs. 19, 20, 23, 26-A) were classified as common in more than one tributary. It is interesting that no advanced teleost is found in either classification.

Of the remaining exotic fishes (26), three were restricted to reservoirs (Figs. 3, 32, 43-0). The remainder were classified as rare or incidental even though one exotic fish *(S. clarki stomias) is* classified as a threatened subspecies in another basin, and some were locally common in small sections (Figs. 13-0, 24-0, 25, 31, 34-A, 39). A total of 11 exotic fishes were classified as incidental in riverine habitat. The remaining 12 exotics were classified as rare.

Native Fishes

Three native fishes *(G. robusta,* ***R. osculus,*** and *C. latipinnis)* (Figs. 16, 22, 28) were classified as abundant in some major tributaries. Common native fishes included *P. williamsoni*, *C. discobolus,* and C. *bairdi.* (Figs. 5, 27, 46). Three native fishes classified as rare [*R. osculus thermalis, S. clarki pleuriticus (Fig.* 7-A) and C. *platyrhynchus* (Fig. 29)] were restricted to headwaters.

The remaining four native fishes classified as rare include threatened and endangered species found primarily in main channels of the major rivers. These fishes have significant differences in distribution; *P. lucius* (Fig. 21) has widespread distribution and *G. elegans* (Fig. 15) is greatly restricted. *G. cypha* and *X. texanus* have sporadic distribution patterns (Figs. 14, 30).

Threatened and Endangered Fishes

Recent changes have occurred in the classification of threatened and endangered fishes of the Upper Colorado River Basin. The U.S. Fish and Wildlife Service (1980a) recently classified the bonytail chub and the Kendall Warm Springs dace as endangered. Although the razorback sucker was proposed for listing as threatened by the Service in 1980, that designation has been withdrawn because of difficulty in identifying critical habitat and performing economic analyses (U.S. Fish and Wildlife Service 1980b). The State of Colorado (1980) lists the Colorado River cutthroat trout as threatened and the razorback sucker as endangered.

Remnant populations of four threatened and endangered endemic fishes are still found in the mainstem rivers of the Upper Colorado River Basin (bonytail chub, humpback chub, Colorado squawfish, and razorback sucker). In addition, two other native fishes also exist in the upper zone (headwaters) — the endangered Kendall Warm Springs dace (a subspecies of the speckled dace) and the threatened Colorado River cutthroat trout (a subspecies of the cutthroat trout). The Kendall Warm Springs dace exists only in a few meters of a small tributary to the Green River (Binns 1978). Colorado River cutthroat trout are restricted to small headwater streams of the Fryingpan River and Parachute Creek, Colorado, and in Trappers Lake, Colorado, from whence it has been stocked into other high-mountain lakes and headwater streams (Behnke and Benson 1980).

The greenback cutthroat trout, *S. clarki stomias, a* native of the Platte and Arkansas rivers, was introduced into Florence Creek (a small tributary of the Green River) in 1967. A few fish were recovered in 1969, but there was no evidence of reproduction. No reports of them have been subsequently received (R.J. Behnke, Colorado State University, Fort Collins, Colorado, 1981 pers. comm.). The greenback cutthroat is mentioned for completeness of record since it is classified as threatened in the Arkansas and Platte river basins. It is classified as exotic to the Upper Colorado River Basin.

Colorado squawfish

Historic distribution of this endangered fish has been reduced (Behnke and Benson 1980), and it is now restricted to the Upper Colorado River Basin (Fig. 21).

Recent studies by the U.S. Fish and Wildlife Service indicate that the Colorado squawfish requires a wide distribution to satisfy life-history requirements. Sexually mature and immature Colorado squawfish exhibited different movement patterns (Tyus *et al.* 1981), and long-distance spawning migrations are made to areas of suitable habitat (Tyus *et al.* 1982b). The distribution and abundance of young (30-70 mm) Colorado squawfish differed from that of adults in the Green River and Upper Colorado River (Tyus *et al.* 1982a; Valdez *et al.* 1982).

Point collections of several Colorado squawfish in one location are often misinterpreted to indicate they are common. Data on abundance should be interpreted only where adequate catch and effort information is available and can be related to similar studies throughout the occupied range of the fish. Colorado squawfish are not distributed homogeneously throughout their range.

The Colorado River Fishes Recovery Team (1981a) recommended stocking Colorado squawfish as a means of improving its status from endangered to threatened. Unfortunately, habitat suitable for all life-history requirements that is not already occupied probably does not exist. With the imminent threat of further water development, it is doubtful that its status will change.

Humpback chub

Distribution of the humpback chub has changed in the last few years (Fig. 14). In over 2 years of intensive sampling by the U.S. Fish and Wildlife Service, few humpback chub have been identified in the Green River above Desolation Canyon, and only two were taken from the Yampa River (Miller *et al.* 1982). Only one humpback chub has been reported from Lake Powell since its closure (W. Gustaveson, Utah Division of Wildlife Resources, Page, Arizona, 1981 pers. comm.), and cold tailwaters below the dam have restricted its downstream distribution (Kaeding and Zimmerman 1982).

New concentrations of humpback chub have been discovered recently in Westwater and Cataract canyons of the Colorado River (Valdez 1980). These concentrations are limited to canyon areas, and the distribution of humpback chub in the basin is sporadic (Colorado River Fishes Recovery Team 1981b).

Holden (1978) reported the humpback chub as: "...'Common' in the Green River from Sand Wash to the town of Green River, Utah." Sampling during 1979, 1980, and 1981, indicates a significant decline in the abundance of *Gila* species in this area, since very few humpback chub have been collected (Tyus *et* aL 1982a).

The humpback chub was listed as endangered by the U.S. Fish and Wildlife Service in 1973. Unless other populations become established elsewhere in the drainage, its status will not change.

Bonytail chub

Historic records indicate the bonytail chub was formerly abundant in main river channels (Jordan and Evermann 1896). Vanicek (1967) found them more abundant than roundtail chub in the Green River. Today, only a few old individuals are found in Lakes Mohave and Havasu of the Lower Colorado River Basin, and only an occasional collection is made in the Upper Colorado River Basin. Its abundance has declined steadily until it is now the most rare endemic fish in the Upper Basin (Fig. 15). The only recent collections of adult bonytail chub from the Upper Basin were made by the U.S. Fish and Wildlife Service from one restricted location in Gray Canyon of the Green River (Tyus *et al.* 1982b). Holden (1978) also reported collecting one juvenile bonytail chub from that general location.

Although not listed as endangered by the U.S. Fish and Wildlife Service until 1980, the fish is so rare that the goal of the recently drafted Bonytail Chub Recovery Plan (Colorado River Fishes Recovery Team 1981c) is oriented toward preventing extinction rather than accomplishing recovery. There is no indication that its status is changing. If island biogeography theories that have been applied to Colorado River fishes are correct (Molles 1980), the rapid decline of the bonytail chub foretells extinction in the near future.

Razorback sucker

The razorback sucker has never been listed as threatened or endangered by the U.S. Fish and Wildlife Service (1980b), but it has twice been proposed for listing. It is currently designated endangered by the State of Colorado (1980).

Although once abundant and widely distributed (Seethaler et *al.* 1979), its riverine existence is primarily limited to the Upper Colorado River Basin, where it is found mainly in the mainstem of the upper Green and Colorado rivers. Although collectors have encountered probable spawning aggregations in recent years, young razorback suckers have seldom been found (McAda and Wydoski 1980; Valdez and Mangan 1980).

Adult razorback suckers are difficult to capture except during the spring spawning period. A radiotagged razorback could not be captured by investigators although its location was pinpointed in less than 1.5 m water (Tyus *et al.* 1981). This indicates the fish may be present in greater numbers than catch records indicate, but does not imply the fish is abundant. Their numbers are known to be decreasing (McAda and Wydoski 1980).

Several possible explanations for so few reports on young razorback suckers include (1) reproductive failure, (2) predation of eggs and young by exotic fishes, and (3) competition with exotic fishes for food and space (McAda and Wydoski 1980). The problem of unsuccessful recruitment, coupled with the adverse impact of further water-resource development, could force the razorback sucker further toward extinction.

Because of its apparent precarious existence, the razorback sucker should be listed as a threatened or endangered species by the U.S Fish and Wildlife Service. Its present status is probably declining, and it may become even more rare in future years.

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NEW IMPACTS BY MAN IN THE UPPER COLORADO RIVER BASIN

Robert D. Jacobsen

ABSTRACT

Increasing energy development and associated activities are causing widespread impacts to fish and wildlife in the Upper Colorado River Basin. Development of coal, oil shale, tar sands, other energy resources, non-energy minerals, water, and transportation is being related to important resource problem areas by the U.S. Fish and Wildlife Service. Fishery managers are challenged to help resolve the conflicts resulting from human activities. *(Editors' abstract)*

Those familiar with the Colorado River Basin are unquestionably aware of the many new impacts by man and some of those yet to come. It is also apparent that a majority of these impacts are taking place in the Upper Colorado River Basin. This paper deals with those impacts.

In discussing human impacts in the Upper Colorado River Basin, it is necessary to focus on human needs and to point out that these needs are not merely regional in scope. Foremost are the national goal of energy independency and our international commitment to Mexico of reducing the salinity of the Colorado River. Increased water supplies for municipalities, industry, and agriculture; non-energy mineral development; and development of other natural resources for timber production, livestock grazing, and recreational uses are other important factors of both national and regional concern. Human populations and population centers are growing, and environmental contamination of air, land, and water is increasing; they are and will continue to expand at exponential rates. Reduction and loss of fish and wildlife populations and their habitats, and resultant imbalanced ecosystems, are the focus of this paper.

RESOURCE DEVELOPMENT

The major factors causing impacts to fish and wildlife resources of the Upper Basin include energy-minerals development and conversion activities, mining of non-energy minerals, water and transportation development and secondary impacts created by the aforementioned. The U.S. Fish and Wildlife Service (FWS) is involved with these developments.

The states of the Upper Colorado River Basin appear to be the major focal points in the nation's goals to achieve energy interdependency because of their storehouse of energy reserves. Thus far, the availability of easily obtainable energy sources has forestalled development of Upper Basin resources. The time is now at hand when these resources are being developed. FWS has addressed development of energy resources and related it to Important Resource Problems (IRP's).

Coal

Coal reserves in the Upper Colorado River Basin states are well known (Fig. 1), particularly for their low sulphur content. These reserves are now being developed at an ever-increasing rate. This year the Bureau of Land Management (BLM) announced the leasing of 102,405 acres of coal lands in Colorado, Utah, and Wyoming; this will yield some 549.7 million tons of coal. Currently, Colorado and Utah have in operation approximately 34 surface or strip mines and 77 underground mines. The order of magnitude of coal production is exemplified by Utah's 23.4 billion tons in reserve, of which 33-50% is considered recoverable from 20 coal fields with current technology. Production has increasd 180% (from 4,175,000 tons to 12,000,000 tons) since 1967.

Oil and Gas

Oil and gas activity in the Upper Colorado River Basin is widespread, and reserves are difficult to evaluate. Activities in the overthrust belt of Colorado, Utah, and Wyoming are well known, particularly the situation in Evanston, Wyoming. For example, in Evanston they are debating as to who owns the streets (for drilling purposes). An oil-drilling rig is working adjacent to the Safeway store in Roosevelt, Utah, and daily TV commercials from Salt Lake City suggest you can "get rich quick" by obtaining oil and gas leasing rights on public lands. Colorado and Utah have approximately 26,393 oil and gas leases covering 30.5 million acres.

Worldwide reserves from oil shale are estimated at 2,000,000 billion barrels of oil. About 168,000 billion barrels underlie the United States; the 1,800 billion occurring in Colorado, Utah, and Wyoming (Fig. 2) represent 2.5 times the oil reserves of the entire free world. Thus far, four prototype leases have been let on 20,000 acres of public lands in Colorado and Utah, and approximately 275,000 acres of state and private lands have been leased in Utah. Seven projects are expected to be in operation in 1984 (Fig. 3), and other major projects are in advanced stages of development. BLM is preparing environmental

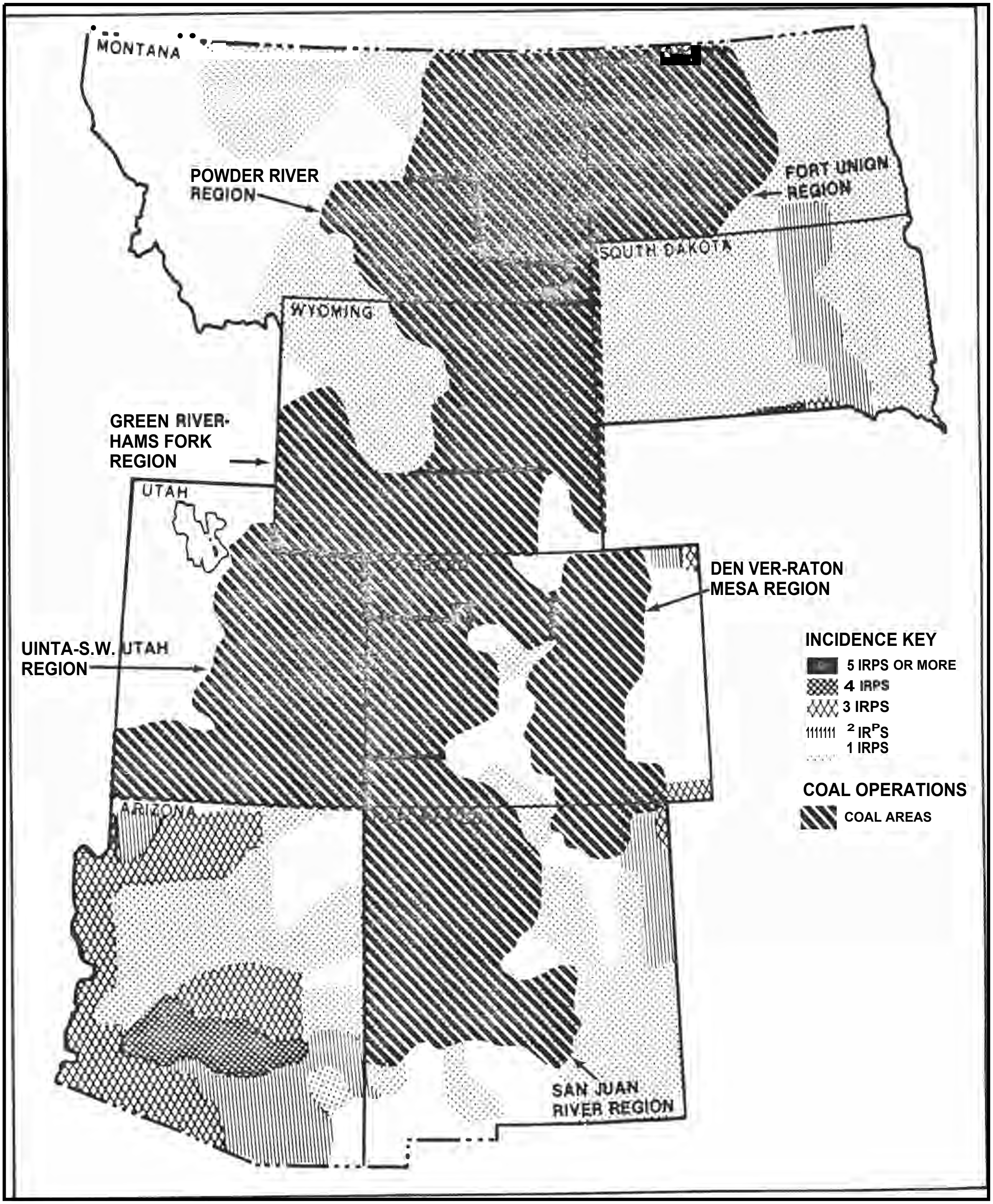

Figure 1. Coal regions in relation to important resource problem (IRP) areas.

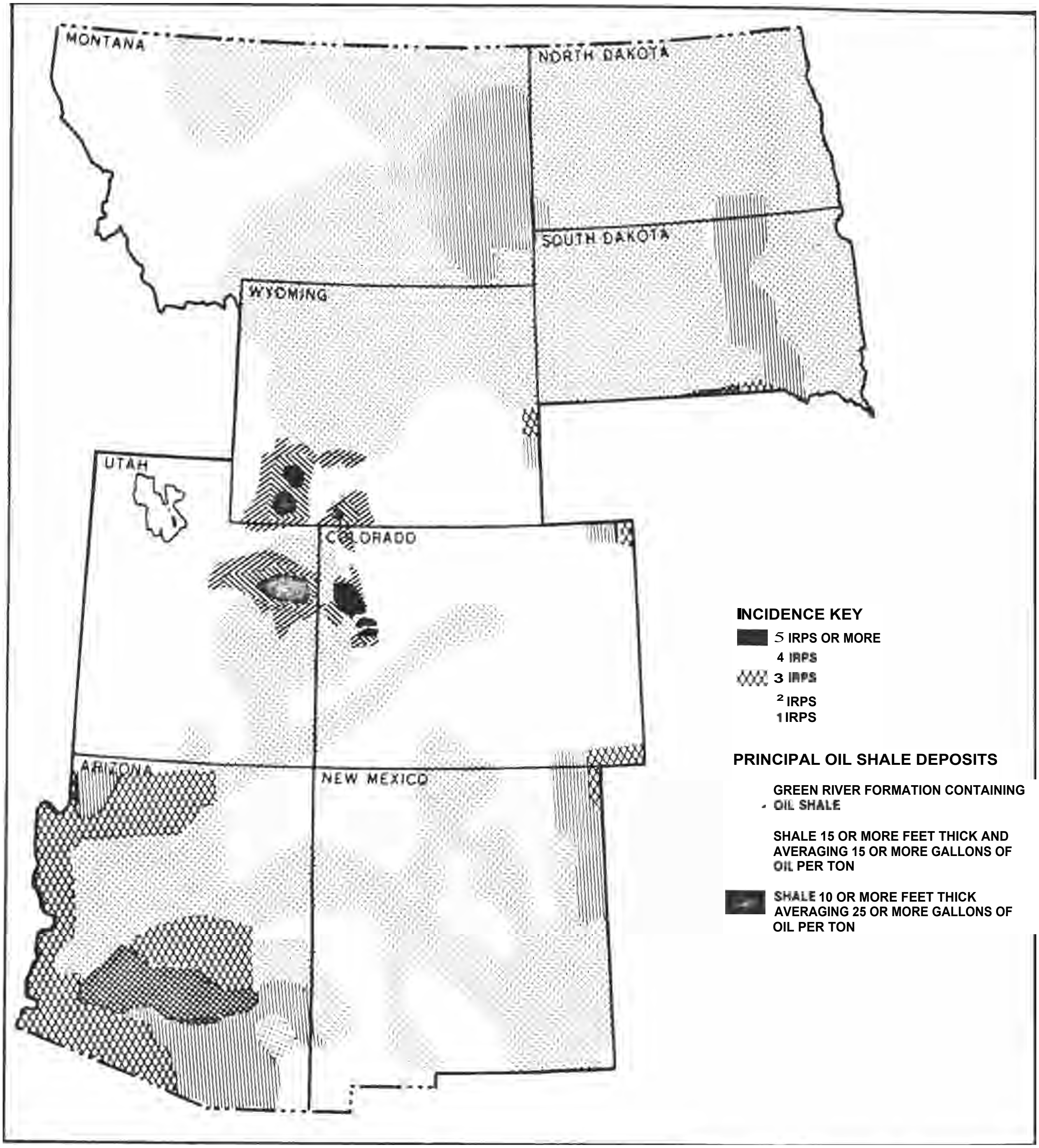

Figure 2. Principal oil-shale deposits in relation to important resource problem (IRP) areas.

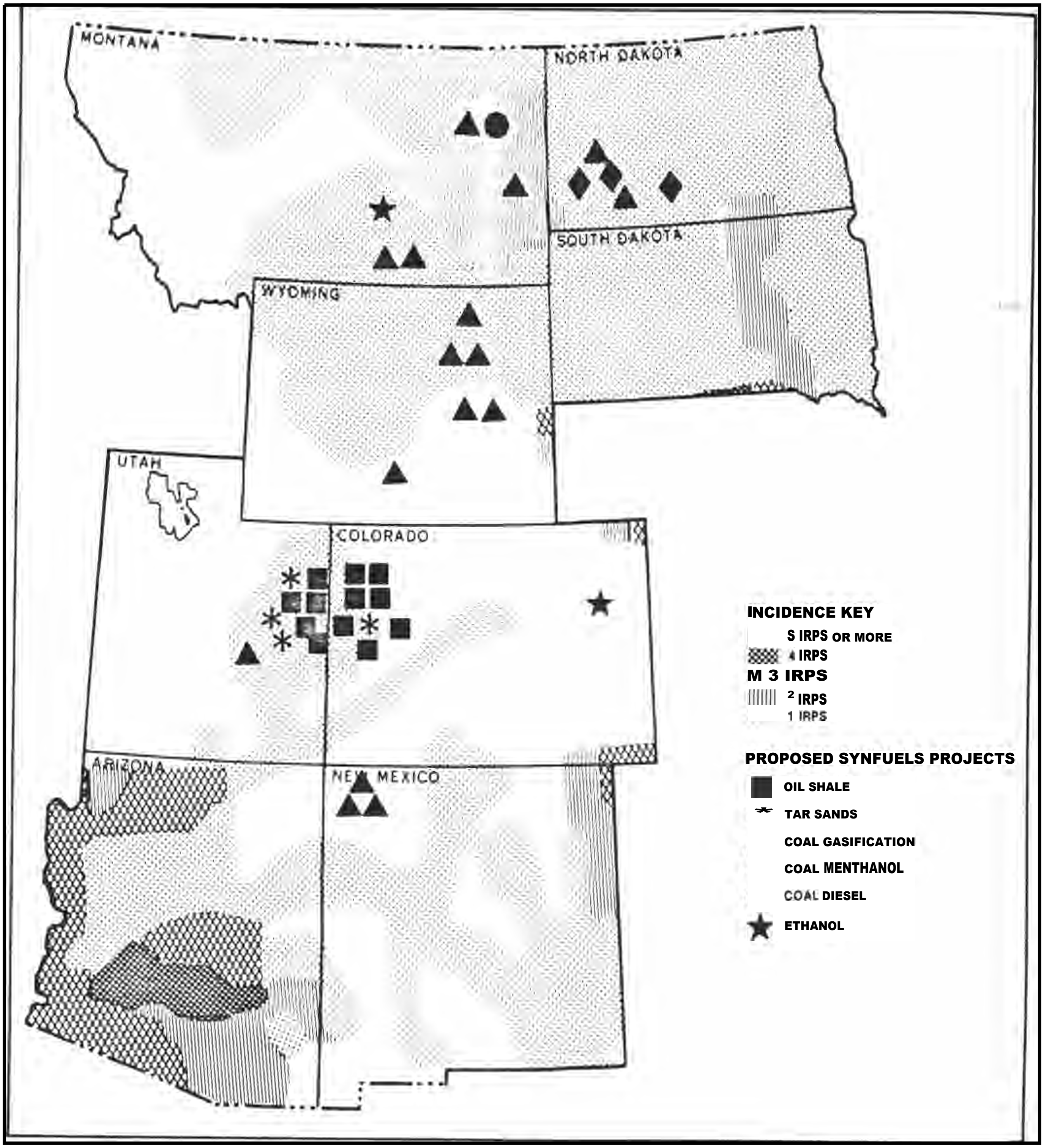

Figure 3. Proposed synfuel projects in relation to important resource problem (IRP) areas.

impact statements (EIS's) and land-use plans which will allow for further leasing and issuance of federal permits in Colorado and Utah within the next 2 years.

An estimated 30 billion barrels of oil from tar sands occur in the United States. Approximately 93% is in the Upper Colorado River Basin (Figs. 3, 4). The Department of Energy is funding a 100-bbl/day pilot plant in Utah, and BLM is preparing an EIS, to be completed in 1982, which will pave the way for tar-sand oil production.

Coal Gasification and Liquefaction

Projects for coal gasification and liquefaction are difficult to enumerate. Estimates indicate approximately 80 coal-conversion facilities in the Upper Basin (Fig. 3). Thus far, FWS is aware of four such facilities and is studying two.

Power Plants

With availability of coal comes siting of major power plants. Within the past few years, federal and state agencies have completed work and issued permits for a number of major plants in Utah, two of which are the Inter-Mountain Power Project and the Moon Lake (Deseret G & T) plants. Others on the drawing boards include the Tri-county and Mack plants of Colorado Ute in western Colorado. Incidentally, the Department of Energy is considering the feasibility of placing a nuclear power plant cluster (three plants) near Green River, Utah; this project could draw more than 200,000 acre-feet of water per year out of the Upper Colorado River System. Currently, in Utah alone, 36 hydroelectric plants, 8 natural-gas-fired plants, 7 oil-fired plants, and 7 coal-fired plants are operating. Utah's electrical generating capacity increased from 87 megawatts (MW) in 1912 to 2,250 MW in 1979. Continued growth seems certain.

Geothermal and Hydroelectric Facilities

Other energy mineral or conversion facilities include geothermal and hydroelectric power. Currently only one geothermal plant is under construction (at the Roosevelt Hot Springs Site in Utah), but more are certain to follow in the Upper Colorado River Basin. New hydroelectric power plants are few, but the Federal Energy Regulatory Commission has recently been deluged with applications for conversion of existing dams in the Upper Basin for hydroelectric purposes.

Nonenergy Minerals

Nonenergy minerals development has mushroomed recently. The search for gold, silver, and uranium is significant; inactive mines are being reactivated. Particularly troublesome for fish and wildlife managers are new mining access roads, dredging of streams, and location of refining plants. For example, gold miners are dredging the Colorado and Green rivers; the end result is loss of fishery habitat. Habitats formerly inaccessible now have major roads providing access not only for miners but for the recreational public. As the population increases, sand and gravel are needed for building and road construction, so sand and gravel operations are expanding. Stream bottoms and riparian habitats are being lost at an alarming rate.

Water

The demand for Upper Colorado River water is well known. Discussing the amount of water in the Colorado River System, and how much has been and will be depleted, is the realm of lawyers and politicians. Most documents that are factual have legal disclaimers such as:

> "Nothing in this report is intended to interpret the provisions of the Colorado River Compact (45 Stat. 1057), the Upper Colorado River Basin Compact (63 Stat. 31), the Water Treaty of 1944 with the United Mexican States (Treaty Series 994, 59 Stat. 1219),..."

Unfortunately, most documents do not provide information on the large number of water projects by federal, state, and private organizations or individuals. Some of these water uses include a number of projects funded by the U.S. Department of Agriculture for salinity control, which may deplete water or accrete water into the system. BLM and U.S. Forest Service soil and watershed projects, and the many measures taken by private landowners which affect the water supply of the Upper Colorado River Basin, are important but difficult to quantify. A FWS effort in 1978 indicated some 226 projects in the Upper Colorado River Basin have been constructed, planned, or had water rights assigned to them. However, it is likely that a number of these projects will not be constructed. Thus far, some 3,963,000 acre-feet have been depleted, and the potential exists for these 226 projects to deplete an additional 2,900,000 acre-feet from the Upper Basin.

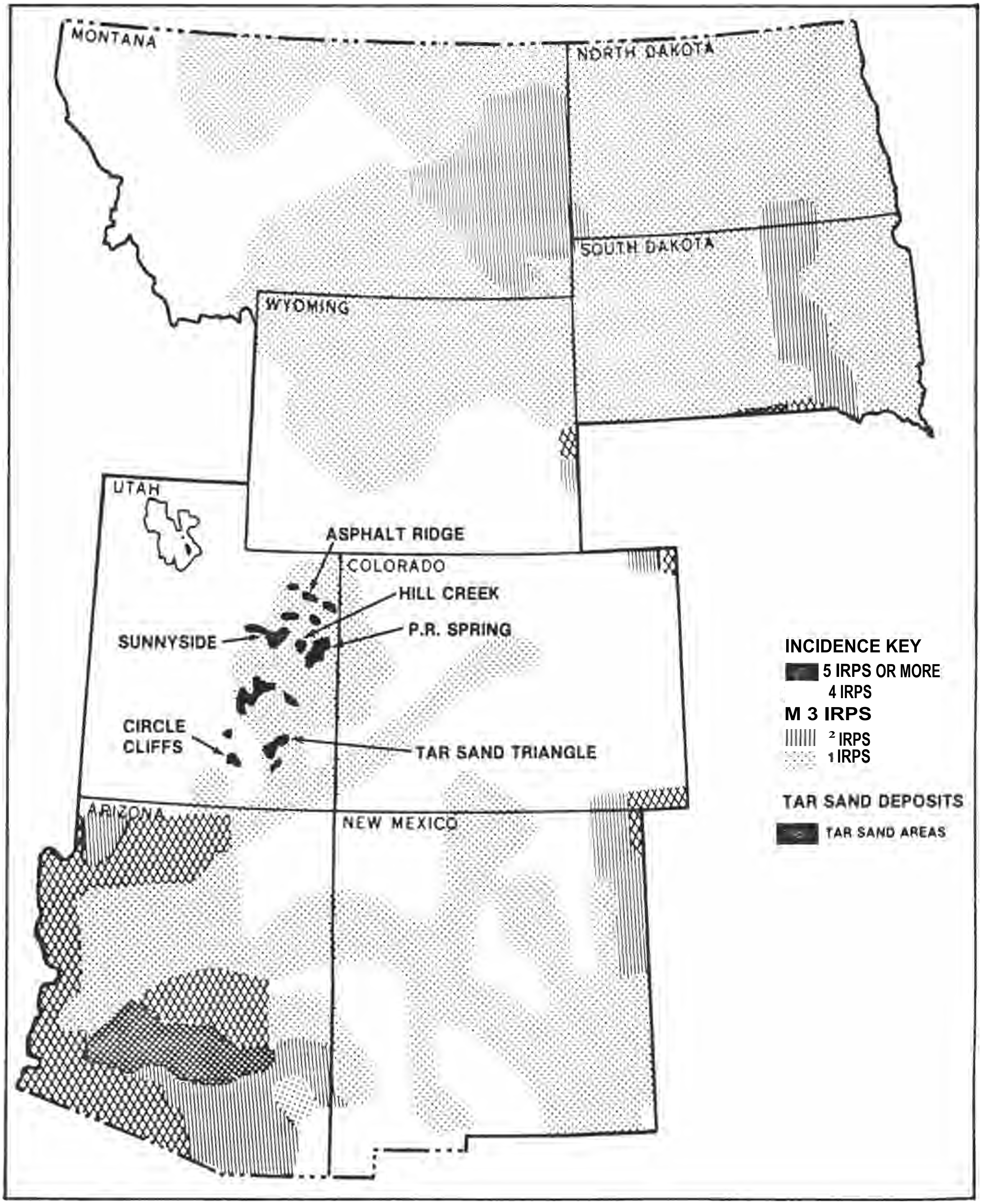

Figure 4. Tar sand deposits in relation to important resource problem (IRP) areas.

OTHER IMPACTS

Adding to the direct impacts of energy development are the associated impacts which involve transportation. These include synfuel pipelines, oil and gas pipelines, coal slurry pipelines, coal hauling by trucks and railroads, canals, ditches and water pipelines, airports, railroads, and electric transmission lines.

All of the above developments induce secondary impacts which, to date, are largely unquantifiable. However, new population centers such as Battlement Mesa (population estimated to be 20,000), and increased populations in existing cities (such as a potential of 20,000 people for DeBeque, Colorado), are occurring. Predictions indicate that 3.5 million additional people will be living in or immediately adjacent to the Upper Colorado River Basin by 2020. With expanded populations come increased demands for recreation, illegal taking of fish and wildlife, loss of riparian and wetland habitats, and increased environmental contamination. Increased development of other natural resources is also occurring and will increase as pressure for more such things as off-road vehicle use and timber use for individual home heating increases.

THE FISH

Impacts to fish and wildlife resources are largely occurring through general habitat degradation. Most important are changes in availability and quality of water for water-dependent habitats. Historically, flows at Lee Ferry have averaged about 14,870,000 acre-feet annually, with a 1917 high of 21,894,000 acre-feet and a 1934 low of 4,396,000 acre-feet. By 1965, 581 reservoirs had been constructed, and estimated depletions totalled 3,450,700 acre-feet. With the construction of these projects and associated water depletions, vast acreages of critical wildlife habitat were adversely affected or lost, and hundreds of miles of stream fishery habitat were lost. As a result, FWS listed the Colorado squawfish and the humpback chub as endangered species in 1967.

Additional projects have depleted approximately 512,000 acre-feet since 1965, and total depletions as of 1980 were 3,963,000 acre-feet. The combined effects of the water projects and their depletions were the basis for FWS listing the bonytail chub as endangered in 1980.

THE FUTURE

FWS initiated a number of actions in cooperation with federal, state and private organizations to identify and quantify the above impacts and recommend courses of action to lessen or remove them. Most of these actions are planning-oriented, such as recovery plans and the Conservation Plan for endangered Colorado River fishes. Other planning includes the application of FWS rapid assessment methodology to northwest Colorado and northeast Utah (a computer-based system for delineating wildlife habitats, their values, and energy-related project impacts), the application of rapid-assessment methodologies for upcoming coal-lease areas in Utah and Colorado, Fish and Wildlife Coordination Act planning on federally-authorized, -licensed, or -constructed projects, and a "Water for Energy" computer-based model of Upper Colorado River water projects.

Other agency planning includes BLM's management framework plans, resource management plans, and regional environmental impact statements, as well as similar actions by the U.S. Forest Service. The U.S. Bureau of Reclamation and U.S. Soil Conservation Service also are involved in site-specific project planning. Thus far, on-the-ground conservation measures for fish and wildlife are few in number and largely inadequately funded to affect compensation or mitigation for the overall magnitude of the numerous impacts. However, mitigation under Section 8 of the Colorado River Storage Project Act has increased dramatically within the past 2 years.

The future of water development impacts in the Upper Colorado River Basin is extremely difficult to predict. Much depends on synfuels development and when such development will take place. It appears that development will occur and that the demands on Upper Basin water will increase dramatically. Table 1, provided by the Upper Colorado River Region of the Bureau of Reclamation in August 1980, appears to be the best recent source of information on future water development.

Table 1 does not include information on a number of water projects, such as the Juniper-Cross Mountain project, which may deplete an estimated 500,000 acre-feet from the system. The table does give insight into projected average annual depletions of 4,878,000 acre-feet by 1990 and 5,362,000 acre-feet by the year 2000.

Fish and wildlife managers and their agencies are faced with the task of ensuring that development takes place with the least long-term impact to natural resources. There is need for prompt action now. Too long have resource agencies forestalled making firm decisions and taking appropriate action to address these issues, and time may be running

TABLE 1. Projected water supply and depletions, Upper Colorado River Basin. (Unit = 1,000 acre-feet) (From Bureau of Reclamation)

State and project	Year 1979	1980	1990	2000	2010
Arizona					
Present	13	13	13	13	13
Navajo Powerplant	22	22	34	34	34
Other municipal		1	3	3	3
Total depletion	35	36	50	50	50
Compact apportionment	50	50	50	50	50
Colorado					
Present	1,794	1,794	1,794	1,794	1,794
Fryingpan-Arkansas	52	52	69	69	69
Ruedi Reservoir MC			16	32	48
Animas-La Plata			11	119	120
Dolores			78	80	81
Dallas Creek			12	17	17
West Divide			1	38	38
San Miguel			8	31	31
Denver Expansion		60	110	160	216
Colorado Springs Expansion				5	5
Homestake Expansion			15	31	31
Pueblo (Eagle River)		3	3	3	3
Hayden-Craig Steam Plants		10	20	20	20
Independence Pass Expansion		7	7	7	7
Englewood		10	10	10	10
Windy Gap			30	54	54
Oil shale development			78	78	100
Hydroelectric development				30	30
Total depletion	1,846	1,936	2,262	2,578	2,674
Evaporation, storage units	269	269	269	269	269
Total	2,115	2,205	2,531	2,847	2,943
State share of 5.8 MAF level	2,976	2,976	2,976	2,976	2,976
Remaining water available	861	771	445	129	33
Wyoming					
Present	333	333	333	333	333
Lyman Project	6	8	10	10	10
Cheyenne-Laramie Diversion	8	8	15	20	50
Seedskadee Project	26	29	50	100	150
Private industrial rights			50	57	57
Total depletion	373	378	458	520	600
Evaporation, storage units	73	73	73	73	73
Total	446	451	531	593	673
State Share of 5.8 MAF level	805	805	805	805	805
Remaining water available	359	354	274	212	132
Upper Colorado River Basin Totals					
Depletions	3,305	3,443	4,358	4,842	4,925
Evaporation, storage units	520	520	520	520	520
Total depletion	3,825	3,963	4,878	5,362	5,445
5.8 MAF level	5,800	5,800	5,800	5,800	5,800
Remaining water available	1,975	1,837	922	438	355

TABLE 1 (concluded)

State and project	Year 1979	1980	1990	2000	2010
New Mexico					
Present	106	106	106	106	106
San Juan-Chama Project	100	110	110	110	110
Animas-La Plata Project			4	27	34
Navajo Reservoir evaporation	26	26	26	26	26
Hogback Expansion	2	5	10	10	10
Utah International Inc.	20	21	39	39	39
Farmington M&I			5	5	5
Navajo Indian irrigation	75	100	254	254	254
Jicarilla Apache			3	3	3
Navajo M&I Contracts	10	13	100	100	
San Juan (NMPSC)[a]	(10)	(13)	(16)	(16)	
Utah International Inc.[a]			(35)	(35)	
El Paso Natural Gas Company[a]			(15)	(15)	
Gallup-Navajo Indian municipal[a] water supply			(18)	(25)	
Other[a]			(16)	(9)	
Total depletion	339	381	657	680	587
Evaporation, storage units	58	58	58	58	58
Total	397	439	715	738	645
State share of 5.8 MAF level	647	647	647	647	647
Remaining water available	250	208	-68	-91	2
Utah					
Present	675	675	675	675	675
Bonneville Unit	31	31	136	166	166
Upalco Unit			12	12	12
Jensen Unit			15	15	15
Uintah Unit			3	28	28
Emery County Powerplants	6	6	15	15	15
Deferred Indian			40	50	50
Mill Creek Project			3	3	3
White River Dam Project			6	24	24
Oil Shale			26	26	26
Total depletion	712	712	931	1,014	1,014
Evaporation, storage units	120	120	120	120	120
Total	832	832	1,051	1,134	1,134
State share of 5.8 MAF level	1,322	1,322	1,322	1,322	1,322
Remaining water available	490	490	271	188	188

[a] Subprojects of Navajo M & I. Values in parentheses.

out. The Craig, Colorado and Evanston and Rock Springs, Wyoming examples already have taken their toll, and they are only indicators of impacts yet to come.

Actions are under way by federal, state and private organizations, but are they enough and in time? Can these agencies meet the challenge of facilitating development to meet man's needs on a regional and national level while assuring the existence and maintenance of balanced aquatic and terrestrial ecosystems? Only time will tell!

Positive indicators bring a ray of hope to this tale of doom and gloom. Funding and action by federal and state agencies to determine the biological requirements of endangered Colorado River fishes and development of action plans such as the Conservation Plan are examples. A genuine effort by conservation agencies to meet the challenge is apparent and will continue. Upper Basin states are recognizing the need for long-range planning and are initiating efforts to address their common problems with recognition of fish and wildlife resource values.

Obviously, much more needs to be done, and there is a special need to address the issues of water availability and use and long-term effects on fish and wildlife resources caused by water depletions. The challenge is clear for fish and wildlife managers; they must collectively apply their meager resources to a common effort to find answers to the problems and impacts created by man.

DISCLAIMER

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MITIGATION OF AQUATIC ENDANGERED SPECIES HABITAT LOSSES IN THE UPPER COLORADO RIVER BASIN: FEASIBILITY AND APPLICATIONS

C.G. Prewitt and C.B. Stalnaker

ABSTRACT

Mitigation of habitat losses from proposed water development in the Upper Colorado River Basin could be accomplished in concert with the maintenance-and-recovery goal of the Endangered Species Act if a structured analytical approach to evaluating development were used as a communication device among concerned interests and agencies. A basin-simulation system may be useful in determining flow conditions necessary for fish-habitat maintenance, but feasibility and effectiveness of possible mitigation activities should be carefully evaluated under various water-supply conditions.

Mitigation of habitat losses for endangered species is not allowed under Section 7 of the Endangered Species Act (Lambertson, this symposium). It also has been considered infeasible, largely because such losses for terrestrial or avian species could be measured as reductions in area which were not retrievable. However, fish habitat losses resulting from streamflow depletions or alterations in flow regimes are not always irretrievable, and they could be compensated by storage and release patterns which provide habitat during most critical periods. The "habitat" (in this case water flowing over a suitable channel structure) may be delivered to the same stream from which it was originally depleted, given deliverable upstream storage and a knowledge of flow-regime requirements of the species of interest.

THE PROBLEM

Mitigation of habitat losses for the endangered fishes of the Upper Colorado River Basin (UCRB) can be viewed both as a very simple and a very complex problem. Most authorities cite only three major suspected causes for the decline of the endangered, large-river endemic species: changes in temperature and flow regimes and the introduction of exotic fish species (Holden and Stalnaker 1975; Holden 1979). It would seem a simple matter to prescribe conditions to which future basin developments must conform to at least maintain present population conditions. This would, of course, require the assumption that introduction of more exotic fish species to the basin is not likely.

Perhaps some of our difficulties in understanding the dynamics of the UCRB problem lie in consideration of these changes as static processes. For example, it is customary to think of water depletions in terms of annual volume (acre-feet, hectare-meters) reductions. The more water volume a dam depletes, in general thinking, the more damage it does to downstream aquatic resources. Certain projects, however, deplete very little water and have profound effects upon downstream biota because they drastically alter the timing of flows. Therefore, in dealing with past and future UCRB storage or diversion projects, we should think in terms of changes in flow regime rather than volumetric depletions. Maintenance of fishery requirements in terms of dynamic flow regimes over long time periods becomes quite complex and requires extensive biologic, hydrologic, and sociologic-economic knowledge.

Similarly, since stream temperatures of about 20 C promote spawning of Colorado squawfish under suitable variations, it would be simple enough to require that water projects ensure a stream temperature of about 20 C during the spawning period. Difficulty arises from the fact that the flow and temperature regimes in rivers are highly correlated. Immediately below a dam, stream temperatures are easy to predict, but prediction of stream temperatures several miles downstream from a dam which alters both temperature and flow regime requires highly sophisticated physical-modeling processes. This modeling may provide insights into the nature of temperature regimes resulting from certain projects or activities, but the biological consequences of these temperatures must also be known. Is the 20 C temperature value necessary for a period of days or weeks? What if this temperature were reached only for short periods each afternoon, or only approached during some period of extremely low flow? Again, simple temperature solutions may be proposed, but they are not likely to be sufficient.

Further, we know that the channels of alluvial streams such as those in UCRB offer predictable physical habitat conditions only if their flow regimes and sediment sources do not change over time (Simons 1979). River channels, as the physical basis for stream habitat, will almost certainly change under UCRB streamflow alterations as extensive as those proposed in recent development scenarios. Channel-change effects of future projects may actually impact fish habitat more than direct changes in flow regime, temperature, or water quality.

Finally, even if all physical, chemical, and biological effects of a basin-wide flow-temperature pattern were known, it would still be necessary to determine the effects of implementing such desired flow conditions upon the water supply system of the river basin. Planning water resources for instream uses would require highly detailed knowledge of present and future water allocation patterns and a firm grasp of the legal position of endangered species with respect to other competing water uses.

MITIGATION

Solutions to these complex problems depend upon mitigation as a conceptual base. By first assessing the potential for habitat mitigation during critical yearly periods, sufficient flows to maintain (and possibly improve) populations of some UCRB endangered fishes can be determined. Maintenance and improvement might be approached as objectives of a plan.

The first phase of developing this plan might involve establishment of minimum and optimal conditions for maintenance and survival of the endangered species. These "conditions" would necessarily address each of the significant parameters, including flow and temperature regime, physical habitat structure, and water-quality maintenance. Establishment of such conditions would provide criteria for evaluation of projects in the Section 7 (Endangered Species Act) consultation process or in other permitting processes such as The Federal Energy Regulatory Commission (FERC) and Section 404 of the Clean Water Act.

Determination of minimum maintenance flows initially appears simple, but it is very complex. For example, the same species of fish could require more flow at an upstream location than at one downstream although no major tributaries entered in the intervening reach. Fish might seem to require more water than could be provided, even under minimal levels of storage project development, and it might be possible to maintain desired flow levels for only one of the three endangered species. Would accepting a development (or proposing an action) which might improve conditions for one species while degrading them for the others violate intentions of the Endangered Species Act? Experience has shown that a single, attainable pattern of flows and/or temperatures for several species across a major river system is not usually possible. To attain maximum benefit, trade-offs will be necessary, and because we are dealing with endangered species, they must be made with maximum reliability within our present capabilities.

The second phase of plan development should involve establishment of habitat- and population-enhancement programs based on stocking of hatchery-reared endangered fishes in association with acquisition of water to provide required flow regimes to selected river reaches. Physical habitat structures would be built to replace riverine habitats lost to construction or inundation. These activities would be funded with monies from the Fish and Wildlife Service (FWS) Conservation Plan assessment process.

The problems with the second phase are much the same as those with the first. Should stocking be permitted and, if so, where will it be most effective? Which flows will be necessary for maintenance of the stocked fish? If habitat-improvement structures are built, what assurance is there that they will be stable and have acceptable effects upon adjacent physical habitats or floodplain conditions? Most importantly, who will be requesting flow regimes? Will compensation be required for the water? From where will the water come? What will be the effect of implemented instream flows upon an already-overburdened water-allocation system?

ANALYSIS

Clearly, an analytical process is needed in which unavoidable disputes among the elements of a complex plan are reconciled by systematic use of knowledge and technological tools. The necessary elements of this process are as follows:

1. **Biological requirements.** The needs of critical life-history stages of each endangered species must be considered in terms of flow and temperature regimes, physical habitat structure, water-quality conditions, and favorable community composition. If competition with or predation by non-endangered fish are factors, biological knowledge of these fish will be necessary. Such biological information is being collected by the FWS Colorado River Fishery Project (CRFP).
2. **Suitability of various flow regimes.** Given the requirements of various life-history stages for depth, velocity, substrate, and cover, the relative availability of physical habitat at a given flow level is estimable using the FWS PHABSIM (Physical Habitat Simulation) system already in use in the basin (Stalnaker 1979). This computer-based system allows expression of the predicted depth, velocity, and substrate distribution at a selected reach (representative of major homogeneous or limited critical or unique reaches) in terms of Weighted Usable Area (WUA) of preferred habitat for a given life-history stage at a given flow. It provides quantitative insights into the relative suitability of flow levels and corn-

parisons among different flow regimes which might be requested. Another phase of the CRFP involves collecting physical habitat data for use in this system at numerous sites in the UCRB (Fig. 1).

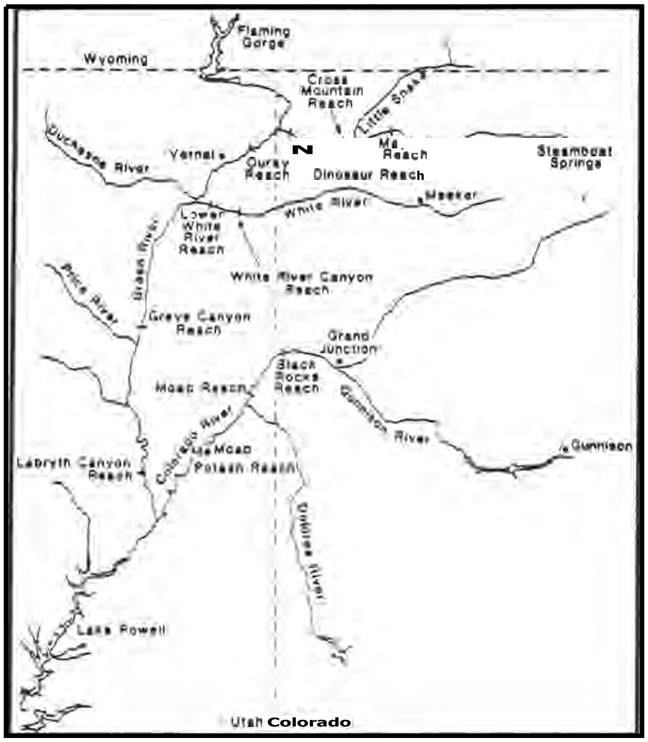

Figure 1. Locations of Upper Colorado River Basin physical habitat sampling sites.

3. **Temperature and water-quality modeling capabilities.** Flow regimes recommended by FWS or proposed by a developer might be adequate with respect to physical habitat but could, for unanticipated reasons, have temperature consequences which might preclude spawning or promote behavior alteration or disease. Also, changes in waste-load assimilative capacity, toxic material input, and suspended sediment are expected as results of land-use changes (Steele 1976; James and Steele 1977) and urban growth; these could modify the UCRB's water-quality baseline conditions. Future temperature and water-quality conditions can be estimated only by reliable simulation modeling. Several agencies are currently engaged in development of a UCRB-wide temperature model for use in (1) depicting steady-state basin temperature patterns expected as a result of new dams, thermal inputs, or revised operations in the present system, and (2) predicting temperatures resulting from a variety of proposed flow regimes. For example, temperature-modeling output involves effects of an altered release temperature upon downstream temperatures. Such capabilities could provide quantification of habitat losses by noting the number of river miles which do not reach desired minimum temperatures for spawning.

4. **Sediment transport modeling capabilities.** Modeling initially is expected to provide insights into the direction of channel changes (aggradation or degradation) and the extent to which major projects might alter the present habitat distribution of the basin. Subsequent modeling efforts might allow analysis of changes in flows and/or sediment loads in terms of changes in microhabitat.

5. **Water-budget models.** Flow regimes acceptable in terms of fish-habitat suitability and channel maintenance would be available only if the basic water budget of the basin could provide the necessary instream flow. A "macro" model which utilized knowledge of present and proposed water uses, out-of-basin diversions, interstate compacts, and reservoir storage target levels could test the feasibility of flow regimes which retained adequate fish habitat (Prewitt 1981; Veenhuis and Hillier 1981). A basic goal in such water-budget modeling would be prediction of project flow conditions over long periods, with ability to determine probabilities of habitat events of interest.

6. Finally, **legal-institutional planning** would determine means of making water available, stocking of endangered fish legally acceptable, and having habitat-improvement structures meet local, regional, state, and federal permit requirements.

MODELING

Habitat Maintenance—Phase I

A simulation model incorporating these elements would require reliable data as input and produce results which would have to be sensibly interpreted. Such models are suggested for use only in performing tedious, repetitious, or highly-complicated tasks.

How would computer simulation facilitate making the decisions we have discussed? Figure 2 illustrates the process of determining flow requirements. In addition to traditional distribution and abundance information, this model requires detailed knowledge of a species' preferences for depth, velocity, substrate, cover, and temperature. Knowledge of the life histories of each species is critical in determining when desired flows must be provided.

The simulation system used in developing flow requirements is straightforward. The PHABSIM system is used to indicate flow levels which offer acceptable amounts of physical habitat for critical life-

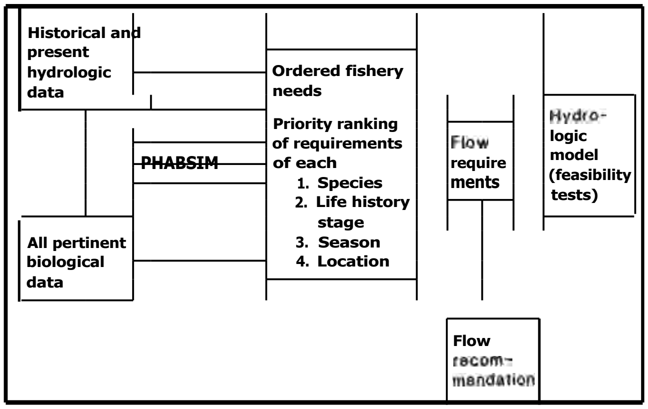

Figure 2. Model of the systematic process involved in developmen of a flow recommendation for several species in multiple river basin locations.

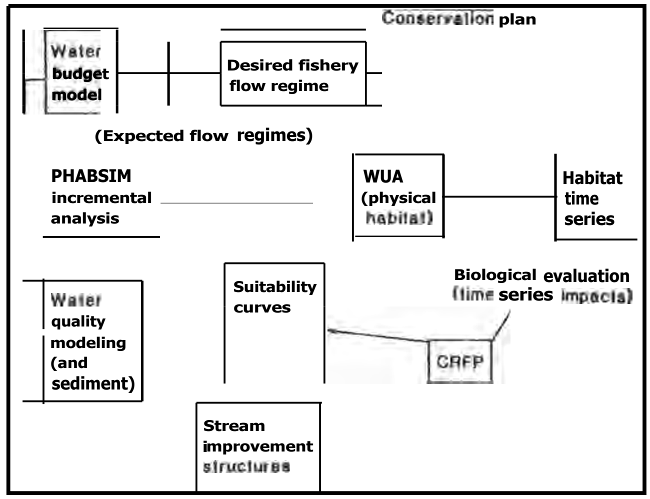

Figure 3. Interactive steps involved in a proposed Upper Colorado River Basin water and aquatic habitat management and planning system.

history stages. The flow requirement for a particular species is determined by PHABSIM results and professional judgement. This differs from a traditional "minimum flow" recommendation in that it is a flow regime or series of successive, yearly regimes which provides necessary long-term conditions for the species.

The second flow diagram Fig. 3 illustrates an iterative process for analyzing probable basin development patterns and developing a plan for implementation of basin-wide flow recommendations. The initial flow recommendations from Fig. 2 can be entered into the process as "desired fishery flow regimes", which are evaluated for feasibility by the macro water-budget model. Of the multiple possibilities, only one or a few flow patterns may emerge which retain acceptable fishery habitat values within the basin's water-supply framework. Perhaps no combination of regimes may offer enough suitable habitat to maintain all species at ideal levels; in that case, the flow requirements for one species might have to be reduced to provide adequate water for another. In any case, use of the macro water model allows rapid habitat evaluation of several regimes, each based upon reasonable simulations of water availability.

The selected regime is then evaluated for temperature and water-quality suitability, again using a simulation model. If none of the attainable regimes offers suitable temperature conditions, the flow recommendation is revised and again evaluated by the same analytical process. Finally, a sediment-routing model is used to screen flow-sediment regimes which might promote excessive scour or aggradation and directly affect the channel structure.

Population and Habitat Manipulation—Phase II

The PHABSIM system may be used to evaluate the relative habitat values of different river segments as an aid in determining favorable stocking locations. It is also a valuable tool in determining favorable channel designs and evaluating structural instream habitat improvements Wegner 1979 . The result of several iterations through the simulation system should be a limited array of management options, each with its own known limitations. These can be offered to planners with reasonable assurance that biological, engineering, and legal concerns have been considered.

Clearly, successful simulation is dependent upon multiagency and multidisciplinary involvement. Because federal agencies can purchase or otherwise acquire water only within the established appropriative water-law framework, instream-flow water rights may be obtained primarily through cooperation with state wildlife and water-planning agencies. Several states have legislative resolutions forbidding the import of endangered fish species for restocking; state-federal coalitions will be necessary to resolve such problems. Local water-planning entities special districts, water-users associations, and planning and zoning districts should be involved to identify changes in water-use patterns and review floodplain alterations expected if stream-improvement structures are proposed.

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MITIGATION AND SECTION 7 ON THE UPPER COLORADO RIVER

Ronald E. Lambertson

ABSTRACT

Traditional mitigation in not permitted for endangered species by the Endangered Species Act of 1973. The concept of mitigation is discussed and applied to the Act, and roles of federal agencies are outlined. Additional information on the Colorado River Conservation Plan for management of endangered fishes is presented. *(Editors' abstract)*

INTRODUCTION

As a result of man's actions to provide food, energy, and other societal needs, dramatic changes have occurred in the natural environment upon which species depend. This has often led to major conflicts between natural values and economic development. The demands on the Colorado River System and its associated ecosystem, brought by the need for energy development and production for expanding local and national growth, will further degrade a unique habitat. To reconcile fish-habitat needs with project development, new approaches are necessary. However, the traditional concept of mitigation cannot be applied to the problems facing us with endangered species. The fact that they are listed as endangered indicates that the habitat is so deteriorated and the species so restricted in abundance and distribution that further habitat loss will have only a greater impact on a precarious situation. The listing of these species was intended as an indication to the public of the importance of applying conservation measures toward a recovery effort to protect and restore them and their natural habitat. The traditional concept of mitigation does not offer this opportunity of protection.

Attempts to provide protection through Section 7 of the Endangered Species Act (ESA) will be discussed in this paper. The discussion will be divided into two sections. The first covers the concept of mitigation as it applies to the ESA, and the second is a discussion of Colorado River problems and past and present attempts to resolve them.

MITIGATION AND THE ENDANGERED SPECIES ACT

The Endangered Species Act mandates consideration of impacts upon endangered, threatened, and proposed species and/or critical habitat resulting from any federal activity or program. Specifically, the Act proclaims a goal of protecting the ecosystems upon which federally-listed species depend, while providing a program for their conservation. This can be accomplished directly through land acquisition and preservation or indirectly through Section 7 of the Act, which states:

> "Each Federal agency shall, in consultation with, and with the assistance of the Secretary, insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of habitat of such species which is determined by the Secretary, after consultation as appropriate with affected States, to be critical. . ." (87 Stat. 884; 16 U.S.C. 1531 et.seg.)

This Section 7 consideration involves four discrete duties for federal agencies:

1. to review and utilize existing programs to further the purposes of the Act;
2. to utilize authorities to further such purposes by carrying out conservation programs;
3. to insure that federal activities are not likely to jeopardize the continued existence of endangered or threatened species; and
4. to insure that federal activities do not destroy or adversely modify habitat determined to be critical to listed species.

This latter point has been interpreted as prohibiting only those modifications to the habitat which have a significant adverse impact on listed species. Federal agencies, in applying the traditional concept of mitigation, have interpreted this to mean that mitigative measures may be reasonably utilized in resolving conflicts between federal projects and any fish and wildlife resource, a definition consistent with that found in the Fish and Wildlife Coordination Act (FWCA), as well as other federal acts.

Mitigation is a viable concept long used by federal agencies. In biological terms, the issue becomes whether project modifications may ameliorate or reduce, but not eliminate, adverse impacts to the habitat and to the species, with the result being a net loss to the species and habitat. In regard to this, the goal of the FWCA is one of conservation and enhancement by preventing loss of or damage to wildlife resources in connection with federal projects. To federal agencies, that means that projects should be modified to incorporate recommendations for conservation, acquisition of lands to compensate for destruction of habitat, or other measures replacing loss, as necessary.

However, Section 7 of the ESA guarantees a higher level of protection. Therefore, federal agencies must respond in such a way that the traditional concept of mitigation may not be adequate. Mitigative measures, and the term itself, are conspicuously absent from the Act. The ESA cannot be satisfied by project modifications which only reduce the extent of the adverse impacts if such reductions do not meet the specific legal standards in the Act.

As noted in a recent Supreme Court decision (TVA vs. Hill, 1977, the Snail Darter Case), "...one would be hard pressed to find a statutory provision whose terms were any plainer than those in Section 7." Under Section 7, two burdens are imposed on federal agencies:

1. affirmative — Section 7 (a) (1) directs federal agencies ". . . to utilize their authorities to carry out conservation programs for listed species;" and,
2. prohibitive—Section 7 (a) (2) requires every federal agency ". . . to insure that its actions are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat."

It was Congress' intent that an agency cannot be excused from the jeopardy prohibition without approval granted in the statutory exemption process. Therefore, it is in an agency's interest to utilize a different concept, that of a "conservation program," as a positive step towards recovery. Such programs have included research, habitat acquisition and maintenance, and species propagation, among other things.

If a potential conflict occurs between a listed species and any federal program or activity, an agency has two avenues of compliance with the ESA. At the early stages of project planning it can consult informally with the hope of identifying modifications of the action which would eliminate the "may affect" situation and satisfy the Section 7 requirements. The Fish and Wildlife Service (FWS) will provide guidance in the form of recommendations with the intent of conserving the species. An agency can also consult formally, resulting in the issuance of a biological opinion by FWS.

In the biological opinion, the Secretary of the Interior can provide recommendations for conservation and, if warranted, "reasonable and prudent" project alternatives which, if adopted, could avoid violation of Section 7 by eliminating jeopardy. This consultation process is an attempt to find ways that would allow planning, construction, and operation of a proposed project to be compatible with the Act. An agency should be aware that no irreversible or irretrievable commitment of resources should be made until its Section 7 obligations have been concluded. For reference, two terms are defined here:

> *Reasonable and prudent alternatives are ".* actions that can be implemented in a manner consistent with the purpose of the action and ... which avoid the likelihood of jeopardy or result in the destruction or adverse modification of critical habitat."
>
> *Conservation is ".use* of all methods and procedures that are necessary to bring a listed species to the point at which it may be removed from the list. Methods and procedures include. .. resources management, such as research, acquisition, propagation. . ."

Conservation cannot be achieved through traditional mitigative measures. Section 7 is applied to prevent jeopardy, not merely reduce or mitigate jeopardy. As species are listed because of man's past and present actions, any further adverse impact could have far-reaching consequences inconsistent with the primary goal of the ESA. It is the goal of the ESA (16 U.S.C. part 446) to "...bring any endangered or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary."

MITIGATION IN THE COLORADO RIVER BASIN

Historically, FWS has looked at each federal project or program on a case-by-case basis when applying Section 7 of the Act. The burden for compliance is, by law, on the action agency to insure that its actions are not likely to jeopardize listed species. However, the initiative to develop a plan of action now lies with FWS in areas of major concern such as the Colorado River System, where negative impacts can have far-reaching results. To take into consideration the biological needs of the fish and the future economic and developmental needs of the region and the Nation, FWS determined that a comprehensive plan for the listed fish is now required.

Since each project will have a biological impact, additive on the system as a whole, those impacts should be reduced or modified to provide beneficial effects to the fish and their associated habitats. This requires cooperation among all interested parties to allow development of a plan of action by FWS consistent with the intent of Congress and the ESA.

With the increased emphasis on water resource development during the past several years, a number of water projects have been proposed for the Upper Colorado River Basin. Of the main rivers involved (Colorado, Green, White, and Yampa), only specific reaches presently contain populations of the three endangered fishes, Colorado squawfish, humpback chub, and bonytail chub. Habitat modifications occasioned by several large projects constructed in the past are believed to have contributed to the decline of these species. As additional projects were proposed for construction, the Bureau of Reclamation, in 1979, proposed that a fisheries study be conducted (Shields in this symposium) to determine the causes for the rapid decline in Upper Basin species and to devise a strategy for their preservation and recovery.

The need for these studies relative to water-development projects exists because there has been a lack of specific biological and technical data for the rivers involved. The rapid decline in the populations of the listed fish is of critical importance as it provides an indication of accelerated habitat deterioration. Impacts on these species and the related ecosystem cannot be assessed on a project-by-project basis, since any further project development could increase the likelihood of jeopardy. Factors such as changes in water quality, temperature, seasonal and diurnal flow, and habitat alteration have contributed to the present status of these fish. Completion of ongoing research will allow collection of the data necessary to better analyze project impacts. These data should be used in conjunction with other data to develop a basin-wide policy toward listed fishes and their habitats. Because of the relationship between flows in the tributaries and in the mainstem Colorado, completion of all studies is important to providing a basis for compilation and analysis of alternatives relative to future projects.

In the past, FWS has dealt with other major western water projects where energy development and/or water rights threatened listed species and habitat. The 1978 Amendments to the Act provided an exemption possibility for the first major western water project controversy, the Grayrocks Dam and Reservoir Project on the North Platte River; the whooping crane and its critical habitat were the primary concern.

Consultation on Grayrocks was conducted in 1978, and a jeopardy opinion was issued in December 1978. However, as with the Tellico Dam controversy, Congress included as part of the Amendments a provision for an exemption if no formal resolution could be attained. Congress also instructed that, if so determined, the federal agencies involved shall require such modifications in the operation or design of the project as they may determine are required to insure that the project is not likely to jeopardize the continued existence of endangered species. An amount of money ($7,000,000) was placed into an irrevocable trust for the maintenance and improvement of whooping crane habitat on the Platte River to offset the impact of the water removed. The expenditure of these funds for a conservation plan on the Platte River is consistent with the intent of the ESA.

In the past, specific projects in the Colorado River Basin have been dealt with on a case-by-case basis with both jeopardy and non-jeopardy opinions rendered. Recommendations, such as maintenance of minimum streamflow, reduction of water diversion during critical periods, replacement of diverted water, conducting studies to determine the presence of listed fish, and the development of a conservation plan for listed fish in the project area have been made and accepted by project sponsors.

Presently, there are over 20 major water projects in the Upper Colorado River Basin awaiting federal approval. Without data on relationships between specific flows and habitat parameters of the listed fish, FWS personnel believe that final determinations and issuance of biological opinions should not be completed. A delay has been requested for most biological opinions until early 1982, following completion of the fisheries studies ongoing on the Colorado, Green, Yampa, and White rivers, and other tributaries. With the completion of these studies, we expect to draw more reliable conclusions about the impacts of proposed projects upon the three endangered fishes and to develop sounder alternatives. Most project sponsors have agreed to await completion of these studies.

However, with the increasing need and demand for energy development and production, another year's delay cannot be tolerated for some projects. Some are under construction and await federal response for completion. Therefore, requests for prompt action have resulted in the development of a conceptual Conservation Plan by FWS as an interim measure until such time as a comprehensive plan is developed.

A preliminary step was taken in February of this year (1981) to resolve a conflict on the Upper Colorado River. The proposed Windy Gap Project is designed to divert from one watershed up to 93,000 acre-feet per year into the Colorado-Big Thompson Project for eventual municipal and industrial use. FWS was concerned that further project development would jeopardize listed fish species.

With the rapidly-approaching deadlines for determinations on Windy Gap and several other projects, FWS developed the concept of providing additional study and the development of a Conservation Plan while allowing the water resource projects to proceed. The central thesis behind this plan is that the continued impacts of further reductions and modifications in streamflows by projects in the Upper Colorado River System will result in the eventual extinction of these species. The proposed Conservation Plan would allow projects to be constructed while providing for (1) the maintenance of current populations of these species in areas where no water projects are planned, (2) artificial propagation, (3) habitat development and improvement, and (4) continued investigations as required to insure success of the program.

In resolution of the Windy Gap Project, the Northern Colorado Water Conservancy District agreed that it would fund certain measures for the conservation of the endangered fish. FWS will work with the District in developing options. As a result, a non-jeopardy opinion was reached, and the project is proceeding. In rendering this opinion, FWS had to evaluate the expected project impacts on the present survival of the species, separate from its future recovery. Obviously, an approach of this nature may not be applicable to other types of projects.

It is proposed that construction of pending projects be authorized in conjunction with plan implementation. Several other project sponsors have agreed to finance a portion of the plan, with costs allocated in direct proportion to the amount of water withdrawn. This plan will be subject to modification as more analyses of fisheries data are made.

A further refinement of this conceptual approach was detailed in a 17 April 1981 letter from Interior Under-Secretary Donald Paul Hodel to the Cheyenne Board of Public Utilities on the proposed Stage II of the Cheyenne Water Supply Project. The proposal, accepted by the Utility Board, "would allow construction to proceed in conjunction with implementation of a management plan." The three points of this proposal include: (1) FWS will continue with the Yampa River Study with a determination at the completion as to the likelihood of jeopardy; (2) FWS will issue a non-jeopardy opinion contingent on point three; and (3) the City of Cheyenne will agree, contingent upon the final study determination, to fund a plan, not to exceed $180,000. It was determined by FWS personnel that, because of the nature of Stage II of the project (small water depletion), survival of the species would not be jeopardized. However, the effect on the eventual recovery of these fish again could not be determined. A non-jeopardy opinion was issued, allowing the project to proceed.

To accomplish the development of the Colorado River Endangered Fish Conservation Plan, FWS has recently appointed a coordinator. The Service will consult with and receive input from all agencies, states, and interested parties in the formulation of this plan. Aspects of the plan to be considered are: identification of those areas of the Colorado River Basin that are critical to the recovery of listed fish, identification of major problems facing listed species and strategies for solving the problems, completion of existing studies and recovery plans for all species, use of the plan in application to upcoming biological opinions, analysis of existing and expected data, management potential and problems, fish culturing and stocking, and estimates of annual costs.

Without a general plan for the conservation of endangered fishes, development actions may be inconsistent and unsound. A comprehensive plan will require the cooperation of myriad and diverse interest groups. The goal will be to assure beneficial impacts from project development that can be applied to the survival and eventual recovery of listed fishes. The ultimate goal is to protect these fishes and, therefore, the natural ecosystem to the extent possible, while permitting responsible economic growth and development in the basin.

PROVIDING WATER FOR ENDANGERED FISHES IN THE UPPER COLORADO RIVER SYSTEM

Reed E. Harris, Harold N. Sersland, and F. Phillip Sharpe

ABSTRACT

The Bureau of Reclamation is responsible for development of water resources and also for protection of endangered fishes. This paper discusses water-supply problems, legal and institutional constraints on water use, and political realities of water management. Compromises in water use will be necessary to preserve endangered fish species in the Upper Colorado River System. *(Editors' abstract)*

Most people recognize the role of the Bureau of Reclamation (Reclamation) in building hydroelectric dams and irrigation delivery systems and in providing municipal and industrial water supplies. However, as a federal agency, Reclamation is charged also with a responsibility to conserve, protect, and restore endangered species. Often our responsibility to develop water conflicts with the responsibility to preserve the fish using that same water. In the Upper Colorado River Basin, this conflict has led to all of our projects (planned, under construction, or operational) having undergone, to some degree, consultation with the Fish and Wildlife Service. The objective of this consultation has been to promote the continued existence of three endangered fish species, the Colorado squawfish *(Ptychocheilus Lucius),* the humpback chub *(Gila cypha),* and the bonytail chub *(Gila elegans).*

A realistic view of the endangered species problem in the Upper Colorado River Basin requires discussion of three important areas which determine water use: (1) natural flow conditions of the Colorado River System, (2) legal constraints imposed on the construction and operation of facilities, and (3) the political climate in an area with limited water resources and enormous growth potential.

NATURAL FLOW CONDITIONS

The natural flow of the Colorado River as it leaves the Upper Basin at Lee Ferry has averaged slightly less than 15 million acre-feet (MAF) annually over the last 80 years. Annual flows have ranged from a low of 6 MAF to a high of 24 MAF, and instantaneous flows varied from 1,000 feet^3/second (cfs) to 300,000 cfs. Flows in major tributaries such as the San Juan, Green, Yampa, and Gunnison rivers have likewise been erratic; some reaches of these tributaries dry up completely during extreme drought periods. Sediment loads in the river have also varied naturally from less than 1% in the Colorado at Lee Ferry to over 10% in lower reaches of the San Juan, Dirty Devil, Escalante, and Paria rivers.

With construction of the Colorado River Storage Project and other multipurpose developments in the Upper Basin, about 25% of the natural flow is being used. Natural and present-day distributions above Lee Ferry are shown in Table 1.

Because numerous small tributaries make up the total Colorado River streamflow, the percentages of large tributaries do not sum exactly. However, a general review of the contributions of the major Upper Basin tributaries shows that Green River Basin flow has been reduced by 5%, Colorado River Basin by 13%, and San Juan River Basin by 3%. Maintenance of remaining flows for instream purposes such as fish, wildlife, and recreation depends primarily on the compacts, agreements, laws, and treaties in and between Upper and Lower Basin states and Mexico.

TABLE 1. Percent of estimated flow of the Colorado River above Lee Ferry, by river basin

River basin	Natural flow	Remaining flow
Upper Green River	13.1	10.2
Yampa River	8.1	8.0
Duchesne River	5.2	3.0
White River	3.8	3.8
Total Green River (above Green River, Utah)	36.2	30.9
Upper Colorado River	23.6	10.8
Gunnison River	15.5	15.5
Dolores River	5.4	5.4
Total Colorado River (above Cisco, Utah)	45.1	32.3
Upper San Juan River	8.0	7.1
Total San Juan River (above Bluff, Utah)	14.4	11.8
Total Colorado River (above Lee Ferry, Arizona)	100.0	75.0

LEGAL AND INSTITUTIONAL CONSTRAINTS

The major legal constraints that impose operational restrictions on our facilities include the Colorado River Compact , Upper Colorado River Basin Compact[2], Mexican Water Treaty[3], and Colorado River Storage Project Act[4].

The Colorado River Compact, completed in 1922, provided for division of water between the Upper and Lower Basin states, anticipated demands of an eventual Mexican Water Treaty, and imposed certain restrictions on quantities and scheduling of flows. The Compact was drafted by representatives of the seven Colorado River Basin states; it apportioned, in perpetuity, 7.5 MAF per year to the Upper Basin states of Colorado, New Mexico, Utah, and Wyoming and 7.5 MAF per year to the Lower Basin states of Arizona, California, and Nevada. The Compact further provided that the states of the Upper Basin would not cause the flow of the Colorado River to be depleted below an aggregate of 75 MAF for any period of 10 consecutive years. If sufficient surplus waters were not available for Mexico's allotment of 1.5 MAF annually, the deficiency would be made up equally by the Upper and Lower Basins.

The 1948 Upper Colorado River Compact permitted Arizona to use 50,000 acre-feet of water annually from the Upper Colorado River System and apportioned the remaining water to the other Upper Basin states, as follows: Colorado, 51.75%; New Mexico, 11.25%; Utah, 23.00%; and Wyoming, 14.00%. These are consumptive-use rights, and the states may divert more than their entitlement provided return flows are sufficient to make up the delivery requirement to the Lower Basin states and Mexico.

The division of water among the states opened the way for development of Upper Basin water projects which Congress had previously not approved. Therefore, in 1956, Congress enacted the Colorado River Storage Project Act, which included four large mainstem storage units on the Colorado River and its tributaries — Glen Canyon, Flaming Gorge, Navajo, and Curecanti (now Wayne N. Aspinall). With the construction of the six reservoirs that are part of those storage units (Lake Powell, Flaming Gorge, Blue Mesa, Morrow Point, Crystal, and Navajo), about 26 MAF of storage space became available for making Compact delivery at Lee Ferry, Arizona during periods of subnormal runoff.

Initial filling of the mainstem reservoir system was completed with the filling of Lake Powell in June 1980. Operation of the system during the current year and in future years will be governed by the terms of the "Long-Range Operating Criteria for Colorado River Reservoirs" that were established in 1970 in accordance with Title VI of the 1968 Colorado River Basin Project Ace. The major purposes of the Operating Criteria are to establish the factors and applicable laws which determine how much water should be stored in Upper Basin reservoirs and to establish minimum quantities of water to be released. The criteria are reviewed every 5 years and are subject to modification by the Secretary of the Interior.

In addition, each reservoir has its own operating procedures, which are generally governed by flood-control criteria, downstream demands, energy-production requirements, and minimum releases for fisheries and recreation. Operational flexibility normally exists within the major mainstem facilities to provide needed flows for a variety of purposes. Balancing those needs now and in the future will be Reclamation's biggest challenge.

POLITICAL REALITIES

As the Upper Basin states develop their entitlement to Colorado River water, consumptive uses will increase and less water will be available for instream uses. Obviously, operational flexibility will decrease as specific uses increase.

With the main-stem Colorado River storage systems in place and filled with water, the useable or controllable yield of the system at Lee Ferry is about 14.0 MAF (the remaining 1.0 MAF is not controllable). The consumptive use in the Upper Basin, including reservoir evaporation, is currently about 4.0 MAF; the remaining 10.0 MAF will be scheduled for future development, meeting downstream commitments, and maintaining instream values.

As projected use increases to 4.9 MAF by 1990, 5.4 MAF by 2000, and 5.8 MAF by 2030, the average annual flow at Lee Ferry will decrease from 10.0 MAF to 9.1 MAF in 1990, 8.6 MAF in 2000, and 8.2 MAF in the year 2030. These reductions will affect the percentage of natural flow in Upper Colorado River streams as shown in Table 2. The remaining percentage of natural flow indicates which streams have been and will be most severely impacted. Streams such as the Duchesne could be reduced 70% in volume by the year 2030, but the majority of the reduction will occur during high spring runoff. Regulation of streamflow may, in some cases, provide increased flows during specified times of the year when the needs of endangered fishes could be critical. Comparing the depletions in the three river basins with the data we are now gathering on distribution, abundance, and flow requirements of

'Colorado River Compact signed 24 November 1922, at Santa Fe, New Mexico.

[2]Upper Colorado River Basin Compact signed 11 October 1948, at Santa Fe, New Mexico.

[3]Mexican Treaty and Protocol signed in Washington, DC, 23 February 1944, and Protocol completed 8 November 1945.

'Act of 11 April 1956, Public Law 84-485, 70 Stat. 105.

[5]Act of 30 September 1968, Public Law 90-537, 82 Stat. 885.

the endangered fishes, we should be able to develop some flexibility in our release patterns to assure continued fish survival.

Ultimately, our challenge will be to determine and weigh the economic and social values of the food and fiber, electric power, recreation, fish and wildlife, and flood control in a highly competitive water-use situation. These values will have to be related to the development and scheduled release of water and will require all of us to make compromises that will allow us to meet human needs while protecting and preserving endangered Colorado River fishes.

TABLE 2. Estimated future flows as a percentage of natural flow in the Colorado River above Lee Ferry

River basin	Natural flow	Present (1980)	1990	2000	2010	2030
Upper Green River (above Flaming Gorge)	100	78	74	71	67	62
Yampa River	100	99	98	95	93	93
Duchesne River	100	37	37	29	29	29
White River	100	100	79	76	74	74
Total Green River (above Green River, Utah)	100	85	79	75	73	71
Upper Colorado River (Colorado River above Cameo)	100	46	42	38	36	36
Gunnison River	100	100	99	99	99	99
Dolores River	100	100	89	86	86	86
Total Colorado River (above Cisco, Utah)	100	72	68	66	65	65
Upper San Juan River (above Navajo Dam)	100	89	89	89	89	89
Total San Juan River (above Bluff, Utah)	100	82	69	67	70	70
Total Colorado River (above Lee Ferry, Arizona)	100	75	67	64	64	61

REALITIES AND ILLUSIONS OF ENDANGERED SPECIES PRESERVATION

Robert J. Behnke

ABSTRACT

Maintenance of endangered fishes in the Upper Colorado River Basin is difficult in light of present sociopolitical and legal constraints on water use. Preservation of these endangered fish is a long-term proposition, essentially forever, while our political and legal concern for the fishes may be short-term. The fate of these fishes is uncertain. An independent agency immune to political changes and changing priorities is recommended to oversee their recovery. *(Editors' abstract)*

The preservation of endangered species is a long-term proposition; for practical purposes, it must last forever. Our political system, which makes laws and establishes policy, however, is subjected to short-term, cyclical fluctuations. It is reasonable to assume that the initial interest, efforts, and determination to save species from extinction will not be maintained in a steady-state condition but will fluctuate with political cycles. It is an illusion to believe that the Endangered Species Act will maintain the present environmental conditions in all sections of the Colorado River Basin where endangered species presently exist. I assume that future dams, diversions, and energy-development projects that alter flow regimes and water quality will continue to be created in the belief that they serve our national interest. Determined efforts can be made, however, to plan and operate new projects in the most environmentally-sound manner and to modify operational regimes of existing works to do minimal harm, and perhaps some good, for the endangered species.

Many reasons have been advanced concerning why it is good and proper to save species from extinction (Behnke and Benson 1980). Most reasons stress practical, economic values associated with species diversity, ecosystem diversity and stability, or some, as yet unknown, value to mankind. Ehrenfeld (1976), however, correctly pointed out that, in most cases, a cost/benefit analysis for saving a rare species in conflict with competing uses of its environment will fail. Ultimately, a philosophical commitment of man's stewardship of the earth and of all its life is the most compelling reason to save species from extinction in a nonselective manner. Unfortunately, the number of people firmly committed to such a philosophy comprises a minor part of the total electorate. The great majority of Americans favor the concept of species preservation, but only in a nebulous way. They think it is right and proper and a nice thing to do, but understanding and enthusiasm to a point of personal sacrifice are characteristics lacking in the majority of voters.

The real question for the Upper Colorado River Basin is: How much influence can be exerted to change the way projects have been constructed and operated in the past to maintain specified flow regimes and water quality in the future in certain sections of the basin? To put some of the problems in perspective, it must be recognized that the Colorado squawfish, razorback sucker, bonytail chub, and humpback chub, which now have an aura of respectability and even some reverence, were considered undesirable trash fish in the not-too-distant past by professional fishery workers and natural resource agencies. At the 1962 annual American Fisheries Society meeting, a brochure was distributed detailing the urgency to rotenone almost 500 miles (805km) of the Green River and its tributaries before the closure of Flaming Gorge Dam. The goal was to eradicate such "trash" fish as Colorado squawfish and bonytail chub and make the waters of the new reservoir safe for the non-native rainbow trout. Indeed, the impoundments in the Colorado River Basin have created multimillion-dollar sport fisheries based entirely on non-native fishes; these fisheries would not be possible without the dams and non-native fishes. Lake Powell now has a thriving, reproducing population of striped bass that were stocked in 1974 and 1975. Conflicts between endangered species and non-native gamefishes, in relation to any action favoring endangered species at the expense of gamefish (such as trapping striped bass moving up the Colorado or Green rivers to spawn), would create a storm of controversy from newspaper columnists and state fishery agencies. These realities must be kept in mind when contemplating the limitations of endangered-species recovery programs.

Given these constraints, can the endangered species be maintained in their present environment? At this time, I really don't know. A hopeful note is that the endemic Colorado River fish fauna evolved in a highly-fluctuating environment. They must have evolved a wide range of adaptive responses and life-history strategies to survive in an unstable and extremely harsh environment.

Mitigation in the traditional sense is not really possible in this situation. We cannot replace a section of the Colorado or Green rivers by a like amount of habitat in the Mississippi or Columbia river basins. It may, however, be feasible to maintain flow regimes, particularly during spawning and rearing, that maintain nursery sites in large river sections where Colorado squawfish and humpback chub still reproduce and exist in moderate numbers. Candidate sections include the lower Yampa River, the Green River below the mouth of the Yampa, and the Colorado River below the mouth of the Gunnison.

The Upper Colorado River Basin officially begins at Lee Ferry, Arizona, about 15 miles (24km) below Glen Canyon Dam. Gradual, cumulative impacts of water diversions and flow depletions began about 100 years ago. Catastrophic events causing a rapid decline in the present endangered species were completion of Flaming Gorge and Glen Canyon dams in 1962 and 1963. The annual average virgin flow of the Colorado River at Lee Ferry was 14.9 million acre-feet (MAF). By 1975 this flow suffered an average annual depletion of over 3.8 MAF (26% of virgin flow). This depletion from consumptive irrigation, transbasin diversions, reservoir evaporation, and by cities and industry may reach about 5 MAF per year by the year 2000. The litany of abuses to the original ecosystem and to its native fishes could cause an attitude of hopelessness regarding prospects for maintaining the endangered fishes. However, 66-75% of virgin flow still offers considerable leeway to create adequate-to-good flows in the critical summer months if the operation of reservoirs storing peak runoff could be coordinated to maintain adequate flows during the critical periods of spawning and rearing of young. A major obstacle to coordinating flows for endangered species is the apportionment of water between the Upper and Lower Basin states according to the Colorado River Compact. An annual average of 7.5 MAF of water at Lee Ferry is guaranteed to the Lower Basin states, but this delivery can be made in varying annual amounts as long as they total at least 75 MAF in a 10-year period.

The original estimate of virgin flow in the Colorado River is probably higher than the actual long-term virgin flow. Considering this overestimate and evaporative loss from Lake Powell, it can be assumed that, in the future, when the Upper Basin states have virtually fully used their entitled water, about 60% of the virgin flow of the Colorado and Green rivers will still be reaching Lake Powell.

Planning an annual hydrograph to deliver 60% of the virgin flow through sections of the Colorado and Green rivers to Lake Powell to favor endangered species involves extremely sensitive political and legal issues regarding states rights of water appropriation. It will take a political figure with the patience of Job, the wisdom of Solomon, and the charisma of a great religious leader to come up with a solution to this problem.

What are "best" flows for reproductive success, and what are the safe limits of diurnal fluctuation in flows from peaking power production at dams? These questions have yet to be resolved. A considerable amount of study and monitoring will be needed for many years before the "best" flow regimes can be determined with some confidence for various river sections. Ensuring that such studies and monitoring are conscientiously carried out is a matter of concern. Interest and funding for Colorado River fish studies have fluctuated through the years like the river environment. Although the Colorado squawfish and humpback chub were included on the first list of endangered species developed by the U.S. Fish and Wildlife Service in 1964, there has been no continuity of study or coordination of efforts among various state and federal agencies until recently.

I propose that an independent agency be set up and funded by a small tax on benefits that cause environmental changes, such as electricity generated by hydropower, in the basin. Such an agency would be largely immune to political changes and changes in priorities by state and federal agencies.

I have noted that biologists personally involved in studies on the Colorado squawfish, humpback chub, and razorback sucker have developed an unusual degree of respect and devotion to these odd fishes. The fishes are recognized as the unique results of evolution in a unique ecosystem. They are worth any efforts or sacrifices necessary to preserve them from extinction.

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COLORADO RIVER FISHES RECOVERY TEAM

Kent D. Miller

ABSTRACT

The Endangered Species Act provided the basis for recovery teams and guides their action. The structure, function, and philosophy of the Colorado River Fishes Recovery Team are presented. New recovery plans for the Colorado squawfish, humpback chub, and bonytail chub are described and related to resource issues. *(Editors' abstract)*

INTRODUCTION

Recover(y): to regain normal health, poise, or status. To bring back to normal position or condition.

The Endangered Species Act of 1973, as amended in 1978, directs the Secretary of the Interior to develop and implement recovery plans for threatened or endangered species. To further this, the Act allows the Secretary to procure the services of appropriate public and private agencies and institutions and other qualified persons to aid in development and implementation of the recovery plans. This is the basis for recovery teams.

The primary duty of the Colorado River Fishes Recovery Team has been the development and timely revision of recovery plans for the Colorado squawfish *(Ptychocheilus lucius),* humpback chub *(Gila cypha),* and bonytail chub *(Gila elegans).* These recovery plans are based on information that is biologically and ecologically practical and feasible. According to U.S. Fish and Wildlife Service (FWS) guidelines, "Plan developers do not consider socioeconomic or political restraints." This statement is important; the Recovery Team is probably the only group that has had at least the potential of developing unfettered plans that would not only prevent extinction but fully recover the endangered Colorado River System endemic fishes to viable, self-sustaining members of their ecosystem.

THE TEAM

Representation On Team

The Team was first organized by FWS as the Colorado Squawfish Recovery Team in December 1975. The Team was formed with members from Arizona Game and Fish Department, California Department of Fish and Game, Colorado Division of Wildlife, Nevada Game and Fish Department, Utah Division of Wildlife Resources, U.S. Bureau of Land Management, U.S. Bureau of Reclamation, FWS, and National Park Service. Membership of the Team remains the same today. Representation from academia and consulting firms has been gained by appointment of consultants to the Team. In 1976, FWS expanded the Team's responsibility to include all Colorado River System fishes that were listed or proposed to be listed, and its name was changed to the Colorado River Fishes Recovery Team.

Team Function

The Team has written recovery plans for the Colorado squawfish and humpback chub. These plans have been recently revised and are currently undergoing review. FWS recently contracted the writing of the Bonytail Chub Recovery Plan. This Plan was directed and reviewed by the Team, and it is also undergoing interagency review.

Team Philosophy Regarding Recovery of Species

Since its inception, the Team has maintained that a species could not be considered fully recovered until populations were sustaining themselves through natural reproduction in their native ecosystem. It has been implicit that enough natural habitat must be maintained to sustain successful reproduction, rearing, and maturation. In furtherance of this philosophy, the Team discussed critical habitat for the Colorado squawfish at its first meeting and recommended critical habitat to FWS in 1976. Habitat was based on recorded occurrence since 1970, basically all we knew about distribution at that time.

As a result of Team recommendations and agency and public review, FWS wrote an environmental assessment and negative declaration for certain river reaches as critical habitat for the Colorado squawfish in 1976. This critical habitat was proposed by FWS in the Federal Register of 14 September 1978. The proposal was subsequently dropped (along with those for many other plants and animals) after the 1978 amendments made necessary economic analysis of critical habitat proposals.

Critical habitat for the humpback chub was discussed by the Team in 1978, and specific river reaches were designated by the Team as candidate areas. However, no action was taken on critical habitat designations.

Neither the Team nor anyone else was able to define critical habitat for the bonytail chub. Consequently, this species was listed at the last moment in April 1980 without critical habitat.

Although officially limited to consideration of Colorado squawfish, the Team at its first meeting recognized that, since much river habitat was being lost, the other large-river fishes of the Colorado System were also suffering the same plight as the Colorado squawfish. The Team recommended to FWS that the bonytail chub and the razorback sucker *(Xyrauchen texanus)* be listed as endangered.

Cognizant that current work on the river system still points to the rarity of the razorback sucker and to lack of evidence of reproduction, the Team again, in 1980, urged FWS to list the razorback sucker as threatened. Critical habitat for the razorback sucker has not been determined.

RECOVERY PLANS

The Bonytail Chub Recovery Plan attempts to deal with the apparent imminent extinction of this species. It does not present a recovery goal, but it states that the threat of extinction will be reduced if a bonytail chub population can be maintained in Gray Canyon and an additional reproducing population is established through hatchery rearing and reintroduction to the best available habitat.

The Colorado Squawfish and Humpback Chub Recovery Plans have similar primary goals for recovery — self-sustaining reproducing populations, dependent on suitable habitat sustained by instream flow rather than on artificial culture. To downlist the Colorado squawfish, the plan calls for maintenance of viable stocks in the Green River from its confluence with the Yampa River to its confluence with the Colorado River, the Colorado River from Palisades to Lake Powell, and the Colorado River (Parker Division and Imperial Division). The plan will allow delisting when additional viable stocks are established in the Salt and San Juan rivers.

The Humpback Chub Plan calls for the restoration and maintenance of five self-sustaining populations in the Colorado River System in 1990. The deadline is unique to this species plan; it is admirable but may be too late.

OUTLOOK FOR THE UPPER COLORADO RIVER SYSTEM

The three recovery plans have three recommended actions in common — protection of existing stocks and habitats, maintenance of captive gene pools, and restoration to former range.

These species are, of course, not yet extinct, but it seems completely reasonable to attempt to protect the remaining fish and their habitat. In recommending that habitat be protected, the Team recognized that existing dams and diversions can, perhaps, be modified in favor of the native fish. Dams cannot be expected to be removed and pristine conditions returned. The Team has recommended that comprehensive research be carried out on the fish and their habitat requirements so that future modification of the river system can be done in a manner that will not harm them and will allow full recovery of the species according to the primary goals of each recovery plan. The Team recognizes the concern that many developers and regulatory agencies have shown about allowing research to seek new solutions. Nonetheless, maintenance of captive reserve gene pools is recommended to prevent some catastrophe from extirpating part or all of the remaining large-river fishes.

The recovery plans call for reintroduction of all three species into some portion of their former range. The Colorado Squawfish Plan requires successful reintroduction in the Lower Basin prior to downlisting or delisting. The Humpback Chub Plan asks for securing humpback chub in five stable habitats, and the Bonytail Chub Plan calls for reintroduction to the areas of best available habitat in the Green River. These reintroductions are important philosophically, for if habitat is preserved and/or managed to sustain the resulting native fish populations, they spell the difference between prevention of extinction and full recovery of the species.

The recovery plans recommend that these major actions be accomplished by the following means:

1. *Research into life history and habitat requirements.* There have been many efforts to gather basic life-history and habitat-requirement data. The Colorado Division of Wildlife and FWS have accomplished much since the first recovery plans were written.
2. *Identifying and monitoring habitat and fish populations.* The recovery plans ask FWS to develop monitoring techniques and the states to do the actual monitoring. No standard monitoring techniques have been promulgated yet. Colorado has an annual monitoring program, and Utah is planning a program.
3. *Enforcement of existing laws to protect habitat and fish stocks.* Effective habitat protection laws and regulations are mainly those of the federal government. Some of the more important are Section 7 of the Endangered Species Act and Section 404 of the Clean Water Act. Laws protecting fish include Section 9 of the

Endangered Species Act and state laws preventing the taking of listed fish.

4. *Information and education programs.* The plans all recommend local and nationwide information and education programs. The Team believes it is imperative to educate the citizenry on values of endemic species and recognizes that only a public that believes in the intrinsic value of each species will allow its full recovery. These species will probably never completely recover unless public attitudes are changed to place high value on native fauna.

5. *Hatchery culture.* Artificial culture in hatcheries will be used to provide fish of all listed species for reintroduction and maintenance of captive gene pools. Hatchery rearing is being carried out at FWS hatcheries.

6. *Stocking for reintroduction into former range and to bolster existing stocks.* This seems an obvious and easily-accomplishable approach to recovery. It is, however, one with serious obstacles. The political bodies of the Upper Basin states believe that these endangered species could prevent development of natural resources, including Colorado River System water. The solution is to convince development interests that stocking listed fish (combined with habitat management) will contribute to recovery and hence delisting. I stress that the Recovery Team generally considers maintenance stocking of cultured fish in a role subordinate to providing habitat and management for self-sustaining populations.

7. *Habitat-management plan.* The Colorado Squawfish and Humpback Chub plans include the preparation of habitat-management plans. The plans recognize that habitat change is the primary factor causing the rarity of these species.

LIFE HISTORY AND PROSPECTS FOR RECOVERY OF COLORADO SQUAWFISH

Paul B. Holden and Edmund J. Wick

ABSTRACT

The endangered Colorado squawfish, *Ptychocheilus lucius,* is restricted to the Green, Yampa, and White rivers in Colorado and Utah and the mainstem Colorado River below Grand Junction, Colorado. Habitat preferences of these long-lived large-river fish change with age, season, and habitat availability. Relatively little is known about their growth and movements. Prespawning temperatures and flows are major determiners of reproductive success. Dam construction was the main reason for squawfish declines in the Upper Colorado River Basin. Reproducing populations remain relatively large only in the Green River System. Prospects for recovery in areas with potentially good habitat are bright from a biological viewpoint, but meager possibilities of assuring adequate streamflows in the future seem a major obstacle to recovery in natural ecosystems of the Upper Basin. *(Editors' abstract)*

INTRODUCTION

The Colorado squawfish *(Ptychocheilus lucius)* is North America's largest native cyprinid, at one time reaching 1.5-2.0 m and 35-45 kg. It was used as food by Indians and early white settlers. Early distributional records established its range throughout the Colorado River System in the main channels and larger tributaries (Girard 1856; Jordan 1891; Jordan and Evermann 1896; Gilbert and Scofield 1898; Ellis 1914). Very few published accounts of the species exist for the first half of the 20th Century. In the 1960's the construction of large dams that threatened the river and its inhabitants spurred investigation of this species and the other rare fish. The Colorado squawfish is the most studied of the four rare, large-river endemics, probably due to its more widespread occurrence and its economic link with the past history of the West.

The Colorado squawfish is one of four species of *Ptychocheilus,* all found in western North America. The Sacramento squawfish *(P. grandis)* is endemic to the Sacramento River System in California. The Umpqua squawfish *(P. umpquae)* is found only in the Umpqua and Siuislaw rivers of Oregon, and the northern squawfish *(P. oregonensis)* is found in the Columbia River and other coastal streams in Washington and Oregon. Of the four, only the northern squawfish is abundant, scorned as a predator on gamefish and the target of specific poisons and other eradication techniques.

The Colorado squaw fish was very common at one time, abundant enough to be pitchforked out of irrigation canals in Arizona (Miller 1961). Presently it is extinct in the Colorado System below Glen Caynon Dam (Minckley 1973), the Green River above Flaming Gorge Darn (Baxter and Simon 1970), and the San Juan River in New Mexico (Frontis.). The Green River System of Colorado and Utah, including the Yampa and White rivers, and the main-stem Colorado River below Grand Junction, Colorado harbor the last remaining populations. One juvenile was recently captured in the San Juan River of Utah (VTN 1978). Reproductive success is highest in the Green River (Holden and Stalnaker 1975a).

This paper will discuss what is presently known concerning Colorado squawfish life history and the chances for survival of this unique animal. Many of the recent findings on this species have not been formally published but are contained in readily-available reports from various agencies and private concerns. An extremely intensive study on this species is presently being conducted by the U.S. Fish and Wildlife Service (FWS). One of us (Wick) has been involved in this study, and some general observations are included in this report. More detailed data should be available in 1982 when FWS completes its study (Miller *et al.* 1982a, b).

LIFE HISTORY AND BIOLOGY

Age and Growth

Vanicek and Kramer (1969) provided the first comprehensive information on age and growth of Colorado squawfish. Their mean calculated total lengths for 658 fish from the upper Green River showed that young squawfish grew about 50 mm per year until after year 3, when annual increments increased for a couple of years and then decreased as the fish became larger. Three-year-old fish were about 162 mm total length, age 4 fish were 238 mm, age 5 fish, 320 mm, and age 8 fish, 499 mm. Seethaler (1978) found similar growth rates for older fish from the Colorado and Yampa rivers.

Fish from the lower Green River, where water temperatures warm earlier each year, probably grow faster. Holden (1977) found young-of-the-year in Gray Canyon were larger than those reported by Vanicek and Kramer (1969) from the upper Green River at about the same age.

Colorado squawfish are long-lived fish; Vanicek and Kramer (1969) found an 11-year-old, 610-mm female. Since fish of 700-900 mm have recently been caught, and the old reports of 2-m specimens appear valid, the potential life of Colorado squawfish must be 20-50 years or more.

Length-Weight Relationship

The Colorado squawfish is a relatively elongated, very pike-like fish. Fish under 400 mm are often quite thin. Vanicek and Kramer (1969) reported a weight-length relationship of log W = —5.4177 + 3.126 log L for fish from the upper Green River. Seethaler (1978) calculated similar relationships for Colorado squawfish from the Colorado and Yampa-Green rivers. This indicates that the weight of Colorado squawfish increases slightly faster than the cube of the length (Vanicek and Kramer 1969).

Food Habits

Young Colorado squawfish start eating small crustaceans (copepods and cladocerans) and small aquatic insect larvae (chironomids), gradually increasing the size of food items (insects) until they are about 100 mm in length; then fish become the major food item. They become almost entirely piscivorous after 200 mm (Vanicek and Kramer 1969). Little is known about major prey species of fish. Vanicek and Kramer (1969) found remains of redside shiners *(Richardsonius balteatus)*, an introduced species, most prevalent. It would appear that young of flannelmouth sucker *(Catostomus latipinnis)* and bluehead sucker *(Pantosteus discobolus)*[1], the two most abundant native species throughout most of the Upper Colorado River Basin, were probably the most common natural prey species. The present abundance of introduced cyprinids [red shiner *(Notropis lutrensis)* and redside shiner] has probably provided additional prey. Recurrent stories of large, dead Colorado squawfish with channel catfish *(Ictalurus punctatus)* wedged in their throats suggest this predator probably feeds on whatever it can catch, including at least this one deadly exotic.

Habitat Requirements

The Colorado squawfish has always been considered a "large river" fish and is seldom found in small tributaries. They inhabit the larger and medium-sized tributaries, including the Yampa, White, Duchesne, Dolores, and Gunnison rivers (Frontis.). No actual size definition has ever been attempted, to our knowledge, to determine if river size is actually a requirement. Adults have been found in the mouths, or short distances upstream, of several small streams along the Green River during high-runoff periods. Habitat formed when the mouths of these streams are dammed by the Green River appears to be preferred.

In many of the tributaries that Colorado squawfish utilize, their upstream range is usually at the lower end of the trout (cold-water) zone. In the Green River of Wyoming, Colorado squawfish were reported to Green River, Wyoming, but not above. In the Yampa River, only one has been taken above Craig, Colorado. In the Gunnison River, Delta, Colorado appears to have been the upstream range of this species, although recently they have not been found this far upstream. Therefore, stream size and summer temperatures appear to be determining factors in habitat selection.

Stream areas used by Colorado squawfish have been intensively studied in recent years. Young squawfish (1-, 2-, and 3-year-old fish) prefer backwaters and other areas with slow current and (usually) a silt or silt-sand substrate (Fig. 1) (Vanicek and Kramer 1969; Holden and Stalnaker 1975a; Holden 1977; Twedt and Holden 1980). Changes in habitat selection during various seasons have not been noted. It is highly probable that flowing portions of the river are utilized during winter, since many backwaters are frozen solid.

Larvae in the Yampa and Upper Colorado rivers are found in a variety of calm habitats, often alongside rather swift currents. Since neither of these rivers has many good backwaters, the larvae probably find the best available habitat and drift downstream looking for better habitat.

As Colorado squawfish become larger (150-200 mm), numbers caught drop dramatically (Holden 1977; Holden and Selby 1979). This same phenomenon was noted by McAda (1977) for juvenile suckers. It appears that this is the size at which these fish begin using the main river channels; hence, they become much more difficult to sample. Food habits changes, from insects and crustaceans (most common in backwater areas) to fish that are found in a larger variety of habitats, also suggest a move. The ability of juveniles to maneuver in the main channels is probably also enhanced after they reach about 200 mm in length.

Adult habitat preferences change with season as well as with the habitat available. Twedt and Holden (1980) summarized much of the available data and categorized habitat preferences for substrate, depth, velocity, and cover for pre-runoff, runoff, and post-runoff periods (Figs. 2, 3, 4). These data indicate that adults prefer run habitat along shores of medium depth during pre- and post-runoff periods. They prefer backwaters during high-flow periods, although runs are also used during this time. This same general pattern was noted in the Yampa River in 1981 (Miller *et al.* 1982a). Adult squawfish were found in eddies and near mouths of irrigation returns (as well as along the shorelines of runs) during pre-runoff, sought out large back-

[1]The authors do not agree with the change of the generic name to *Catostomus,* as proposed in the *List of Common and Scientific Names of Fishes* published by the American Fisheries Society.

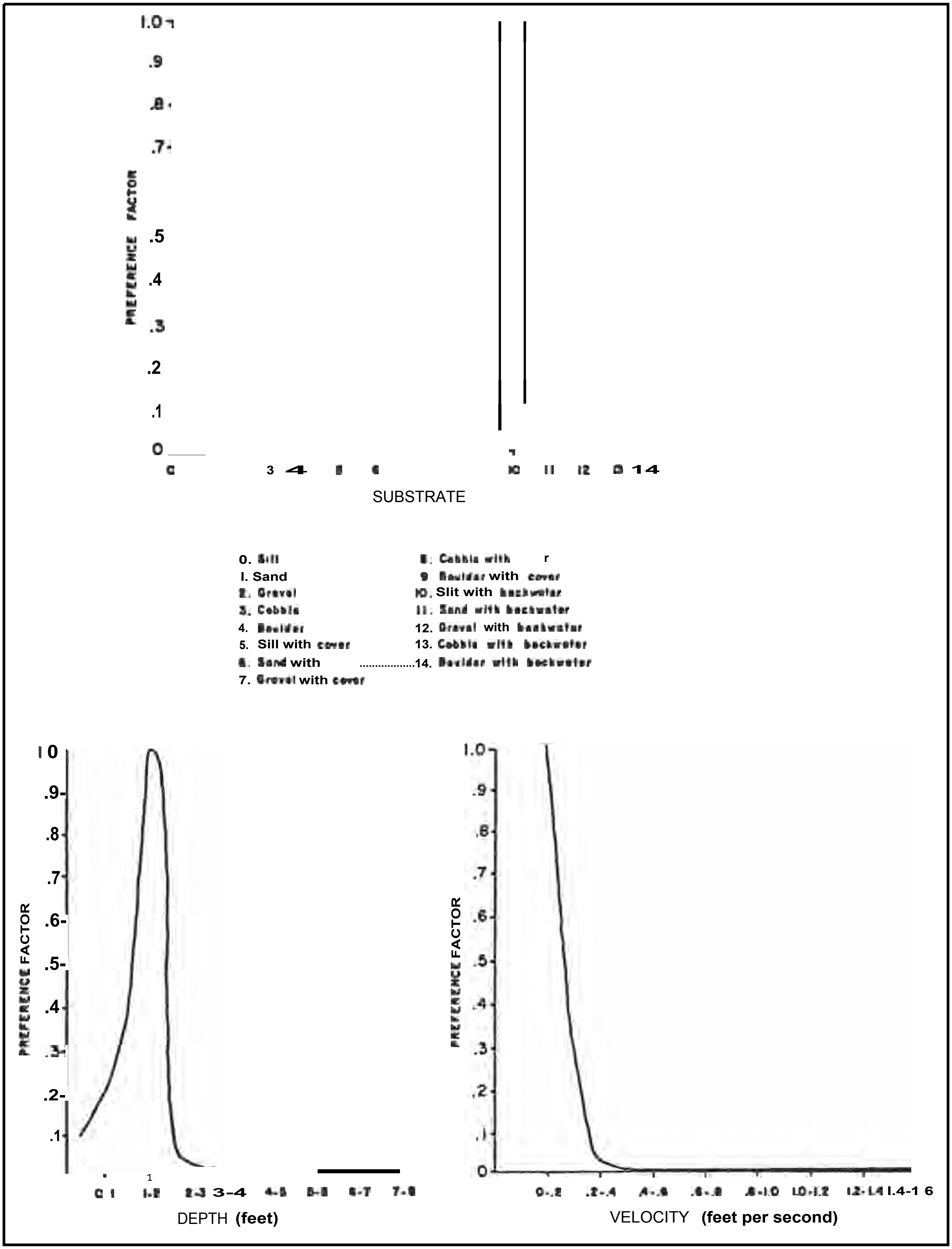

Figure 1. Habitat suitability curves for young-of-the-year and juvenile Colorado squowfish (from Twedt and Holden 1980).

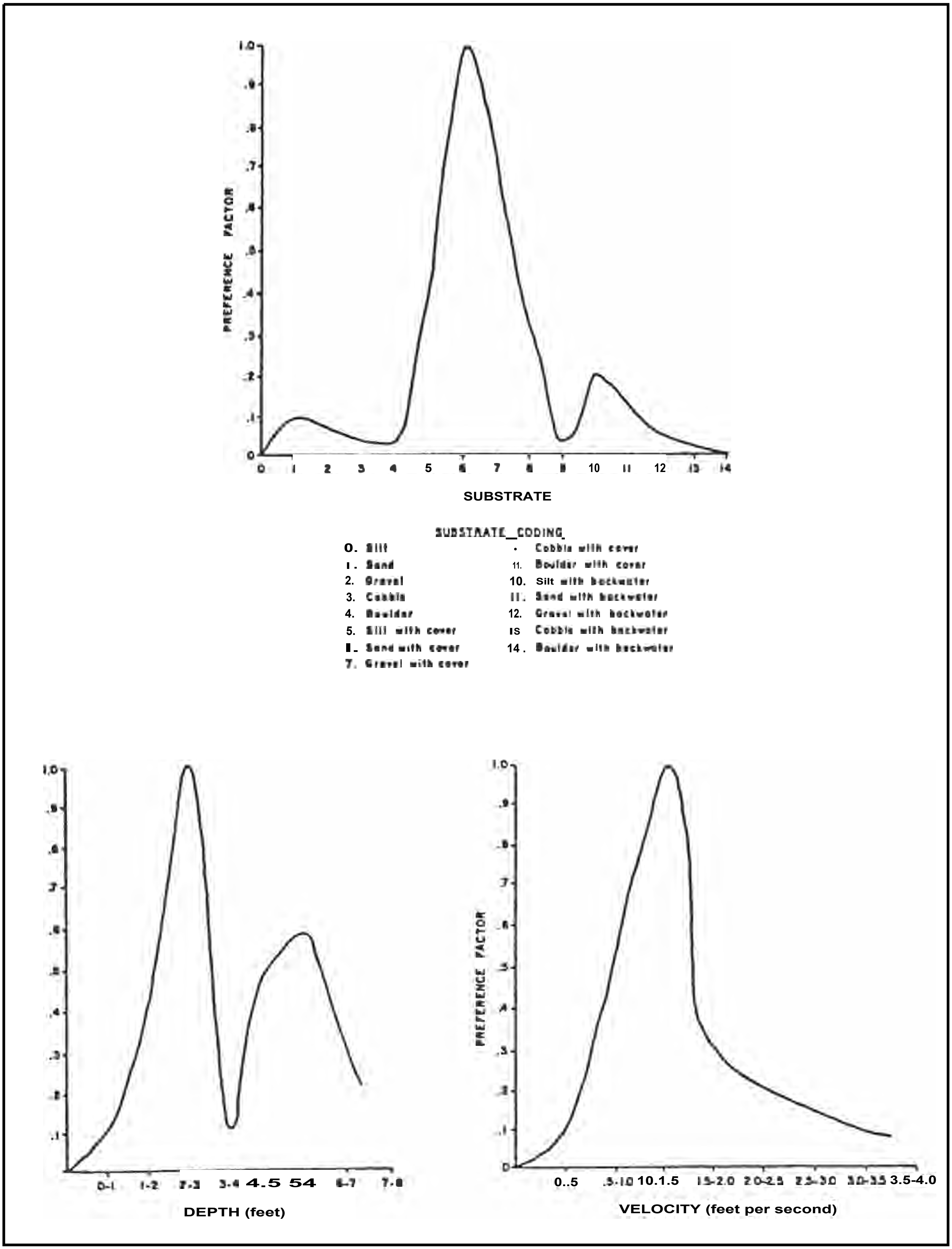

Figure 2. Habitat suitability curves for adult Colorado squawfish during the pre-runoff season (from Twedt and Holden 1980).

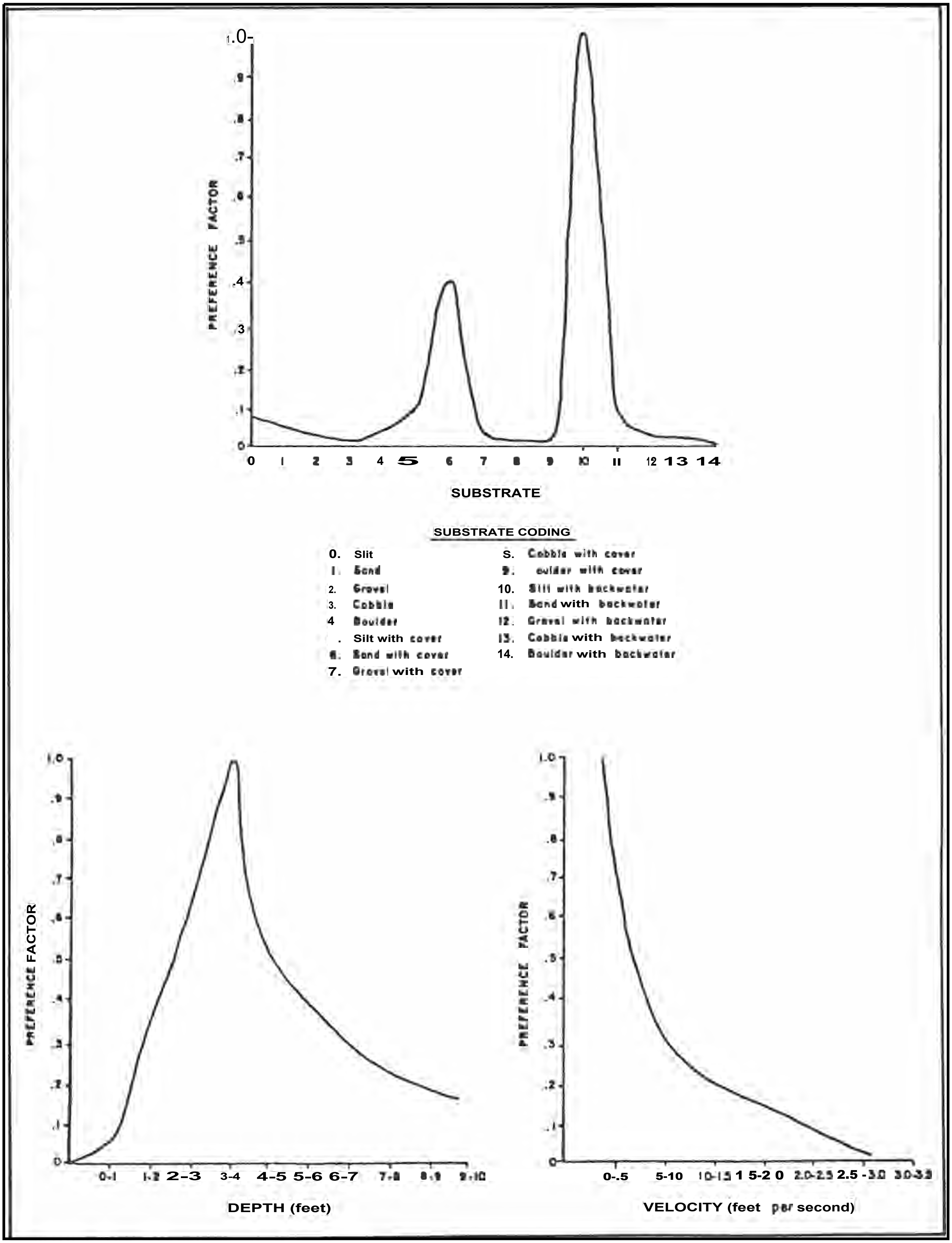

Figure 3. Habitat suitability curves for adult Colorado squawfish during the runoff season (from Twedt and Holden 1980).

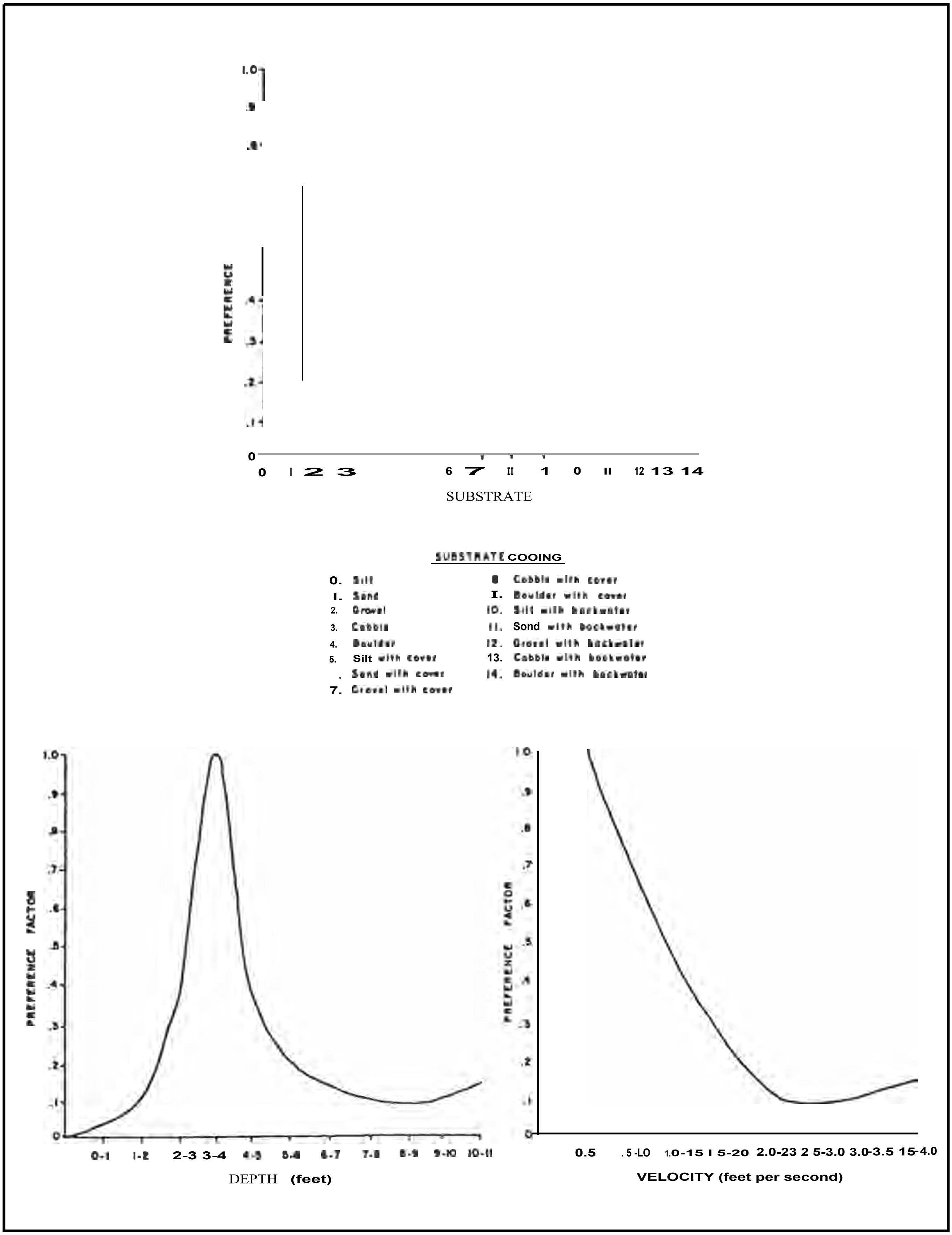

Figure 4. Habitat suitability curves for adult Colorado squawfish during the post-runoff season (from Twedt and Holden 1980).

waters during runoff, and utilized deep holes and diverse habitats in post-runoff periods. Habitat preference curves have been constructed by the Cooperative Instream Flow Service Group (Miller *et al.* 1982b), and are in general agreement with those shown here.

Valdez *et al.* (1982) presented habitat curves for 34 adult squawfish collected in the Colorado River in 1979. Those curves indicate a preference for boulder-bedrock substrate and some smaller preference for deep areas (20-30 ft; 6-9 m). The fish used in that analysis primarily came from Black Rocks, a deep, incised, 0.25-mile (0.40 km) portion of the Colorado River with an extruded black schist substrate. Since that area is unusual, and similar habitat is not generally available in other portions of the Upper Colorado Basin, these data must be used with caution when projecting habitat availability in other areas. This raises the general question: Is there a dramatic variation in habitat preference between portions of the Upper Basin? The answer appears to be no, although some local preference changes do occur with the type of habitat available.

Movement

Many accounts of Colorado squawfish "spawning migrations" can be found in the early literature and in discussions with "old timers" (Minckley 1973), and movement of large numbers of ripe males into the Yampa River during mid- and late summer was observed in squawfish from the upper Yampa River in 1968-1970 (Holden and Stalnaker 1975b). In 1981, radio-tagged adult Colorado squawfish from the upper Yampa River moved as much as 145 km downstream to the lower Yampa (Tyus *et al.* 1982). Other adults tagged in the Green River moved upstream about 80 km into the Yampa River. These radio-tagged fish were located near several ripe males and a female that had apparently just spawned. The seasonal increase in adult numbers in the Yampa River was also noted by Seethaler (1978). The probable reason for this movement into the Yampa is for spawning, as noted by Tyus *et al.* (1982). Holden (1977) suggested that spawning occurred at various locations in the Green River as evidenced by location of young-of-the-year. This indicates that migrations may not be very long, that all fish may not move to spawn, and that spawning occurs at several locations in the Green River System.

Daily (short-term) movements are poorly understood. A general pattern of movement at dawn or dusk has been noted by a number of researchers; catch rate increases at these times. Radiotelemetry studies by FWS (Miller *et al.* 1982b) have indicated most adult Colorado squawfish select rather sheltered areas near shore, to which they often return after moving about a section of river. These short-term movements are intensified during dawn and dusk. This suggests that adults may move about to feed, which might be expected for a piscivore in a turbid river.

Mark-recapture efforts have not provided much data on movement, although many adult Colorado squawfish have been tagged. Holden and Crist (1981) recaptured one adult Colorado squawfish near Jensen, Utah that had moved less than 1 km in more than a month. Another adult was tagged near Jensen by FWS in August 1979 and was recaptured in the Yampa River in October 1980 (Wick *et al.* 1981). The FWS (Tyus *et al.* 1982) recaptured two Colorado squawfish in the Yampa River in 1981 that had been tagged in the Yampa River 65-130 km upstream. Another fish had originally been tagged near Ouray, in the Green River, and was recaptured in the upper Yampa River, 173 km above its mouth. The two Green River fish moved considerable distances upstream. Recent radiotelemetry studies by FWS (Tyus *et al.* 1981) have shown that some adults move very little for rather long periods of time (1-2 months), others move more regularly, and sudden movements of over several hundred km up- or downstream occur.

Movements of young fish in a backwater studied by Holden (1977) suggested considerable movement either within a backwater or between the main channel and the backwater. This was based on a mark-recapture study for 2.5 days. The FWS is presently studying young fish movement, and they have found a daily movement pattern in and out of backwaters (Charles McAda, U.S. Fish and Wildlife Service, Vernal, Utah, 1980 pers. comm.). Just where the young fish are when they are not in the backwater has not been determined.

To our knowledge, there are no data to suggest how far downstream young Colorado squawfish move after hatching. Holden and Crist (1981) suggested downstream drift was not for long distances but probably lasted only until suitable habitat was reached. Bill Pearson (University of Louisville, Louisville, Kentucky, 1980 pers. comm.) studied invertebrate drift in the Green River in the mid-1960's; he caught no larval fish and saw only one fish egg in his nets. Recent collections of larval and young-of-the-year Colorado squawfish in the Yampa and Upper Colorado rivers (Miller *et al.* 1982b) suggest some downstream movement, perhaps as much as 150 km, may be occurring. Collections of young-of-the-year for the past 15 years (Vanicek and Kramer 1969; Holden and Stalnaker 1975a; Holden 1977) in the Colorado and Green rivers do not support a hypothesis of long-distance downstream movement by larvae. These data, along with general observation in the field, suggest downstream larval fish movement of all the native species of fish in the Upper Colorado System did not evolve as a reproductive or distributional attribute but may be used by young to locate acceptable habitat. Movement may be greatest in areas of marginal habitat, such as the Colorado River in Colorado, where streamflow has been greatly reduced and backwater habitat is relatively scarce.

Reproduction and Early Life History

Colorado squawfish mature in 5-7 years (Vanicek and Kramer 1969; Seethaler 1978). Hamman (1980) stated that captively-spawned and reared Colorado squawfish males and females matured in 5 and 6 years, respectively. Spawning occurs when river temperatures are about 20 C (Holden and Stalnaker 1975b), usually in July and August, in the Upper Colorado Basin. Spawning behavior has never been observed in the wild, but Hamman (1980) observed spawning of captive fish at Willow Beach National Fish Hatchery. Two males nudged a female's vent, causing her to vibrate and release eggs while the males extruded milt. The adhesive eggs were broadcast with little regard for substrate, and the spawning act was repeated several times. Spawning took place over a 48-hour period in shallow depths (20-55 cm), and the eggs hatched in 96 hours in 20 C water. The young fish fed on natural crustacean plankton in the raceways and were 48-55 mm in length in 110 days.

Observation of Colorado squawfish in the Yampa River in 1981 (Miller *et al.* 1982b) suggested spawning occurs over riffles, adults spawn in fairly large groups of males (8-10) with fewer females, and they reside in adjacent pools between spawning runs. The preponderance of males over females, especially during spawning time, has been noted by several authors (Holden and Stalnaker 1975b; Seethaler 1978). This is also the case with northern squawfish (McPhail and Lindsey 1970).

Prespawning temperatures and flows appear to be important in determining reproductive success in Colorado squawfish. Vanicek and Kramer (1969) indicated that Colorado squawfish did not spawn in the Green River in the cool tailwaters of Flaming Gorge Dam from 1964 to 1966 because temperatures were not adequate. They did find young, evidence of successful reproduction, in the Green River of Dinosaur National Monument below the mouth of the Yampa River and hypothesized the natural temperatures of the Yampa ameliorated the cool flows of the Green River. Holden and Stalnaker (1975a) and Seethaler *et al.* (1979) sampled the Green River in Dinosaur National Monument and found no young Colorado squawfish below the mouth of the Yampa in 1968-1971 and 1974-1976, respectively. Holden (1980) and Holden and Crist (1981) showed that this lack of reproductive success was correlated with higher, and therefore colder, flows from Flaming Gorge Dam after 1966. These flows were apparently too large to be ameliorated by the Yampa River.

Young Colorado squawfish were again found in Dinosaur National Monument below the Yampa's mouth in 1980, following inlet modification of Flaming Gorge Dam that raised tailwater temperatures. Young Colorado squawfish were also found in the lower 15.3 km of the Yampa River in 1980 and may have been the source of the young Colorado squawfish found immediately below the confluence. Holden and Crist (1981) hypothesized that adult Colorado squawfish that lived in the Green River moved into the Yampa to spawn. But spring and summer river temperatures after 1966 were too low to allow proper egg maturation in the females. The inlet modification of Flaming Gorge Dam warmed the river sufficiently for successful spawning in the lower Yampa River and the Green River of Dinosaur National Monument.

This hypothesis indicates that rather small changes in temperature during an apparently critical stage, egg maturation in the female, may determine reproductive success. Observations in 1981 (Tyus *et al.* 1982) showed that many of the fish spawning in the Yampa River originated from the upper Yampa, not the Green River. Therefore, the above hypothesis does not fully resolve this dilemma, and more information will be required to determine all the factors necessary for good reproductive success.

Holden (1977) did not find young-of-the-year Colorado squawfish in the Green River from Jensen to Gray Canyon in 1977, a drought year. Holden and Crist (1981) did not find any 1977-year-class fish near Jensen in either 1978 or 1979, and Holden and Selby (1979) found only one potential 1977 fish during extensive sampling in 1979. Holden (1980) showed the river temperature in 1977 at the Jensen U.S. Geological Survey gage did not indicate an abnormally cool year; in fact, good Colorado squawfish reproductive success occurred in several colder years. Flow, primarily the lack of a high spring peak in 1977, was apparently the reason for unsuccessful Colorado squawfish reproduction. Colorado squawfish reproduction was noted in 1981 (Miller *et al.* 1982b) in the Yampa River, another low-flow year, although the relative success as indicated by abundance of young-of-the-year has not been determined.

Other data suggest that high spring flow is important to successful Colorado squawfish reproduction. Dams of the Wayne N. Aspinall Unit were completed on the Gunnison River in 1964 and reduced spring flows after that time (Joseph *et al.* 1977). Taba *et al.* (1965) found young-of-the-year Colorado squawfish to be quite abundant near Moab, on the Colorado River, in 1962-1964. Holden and Stalnaker (1975a) found only three juveniles near Moab in 1971 and none in 1968-1970. Kidd (1977) did not find young Colorado squawfish in the Colorado River near Grand Junction. These data indicate a major reduction in young Colorado squawfish numbers coincidentally with reduced flows caused by Wayne N. Aspinall Unit dams. Valdez and Mangan (1981) found young Colorado squawfish near Moab, but not in the numbers reported by Taba *et al.* (1965). Young-of-the-year Colorado squawfish were also caught just below Grand Junction in 1979 and 1980, but numbers were also low (Wick *et al.* 1981). This all suggests that Colorado squawfish reproductive success in the Colorado River probably was affected by altered flows, with the loss of spring flows having a major effect.

Therefore, temperature and flow, and probably the combination of these two factors, appear to be extremely important to the reproductive success of Colorado squawfish. Additional study is needed to clarify this relationship because poor, or total loss of, reproductive success is the major problem facing this species in the Colorado River Basin.

Disease and Parasites

Colorado squawfish are infested with a number of parasites. The external copepod *Lernea* is common on juveniles and adults. Vanicek (1967) found a tapeworm *(Proteocephalus)* in 65% of the Colorado squawfish over 200 mm he examined. Seethaler (1978) indicated that the protozoan *Myxobolus* has been found on the gills of Colorado squawfish from the Green River. Seethaler (1978) also stated that *Lernea* was most abundant on Colorado squawfish from Walter Walker Wildlife Refuge, an abandoned gravel pit along the Colorado River near Grand Junction, Colorado. Seethaler (1978) suggested that parasites such as *Lernea* were introduced to the Colorado River system with exotic fishes, and Flagg (1980) supported this hypothesis by noting that the introduced fishes were more parasitized than native forms.

Population Decline

The construction of Colorado River Storage Project dams (Flaming Gorge, Glen Canyon, Wayne N. Aspinall Unit, Navajo Dam) in the 1960's was the major reason for the decline of Colorado squawfish in the Upper Colorado Basin. A number of authors have pointed this out, including Miller (1963), Holden and Stalnaker (1975a), and Seethaler (1978). Holden (1979) summarized the effects of these dams as they are currently understood.

1. Preimpoundment eradication programs were responsible for extinction of Colorado squawfish in the Green River above Flaming Gorge Dam, and they probably caused reductions in numbers in Dinosaur National Monument and loss of populations in the San Juan River.
2. Habitat loss due to reservoir construction was responsible for loss of the Colorado River under Lake Powell (Glen Canyon Dam) as viable Colorado squawfish habitat.
3. Loss of habitat below dams due to cold flows was responsible for loss of 105 km of habitat below Flaming Gorge.
4. Loss of reproductive success due to altered temperatures and/or flows was responsible for declines in reproductive success in the Green and Yampa rivers in Dinosaur National Monument from 1966 to 1980 and in the Colorado and Gunnison rivers of Colorado and Utah.
5. Loss of habitat, especially backwaters for young, due to reduced spring flows and fluctuations for power generation during low-flow periods, was also a factor.

Several other factors have been suggested as affecting Colorado squawfish populations, including predation-competition from exotics, disease and parasites, and changes in water quality (Seethaler 1978). We suspect these are complicating factors that only affect Colorado squawfish in marginal habitat conditions caused by dams and other water-depletion developments.

CHANCES FOR SURVIVAL

Colorado squawfish populations in the Green River System (including the Yampa and White rivers) are relatively large, as evidenced by few recaptures of tagged adults (Miller *et al* 1982a). Reproduction has been consistent for most of the last 10-15 years in the Green River. If the Colorado River population could reproduce as successfully as the Green River stock, recovery would be nearly complete in the remaining potentially good habitat. Establishment of other populations may be possible, especially in the San Juan River, after we know more about reproductive and habitat requirements. Artificial propagation can readily supply young or adult fish for transplanting. Therefore, biologically, the outlook appears to be optimistic.

Unfortunately, demands on the water of the Upper Colorado River Basin are great, and chances of protecting sufficient flows for the future appear low. Protection of Upper Colorado Basin flows is no longer being attempted by the cognizant federal agencies, and basic Colorado squawfish requirements are being lost just as we are learning the factors important to their continued survival. Hopefully we can learn enough to prevent this unique species from becoming a hatchery-reared entity, an untenable situation for those who appreciate natural ecosystems.

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LIFE HISTORY AND PROSPECTS FOR RECOVERY OF THE HUMPBACK AND BONYTAIL CHUB

Richard A. Valdez and Glenn H. Clemmer

ABSTRACT

The endangered humpback chub, *Gila cypha*, and bonytail chub, *Gila elegans,* occupy restricted areas of the Colorado, Green, and Yampa rivers in Colorado, Utah, and Arizona. Three self-sustaining populations of humpback chub indicate this species is capable of continued existence. But, low numbers of bonytail chub and the absence of natural reproduction strongly suggest a trend toward extinction. Much of the habitat of these endemic chubs is inundated by reservoirs or degraded by altered flow regimes. Their survival depends on maintaining the remaining deep, swift, rocky reaches inhabited by the species by curtailing further flow depletions. Introduction of non-native fishes must also cease. Habitat enhancement, including artificial backwaters, deepened river channels, and riprapped shorelines, is not a reasonable recovery step for either species because of the dynamics of river hydraulics and remoteness of most habitable areas. Recent success in rearing these two species in hatcheries may be important if supplemental stocking and reintroduction develop as feasible recovery steps. Introduction of hatchery-reared bonytail chub warrants consideration for recovering the species in the wild. Introduction of humpback chub, except in one area, is not recommended because of lack of suitable habitat presently unoccupied by the species.

INTRODUCTION

The humpback chub, *Gila cypha;* bonytail chub, *G. elegans;* and roundtail chub, *G. robusta* are large-river cyprinids endemic to the Colorado River System. Depletions of humpback chub and bonytail chub threaten their existence and have prompted their protection under federal and state statutes. The humpback chub and allied Colorado squawfish, *Ptychocheilus lucius,* were on the original list of endangered species prepared by the Office of Endangered Species in 1964. Strong legislation to protect these fishes and their habitat was afforded by the Endangered Species Act of 1973, P.L. 93-205 (87 Stat. 884). The bonytail chub was listed as endangered on 23 April 1980 (U.S. Fish and Wildlife Service 1980).

Life history studies of humpback chub, bonytail chub, Colorado squawfish, and the imperiled razorback sucker *Xyrauchen texanus,* began after 1960, and efforts intensified after 1970. The Fish and Wildlife Service (FWS) began an investigation of these fishes in the Upper Colorado River System in April 1979 (see Shields in this symposium). The Colorado River Fishery Project (CRFP) was designed to assess habitat and flow requirements of these endemics and is the source of much information presented herein. CRFP was funded by the Bureau of Reclamation, Bureau of Land Management, FWS, National Park Service, and Congress. The Colorado Division of Wildlife (CDW) and Utah Division of Wildlife Resources (UDWR) provided equipment, personnel, and technical assistance for various phases of the project.

DISTRIBUTION AND ABUNDANCE

The distribution and abundance of humpback chub and bonytail chub are summarized in several recent documents (Joseph *et al.* 1977; Joseph 1978; Smith *et al.* 1979; Behnke and Benson 1980; Colorado River Fishes Recovery Team 1981a, 1981b; Tyus *et al.* in this symposium). Some authors suggest the species were once abundant throughout the Colorado River System, based on reports at the turn of the century (Cope 1872; Cope and Yarrow 1875; Kirsch 1889; Jordan 1891; Jordan and Evermann 1896; Gilbert and Scofield 1898; Chamberlain 1904); fish collections by these investigators were too few and scattered to provide an accurate assessment of the status of these fishes. Bonytail chub were apparently common in collections from the Lower Basin around the turn of the century, but collections in the Upper Basin were too few to suggest more than the presence of the species. Confusion in vernacular and scientific nomenclature and a failure to recognize *G. cypha* until 1946 (Miller 1946) render tenuous an interpretation of historic distribution and, especially, abundance of the two species.

Bonytail chub were reported in decreasing numbers in the Lower Basin as early as 1960 (Miller 1961). Humpback chub were not known from the Upper Basin until 1950, when they were reported from Hideout Canyon on the Green River (Smith 1960). Pre- and post-impoundment studies (Bosley 1960; McDonald and Dotson 1960; Smith 1960) reported humpback chub in Flaming Gorge, but abundance is difficult to assess because of common use of the term "bonytail" for all members of the genus *Gila.* Similar investigations in Glen Canyon (McDonald and Dotson 1960) did not reveal the presence of either species, but humpback chub were collected in Lake Powell soon after closure of Glen Canyon Dam in 1962 (Holden and Stalnaker 1975). Both species of chubs were reported from Lake Powell in the late 1960's, but UDWR has not reported any in recent years.

Bonytail chub were numerous in the Green River within Dinosaur National Monument from 1964 to 1966 (Vanicek and Kramer 1969) but less common from 1968 to 1971 (Holden and Stalnaker 1975). The species was also reported in the latter period from the lower Yampa River within Dinosaur National Monument and from the Green River within Desolation Canyon.

The reported range of the humpback chub in the Green and Yampa rivers after 1970 (McAda and Seethaler 1975; Holden 1977; Joseph *et al.* 1977) was extended, but total numbers of bonytail chub continued to diminish. New populations of humpback chub were also found in the Colorado River at Black Rocks, Colorado (Kidd 1977) and Westwater Canyon, Utah (Valdez 1980). But, bonytail chub continued to be absent from samples in Colorado (Wick *et al.* 1981), despite reports of the species in the White and Colorado rivers by T.M. Lynch (Joseph 1978). These reports are discounted after interviewing biologists (G. Kidd, 3361 G Road, Clifton, Colorado, 1981 pers. comm.) with CDW at that time. Apparently, roundtail chub were commonly called "bonytail" by some Conservation Officers, and these reports were interpreted to mean that *G. elegans* was found in Colorado from 1940 to 1960.

Concentrations of humpback chub now occur in (1) Black Rocks, Colorado; (2) Yampa Canyon, Colorado; (3) Westwater Canyon, Utah; (4) Gray Canyon, Utah; and (5) Little Colorado River (LCR), Arizona (Fig. 1). Fishes of all age-groups have been recently identified from sites 1, 3 and 5 listed above. Adults and young, tentatively identified as *G. cypha,* were recently reported in site 2 by the CDW (Wick *et* aL 1981) and indicate a fourth self-sustaining population of humpback chub in the Colorado River System. Individual humpback chub were also found in Moab and Cataract canyons of the Upper Colorado River (Valdez and Mangan 1980) and Desolation Canyon of the Green River (Tyus *et al.* 1982). Bonytail chub are present in small numbers in Gray Canyon, Utah and Lake Mohave, Arizona.

HABITAT

Humpback Chub

The preferred habitat of humpback chub in the Green, Colorado, and Little Colorado rivers is very similar in these disjunct populations. The species prefer deep, swift water with rocky substrate.

Young and juvenile *Gila* sp. in the Green River (Holden 1978) showed a preference for firm silt substrates in water 0.6 m deep and 0-0.15 meter per second (mps) velocity. Most young were caught in backwaters, and juveniles were in backwaters and runs. Adults preferred depths of 0.6-1.2 m and velocities of 0-0.24 mps.

Collections from the same habitat in Gray Canyon in the Green River (Tyus et aL 1982) yielded *G. cypha, G. elegans,* and *G. robusta.* The area has deep, swift water and rock substrate. Humpback chub in the Lower Colorado River were also often found in the deeper pools (Kaeding and Zimmerman 1981).

Young fish tentatively identified as *G. cypha* in Black Rocks and Westwater Canyon were found in small, quiet pockets along steep rock walls, often adjacent to deep and swift water. These fish were also found in the few backwaters that occur in these areas (Fig. 2). Juveniles in the same area were found over sand-silt and boulder-bedrock substrates (Fig. 3) in water 0.4-10.7 m deep $(\bar{x} = 3.5)$ and velocities of 0.06-0.60 mps $(\bar{x} = 0.24)$. Most were found in small eddies and pools or in angular pockets along rock walls. A few age-group I fish were found in backwaters. Adult humpback chubs were found in depths of 0.7-12.2 m = 4.3) and velocities of 0.03-1.16 mps = 0.18). These adults preferred deep runs and eddies over bedrock, boulders, and sand.

CRFP investigations in 1980 and 1981 yielded ripe humpback chub from Black Rocks along intermittent sand beaches between protruding rock pillars. The fish were in depths of 1.8-3.8 m and velocities of 0.15-0.30 mps. Spawning may occur on nearby submerged gravel bars as indicated by observed spawning in cobble raceways at Willow Beach National Fish Hatchery (NFH) where adhesive eggs were deposited on cobble 4-10 cm in diameter in 35-45 cm of water (R. Hamman, Willow Beach National Fish Hatchery, Boulder City, Nevada. 1981 pers. comm.).

Bonytail Chub

Little is known about the habitat of bonytail chub, except that the few individuals caught recently in the Upper Basin occupied deep, swift, rock-sand areas in main channels. No difference in habitat selection was detected between roundtail and bonytail chubs in the Green River, nor were any seasonal changes observed (Vanicek 1967). Young *Gila* sp. (ages 0-II) were commonly captured in pools and eddies in the absence of (although often adjacent to) strong current and at varying depth over silt and silt-boulder substrate. Recent catches of bonytail chub in Gray Canyon in the Green River also suggest that the fish prefer areas adjacent to deep, swift water (Tyus *et al.* 1982). Small numbers of bonytail chub found in Lake Mohave are probably excluded from using the riverine habitat above the reservoir by the cold-water releases from Hoover Dam (Colorado River Fishes Recovery Team 19814

Figure 1. Concentrations of *Gila* cypha and Gila elegons in the Colorado River System.

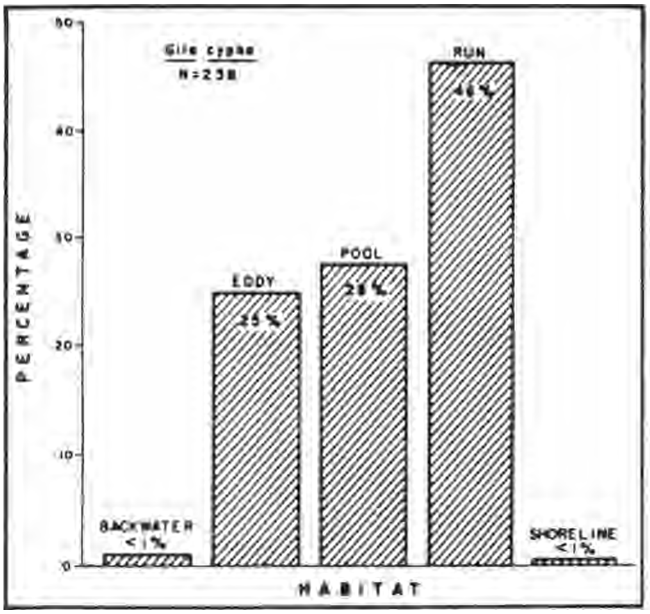


Figure 2. Habitats used by all ages of *Gila cypha*, as percent of total catch, in the Upper Colorado River.

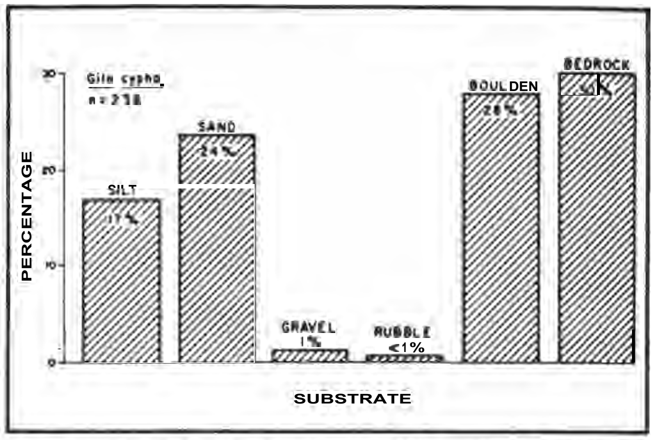


Figure 3. Substrate used by all ages of *Gila cypha*, as percent of total catch, in the Upper Colorado River.

MOVEMENT

Mark-recapture studies with Carlin tags indicate that humpback chub move little within Black Rocks, Westwater Canyon, Gray Canyon, and the Lower Colorado River. Sixteen of 218 fish tagged in Black Rocks and Westwater were recaptured between 1 and 434 days after release. Recapture sites ranged from 0 to 23 km from release sites, for an average distance of 1.6 km (Table 1). All but one fish were recaptured less than 0.7 km from their release site. One fish, initially tagged in Westwater Canyon 10 September 1980, was recaptured 232 days later 23 km upstream in Black Rocks. This was the greatest observed movement by a humpback chub and was the only recorded exchange of a fish between Westwater Canyon and Black Rocks.

TABLE 1. Movement of *Gila cypha* equipped with Carlin tags and radio transmitters in the Upper Colorado River, 1979-1981

Tag	Average movement per fish, km (Range)	Average days monitored (Range)
Carlin	1.6 (0-23.0)	137 (1-434)
Radio	0.8 (0-3.7)	38 (4-93)

Preliminary observations on Gila sp. in Gray Canyon of the Green River showed similar trends. One G. *robusta,* one G. *elegans,* and seven G. *cypha* were recaptured at the original capture sites 1.5 to 11 months after release (Tyus et *aL* 1982). Chubs caught in the Lower Colorado River 3.5 weeks to 13 months after tagging were 0-2.7 km (x = 0.6) from their release point (Kaeding and Zimmerman 1981).

Movement of fish equipped with radio transmitters was similar to movement observed with Carlin tags. Eight humpback chub with transmitters in Black Rocks moved 0-3.7 km, for an average of 0.8 km, over periods of 4-93 days (Table 1). The average net movement was less than 0.1 km upstream from the release point.

Movement of radio-equipped fish is illustrated by one individual that moved a total of 0.3 km upstream over a period of 67 days (Fig. 4). The fish spent 26 days near the release point and then moved for 2 days to the original capture site, where he spent the remaining 39 days of monitoring. A second fish returned to the original capture site 64 days after release and spent the remaining 34 days monitored within a 100-m radius. Similar movement was seen for all eight fish within the 3-km Black Rocks area, except for one fish that moved upstream nearly 2 km and returned within 2 weeks. Possible effects of the implant and transmitters on behavior is acknowledged but was not evaluated.

Three fish with transmitters exhibited patterned diurnal and nocturnal movements (Fig. 5). These fish were monitored for approximatley 24 hours on several occasions in May, June, and July 1981. Generally, the fish spent dawn (0600-0800) and evening (2000-2300) hours along the relatively shallow shore in less than 2 m of water. Their longitudinal position on shore often varied by 30-50 m daily, and they often remained for long periods in eddies formed by submerged rocks. Fish were found in midmorning (0800-1100) and midafternoon (1700-1800) in 3-5 m of water and farther toward midchannel at midnight (2400-0600) and midday (1100-1700), especially in warm, sunny weather. Signal reception varied inversely with depth, and constant monitoring for precise location was impossible in water deeper than 5 **m.**

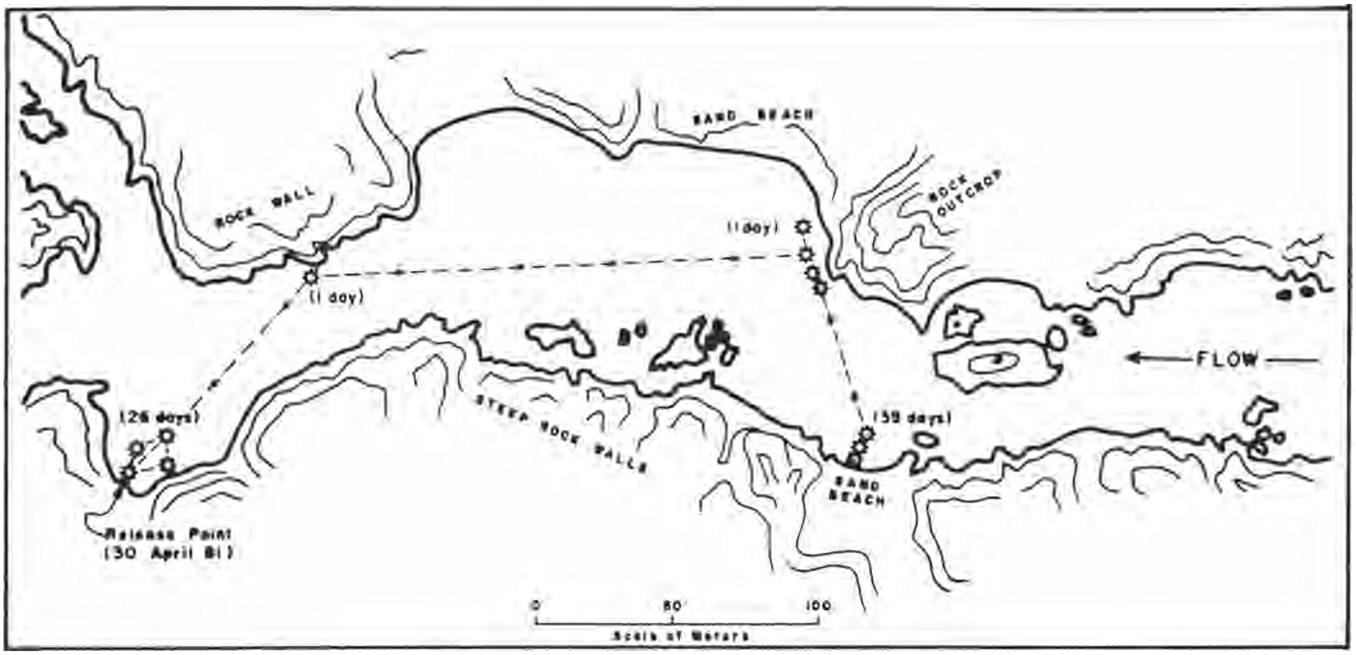


Figure 4. Movement of a mole *Gila cypha* in Black Rocks, Colorodo, monitored by rodiotelemetry.

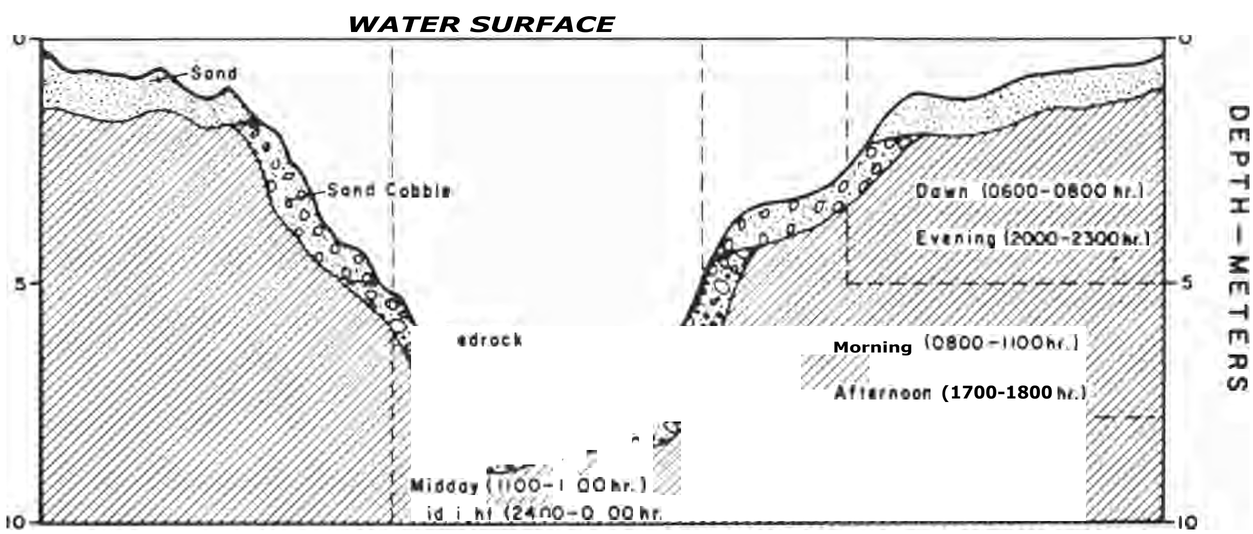


Figure 5. River depths and regions occupied by Gila cypho monitored by radiotelemetry in Block Rocks, Colorado, May-July 1981.

REPRODUCTION

Humpback Chub

Natural reproduction of humpback chub occurs in Black Rocks, Westwater Canyon, the Lower Colorado River, and, apparently, Yampa Canyon. Reproduction in these areas is indicated by recent collection of young, juveniles, and subadults in the presence of adults. Little is known about the natural reproduction of humpback chub, primarily because spawning occurs at or near spring runoff, a difficult time to sample the deep, turbulent waters inhabited by the species.

Spawning in the Little Colorado River was reported in June and July, based on captures of young-of-the-year and tuberculate adults (Suttkus and Clemmer 1977), and from March through June (and possibly July) at 16-19 C, based on fish in reproductive condition and on the collection of young in June and July (Minckley *et al.* 1979). Spawning was recently documented in the lower 11 km of the Little Colorado River in June 1980 and May 1981 (Kaeding and Zimmerman 1981).

Spawning time and water conditions for humpback chub were documented in Black Rocks in 1980 and 1981. In 1980, tuberculate fish were first seen 14

May at a water temperature of 11.3 C and flow of 18,000 cfs (510 m^3/s) (Fig. 6). Seven of eight males had light orange abdomens and tubercles on their heads and paired fins. But, only two of the six females exhibited these prenuptual features. Similar tuberculation and coloration were described for the species in the Grand Canyon area (Suttkus and Clemmer 1977). Eighteen fish collected on 2 June were all tuberculate and colored at a water temperature of 11.5 C and flow of 21,500 cfs (610 m^3/s). All males produced milt, but eggs could not be naturally stripped from females. Three females, injected with a preparation of carp pituitary released 18,000 eggs (4,000; 4,000; 10,000 per fish) for transport to the Willow Beach NFH. Eggs incubated at 12-13 C in the hatchery failed to develop and died after 110 hours, while those incubated at 20-21 C hatched in 120-160 hours (Hamman 1980). Maximum daily water temperature at Black Rocks in 1980 did not reach this hatchery incubation level of 20 C until 26 June, and a mean of 20 C was not recorded until 29 June. Spent fish were found 15 June, indicating that spawning in Black Rocks probably occurred 2-15 June 1980 at water temperatures of 11.5-16.0 C and flows of 21,500-26,000 cfs (610-740 m^3/s).

Flow in the Colorado River in 1981 was unusually low, and humpback chub spawned earlier than in 1980 (Fig. 6). Tuberculate fish were found in Black Rocks on 10 April at a mean daily water temperature of 14.0 C and a flow of 4,300 cfs (120 m^3/s). Tuberculation and coloration were extensive on 15 May at 16.5 C and a flow of 3,000 cfs (85 m^3/s). Spent fish were captured 27 May, indicating that spawning occurred 15-27 May at water temperatures of 16.0-16.5 C and flows of 3,000-5,000 cfs (85-140 m^3/s). Spawning in 1981 occurred about 2 weeks earlier than in 1980, probably because of the early warm-water temperatures and the absence of a high-volume runoff to cool the water as in normal water years. Relative survival of these two year-classes is yet unknown.

Bonytail Chub

The most recent report of natural reproduction of bonytail chub was in Dinosaur National Monument in the Green River in 1959, 1960, and 1961 (Vanicek and Kramer 1969). The presence of gravid and ripe fish indicated that spawning occurred from mid-June to early July at a water temperature of 18 C. Spawning by bonytail and roundtail chub was considered spatially separated because of the absence of ripe adults of both species in the same gillnet samples (Vanicek 1967).

Spawning was observed in Lake Mohave in May 1954 (Jonez and Sumner 1954) when about 500 bonytail chub congregated over a gravel bar in 9 m of water. Females seemed to be "escorted" by 3-5 males, and eggs were broadcast randomly on the gravel shelf. A sample of 42 males and 21 females included one female that yielded 10,000 eggs. A total of 35 young bonytail chub (13-26 mm SL, UMMZ 162846) were collected by R.R. Miller and H.E. Winn 15 June 1950 from 17 km east of Searchlight near Cottonwood Landing, Nevada in the then-filling Lake Mohave. Concentrations of 30-100 adult bonytail chub were observed in Lake Powell in 1965, but no spawning activity or young were observed (Colorado River Fishes Recovery Team 1981a). The species has not been reported from Lake Powell since about 1968.

The diminished numbers of bonytail chub throughout the basin prompted collections of brood stock to assess the feasibility of hatchery culture. Adults were collected in Lake Mohave in 1979 (two females), 1980 (three females), and 1981 (five males, three females), and transported to the Willow Beach NFH. Females were successfully stripped of eggs after injection of carp pituitary. Eggs of bonytail chub, like those of humpback chub, yielded higher hatching success when incubated at 20-21 C than when incubated at lower temperatures (16-17 C and 12-13 C) (Hamman 1980).

ASSOCIATED SPECIES

A total of 42 non-native fish species and 13 natives (including 8 endemics) inhabit the Upper Colorado River System (Tyus *et al.* in this symposium). The potential negative impacts of non-native fishes on native species are acknowledged as competition for food and space, and predation on eggs, larvae, and young (Miller 1961; Minckley and Deacon 1968; Holden and Stalnaker 1975). The possible effect of foreign pathogens, for which the native and endemic species may have little resistance, should also be considered. For example, the parasitic copepod, *Lernea cyprinacea,* introduced into the Colorado River via an unknown non-native host is often found on native and endemic species. The parasite was found near fin bases of 26% of the 234 humpback chub examined from the Upper Colorado River (Table 2). The parasite was not found on young fish, but 17% of juveniles and 31% of adults were infested with 1-13 copepods. A high incidence of this parasite was also reported in humpback chub of the

TABLE 2. Occurrence of *Lernea cyprinacea* on *Gila cypha* of the Upper Colorado River, 1979-1981

Fish age (No.)	Number infested	Percent infested	Number per fish Mean	Number per fish Range
Young (16)	0	0		
Juvenile (36)	6	17	1.3	1-3
Adult (182)	56	31	2.8	1-13
Summary: (234)	62	26	2.7	1-13

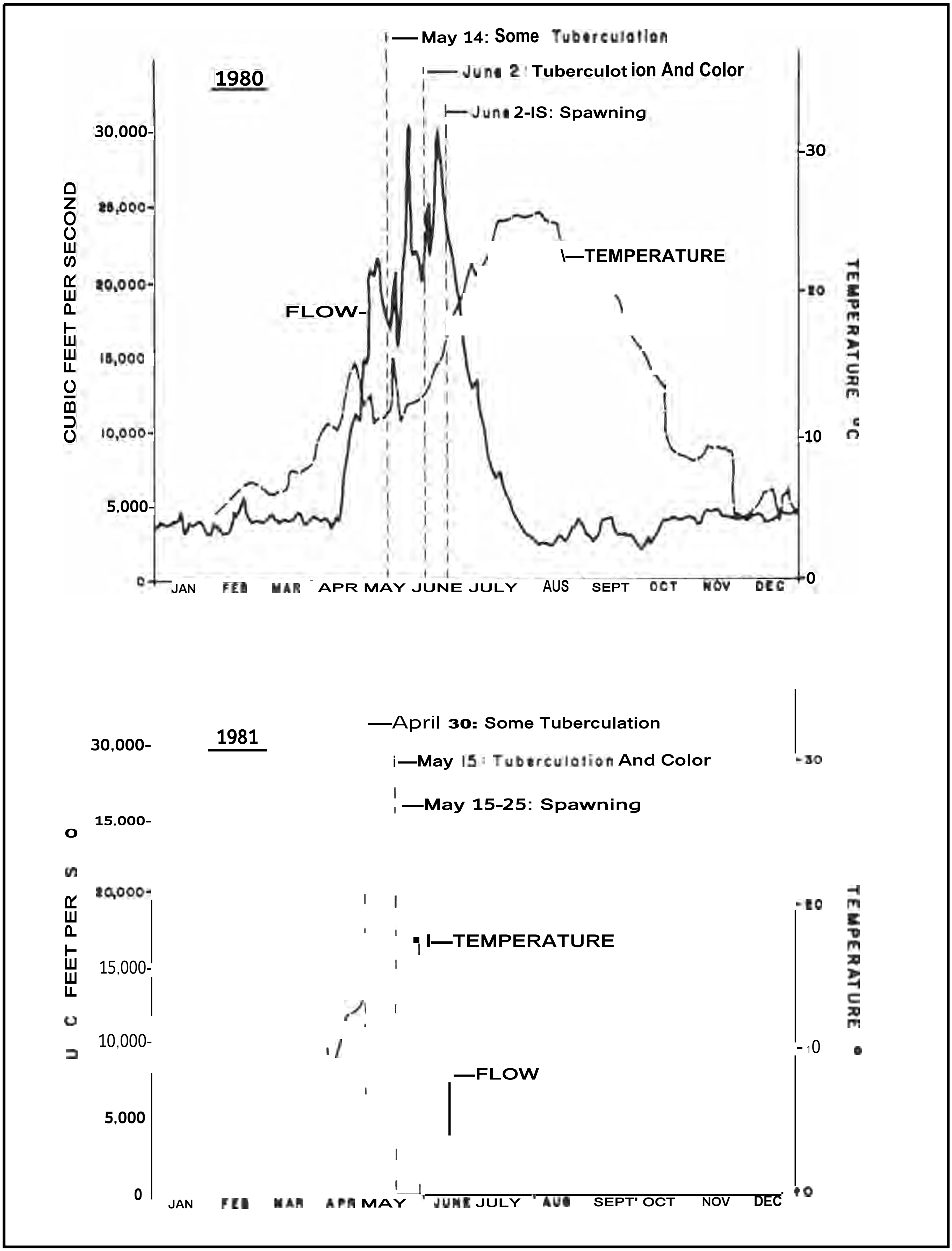


Figure 6. Water temperatures and flows associated with spawning of *Gila cypha* in Black Rocks, Colorado.

Lower Colorado River (Kaeding and Zimmerman 1981). The effect of this parasite on chubs is unknown, but it may contribute to stress that may lead to mortality.

Non-native and native fishes may be infringing upon the depleted habitat of the humpback and bonytail chub and contributing to competition, predation, and population stress. At least four sections of the Upper Colorado River, unique in depth, velocity, and fish composition, harbor humpback chub (Valdez 1980). Black Rocks and Westwater Canyon each harbors 14 species of fishes, including 6 and 5 natives, respectively (Table 3). Equal lengths of river adjacent to these restricted habitats harbor 19 and 18 species, respectively, with 6 and 4 natives. Similar differences in fish composition also occur in Cataract Canyon, an area similar to Westwater Canyon but with fewer humpback chub.

This difference in fish diversity and composition between the three restricted habitats and the surrounding river indicates that habitats unfavorable to some non-natives still exist. But, subtle depletions in flow could reduce velocities and depths and continue to render these areas favorable to more non-natives.

TABLE 3. Number of fish species associated with *Gila cypha* within and adjacent to three areas of the Upper Colorado River. (Numbers of native species in parentheses)

Area	Number of associated species: Within area	Outside area
Black Rocks	14 (6)	19 (6)
Westwater Canyon	14 (5)	18 (4)
Cataract Canyon	13(6)	19 (6)

Non-natives most commonly associated with adult humpback chub in runs, eddies, and pools were channel catfish and common carp, while commonly associated natives were roundtail chub, bluehead sucker, and flannelmouth sucker. Juvenile and young humpback chub were often caught with channel catfish, common carp, red shiner, fathead minnow, and sand shiner. Native fishes often associated with juvenile and young humpback chub were bluehead sucker, flannelmouth sucker, and roundtail chub.

SYSTEMATICS

The genus *Gila* is represented in the Upper Colorado River System by *G. cypha, G. elegans,* and *G. robusta.* Variations or possibly hybrids of these species also occur. Adults of the three species are readily identified afield by gross morphology, but because the young and juveniles are difficult to examine afield, their identity is often considered 'tentative'. Variants or hybrids are also difficult to identify in the field. Several meristic features, including fin-ray counts, scale counts, fin lengths, nuchal hump depth, eye diameter, and squamation were used by CRFP to help identify the three species of *Gila* afield. No single meristic or set of meristics appear to readily identify young, juveniles, and intermediates.

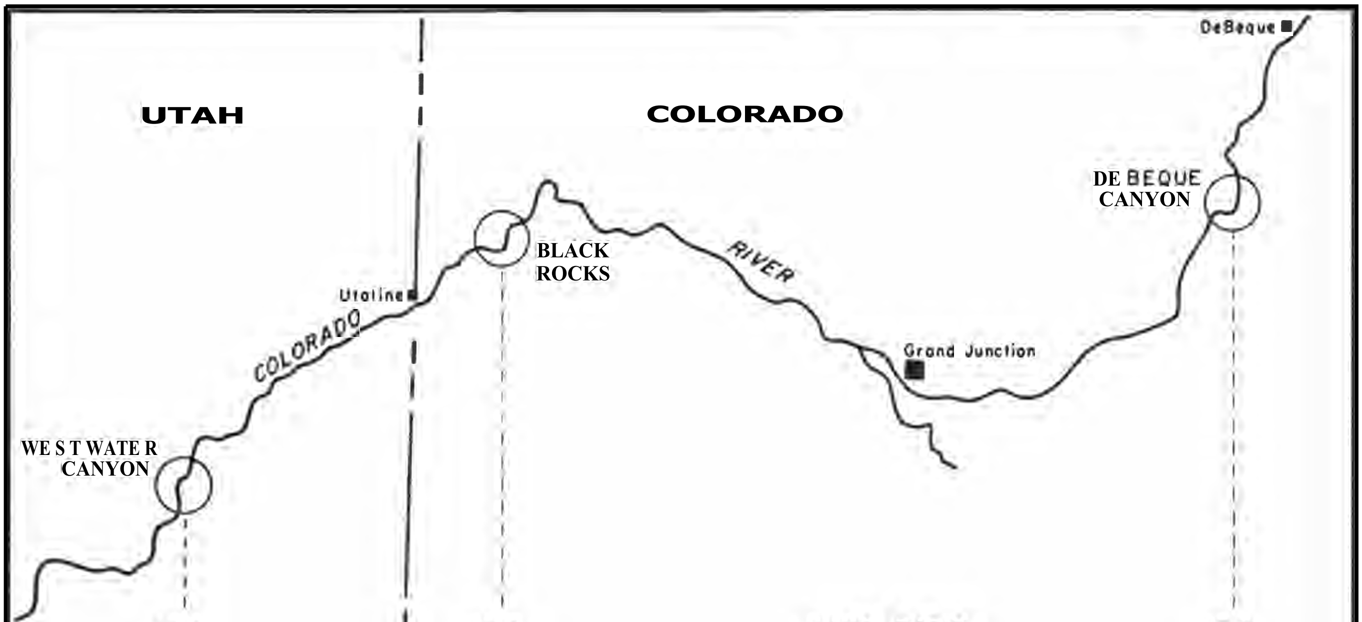
The nuchal hump ratio, developed by Smith *et al.* (1979) for identifying adults, was used to help identify the three species. The ratio is derived by dividing the distance between the origin of the pelvic and pectoral fins by the greatest depth of the nuchal hump, which is the distance from a straight line between the highest part of the nuchal hump and dorsal tip of the snout and the frontal depression. Nuchal hump ratios for preserved specimens of *G. cypha* (6-13), *G. elegans* (15-29), and *G. robusta* (28-207) (Smith *et al.* 1979) were compared with those derived from live fish. Mean ratios for samples of *G. cypha* from Westwater Canyon (13.3) and Black Rocks (12.9) were near the upper range of ratios generally associated with the species (Fig. 7). A few small adults and large juveniles in the samples probably raised the means disproportionately; this reinforces application of the ratio only to mature adults. The methodology was further tested on a group of 35 humpback-like fish from DeBeque Canyon, Colorado. Of the 10 fish sent to R.R. Miller for examination, 6 were tentatively identified as hybrids of *G. cypha* and *G. robusta* and the remainder as *G. robusta.* The mean ratio of 18.5 for these 35 fish falls within the expected range of *G. elegans;* however, these fish fail to exhibit other features of the species, including anal and dorsal fin-ray counts. We are conducting a complete analyses of meristics, including a discriminant function analysis.

Identifying young, juveniles, and intermediates of the genus *Gila* is the paramount problem for field biologists in the Upper Colorado River System. We often capture specimens for which no confident field identification can be made, and the paucity of these endangered species precludes extensive collection and preservation for verification. Questionable specimens are being photographed for future examination.

PROSPECTS FOR RECOVERY

Bonytail Chub

The prospect for natural survival of the bonytail chub is poor. The present reduced wild population indicates a trend toward extinction, particularly since natural reproduction cannot be documented. Wild brood stock and progeny in hatcheries are the only large numbers of bonytail chub known today.



Westwater Canyon	Black Rocks		DeBeque Canyon
13.3	12.9	HUMP RATIO	18.5
9.0 (9)	9.0 (8-10)	DORSAL FIN	8.9 (8-10)
9.5 (9-10)	9.8 (9-10)	ANAL FIN	8.5 (8-10)
28	33	SAMPLE SIZE	35

Figure 7. Mean nuchal hump ratios and fin-ray counts for adult *Gila cypho* from Block Rocks and Westwater Canyon and *G. cypho* X *G. robusta* from DeBeque Canyon.

Hatchery culture of large numbers of the species appears feasible, and release of hatchery-reared fish seems to be the only viable approach to recovery. However, the habitat presently occupied by the few surviving individuals is apparently unsuitable, as indicated by recent reductions in numbers.

Introductions of bonytail chub in Cataract Canyon on the Colorado River and either Gray or Desolation Canyon on the Green River warrant consideration. Releases would have to be made within a suitable habitat identified by experienced field biologists. This release program may be detrimental to wild stocks by increasing competition for limited habitat, introducing gene pools from a different part of the system, and enhancing the possibility of hybridization with humpback chub and roundtail chub.

The recent apparent success with hatchery-reared Colorado squawfish in the wild should not shed optimism on a similar program for bonytail chub. The Colorado squawfish is a mobile piscivore apparently capable of gaining access to most natural features of the basin, whereas bonytail chub may be like humpback chub — relatively sedentary insectivores that inhabit very restricted habitats.

Humpback Chub

The status of the humpback chub is more favorable than that of the bonytail chub. Four apparently self-sustaining populations exist in the Upper and Lower Colorado River basins. All are located in restricted habitats of relatively deep, swift water. Maintaining the biological, chemical, and physical integrity of these "islands" is critical to the survival of the species. Temperature regimes of "normal" water years (e.g., 1979, 1980) must be maintained for successful reproduction, since temperature appears critical in spawning and hatching success.

Changes in flow regime have reduced geographical barriers that isolated the species for centuries. This has allowed a breakdown of isolating mechanisms and permitted other native and nonnative fishes to invade their habitat. The presence of intermediate forms of *G. cypha* and *G. robusta* in Black Rocks, Westwater Canyon, and DeBeque Canyon, and of *G. cypha*, *G. elegans*, and *G. robusta* in Desolation, Gray, and Yampa canyons, suggests the possibility of hybridization as a result of habitat degradation. Such crosses are possible and have been documented at the Willow Beach NFH. This hybridization may threaten the integrity of the species' gene pools.

A habitat-enhancement program for humpback chub is inadvisable. Fish of all ages prefer runs, eddies, and pools near deep, swift water with silt-sand and boulder-bedrock substrate. Backwaters are also used, but few occur among the steep canyon walls. Enhancing these habitats in remote locales suitable for the species is not feasible because of limited access and the dynamic river hydraulics that can fill excavations or make unnatural changes. Boulder riprap associated with railroad and highway construction is sometimes occupied by humpback chub, but a high degree of variation, or possibly hybridization, is implicated; e.g., the population of apparent *G. cypha* x *G. robusta* hybrids in DeBeque Canyon lives among the boulder riprap of the highway system.

Supplemental introductions of hatchery-reared humpback chub are inadvisable except in one area. The introduction of hatchery-reared humpback chub into Cataract Canyon deserves consideration, since the area appears physically and biologically similar to others inhabited by the species. Introducing additional fish into areas already occupied by the species could intensify competition for food and space, and increase predation on young. Danger also exists of weakening wild stocks of one area by superimposing less rigorous stocks of another.

The problem of identifying young, juveniles, and intermediates of the genus *Gila* must be resolved if field biologists are to confidently identify live specimens. Many fish are now identified as *Gila* sp. in lieu of risking an erroneous judgement in identification. Even though the Endangered Species Act protects the listed species and their variations, an acceptable field identification procedure is necessary to enable continued protection and management of the species.

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LIFE HISTORY AND PROSPECTS FOR RECOVERY OF THE RAZORBACK SUCKER

Edmund J. Wick, Charles W. McAda, and Ross V. Bulkley

ABSTRACT

Hybridization, reproduction, food, growth, habitat, and movements of the rare razorback sucker, *Xyrauchen texanus,* are summarized. Despite severe changes produced by dams, channelization, and water-use patterns in the Upper Colorado River System, adult razorbacks are capable of surviving. Reproduction, however, has failed for reasons not yet understood. Since razorbacks are easy to study and are not federally endangered, they can be the subject of innovative research to gain insight on all rare large-river fishes of the Upper Basin. Artificial propagation can provide time and specimens needed to study means of establishing self-sustaining wild razorback populations. Formation of a "razorback sucker recovery team" is urged, and a task outline for recovery of the species is presented. *(Editors abstract)*

INTRODUCTION

The razorback sucker, *Xyrauchen texanus,* is one of many native fishes of the Colorado River Basin that have suffered population declines during the past century, primarily because of drastic modification of the river system. Several authors have addressed these modifications and their impacts on the native fish fauna (Minckley and Deacon 1968; Minckley 1973; Stalnaker and Holden 1973; Holden and Stalnaker 1975; Seethaler *et al.* 1979; Carlson and Carlson in this symposium). Because of concern for its survival, the razorback sucker was proposed for listing as threatened under the Endangered Species Act by the U.S. Fish and Wildlife Service (1978). However, that proposal was withdrawn after the Act was amended in 1978, probably because a critical habitat designation and an economic assessment must accompany the proposal (U.S. Fish and Wildlife Service 1980). The razorback is listed as endangered by the State of Colorado.

This paper emphasizes knowledge gained since 1975 and lists data gaps that should be targeted for continued research.

SYSTEMATICS

The razorback sucker is in a monotypic genus. Although many of the razorback's characteristics resemble those of the genus *Catostomus,* the sharp-edged hump on its back is so distinctive that the species was placed in its own genus, *Xyrauchen,* literally "razornape," by Eigenmann and Kirsch (Kirsch 1889).

Abbott (1860) first described the species from a single stuffed specimen collected from the Colorado River (LaRivers 1962). In his original description, Abbott named the species *Catostomus texanus;* the name "texanus," which denotes 'of Texas origin,' was used because he thought the specimen came from the Rio Colorado in Texas, a different river system (Baxter and Simon 1970). Minckley (1973) provided a good description of the razorback sucker.

The razorback sucker hybridizes with other catostomids in the Upper Colorado River Basin. A hybrid with the flannelmouth sucker *(Catostomus latipinnis)* was initially described as a new species, *Xyrauchen uncompahgre* (Jordan and Evermann 1896). The specimen, collected from the Uncompahgre River in Colorado, was redescribed as a hybrid by Hubbs and Miller (1953). Since then this hybrid has been reported in the Upper Basin on several occasions (Banks 1964; Vanicek *et al.* 1970; Holden and Stalnaker 1975; McAda and Wydoski 1980).

Hybridization with *C. ardens* and *C. insignis* has been reported in the Lower Basin by Gustafson (1975) and Hubbs and Miller (1953), respectively.

LIFE HISTORY

Reproduction

Spawning time and location

Although spawning has not been observed in the Upper Colorado River Basin, ripe razorback sucker have been collected at several locations. McAda and Wydoski (1980), during a 2-week period in May 1974, collected 14 razorback sucker in spawning condition over a gravel bar in the lower 0.6 km of the Yampa River. Two ripe males and one ripe female razorback sucker were collected over the same gravel bar 6-7 May 1981 by the U.S. Fish and Wildlife Service (Miller *et al.* 1982); this indicated a tendency to spawn in the same location over a period of years. In the Green River, 31 razorback sucker were collected at the confluence with Ashley Creek during a 3-day period in early May 1981 (Tyus *et al.* 1982); only one fish, a male, was ripe. Holden and Crist (1981) collected 38 razorbacks in June 1978 in the same area in backwaters formed at the mouth of Ashley Creek and Stewart Lake Drain. These fish could represent spawning aggregations.

Razorback sucker are apparently also spawning in the Colorado River, as suggested by collection of ripe fish in and near flooded gravel pits. In 1975, McAda and Wydoski (1980) collected ripe fish of both sexes in Walker Wildlife Area, a gravel pit connected to the Colorado River near Grand Junction. In addition, Colorado Division of Wildlife (CDOW) and U.S. Fish and Wildlife Service (FWS) personnel noted a few ripe male razorbacks in Walker Wildlife Area in May and early June 1979 and 1980. CDOW personnel noted aggregations of razorbacks in late May and early June 1979 and 1980 in backwater areas created by flooded gravel pit excavations on the Colorado River near Clifton, Colorado. To enter these off-stream impoundments, the razorbacks had to swim up drainage ditches and culverts. Some fish were spent, whereas others were not ripe or ready to spawn. It was not known whether the fish had spawned in the adjacent river and entered the warmer backwaters to rest and feed or were spawning in the backwaters.

Spawning requirements

Razorback sucker spawn in spring when water levels are rising and water temperatures are increasing. McAda and Wydoski (1980) reported ripe razorbacks in water temperatures of 7-16 C. Razorbacks in spawning condition were collected in the Yampa and Green rivers in 1981 at water temperatures of 12 C. Temperatures of 17-19 C were reported by CDOW and FWS personnel when they captured ripe razorbacks in gravel pits near Clifton, Colorado.

Ripe razorback sucker are often collected over or near gravel bars in flowing water. McAda and Wydoski (1980) reported collections from areas with water velocities of about 0.3 meters per second (m/s) and water depths of 0.7-1.0 m. Conditions in the Yampa River were similar in 1981; ripe fish were collected from areas with water velocity ranging from 0.1 to 0.6 m/s ($\bar{x}$ = 0.4 m/s, n = 4).

The single ripe male collected in 1981 in the Green River by FWS was in quiet water over sand substrate. Cobble substrate was available in small amounts in the general area. Other ripe razorbacks have been collected in the still water of flooded gravel pits where available substrates ranged from cobble to silt.

Spawning observations from Lower Basin reservoirs

Although detailed observations of reproductive behavior have not been made in Lower Basin rivers, Douglas (1952), Jonez and Sumner (1954), and Wood (personal communication cited by Minckley and Deacon 1968) observed spawning activities in several Lower Colorado River Basin reservoirs. Minckley (1973) summarized these spawning observations as follows: "Spawning occurs along shorelines or in bays. One female is attended by 2 to 12 males, and the group moves in circles less than two meters in diameter, randomly spiraling over the bottom. The males appear to herd the female by nudging with their heads and predorsal keels against her genital region. When a site is selected, the female simply settles to the bottom with a male closely pressed to each side. Vibrations then commence that culminate in a convulsive female, at which time gametes are presumably emitted. The three fish then move forward and upward, leaving a cloud of silt and sand, marking the spot of activity. Females spawn repeatedly with numerous males. The eggs are transparent and adhesive, attaching to the substrate upon which they are deposited."

Spawning success

Successful reproduction in the wild has never been documented for the Upper Basin. Numerous investigators have worked in the basin over the last 10 years, but a verified collection of small razorback suckers has not been reported. Recent success in artificial propagation of razorback sucker has provided specimens for comparison and will facilitate identification of young razorback sucker collected in the wild.

Food Habits

No new information has been collected concerning food habits of razorback sucker. McAda and Wydoski (1980) summarized information to date.

Minckley (1973) reported that razorbacks he examined from Lake Mojave had intestines filled with planktonic crustaceans in May. He observed razorbacks feeding in about 6 m of water and noted that: "The fish moved with mouths projecting forward and with a 'bouncing,' up-and-down pattern produced by slow, alternating sweeps of the caudal fin. The pectoral fins were held stiffly extended, producing a plane effect, and little lateral movement of the head was evident, perhaps as a result of the keel-like anterodorsal surface which may act as a lateral stabilizer."

Hubbs and Miller (1953) reported that razorbacks in riverine environments in the Upper Basin used plankton for food and described the length and fuzziness of their gill rakers. Razorbacks are apparently opportunistic in their feeding; razorback gut samples have included plant debris, larvae of Ephemeroptera, Trichoptera, and Diptera, and algae (Jonez and Sumner 1954; Banks 1964; Vanicek 1967).

Temperature Preferences of Razorbacks in Controlled Experiments

Recent experiments (Bulkley *et al.* 1981) involving use of a temperature preference chamber have provided information about the optimum temperature for most efficient body functioning for rare Colorado

River species. In these tests, razorbacks seemed to prefer warm water. Subadult razorback sucker raised in captivity preferred temperatures of 23-29 C, depending on prior acclimation temperature in the laboratory studies. Certain fish died in the tests when water temperature exceeded 34 C. This species also exhibited reduced activity levels at water temperatures of 14 C or lower. The proportion of razorbacks which were active in the temperature preference chamber was 20% for fish acclimated to 8 C and 48% for 14 C fish. In contrast, 91% of 20-C acclimated fish and 87% of fish acclimated to 26 C actively used the temperature control mechanism.

Age and Growth

McAda and Wydoski (1980) aged razorback sucker, using scales; the oldest fish they found was 9 years old and 592 mm in length. However, evidence that they presented and that has since been verified indicates that scales may be unreliable for ageing larger razorbacks. McAda and Wydoski (1980) recaptured one fish 1.5 years after its release; it had not increased in length, and they could not detect an additional annulus. A second fish, 504 mm in length when tagged had only increased 8 mm in length after 3.5 years (McAda and Wydoski 1980).

Disease and Parasites

Little information is available concerning diseases and parasites of razorback sucker. Flagg (1980) examined five specimens from the Colorado River and found a bacterium, *Erysipelothrix rhysiopathiae;* a protozoan, *Myxobolus* sp.; and a crustacean, *Lernaea cyprinacea. L. cyprinacea* was commonly found on exotic and endemic species from the Colorado River System. *Myxobolus* sp. was found on nearly every endemic fish examined but was not found on exotic species. *E. rhysiopathiae* was unique to razorback sucker. Flagg concluded that disease agents were likely not a factor in the decline of native fish populations.

Habitat Preferences

Razorback sucker are usually collected from quiet eddies and pools. In the Colorado, Green, and Yampa rivers, these fish are most commonly collected in spring during high water, when they apparently congregate in large backwaters or eddies out of the main current. They are less common in collections during other seasons but are still found in quiet water. In the Colorado River, razorback sucker have frequently been collected in flooded gravel pit excavations adjacent to the river near Clifton and Grand Junction, Colorado.

FWS (Tyus *et al.* 1982) recorded depth, velocity, and substrate at razorback sucker collection sites in the Green River over the last 3 years. Excluding fish collected on or near suspected spawning areas, razorback sucker were collected at an average depth of 1.1 m (n = 59, range = 0.18-2.07 m) and an average water velocity of 0.12 m/s (n = 59, range = 0.0-0.7 m/s). Fish were usually collected over sand or silt substrates.

Tyus *et al.* (1981) also studied habitat preferences of one razorback sucker by radiotelemetry. The fish was released in April and monitored until June. Depth, velocity, and substrate measurements were made whenever the fish was located. On two occasions, the fish was monitored for 24 hours and habitat parameters were recorded on a regular basis. Over the 3-month period, the fish selected an average water depth of 0.76 m and a water velocity of 0.13 m/s. It was always located over sand or silt substrate (Table 1).

Movement

McAda and Wydoski (1980) reported recaptures of 11 of 98 razorback sucker tagged with numbered anchor tags. Of these, 8 were recaptured at the original point of capture, a flooded gravel pit adjacent to the Colorado River near Grand Junction, Colorado (Walker Wildlife Area). This indicated a tendency for individual fish to remain in one area for periods up to 1 year. They also reported movements by fish of 21 km (in 2 weeks), 26 km (in 6 months), and 130 km (in 3.5 years).

Tyus *et al.* (1982) subsequently captured several razorback sucker tagged by McAda and Wydoski and other investigators. One razorback was initially tagged in the mouth of the Yampa River in the spring of 1975. It was recaptured 5.2 years later 207 km downstream in the Green River. A ripe female razorback sucker was captured in the lower Yampa River in spring 1981 after being tagged by BIO/WEST, Inc. (Logan, Utah) in the Green River about 20 km downstream in March 1978. While razorback sucker were congregated in and near Ashley Creek in 1981, four fish were recaptured in the same vicinity up to 3 weeks after initial capture.

During 1980, Tyus *et al.* (1981) followed movements of a single razorback sucker in the Green River, using radio equipment. After release in March, the fish moved downstream about 6 km and entered the Duchesne River (Fig. 1). It remained in the lower 1 km of the Duchesne River until early June, when flooding occurred. The fish then moved into a large eddy in the Green River at the mixing zone of the two rivers. It remained within 1 km of the Duchesne River until early July, when contact with the fish was lost. Contact was reestablished in late July about 11 km upstream from the Duchesne River. The fish remained in this area until surveillance was terminated in mid-August.

TABLE 1. Habitat preferences of a razorback sucker, determined by radiotelemetry, Duchesne and Green rivers, 1980. (From Tyus et al. 1981)

River	Month	Depth ($\bar{X}$) m	Velocity ($\bar{x}$) m/s	Primary substrate	Habitat
Duchesne	April (n=1)	1.34	.18	sand	shore
(n=37)	May (n=1)	1.37	.06	silt	shore
	May (n=1)	1.74	.18	sand	main channel
	May (n=34)	.61	.06	silt	shore
Green	June (n=6)	1.01	.49	sand	shore
(n=7)	June (n=1)	2.44	.21	sand	main channel
All observations	(n=44)	.76	.13	sand/silt	shore/main channel

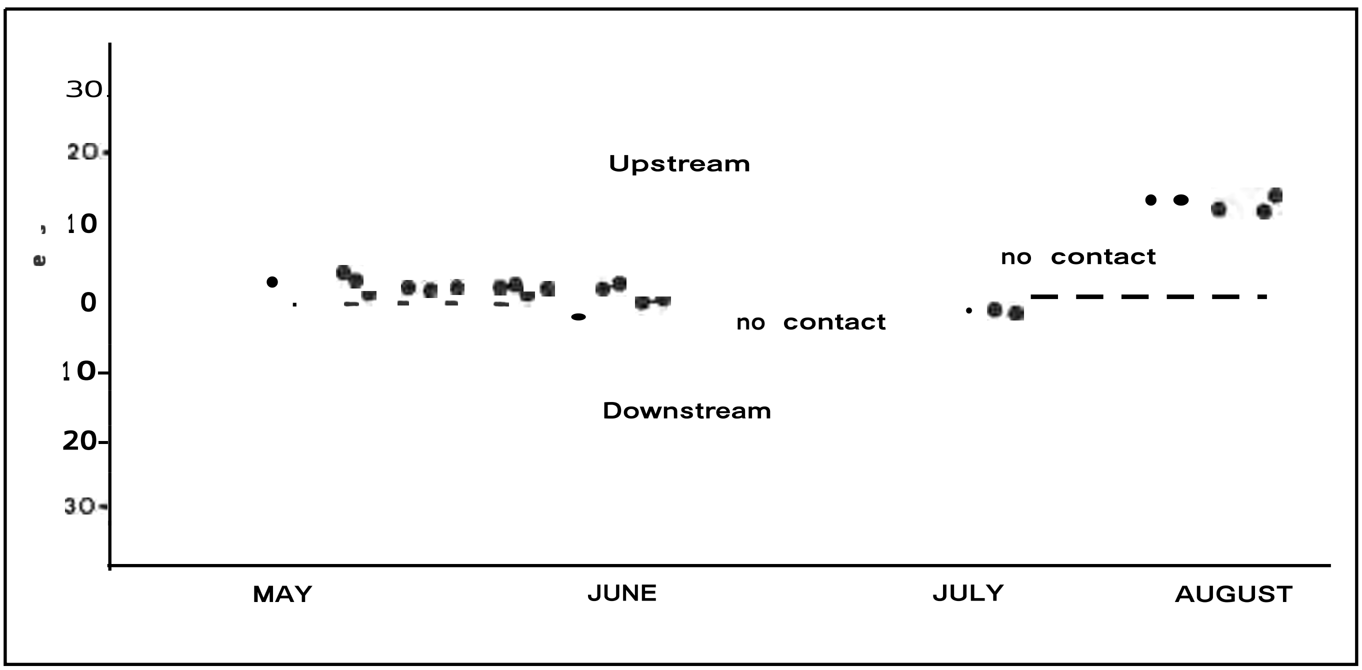

Figure 1. Long-distance movement of a razorback sucker in the Green and Duchesne rivers, as determined by radiotelemetry, 1980. The mouth of the Duchesne River is token as zero. Points above the zero-line indicate upstream movement; points below the zero-line indicate downstream movement. The fish was in the Duchesne River until early June, when it moved into the Green River. (From Tyus et al. 1982b).

REASONS FOR DECLINE

Behnke and Benson (1980) summarized possible reasons for the decline of razorback sucker. They pointed out that dams, impoundments, and land- and water-use practices are probably major reasons for drastically-modified natural flows and river channel characteristics in the basin. Dams on the mainstem have essentially segmented the river system, blocking spawning migrations and drastically changing river characteristics, especially flows and temperatures. Channelization, dams, and water-use patterns in the main-stem and tributary streams have reduced or nearly eliminated embayments, backwaters, and off-stream impoundments.

In spite of the severe changes that have occurred in the river system, adult razorbacks may be able to survive. The real problem is the evident disruption of their reproductive cycle. The exact reasons for this disruption are not known, because optimum spawning requirements are not clearly understood and there could be various reasons for reproductive failure. Assuming that tributary streams were preferred to rivers and impoundments as spawning habitat, reduction in access to and quality of these streams may be an important factor in the decline of razorbacks, especially when combined with the loss of larval nursery habitat and competition and predation from introduced species.

Razorbacks may be attracted to off-stream impoundments by irrigation ditches and drains from these areas. They may swim up these outlets into the impoundments and become disoriented. Likewise, razorbacks inhabiting reservoirs may move shoreward during spawning time in search of a suitable spawning stream or substrate. Unable to find suitable spawning areas, razorbacks may spawn on marginal shoreline substrate in reservoirs and impoundments and be successful only to the degree to which requirements for developing eggs are met. Many impoundments are silty; eggs in these reservoirs may not receive sufficient oxygen. Predation by introduced species (i.e., carp, catfish, sunfish, bass, and mosquitofish) on eggs and larvae may severely reduce survival at these critical stages. Gustafson (1975) reported that developing razorback embryos deposited in water less than 1 m deep in river reaches below impoundments were destroyed by fluctuating water levels.

The reasons for reproductive failure must be identified, and means to correct this failure must be developed to preserve the razorback. Knowledge gained by studying the razorback may be applicable to the Colorado's other endangered fishes and provide valuable insights to their problems. Since razorback sucker are relatively easy to study and their current legal status is less controversial than those of federally-endangered species, they are a logical choice for bold and innovative studies.

Prospects for Recovery

If the present level of interest in conducting research and recovery efforts in the Upper Basin continues, the future of the razorback does not look promising. If reliable information is to be obtained, we must begin reproduction studies while we still have some razorbacks to study and a few relatively-natural river sections in which to study them. Recent studies have shown that artificial progagation of razorbacks is quite feasible. This is encouraging for short-term recovery efforts and experiments on competition and predation. Artificial propagation can provide the time needed to study the likelihood of establishing self-sustaining razorback populations in the wild.

At present, political roadblocks and attitudes of agencies charged with the razorback's protection are hindering progress in recovery efforts. Artificial propagation of the species is strongly discouraged by state agencies in the Upper Basin, and stocking of the species in Upper Basin waters probably would meet with resistance. Means to overcome these obstacles need to be developed. Funding is needed to support studies on the razorback.

What is urgently needed at this point is the formation of a group of concerned biologists and administrators to act as a recovery team with authority to guide research and recovery efforts and to obtain necessary funding. No such group is now acting on behalf of the razorback; recovery efforts are fragmented and uncoordinated. It would be advantageous to act quickly while equipment and experienced personnel from FWS and state agencies are available to conduct the research. Closer coordination between researchers in the Upper and Lower Basins is also needed. The following task outline is provided as a possible guide to future research efforts.

TASK OUTLINE: RECOVERY OF THE RAZORBACK SUCKER

Primary Goal: Describe, maintain, and enhance razorback sucker habitat and convert the razorback to non-threatened status in its native range.

A. Accurately describe larval and juvenile razorback sucker morphology to facilitate determination of recruitment and reproductive success.
   1. Obtain a series of early-life-history specimens of razorback sucker.
   2. Compare key characteristics of razorbacks to those of other native sucker.
   3. Prepare and distribute literature on identification of early life stages.
   4. Sample suspected spawning areas for larval razorbacks to determine if reproduction is occurring.

B. Identify and describe optimum spawning habitat.
1. Radio-tag adult razorbacks prior to spawning and monitor activities before, during, and after spawning in river and backwater areas.
2. Trap-net inlets to off-stream impoundments. Monitor movement in and out, determine activity patterns, and describe condition of fish.
3. Sample suspected spawning areas for eggs and larvae.
4. Describe spawning areas.

C. Identify river habitat modifications that select against or favor razorback sucker.
1. Search for and monitor razorback populations in the Upper Basin.
2. Describe habitat in which razorbacks are collected to determine habitat preferences.
3. Compare in detail all areas used by the razorback; analyze depth, substrate, velocity, bottom contours, and water quality.
4. Compare egg-hatching rates and larval survival in various habitats and physical conditions. Consider various combinations of substrates, temperatures, velocities, and water-quality parameters.
5. Establish a coordinated habitat-improvement program.
6. Monitor activity patterns in various habitat-improvement areas by radio-tagging.
7. Conduct experiments with adult razorbacks under controlled spawning conditions, and evaluate spawning success under various conditions in specially-constructed areas.

D. Analyze interspecific relationships between non-native species and razorback sucker.
1. Select existing sites or build backwater and gravel-pit situations in which to conduct experiments.
2. Conduct experiments in field and laboratory to analyze competition and predator-prey relationships between various non-native species and razorback eggs, larvae, juveniles, and adults.

E. Develop culture and rearing techniques for razorback sucker.
1. Develop procedures for taking eggs from wild stock.
2. Analyze egg-hatching success under various laboratory and controlled field conditions.
3. Experiment with feeding techniques and rearing densities to obtain maximum (or desired) growth rates.
4. Rear razorbacks under various conditions in off-river impoundments and backwaters for possible release to the wild.

F. Develop an information and education program.
1. Prepare list of all agencies and researchers studying the razorback sucker.
2. Arrange regular meetings of key researchers and agency representatives to report research plans and results.
3. Distribute progress reports and encourage special news releases and presentations of significant data and accomplishments.

G. Develop a regional management policy specific to the razorback sucker.
1. Establish guidelines on how to protect razorback habitat.
2. Review current local, state, and federal laws and regulations which may be applicable in various situations.
3. Develop procedures for responses to development activities and establish monitoring programs.
4. Train a special team of biologists in response procedures. Review procedures specific to the razorback and relationships to other endangered fishes.
5. Prepare list of mitigation projects which may be useful to management and research activities.
6. Develop goals for desired razorback population levels and establish a procedure to reach these goals.

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CONCERNS ABOUT THE STATUS AND PROTECTION OF ENDEMIC FISHES, ESPECIALLY THREATENED AND ENDANGERED SPECIES: SYNTHESIS OF A PANEL DISCUSSION

Richard S. Wydoski

This synthesis was compiled from the concerns expressed by persons attending the panel-discussion portion of this symposium. Major topics were status of the endemic fishes in the Upper Colorado River and means to prevent jeopardizing their continued existence by adverse effects from water-development projects. This synthesis was organized from audio tapes into a logical sequence to express the major thrust of the discussion.

The Colorado River is probably the most utilized and controlled river in the world and has been the key to development in the Southwest. Historically, the dominant emphasis in this area of the United States was "mastery over nature", and the river had to be altered and controlled to provide water for municipal, agricultural, and industrial uses after runoff. Future demands by American society for water-development projects on the river will result in additional modification.

Perhaps a Colorado River Fishery Commission, similar to the Great Lakes Fishery Commission, is needed. The commission could hear and act upon recommendations of various agencies and institutions. Bob Shields posed several pertinent questions related to establishment and operations of a central regulatory body such as a commission, including (1) Which agency would administer mitigation funds and carry out management practices called for by a Conservation Plan?, and (2) How would decisions be prioritized to most effectively allocate mitigation money? Obviously, cooperation of the various federal and state agencies would be necessary in making final decisions after all possible alternatives were explored. Bob Behnke posed similar questions and offered the suggestion that a strong leader who is well versed in the art of biopolitics would be needed to provide the "clout" necessary to accomplish the goals of preserving threatened and endangered species. He also emphasized that economics play an important role in management decisions and suggested that a species such as the Colorado squawfish that is readily captured by conventional fishing tackle could generate interest among anglers. Many would be eager to catch this unique fish (the largest piscivorous cyprinid in the United States) that is endemic to the Colorado River. Economic values are established for water-development projects on the Colorado River, and perhaps such values need to be established for the fish.

Endemic fish studies that have continued for a number of years have provided information about the distribution and abundance of the fish and increased knowledge about their biology and habitat preferences. Gaps still remain in biological and ecological knowledge that is essential to the continued existence of the threatened and endangered fishes. Bill Miller stated that efforts are underway to determine instream flow needs, spawning and nursery areas, and acute toxicity of various substances.

Federal water development of the Upper Colorado River has been done through the Bureau of Reclamation. Phil Sharpe of Reclamation pointed out that two sets of laws apply to water development of the Colorado River: (1) older laws, such as the 1922 Compact that allowed water development projects, and (2) newer laws, such as the 1956 Fish and Wildlife Coordination Act and the 1973 Endangered Species Act that pose certain constraints in complying with the Colorado River Storage Project Act. The Bureau of Reclamation has a policy in developing all water projects that covers the full range of multiple uses; fish, wildlife, and other uses are considered. However, the states have rights for use of the water, and those rights will remain with them. The Bureau of Reclamation is flexible in its operations and can frequently regulate flows to meet needs suggested by personnel from state agencies, other federal agencies, and universities. If the habitat requirements of threatened or endangered fish are known, water releases can probably be adjusted to meet these needs. Cooperative efforts should focus on the consumptive needs of society, but modifications, such as using storage water rather than completely dewatering a river reach that may be critical to the fish, are possible.

Water flows are important, but food sources are also important to endangered fishes. Some invertebrate studies have been accomplished on the Colorado River, but little emphasis has been placed on the food habits of the threatened and endangered species. Effects of altered flow regimes on the food base are not known. The history of the Colorado River System has documented high fluctuations in flow which varied greatly with precipitation. The scouring effect of high flows may have been important in producing backwater areas that serve as nursery areas for some species. Scouring may have also been important in cleaning rocky substrates that are productive habitats for invertebrates. Dams have stabilized streamflows and may have adversely affected the food sources of endemic species.

Clair Stalnaker emphasized that biologists and engineers must work closely together. People in one discipline must be tolerant of the needs of other disciplines, understand the rationale for these needs, and compromise to reach the best decisions on managing this important river. Biologists must communicate the best knowledge about the biological requirements of the fish and must be willing to make some mistakes rather than waiting until "all" data are in hand. Biologists must also use the tools of engineers to the advantage of the fish. On the other hand, engineers must examine carefully alternatives that may not be most cost-effective but that will provide ways to maintain critical fish habitat while meeting the objectives of water development in the system. Several participants in this symposium stated that 60% of the water that remains in the river is adequate to maintain and preserve at least three of the river's rare fish species.

Water flows and temperatures (and perhaps other environmental factors) can be modified, in some cases, to fulfill environmental needs of rare fish at critical times and still meet the water-use requirements of the river system. For example, modified flow regimes may still be suitable for fish or even enhance conditions for fish. Mike Prewitt emphasized that various models developed on streamflow, water temperature, and sediment may be extremely useful for effective management of the river for fish as well as for water use.

Biologists must focus on the problems responsible for declines of endemic fishes; the symptom is low populations, but the major problem appears to be a curtailment of reproduction or reduced critical habitat during certain life stages. Research must be focused on species that are probably still present in numbers that will allow them to survive. Species such as the bonytail chub, which may have declined to the point of extinction, are difficult to manage. The ultimate goal is to delist species (i.e., recover populations to some acceptable level).

Paul Holden suggested that different goals be developed for different river systems. All of the water available is not necessarily useable habitat for fish. The San Juan River is probably already lost as habitat for endangered species because of dewatering. Perhaps highly-modified riverine habitats should be sacrificed to allow emphasis on saving reaches of the White or Yampa rivers that have potential critical habitat for the rare species. In other words, efforts should be concentrated on reaches with habitat that will do the most good for the fish. Logic dictates that such action be taken, since future water development will continue to modify riverine habitats, perhaps in an adverse way for rare or unique fishes.

Pros and cons of listing a species or keeping it from being listed were discussed. Advantages of listing include habitat protection and restoration measures. However, flexibility to manage listed species is decreased. Personnel from the Bureau of Land Mangement and the Forest Service have been especially effective at identifying depleted species and taking measures to prevent listing by protecting and improving habitat. Jim Johnson (Fish and Wildlife Service, Albuquerque) discussed a cooperative agreement between Arizona and the Forest Service to stock a million razorback sucker in the Lower Colorado River Basin in the next 10 years. If the species can reproduce in a natural habitat, it may not be a candidate for listing.

However, some species, such as the humpback chub, are still maintaining themselves in restricted habitats. Such a species cannot be saved in the Upper Colorado River without saving its critical habitat. Entire ecosystems cannot be saved, but certain critical habitats may be protected through cooperative efforts. Other species, such as the Colorado squawfish, appear to need extensive areas of suitable habitat (at least for adults). Areas needed for spawning may not be as extensive. However, there is a major difference between maintaining critical habitat for selected species and maintaining (i.e. preserving) an entire ecosystem. As demands for water continue in this river system, society will have to decide where habitat should be maintained, and for what species.

It is extremely important philosophically to have some successes in restoration efforts. Therefore, species such as the Gila trout, Arizona trout, and Gila topminnow have been the object of such efforts by the states, Fish and Wildlife Service, and Forest Service. Success could be demonstrated by restoring the species in an area of habitat large enough so that they can be safely delisted.

The panel concluded that the bonytail chub is in jeopardy and may be on its way to extinction. The razorback sucker is still abundant in Lakes Mead and Mohave, but this species is believed to be long-lived and may disappear if sufficient recruitment does not occur within the population. We do not fully understand its reproductive requirements but may have some time to save this long-lived species. Paul Holden commented that the razorback sucker disappeared from the Gila River in about a 30-year period. The same thing could happen in Colorado River reservoirs such as Lakes Mead and Mohave unless spawning requirements are determined and steps are taken to provide such requirements, if possible. The razorback sucker in Lake Powell apparently moves upstream to riverine conditions above the reservoir, perhaps because of biological requirements.

Ron Lambertson stated that limited resources exist in the Endangered Species Program and that compromises must be made. For example, problems that can be solved within the resources of personnel and budgets must be identified. If such problems cannot be identified, species restoration efforts may have to be discontinued, as in the case of the dusky seaside sparrow.

Bob Behnke stated that strict enforcement of the Endangered Species Act may be needed to save the endangered fishes of the Upper Colorado River. For example, water releases can be made from near the surface of a reservoir rather than from deep water so that water temperatures are more suitable for endangered species. Also, fish stocking in the Colorado

River may be detrimental to threatened and endangered species through competition and predation. Such stocking continues but could be terminated.

The Endangered Species Act requires Reclamation to work within its guidelines on water-development projects. If ecological limits or tolerance to certain factors are known for a fish, personnel from Reclamation will work closely for restoration. Phil Sharpe stated that Reclamation will probably continue to support research to identify habitat that is critical for rare fishes, since their mission of multi-purpose water development on the Colorado River System must continue.

Ron Lambertson was asked to comment on the future re-authorization of the Endangered Species Act. He pointed out that there are many different options for changes in the Act, and many factors will be considered before the Act is re-authorized and/or changes are made. For example, 21 environmental groups have joined together to provide suggested changes during the re-authorization process, and other groups have provided additional suggestions. The Fish and Wildlife Service is in the process of making recommendations that will affect the Act during re-authorization.

Recovery team efforts have been extremely sincere. However, the wide range of factors or studies that are considered by such teams require large budgets for total restoration efforts. Because of inflation and budget reductions in federal and state agencies, realistic biological goals and objectives must be outlined to fit the social, political, and economical constraints that affect processes in natural resource management. "Realistic" management of endangered species was discussed by Johnson (1977), Schreiner (1977), Smith (1977), and Wydoski (1977).

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CLOSING REMARKS

William H. Miller

In this symposium we discussed the listing of endangered Colorado River fishes and the legal requirements of the Endangered Species Act (ESA). We heard from the Fish and Wildlife Service (FWS) on their attempt to carry out ESA regulations and learned that there are problems with conserving these fish in light of development.

The Bureau of Reclamation (Reclamation) emphasized the flexibility in the operation of their program. We have expressed a concensus belief that it is not too late to save the endangered Colorado River fishes, particularly the Colorado squawfish and humpback chub. A Colorado River Fishery Commission has been suggested as a possible regulatory or clearing-house body to assist in the control of the Colorado River aquatic system.

Development of the waters of the Upper Basin will continue, probably at a faster pace than in the past. Therefore, we are confronted with the problem of *"How to Conserve these Endangered Colorado River Fishes and Habitat in Light of the Prospects of Rapid Energy Development in the West."*

The first step to approaching the development-vs-endangered-species problem was to gather biological data on the fish; this has been done over the past few years. Many new things have been learned about these fish, such as: (1) Colorado squawfish were found to move over great distances; (2) spawning requirements and needs of species have been determined; (3) new populations of humpback chub have been discovered; (4) the very tenuous status of the bonytail chub has been documented and a remedial hatchery propagation program undertaken; and (5) many other factors relative to the biological requirements of these fishes are now understood.

This symposium is a synopsis of what is known about the Colorado River endangered fishes. But, in recapping the symposium, I believe we need to go further back and look at a river system in a state of change.

Do we have a Colorado River as it was at the turn of the century? The answer is no! The Lower Colorado River Basin is what developers would term "completely controlled". Some of the facts presented by Reclamation people have described how the Upper Basin will become even more controlled/altered.

So, what is the habitat of the large-river fishes? It originally consisted of over 1,500 miles (2,400 km) of river habitat and is now physically restricted to 600 + miles (965 km). Of these remaining 600 + miles, (965 km), only certain areas have retained their viability as large-river fish habitat. In the past 10 years, we have documented a decline in the large-river fishes, especially in the bonytail chub.

The status of these fish can probably be characterized as in a shrinking-population mode. The bonytail chub may be the first to become extinct. Will the humpback chub or Colorado squawfish be next? I don't believe we know. However, we have heard that, if the trend in wild populations continues, with depletions and associated habitat losses, all these species will remain endangered with a high probability of continued decline.

Where do we go from here? The Colorado River Fishes Recovery Team provided plans to assist these species to recovery. Their plans started with acquiring biological data, and much of that has been done. The plan also calls for reintroduction into original habitat; this is being actively pursued in the Lower Basin. But, as we have heard from Bob Shields and others, we do not have the luxury of time on our side. We really needed answers to some of these biological questions yesterday. And now, with the revived thrust toward energy development in the Upper Basin, these fish are under a much greater seige.

Let's look at the options. As indicated by the speakers, FWS has undertaken development of what they are calling a Conservation Plan. This plan is concerned with the protection and enhancement of endangered fish in the Upper Colorado River Basin in habitat in which they now reside. It is basically a management plan to provide guidance in the preservation of Upper Basin fish stocks. The Conservation Plan has the potential for a number of options, depending upon what the political and legal preserves may dictate. My attempt to summarize these follows:

1. The first option is to establish optimum populations of endangered fishes in the Upper Basin by requiring flow and water quality needed for these fish at selected points. This may be possible, as Mike Prewitt pointed out. But species such as the bonytail chub and razorback sucker are already going down under present conditions. The question is — do we have flexibility in the system to provide what is needed for all the species?
2. The second option is to concentrate our efforts where the fish now are doing well and maintain populations at present levels or less than present levels at a few key locations. This, however, defies the recovery concept and negates complete recovery as provided in the Recovery Plans.
3. A third option is to establish a few selected key areas in which to maintain habitat as much as possible and stock from hatcheries.
4. The final option is to move entirely toward the "zoo," or hatchery, approach, relying on the hatchery to provide all specimens with the option of stocking into completely changed environments or different geographical areas.

Only one species of the four we have talked about can be described as maintaining a viable population in the altered Lower Colorado River — the humpback chub. Thus, if the Upper Basin follows the trend seen in the Lower Basin, we have sealed the fate of at least three species.

We have flexibility in the system in the Upper Basin, legal protection for the species, and the capability to manage the species. We also can use the approach of assessing developers, as Bob Shields described, to get funds for managing the species.

I hate to sound the anti-preservationist's note, but I believe we must manage these species. I believe information presented here reinforces that belief. The historic Colorado River no longer exists. We now have something less natural. But, we also have knowledge of the fish, the legal mandate to regulate impacts, and the commitment of resource agencies to manage these species.

As Bob Behnke stated, "The preservation of endangered species is a long-term proposition; for practical purposes, it must last forever". Therefore, we, as biologists and representatives of resource management agencies, must make a commitment for a long-term management-recovery effort. Are we ready to make that commitment? I surely hope so.