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A SURVEY AND ANALYSIS OF EXISTING INFORMATION ON FISHES IN NORTHWEST COLORADO*

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October 29, 1982
(Annotated Bibliography Current to May, 1983)

* Volume 6 of a 14-volume series of reports on Wildlife Conservation and Energy Development in Northwest Colorado" published by the Ecological Services Section, Colorado Division of Wildlife, 6060 Broadway, Denver, Colorado 80216

Suggested Citation

Behnke, R.J., C.A. Carlson, D.L. Miller, D.E. Snyder, E.J. Wick, and L.D. Zuckerman. 1982. A survey and analysis of existing information on fishes in northwest Colorado. 216 pp. (including annotated bibliog. current to May, 1983). Vol. 6 in D.W. Crumpacker, ed. Wildlife conservation and energy development in northwest Colorado. Prepared by Northwest Colo. Wildl. Consortium and publ. by Ecol. Serv. Sect., Colo. Div. Wildl., Denver, Colo. 14 vol. series.

NORTHWEST COLORADO WILDLIFE

CONSORTIUM

University of Northern Colorado

Colorado State University

Colorado Division of Wildlife

University of Colorado

A SURVEY AND ANALYSIS OF EXISTING INFORMATION ON FISHES IN NORTHWEST COLORADO*

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* Volume 6 of a 14-volume series of reports on "Wildlife Conservation and Energy Development in Northwest Colorado" produced by the Northwest Colorado Wildlife Consortium with funds provided by the Bureau of Land Management to the University of Colorado through Contract No. YA-553-CT1-130. Copies of this and other volumes in the series can be obtained at a nominal cost from the Colorado Division of Wildlife or the Bureau of Land Management.

ABSTRACT

Northwest Colorado is part of the Upper Colorado River Basin. The area is drained by the Yampa, White, and Mainstem Colorado rivers. This report emphasizes those segments of these river drainages in Moffat, Routt, Rio Blanco, Garfield, and Mesa counties. Information is given on the fishes occurring in the region. The fish fauna is delineated by ecological groupings -- coldwater and warmwater species -- by native and non-native species, by sport and non-sport species, and by threatened and endangered species. Emphasis is given to threatened and endangered species and to sport fishes. The information given includes habitat requirements, trophic characteristics, distribution by elevation, and status as threatened, endangered, sport or non-sport. This information has also been condensed into tables for ready reference. Species narratives for threatened and endangered fishes include their occurrence in northwest Colorado, important river sections, life history information, and their susceptibility to anthropogenic environmental changes.

A section on mitigation discusses three basic aspects of mitigation: prevention, compensation, and modification. It is pointed out that necessary requirements for adequate mitigation plans are a thorough knowledge of the ecosystem and an elucidation of potential direct and indirect effects of an action. Potential impacts on aquatic ecosystems can be reduced to three major types of physical/chemical disruption -- habitat destruction or modification, changes in flow and/or temperature regimes, and pollution. Primary impacts are associated with such actions as impoundments, river regulation, channelization, and toxic pollution.

Secondary impacts are associated with changes in land use and increased population. A critique is provided of several database methods and models in current use for ecological classification and prediction. The advantages and limitations of each method or model are discussed in relation to its application as a mitigation tool for assessing impacts on the fishes and fisheries of northwest Colorado.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
FISHES OF NORTHWEST COLORADO RIVERS	7
THE FISH FAUNA OF NORTHWEST COLORADO	24
Non-Native Warmwater Sport Fishes of Northwest Colorado	31
Coldwater Sport Fishes of Northwest Colorado	41
Native Non-Endangered Non-Sport Fishes of Northwest Colorado	48
Non-Native Non-Endangered Non-Sport Fishes of Northwest Colorado	59
Federal and State Endangered or Threatened Species	67
Colorado River Cutthroat Trout, *Salmo clarki pleuriticus*	67
Colorado Squawfish, *Ptychocheilus lucius*	76
Humpback Chub, *Gila cypha*	81
Bonytail, *Gila elegans*	85
Razorback sucker, *Xyrauchen texanus*	88
MITIGATION AND NORTHWEST COLORADO	94
(A) Classification, Inventory and Database Management Systems	99
(B) Evaluation, Prediction and Mitigation Methodologies	122
LITERATURE CITED	140
ANNOTATED BIBLIOGRAPHY	173
GLOSSARY	212

TABLES

Number		Page
1	Summary of fishes reported (X) from the Yampa River in Colorado	8
2	Summary of fishes reported (X) from the White River in Colorado	14
3	Summary of fishes reported (X) from the Green River in Colorado	18
4	Summary of fishes reported (X) from the Upper Mainstem Colorado, Gunnison and Dolores rivers in northwest Colorado	21
5	Status and recent distribution of fishes within 11 subregions of the Colorado River System in Colorado	25
6	Numbers of fish families and species in the Green and Upper Mainstem Colorado river basins	27
7	Important fishes of northwest Colorado with general habitat requirements, trophic characteristics and legal status	28
8	Character analysis of 1980 collections of Colorado River cutthroat trout (*Salmo clarki pleuriticus*) from the Upper Colorado Drainage in Colorado	68
9	1981 collections of *S. c. pleuriticus*	71

FIGURE

1	Map of the Green River and Upper Mainstem Colorado River basins in western Colorado divided into 11 drainage-based subregions.	26

INTRODUCTION

All of northwest Colorado is drained by the Colorado River System. Along the Continental Divide at elevations of 3,000 to 4,000 m first order streams fed by snowmelt initiate the headwaters that form the three major subdrainages of northwest Colorado. The northernmost segment of the basin is drained by the Yampa River, which enlarges to a sixth order river before it joins the Green River at Echo Park in Dinosaur National Monument--a distance of about 250 km from its origin. Major Yampa River tributaries include Elk River, Elkhead Creek, Williams Fork, and the Little Snake River (which has most of its watershed in Wyoming). The Yampa River is a significant source of water in the Colorado River Basin. Combining USGS gauging records for the Yampa River at Maybell and Little Snake River at Lily Park for the period from 1951 through 1978 gives an average daily flow from the basin of 1986 cfs (1.5 million acre-feet annual average volume). Of this long-term average daily flow, the Yampa Drainage contributes 1,452 cfs and the Little Snake 534 cfs. In comparison to other Colorado River Basin tributaries, the Yampa transports a light sediment load until it is joined by the Little Snake River. The Little Snake has a much greater relative sediment load than the Yampa. The average annual sediment yield from the Yampa Drainage, recorded at Maybell, is 34 tons/km^2; the Little Snake River Drainage sediment yield averages 114 tons/km^2 (Yorke 1980).

The Upper Yampa and its tributaries descending to about 1,800 m elevation are typically trout waters. At lower elevations, a transition to warmwater fishes occurs. The Yampa River in Moffat County is significant for the endangered Colorado squawfish (Ptychocheilus lucius). From the

standpoint of endangered species, numerous adult squawfish inhabit the river; some move upstream above Juniper Canyon to about 24 km below Craig. In 1981, the U.S. Fish and Wildlife Service traced sexually mature squawfish by radiotelemetry and documented spawning in the Lower Yampa in Dinosaur Monument; larval squawfish were found in the Lower Yampa in 1980, 1981, and 1982 (Wick et al. 1981, Miller, Archer, Tyus and McNatt 1982). Occasional specimens of humpback chub (Gila cypha) and razorback sucker (Xyrauchen texanus) have been found in the Lower Yampa up to Cross Mountain Canyon (U.S. Dept. Interior 1980).

The area immediately to the south of the Yampa watershed is drained by the White River. The White River forms with the junction of the north fork and the south fork above the town of Buford. The upper segment of the drainage is mainly a coldwater trout environment. Below Meeker, the watershed is highly erosive and the White carries a heavy sediment load with much evidence of active erosion. Piceance and Douglas creeks are the main tributaries to the White River in Colorado and contribute high sediment loads. The erosional history of the Douglas Creek watershed was the subject of graduate research by Womack (1975). The greatly accelerated erosion began soon after intensive livestock grazing was initiated in the watershed in the late nineteenth century during the era of the open range. This pattern of accelerated erosion was essentially duplicated in most Colorado River drainages of the foothills and lowland region. The impact on water quality, mainly resulting from livestock grazing and return irrigation flow, is such that present sediment loads and total dissolved solids (TDS) concentrations are approximately twice as high as virgin conditions in the Colorado River (Bentley et al. 1978).

After leaving Colorado, the White River continues about 75 km through Utah to join the Green River near Ouray. The White River's average annual flow volume is 502,800 acre-feet at the state line. The White River is important for squawfish; 58 specimens were captured in 1981 (most in Utah) during sampling by the U.S. Fish and Wildlife Service (Miller, Archer, Tyus, and Harper 1982). Squawfish have been captured in the White River in Rio Blanco County, Colorado, upstream to the confluence with Piceance Creek (Carlson et al. 1979).

Southeast of the Yampa and south of the White River watersheds, the land is drained by the mainstem of the Colorado River. The Colorado River has its headwaters in Rocky Mountain National Park. Near the headwaters the Colorado River forms Grand Lake, the only natural lake on the mainstem of the Colorado, White, or Yampa rivers. Immediately below Grand Lake, Shadow Mountain Reservoir and Lake Granby, constructed as part of the Colorado-Big Thompson Project, divert an average of 240,000 acre-feet of water per year from the Colorado River Basin to the eastern slope of Colorado. From Lake Granby, the Colorado River flows in a general southwesterly direction for about 350 km to the state line.

The Gunnison River (comparable to the Yampa in flow volume) is the largest tributary to the Colorado. Other major tributaries include the Blue, Eagle, and Roaring Fork rivers. The Dolores River Drainage includes a part of Mesa County. The average annual volume of virgin flow in the Colorado River at the state line is estimated to have been about 5,000,000 acre-feet. The flows during the past 30 years have been depleted to an annual average of 4,200,000 acre-feet (Joseph et al. 1977). Because of the contribution of cold, high-quality water from tributaries (Blue, Eagle, and

Roaring Fork rivers), trout maintain moderate, but sporadic abundance in the Colorado River of Garfield County as far downstream as Rifle. Outstanding wild trout fisheries are found in tributary rivers.

In regard to endangered species, Ruby Canyon below Grand Junction, Mesa County, and Westwater Canyon immediately downstream across the state line in Utah contain the greatest concentration of humpback chub known in the upper basin. These canyon areas are of significance also for Colorado squawfish. Young-of-the-year squawfish have been found from 1978 through 1982 in these canyon areas and above (a few km below Loma) by U.S. Fish and Wildlife Service and Colorado Division of Wildlife biologists (Haynes, Muth, Skiba, and Wycoff 1982; Haynes, Muth, and Wycoff 1982; Miller, Valentine, and Tyus 1982; Valdez, Mangan, Smith, and Nilson 1982; Miller, Kaeding, and Tyus 1983; Miller, Tyus, and Kaeding 1983). Squawfish and humpback chub have not recently been found in the Colorado River above the Grand Valley diversion dam at Palisade about 25 km above Grand Junction, but squawfish do occur in the Lower Gunnison River to above the town of Whitewater (Valdez, Mangan, McInerns, and Smith 1982). The razorback sucker occurs in the Colorado River below the Highline dam at Cameo. They have been found upstream as far as the Debeque-Rifle area (Valdez, Mangan, Smith, and Nilson 1982).

Due to the long isolation of the Upper Colorado River Basin, its native fish fauna is not rich in species diversity. Only 13 species are native to the upper basin and these were not ubiquitously distributed (Behnke and Benson 1983). For example, the mountain whitefish, Prosopium williamsoni, is native only to the Green River division of the basin, in the Yampa and White drainages of Colorado, and was not found originally in the Mainstem Colorado or its tributaries (it was introduced into the Roaring Fork River where it is now abundant). The mountain sucker, Catostomus platyrhynchus, is also native only to the Green River division, and in

Colorado its distribution is limited to only a few tributaries to the White and Yampa rivers. The eagle sculpin, Cottus annae[1], on the other hand, is only known from a few sites in the Mainstem Colorado Drainage in Colorado. These unusual distribution patterns have no ready explanation.

Originally, the cutthroat trout (Salmo clarki) was the only species of fish inhabiting the highest elevation headwater streams near their sources. As the streams descend in elevation and become larger, sculpin (Cottus bairdi), speckled dace (Rhinichthys osculus), whitefish, bluehead sucker (Catostomus discobolus), and roundtail chub (Gila robusta) would have been found. The "big river" species, Colorado squawfish, humpback chub, bonytail (Gila elegans), razorback sucker, and flannelmouth sucker (Catostomus latipinnis), were essentially restricted to the larger main river channels of the Colorado, Green, White, and Yampa. The flannelmouth sucker typically extends farther upstream than the other "big river" species, and it may occur in lower reaches of tributaries for at least parts of its life cycle. The flannelmouth sucker is still abundant; it is the only historical "big river" species not on the state or federal list of endangered species.

About 100 years ago non-native fishes began to be introduced into the basin. In such a large basin, with such environmental diversity, it would

[1]Robins et al. (1980) did not recognize Cottus annae but considered annae a synonym of Cottus beldingi, the Paiute sculpin. Since no publication presenting data on which this synonymy was based is available, we list the sculpin native to the upper mainstem drainage of the Colorado River in northwest Colorado as the eagle sculpin, Cottus annae.

appear that the relatively few native fishes did not fill all available niches, and the stage was set for successful establishment of non-native species (Molles 1980). Environmental changes (reservoir construction, changing flow regimes, sediment loads, etc.) greatly enhanced the establishment of non-native fishes.

Forty-two species of non-native fishes have been introduced into the Upper Colorado River Basin. About twelve of these are relatively common (often locally dominant) in the waters of northwest Colorado.

Brook trout (Salvelinus fontinalis) have almost completely replaced the native cutthroat trout in small, headwater streams, and rainbow trout and brown trout have replaced the cutthroat in the larger streams. The bonytail (Gila elegans) appears to have been eliminated from Colorado and probably from the entire Upper Colorado River Basin (Behnke and Benson 1983). The Colorado squawfish still occupies most of its original range in Colorado (Mainstem Colorado, Lower Gunnison, White, and Yampa rivers), but its present maximum body size is only a fraction of its historical size (Behnke and Benson 1983). Humpback chub are rare except in very localized areas of Ruby, Westwater, and perhaps Yampa canyons. The razorback sucker was rarely found during the sampling of recent years.

FISHES OF NORTHWEST COLORADO RIVERS

Research on fishes of northwest Colorado rivers intensified in the 1970s and early 1980s, and we are now in a position to review results of work on the Green, Yampa, White, Upper Mainstem Colorado, Gunnison and Dolores rivers in that part of the state. Major studies have been conducted in recent years by the Colorado Division of Wildlife, the U.S. Bureau of Land Management, the U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service (most notably the Colorado River Fishery Project headquartered in Salt Lake City, Utah), and private consulting firms. Biologists from Colorado State University, including the authors of this report, have played an active role in these investigations.

Following is a brief introduction to the most significant studies of fishes in the major streams of northwest Colorado. We have devoted most attention to streams with which we have greatest personal experience, the Yampa and White rivers.

Yampa River

Much of the early work on this river was conducted to facilitate sport-fish management (Carlson et al. 1979). Carlson et al. (1979) described major studies on the Yampa River. Results of these and more recent investigations are summarized in Table 1.

The Lower Yampa (from Hayden, Colorado, to the confluence with the Green River) was studied by Baily and Alberti (1952). Fishes were collected by electrofishing (Hayden to Craig) and use of gill and fyke nets (Craig to Lily Park). Speckled dace, flannelmouth sucker, and mottled sculpin were

Table 1. Summary of fishes reported from the Yampa River in Colorado.

Species	(1) Baily & Alberti (1952)	(2) Banks (1964)	(3) Holden & Stalnaker (1975a)	(4) Holden & Stalnaker (1975b)	(5) USDA, REA (1974)	(6) Seethaler, McAda and Wydoski (1976)	(7) Prewitt, Wick & Snyder (1978)	(8) Ecology Consultants (1976a,b,c,d)	(9) Carlson et al. (1979)	(10) Miller, Archer, Tyus, & McNatt (1982)	(11) Tyus, Burdick et al. (1982)
Prosopium williamsoni	X		X	X	X	X	X	X	X	X	C
Salmo clarki	X		X	X		X					R
S. gairdneri	X		X	X	X	X		X	X	X	R
S. trutta	X		X	X		X		X	X	X	R
Salvelinus fontinalis											I
Esox lucius										X	R
Cyprinus carpio	X	X	X	X		X	X		X	X	C
Gila atraria						X					I
G. cypha			X	X		X				X	R
G. elegans			X	X							-
G. robusta		X(?)	X	X	X	X	X	X	X	X	A
Notropis lutrensis			X			X				X	C
N. stramineus						X	X		X	X	C
Pimephales promelas		X	X	X		X	X	X	X	X	C
Ptychocheilus lucius	X(Gila?)	X	X	X		X			X	X	R
Rhinichthys osculus	X	X	X	X	X	X	X	X	X	X	A
Richardsonius balteatus		X	X	X	X	X	X	X	X	X	C
Semotilus atromaculatus	X	X	X			X			X	X	R
Rhinichthys osculus x Richardsonius balteatus?							X		X		
Catostomus commersoni			X	X	X	X	X	X	X	X	R
C. discobolus	X	X	X	X	X	X	X	X	X	X	C
C. latipinnis	X	X	X	X	X	X	X	X	X	X	A
Xyrauchen texanus			X	X		X				X	R
C. commersoni x discobolus			X			X	X		X		
C. commersoni x latipinnis			X			X	X		X		
C. discobolus x latipinnis									X		
C. latipinnis x X. texanus			X			X			X		
Ictalurus melas	X		X	X		X	X		X	X	I
I. punctatus	X	X	X	X		X			X	X	C
Fundulus zebrinus						X	X		X	X	I
Lepomis cyanellus	X	X	X	X						X	I
L. macrochirus			X	X							
Micropterus dolomieui										X	I
M. salmoides			X	X							I
Stizostedion vitreum			X	X							I
Cottus bairdi	X	X	X		X	X	X	X	X	X	R

* A = abundant, C = common, R = rare, I = incidental

listed as numerous; bluehead sucker and mountain whitefish were listed as common. Colorado squawfish were considered common from Hayden to the Green River, but since roundtail chub were not listed among collected fishes, an erroneous identification of the latter is possible. Few carp (Cyprinus carpio), channel catfish (Ictalurus punctatus), rainbow trout (Salmo gairdneri), and brown trout (S. trutta) were collected. Creek chub (Semotilus atromaculatus), black bullhead (I. melas), cutthroat trout and green sunfish (Lepomis cyanellus) were rarely collected. A summary of this information on fishes present is in Column 1 of Table 1.

Banks (1964) surveyed fish distribution within Dinosaur National Monument in 1961 and 1962 (see Table 1, Column 2). Yampa River data (from Echo Park and Castle Park sites) showed speckled dace, bonytail (and/or humpback and roundtail chub?) and flannelmouth sucker were most frequently collected. Stream flow, temperature and turbidity were considered influences upon fish distribution in the Yampa and Green rivers. Habitats in which various fishes were caught and fish food habits were also discussed by Banks (1964).

Holden and Stalnaker (1975a) studied fishes of the Yampa and Little Snake rivers as part of a 1968 to 1973 study. Yampa River stations consisted of an upper one from Craig to Juniper Springs, Colorado, and a lower one in Yampa Canyon in Dinosaur National Monument (Table 1, Column 3). Distribution, trends in abundance and historical background of each species were discussed. Habitat preferences and reproductive success were included for selected species as were reasons for declines of native species. Using much of the same data, Holden and Stalnaker (1975b) reported on fish collected by electrofishing, gill nets, and seines from Craig to the mouth

of the Yampa River between 1968 and 1971 (Table 1, Column 4). The walleye (Stizostedion vitreum), bluegill (Lepomis macrochirus), and largemouth bass (Micropterus salmoides) collected were considered "wanderers" from reservoirs on the Upper Green River System.

The Final Environmental Impact Statement on the Yampa Project (U.S. Dept. of Agriculture, Rural Electrification Administration 1974) contained information on biota collected near Craig, Colorado. Fishes collected in 1971 and 1972, in decreasing order of numerical abundance, were speckled dace, mottled sculpin, redside shiner (Richardsonius balteatus), mountain whitefish, bluehead sucker, white sucker (C. commersoni), flannelmouth sucker, rainbow trout and roundtail chub (see Table 1, Column 5).

Seethaler, McAda and Wydoski (1976) compared their 1974 to 1976 collections from Dinosaur National Monument to Holden's data from the Lower Yampa River. Their observations were similar to Holden's, but they did not collect bonytail, largemouth bass, bluegill, green sunfish, or walleye (Table 1, Column 6). Species in their collections from the Lower Yampa not collected there by Holden were Fundulus zebrinus (plains killifish), Gila atraria (Utah chub), and Notropis stramineus (sand shiner). Colorado squawfish were said to ascend the Yampa River when water levels were high and additional food and habitat were available. Squawfish reproduction was said to have declined since the 1960s. Ripe razorback sucker of both sexes were reported on two spawning bars in the Yampa River. Evidence of increased hybridization between flannelmouth and razorback sucker was also reported. Six humpback chub were collected from the Lower Yampa River in 1975 and 1976. The Yampa River was mentioned as a possible

refuge for some of the large-river endemic fishes that are threatened or endangered. The major contribution of the Yampa to continued survival of these fishes was considered to be its warming effect on the Green River below the confluence of the two streams.

Prewitt, Wick and Snyder (1978) reported on fish collected by seine, dipnet, and electrofishing at eight stations between Maybell and Sunbeam, Colorado, in 1977 (see Table 1, Column 7). Their Yampa River collections were much more diverse but contained a lower percentage of native species than their collections from the White River (considered below).

Studies related to the Yampa Project were conducted by Ecology Consultants, Inc. (1976a, b, c and d) to census fishes near and in the intake structures at Craig and Hayden power plants in November 1975 and May 1976. Rainbow trout, brown trout, mountain whitefish, roundtail chub, redside shiner, speckled dace, white sucker, flannelmouth sucker, bluehead sucker and mottled sculpin were collected near Craig Station by electrofishing, gill netting and seining. Longnose sucker (Catostomus catostomus) were listed among the fishes collected, but identification was said to be "uncertain due to hybridization." Mottled sculpin were most abundant, in spite of collection of only one specimen in May 1976. Mountain whitefish (the predominant game fish caught) and white sucker were second in overall abundance. Data from these reports are summarized in Table 1, Column 8.

Carlson et al. (1979) presented data on fishes collected from 1975 to 1978 between Lily Park Pool near Cross Mountain and Hayden, Colorado (see Column 9, Table 1). Fish distribution, relative abundance, reproduction, growth, foods and habitat were discussed. Flannelmouth sucker were the most

abundant fish in electrofishing samples; white sucker, bluehead sucker, redside shiner, fathead minnow (Pimephales promelas), and speckled dace were also commonly collected.

Miller, Archer, Tyus and McNatt (1982) collected in 1981 at eight relatively homogeneous reaches (strata) on the Yampa River (Round Bottom to the confluence with the Green River). Twenty-four species were collected from the Yampa River (Table 1, Column 10), and eleven species were collected in related work on the Little Snake River, a Yampa River tributary. Numbers of fishes collected generally increased upstream due to greater incidence of exotic species. Most abundant native fishes were bluehead and flannelmouth sucker, roundtail chub, and speckled dace. Most abundant exotics were red shiner (Notropis lutrensis), sand shiner, redside shiner, fathead minnow, and channel catfish. Rainbow and brown trout, northern pike (Esox lucius), razorback sucker, humpback chub, Colorado squawfish, creek chub, black bullhead, plains killifish, green sunfish, smallmouth bass (Micropterus dolomieui), and mottled sculpin were rare or incidental in collections. However, any of these species could be locally common (John Woodling, pers. commun., Colorado Division of Wildlife).

The last column (11) in Table 1 was derived from the review by Tyus, Burdick et al. (1982) and letters were used to code relative abundance of fishes in the Yampa River.

White River

Most early work on the White River was conducted for sport-fish management purposes (Carlson et al. 1979). Carlson et al. (1979) summarized major investigations which have contributed to understanding of distribution

and abundance of White River fishes; results of these and more recent work are outlined in Table 2 and discussed below. The salmonid populations in the White River Drainage above Piceance Creek were inventoried during the summer of 1955 by Klein (1957) as a preliminary step in evaluating whitefish management in Colorado (see Table 2, Column 1). Mountain whitefish, rainbow trout, brook trout, brown trout, cutthroat trout, specked dace, flannelmouth sucker, and bluehead sucker were collected. Hill (1964) reported on fishes of the South Fork of the White River (Table 2, Column 2). Rainbow trout were the most abundant fishes, but brook trout, brown trout, cutthroat trout, and sculpin were also collected by electrofishing.

Everhart and May (1973) stated that fish species diversity of the White River was slightly higher than that of Piceance Creek in 1968 and 1969 (see Table 2, Column 3). Flannelmouth sucker, mountain sucker, mottled sculpin roundtail chub, black bullhead, channel catfish, red shiner, Colorado squawfish, speckled dace, brown trout, and rainbow trout were collected from the White River. Everhart and May (1973) reported collection of G. elegans (bonytail) instead of G. robusta (as in May's 1970 thesis); this was probably due to an error in transcription or some taxonomic confusion.

Studies coordinated by Thorne Ecological Institute and conducted in the Piceance Creek Basin (Regional Oil Shale Study) included peripheral reference to the White River near Piceance and/or Yellow creeks. Pettus (1973 and 1974) collected fishes from White River stations by electrofishing, angling, and seines (Table 2, Column 4). White sucker were reported from the White River and Piceance Creek, but to our knowledge

Table 2. Summary of fishes reported (X) from the White River in Colorado

Species	(1) Upper drainage Klein (1957)	(2) S. Fork Hill (1964)	(3) Everhart & May (1973)	(4) Pettus (1973 & 1974)	(5) Ashland & Shell Oil (1975-1976)	(6) Gulf & Standard (1975-1977)	(7) Prewitt et al. (1978)	(8) McKean & Burkhard (1978)	(9) Carlson et al. (1979)	(10) Miller, Archer Tyus, & Harper (1982)	(11) Tyus, Burdick et al. (1982)**
Prosopium williamsoni	X	X	X	X	X	X	X	X	X	X	C-I
Salmo clarki	X	X				X		X			R
S. gairdneri	X	X	X	X		X		X			R
S. trutta	X	X	X	X		X		X			R
Salvelinus fontinalis	X	X						X			
Esox lucius											I
Cyprinus carpio				X		X	X		X	X	R
Gila robusta	X		X			X	X	X	X	X	C
Notropis lutrensis			X			X	X		X	X	A-C
Pimephales promelas				X		X	X		X	X	R
Ptychocheilus lucius			X						X	X	R
Rhinichthys osculus	X		X	X	X	X	X	X	X	X	A-C
R. cataractae						X					
Richardsonius balteatus								X(?)			
Catostomus commersoni				X(?)							
C. discobolus	X			X		X	X	X	X	X	R
C. latipinnis	X		X	X	X	X	X	X	X	X	A
C. discobolus x latipinnis						X			X		
C. platyrhynchus			X			X		X	X		R
Ictalurus melas			X			X			X	X	I
I. punctatus			X			X	X		X	X	R
Fundulus zebrinus										X	I(?)
Lepomis cyanellus										X	I
Cottus bairdi	X	X	X	X	X	X	X	X	X	X	R

** A = abundant, C = common, R = rare, I = incidental

verified specimens have not been found in these streams by any other investigator.

Woodward-Envicon in 1974 began studies reported to the Area Oil Shale Supervisor of the U.S. Geological Survey (Ashland Oil, Inc. and Shell Oil Co. 1975-76) related to the Colorado Oil Shale Lease Tract C-b Environmental and Exploration Program. Although their aquatic studies were concentrated on Piceance, Willow, and Stewart creeks, two White River stations were also sampled (Table 2, Column 5). In 1974, flannelmouth sucker, mottled sculpin and speckled dace were collected from the White River stations by electrofishing. In 1975, mountain whitefish were added to the list of fish species collected. Similar reports on Colorado Oil Shale lease Tract C-a (Gulf Oil Corp. and Standard Oil Co. 1975-77), were based on data collected by NUS Corporation. Fifteen stations were established on the White River near the mouth of Piceance Creek (see Table 2, Column 6). Fishes most frequently collected by electrofishing and dipnetting in late 1974 and 1975 were suckers, dace, fathead minnow, and mottled sculpin. In 1975 and 1976, flannelmouth sucker, speckled dace, bluehead sucker, and mottled sculpin dominated the catch from the White River.

Prewitt, Wick and Snyder (1978) discussed populations and habitat of humpback chub and Colorado squawfish in a White River reach which extended from Rio Blanco Lake to the County Road 65 bridge in Rio Blanco County. Their 1977 collections at eight stations on the White River are summarized in Table 2, Column 7.

McKean and Burkhard (1978) described the aquatic resources in the area of the Yellow Jacket Project, a flow-regulation project involving the North Fork and several other tributaries of the White River above Meeker. Fish

populations were inventoried by electrofishing in 1975 and 1976. Fishes reported in the White River Drainage included redside shiner (Table 2, Column 8); presence of redside shiner was probably mistakenly reported.

Carlson et al. (1979) reported on fishes collected at two stations between Spring Creek and Rio Blanco Lake from 1975 to 1978 (Column 9, Table 2). Flannelmouth sucker made up the greatest percentage of eight fish species and one hybrid collected by electrofishing. Predominant species collected by seine and dipnet were speckled dace, flannelmouth sucker, bluehead sucker, and roundtail chub.

Miller, Archer, Tyus and Harper (1982) reported on three stations sampled in 1981 from Rio Blanco Lake to the Colorado-Utah border. Their middle stratum (X) of five sampled included portions of both states, but collections from that stratum were included in the summary in Table 2 (Column 10). Speckled dace were the most abundant native species, and red shiner were the most abundant exotic fish. The mottled sculpin was collected only in the upper stratum; this species, Colorado squawfish, black bullhead, plains killifish, and green sunfish comprised less than one percent of collections where they were taken in Colorado.

The final column (11) in Table 2 is derived from Tyus, Burdick et al. (1982) and includes information on abundance of fishes in the White River in Colorado. They listed Fundulus sciadicus (Plains topminnow), rather than F. zebrinus, as incidental in the White River; this report or that of Miller, Archer, Tyus and Harper (1982) must be in error.

Green River

In early September 1962, prior to the closure of Flaming Gorge Dam, the Green River and its tributaries, for 225 miles (362 km) above the dam site, were treated with rotenone to cause large-scale reduction of "coarse" fish populations (Dexter 1965) to allow the reservoir and river to realize their full potential as trout fisheries. The result of the introduction of rotenone into the complex river ecosystem was a biological catastrophe (Dexter 1965). However, Dexter reported that there had been 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.

Vanicek, Kramer, and Franklin (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 1963-66 distribution of fishes with preimpoundment collections. Seasonal flows changed from high spring and low winter flows to a relatively stabilized seasonal flow pattern, and water temperatures and temperature fluctuations decreased. Their 1963-66 data for two stations in Dinosaur National Monument are summarized in Table 3, Column 1. Native fish populations (Colorado squawfish, roundtail chub, humpback chub, and razorback sucker) were replaced by exotics (rainbow trout) in the 26-mile (42-km) section from the dam site to Browns Park. Only 65 miles (105 km) downstream, at the mouth of the Yampa River, were abundance of indigenous and introduced species apparently unaffected. Stalnaker and Holden (1973) substantiated the work of Vanicek et al. (1970). None of the native species was known to have reproduced in the 65-mile area from the dam to the mouth of the Yampa River,

Table 3. Summary of fishes reported (X) from the Green River in Colorado.

Species	(1) Vanicek et al. (1970)	(2) Holden & Stalnaker (1975a)	(3) Miller Archer, Tyus, & McNatt (1982)	(4) Tyus, Burdick et al. (1982)*
Prosopium williamsoni	X	X		R-I
Salmo clarki		X		R-I
S. gairdneri	X	X	X	C
S. trutta	X	X	X	R-I
Salvelinus fontinalis				R-I
Esox lucius				R-I
Cyprinus carpio	X	X	X	C
Gila atraria				R-I
G. cypha	X	X	X	
G. elegans		X		
G. robusta	X	X	X	C
Notropis lutrensis		X	X	C-R
N. stramineus			X	R
Pimephales promelas	X	X	X	C
Ptychocheilus lucius	X	X	X	R-I
Rhinichthys osculus	X	X	X	C-R
Richardsonius balteatus	X	X	X	C-R
Semotilus atromaculatus	X	X	X	C-I
Catostomus commersoni	X	X	X	R-I
C. discobolus	X	X	X	C-I
C. latipinnis	X	X	X	A-I
C. platyrhynchus				R-I
Catostomus X Xyrauchen	X			
Xyrauchen texanus	X	X	X	R-I
Ictalurus melas	X	X		
I. punctatus	X	X	X	C-I
Lepomis cyanellus	X	X		R-I
L. macrochirus				R-I
Micropterus dolomieui			X	
Stizostedion vitreum	X			
Cottus bairdi	X	X	X	C-I

* A = abundant, C = common, R = rare, I = incidental

and trout had replaced native species to the confluence with the Yampa. Humpback chub, Colorado squawfish, bonytail, and razorback sucker were considered rare by Stalnaker and Holden (1973).

Holden and Stalnaker (1975a) collected in a 32-km section on the Green River extending from the mouth of the Yampa River to the south boundary of Dinosaur National Monument in Utah. Their data for that station are summarized in Column 2 of Table 3.

Miller (1965) discussed the fishes of Dinosaur National Monument and reviewed changes in flow and temperature resulting from the closure of Flaming Gorge Dam. Seethaler, McAda, and Wydoski (1979) reviewed earlier work, discussed reasons for declines in abundance of rare fishes, and emphasized the importance of waters in Dinosaur National Monument for the continued existence of endemic fishes. The Green River depends upon the Yampa River to ameliorate conditions caused by Flaming Gorge Dam below their confluence, and any change in that status could have a serious negative impact (Seethaler et al. 1979).

In 1978, the Bureau of Reclamation installed an inlet modification to aid the failing trout fishery in the Flaming Gorge Dam tailwater. Warmer water was drawn from higher reservoir levels, and Holden (1979) expected that warmer summer stream temperatures would restore successful reproduction of Colorado squawfish in 40 km of the Green River below the dam.

Miller, Archer, Tyus and McNatt (1982) collected at two stations on the Green River from Lower Whirlpool Canyon in Utah to the confluence with the Yampa River. Their data for these stations are summarized in Column 3 of Table 3. Data from Tyus, Burdick et al. (1982) on relative abundance of fishes in the Green River in Colorado are included in Table 3, Column 4.

Colorado River

Native and introduced fishes of the Upper Mainstem Colorado River were discussed by Joseph et al. (1977). Recreational development along the Upper Mainstem Colorado has exploded with extensive winter sports facilities and summer recreational homes and facilities. High demand for water necessitated construction of water storage reservoirs, and water depletions due to high consumption were substantial. Introduction of exotics and water flow reductions appear to have been the main factors involved in reduction of populations of native species (Joseph et al. 1977). Future development of oil shale will surely add another major obstacle to survival of native fishes.

Jordan (1891) reported that Catostomus latipinnus was common in the Grand (Colorado) River at Glenwood Springs. Holden and Stalnaker (1975a) listed species collected at two stations (from Grand Junction to Fruita and near Rifle, Colorado) on the Colorado River. Their data are summarized in Column 1 of Table 4. Valdez, Mangan, Smith and Nelson (1982) discussed collections made in 1979-81 from four strata (H, I, J, and X) extending from Westwater (river mile, RM 125, west of the Colorado-Utah border) to Rifle, Colorado (RM 241) and four special strata (K, M, N, and O) within that river reach. Their data on occurrence of fishes in that study area are summarized in Column 2 of Table 4. Relative abundance of fishes was reported.

Data of Tyus, Burdick et al. (1982) on the fishes of the Upper Mainstem Colorado River in Colorado are summarized in Column 3 of Table 4; relative abundance data are included. Salvelinus namaycush (lake trout) were reported from reservoirs in the Colorado River Drainage. Haynes, Muth and

Table 4. Summary of fishes reported (X) from the Upper Mainstem Colorado, Gunnison, and Dolores rivers in northwest Colorado.

Species	Colorado River			Gunnison River				Dolores River		
	(1) Holden & Stalnaker (1975a)	(2) Valdez, Mangan, Smith, & Nelson (1982)	(3) Tyus, Burdick et al.* (1982)	(4) Holden & Stalnaker (1975a)	(5) Wiltzius (1978)	(6) Valdez, Mangan, McInerns, & Smith (1982)	(7) Tyus, Burdick et al.* (1982)	(8) Holden & Stalnaker (1975b)	(9) Valdez, Mangan, McInerns, & Smith (1982)	(10) Tyus, Burdick et al.* (1982)
Prosopium williamsoni	X	X	C-I							
Salmo clarki			R-I**		X(?)					
S. gairdneri	X	X	C-I		X	X	C		X	
S. trutta		X	C-I	X	X	X	C		X	
Salvelinus fontinalis			I**		X					
Esox lucius		X	I		X	X	I			
Cyprinus carpio	X	X	A	X	X	X	C	X	X	C
Gila cypha		X	R							
G. robusta	X	X	C	X	X	X	A	X	X	C
G. robusta x cypha		X								
Hybognathus hankinsoni			I							
Notropis lutrensis	X	X	A	X	X	X	C	X	X	C
N. stramineus	X	X	C-R		X	X		X	X	R
Pimephales promelas	X	X	C	X	X	X	C	X	X	C
Ptychocheilus lucius	X	X	R	X	X	X	R			
Rhinichthys cataractae					X					
R. osculus	X	X	C-R	X	X	X	A	X	X	A
Richardsonius balteatus			I							
Semotilus atromaculatus			I							
Catostomus catostomus	X				X		R			
C. commersoni	X	X	R		X	X	C		X	I
C. discobolus	X	X	C	X	X	X	C	X	X	C
C. latipinnis	X	X	A-C	X	X	X	C	X	X	C
C. commersoni x discobolus		X			X	X				
C. commersoni x latipinnis		X		X	X					
Xyrauchen texanus	X	X	R		X		R			
C. latipinnis x Xyrauchen	X	X								
Ictalurus melas		X	R		X	X			X	
I. punctatus	X	X	C	X	X	X	I	X	X	C
Fundulus zebrinus	X	X	I	X	X	X			X	
Gambusia affinis			I							
Lepomis cyanellus	X	X	R	X	X	X	I	X	X	I
L. macrochirus		X	I							
Micropterus dolomieui		I			X(?)		I			
M. salmoides	X	X	R		X	X	I	X	X	I
Pomoxis nigromaculatis		X	R				R			R
Cottus bairdi		A	A		A		C			

* A = abundant, C = common, R = rare, I = incidental.

**Reported in headwaters outside five-county area of Northwest Colorado

Wycoff (1982) extended the range of redside shiner to include the Colorado River.

Gunnison River

The Gunnison River at one time contained all threatened or endangered fishes of the Upper Colorado River System except the Kendall Warm Springs dace and the humpback chub. Jordan (1891) reported collecting flannelmouth, bluehead and razorback suckers, bonytail, roundtail chub, Colorado squawfish, speckled dace, cutthroat trout and mottled sculpin in the Gunnison River. With the introduction of exotics, the abundance and distribution of these native fishes was drastically curtailed (Joseph et al. 1977). Holden and Stalnaker (1975a) collected from the mouth of the Gunnison to below Delta. Their data are summarized in Table 4, Column 4. Wiltzius (1978) reviewed studies done on the Gunnison from 1937, prior to the construction of Taylor Park Reservoir, to the time of his report. He also discussed the quality and quantity of the Gunnison's salmonid fisheries from the 1880s to the present. Several species were introduced in that period; these, 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. His statements regarding fishes of the Gunnison River are summarized in Column 5 of Table 4. Mottled sculpin were mentioned as a rare native species, and smallmouth bass were mentioned as the only introduced non-salmonid that had not been collected recently. Two species mentioned by Wiltzius (1978) were not included in Table 4; the bonytail because it is probably extirpated, and the Paiute (eagle?) sculpin because of taxonomic uncertainty. Sucker hybrids

present but not included in Table 4 were bluehead x white, longnose x white, and bluehead x longnose.

Valdez, Mangan, McInerns, and Smith (1982) reported on sampling from 1979 to 1981 of the Gunnison River from Escalante Canyon (RM 42) to its confluence with the Colorado River. Their data are summarized in Column 6 of Table 4. The conclusions of Tyus, Burdick et al. (1982) on occurrence and relative abundance of Gunnison River fishes are in Table 4, Column 7. Lake trout were reported only from reservoirs of the Gunnison Basin.

Stanford and Ward (1983) reported on effects of mainstream dams on physical and chemical conditions in the Gunnison River.

Dolores River

Holden and Stalnaker (1975b) discussed results of 1971 fish sampling by seine from the mouth of the Dolores River to Dolores, Colorado. Their findings are summarized in Column 8, Table 4. The authors concluded that the Dolores River System appeared to have little importance regarding preservation of rare and endangered fish species and that it was far from its natural state due to irrigation and severe pollution. Valdez, Mangan, McInerns, and Smith (1982) described 1981 sampling of the Dolores River from its confluence with the Colorado River to Paradox Valley, Colorado (RM 68). Results of their collections are summarized in Table 4, Column 9. Column 10 in Table 4 represents data from Tyus, Burdick et al. (1982) on occurrence and relative abundance of Dolores River fishes.

Data limitations do not allow us to specify which of the fishes in each major stream of northwest Colorado are likely to exist primarily in Moffat, Routt, Rio Blanco, Garfield, and Mesa counties. In general, salmonids are most commonly taken in headwater streams, and they decrease in abundance downstream. Some salmonids (Oncorhynchus nerka, Salmo aguabonita, and Salvelinus namaycush) have been introduced in upper reaches of the streams and are primarily restricted to reservoirs. Longnose sucker, darters (Etheostoma spp.), and yellow perch (Perca flavescens) are also likely to be found only in reservoirs in upper reaches of streams. Table 5 is an attempt to list fishes of the Colorado River System in Colorado; the area considered subsumes the five-county area in northwest Colorado (Figure 1). Tables 6 and 7 abstract supplemental information on these fishes.

More specific information on fishes of streams and lakes in northwest Colorado may be obtained by consulting records of the Colorado Division of Wildlife. Sealing (1981b) prepared a summary of data collected from public fishing waters in the Division's Northwest Region from 1964 through 1980. Included are physical, chemical, biological (including fish sampling records), political, and legal data on lakes and streams. The compilation is available at the Division's headquarters (6060 Broadway) in Denver. Sealing (1981a) also developed a complete record of "pertinent" data on lakes open to public fishing in the Division's Northwest Region from 1964 through 1980. Lakes are arranged alphabetically by name, and data cover

Table 5. Status and recent distribution of fishes within 11 subregions of the Colorado River System in Colorado (also see Fig. 1). Relative abundance refers to abundance within at least one principal habitat zone within the subregion of concern and is designated on the basis of available reports and communications* as: C - generally common (1% of all fish collected), O - only occasionally common or generally less common (1% of all fish but regularly collected), and R - rare (rarely or infrequently collected). Modified and updated from Snyder (1981).

				Green					Upper Mainstem Colorado					
System Subbasins:				Yampa			Green	White	Colorado			Gunnison		Dolores
Drainage Systems:														
Subregions:				1	2	3	4	5	6	7	8	9	10	11
Habitat Zones[1]:				HI	HI	LI	HI	HI	HIR	HIR	LI	HIR	HI	HI
Species	Status[2]:	N	E	T	—	—	—	—	—	—	—	—	—	—	—	—
Salmonidae														
Oncorhynchus nerka		-	-	-	-	-	-	-	-	C	-	-	C	-	-
Prosopium williamsoni		X	-	-	O	O	R	R	C	C	C	R	-	-	-
Salmo aquabonita		-	-	-	-	-	-	-	-	-	-	-	R	-	-
Salmo clarki		X	X[3]	X[3]	O[4]	R	R	O	C[4]	O[4]	O[4]	-	O	-	O
Salmo gairdneri		-	-	-	O	C	O	C	C	O	O	R	C	O	O
Salmo trutta		-	-	-	O	R	R	R	O	O	O	R	O	O	O
Salvelinus fontinalis		-	-	-	C	O	-	-	C	C	C	-	C	C	C
Salvelinus namaycush		-	-	-	-	-	-	-	-	O	-	-	R	-	-
Esocidae														
Esox lucius		-	-	-	R	-	R	-	R	R	R	R	R	R	-
Cyprinidae														
Cyprinus carpio		-	-	-	C	O	C	C	O	-	-	C	O	C	C
Gila atraria		-	-	-	-	-	R	R	-	-	-	-	-	-	-
Gila cypha		X	X	X	-	-	R	R	-	-	-	O	-	-	-
Gila elegans		X	X	X	-	-	R	-	-	-	-	-	-	-	-
Gila robusta		X	X	-	C	C	C	O	C	-	C	C	C	C	C
Hybognathus hankinsoni		-	-	-	-	-	-	-	-	-	-	R	-	-	-
Notropis lutrensis		-	-	-	-	-	C	C	C	-	-	C	-	C	C
Notropis stramineus		-	-	-	C	-	C	R	-	-	-	C	-	C	C
Pimephales promelas		-	-	-	C	C	C	C	C	-	C	C	C	C	C
Ptychocheilus lucius		X	X	X	R	R	O	R	R	-	R	O	-	R	R
Rhinichthys cataractae		-	-	-	-	-	-	-	-	-	-	-	O	-	-
Rhinichthys osculus		X	-	-	C	C	C	C	C	C	C	C	C	C	C
Richardsonius balteatus		-	-	-	C	C	C	C	-	-	R	-	-	-	-
Semotilus atromaculatus		-	-	-	O	R	R	R	-	-	-	-	-	-	-
Catostomidae														
Catostomus catostomus		-	-	-	-	-	-	-	-	-	O	-	C	O	-
Catostomus commersoni		-	-	-	C	O	O	O	-[5]	C	O	O	C	O	O
Catostomus discobolus		X	-	-	C	C	C	C	C	-	C	C	C	C	C
Catostomus latipinnis		X	X	-	C	C	C	C	C	-	C	C	C	C	C
Catostomus platyrhynchus		X	-	-	O	R	R	O	O	R	-	-	-	-	-
Xyrauchen texanus		X	X	X	-	-	R	R	-	-	R	O	-	R	-
Ictaluridae														
Ictalurus melas		-	-	-	O	-	O	R	R	-	-	O	-	O	-
Ictalurus punctatus		-	-	-	O	R	C	O	O	-	-	C	-	O	C
Cyprinodontidae														
Fundulus zebrinus[6]		-	-	-	O	-	O	-	-	-	-	O	-	O	-
Fundulus sciadicus		-	-	-	-	-	-	-	O	-	-	-	-	-	-
Poeciliidae														
Gambusia affinis		-	-	-	-	-	-	-	-	-	-	O	-	-	-
Centrarchidae														
Lepomis cyanellus		-	-	-	-	-	O	O	-	-	-	O	R	O	O
Lepomis macrochirus		-	-	-	-	-	R	R	-	-	-	R	-	-	-
Micropterus dolomieui		-	-	-	-	-	-	-	R	-	-	R	-	R	-
Micropterus salmoides		-	-	-	-	-	R	R	-	-	-	O	-	R	R
Pomoxis nigromaculatus		-	-	-	-	-	-	-	-	-	-	R	-	-	-
Percidae														
Etheostoma exile		-	-	-	-	-	-	-	O^7	-	-	-	-	-	-
Etheostoma nigrum		-	-	-	-	-	-	-	O^7	-	-	-	-	-	-
Perca flavescens		-	-	-	-	-	-	-	-	-	-	R	-	-	-
Stizostedion vitreum		-	-	-	-	-	R	R	-	-	-	-	-	-	-
Cottidae														
Cottus annae		X	-	-[8]	-	-	-	-	-	R	R	-	R	-	-
Cottus bairdi		X	-	-	C	C	O	C	C	C	C	R	O	R	O

[1]H - headwater streams and lakes, cold and clear; I - intermediate rivers and streams, cool to tepid and occasionally turbid; L - large rivers, warm and usually turbid; and R - major reservoirs.
[2]N - native, natural inhabitant of the system; E - endemic, native species found only in the Colorado River System; T - threatened or in danger of extinction (endangered) as per Deacon et al. (1979) or the federal or Colorado lists.
[3]Subspecies *S. c. pleuriticus* only.
[4]Includes relatively pure populations of the endemic subspecies which are common only in Trappers Lake (subregion 5) and mountain lakes in other subregions stocked with Trappers Lake fish.
[5]Reported only in Piceance Creek by Pettus (1974); probably *C. latipinnis* misidentified as *C. commersoni*.
[6]Many of these specimens were previously identified as *Fundulus kansae*. The two presumed forms are now recognized as being conspecific and are listed by Robbins et al. (1980) as *Fundulus zebrinus*, the senior synonym.
[7]Reproducing populations in Shadow Mountain Reservoir.
[8]This sculpin was recently recognized by R. R. Miller as having been improperly synonomized with Cottus beldingi and will probably soon be considered for state and federal threatened and species lists.

*Literary Sources: Baxter and Simon (1970), Behnke and Benson (1983), Carlson et al. (1979), Colorado River Fishes Recovery Team (1978, 1979), Eiserman (1958), Goettl and Edde (1978), Holden and Crist (1979, 1980), Holden and Stalnaker (1975a,b), Joseph (1978), Joseph et al. (1977), Koster (1957), Lanigan and Berry (1979), McAda (1977), McAda and Wydoski (1980), Miller, Archer, Tyus and Harper (1982), Miller, Archer, Tyus and McNatt (1982); Olson and McNall (1965), Prewitt et al. (1978), Seethaler (1978), Seethaler et al. (1979), Sublette (1976), Tyus, Burdick et al. (1982), Valdez, Mangan, McInerns and Smith (1982), Valdez, Mangan, Smith and Nelson (1982); Vanicek et al. (1970), Wick et al. (1979, 1981), and Wiltzius (1978). Personal Communications: Paul B. Holden, John P. Hubbard, David Langlois, Steven H. Lanigan, David L. Propst, Richard Valdez, William C. Weiler and William J. Wiltzius.

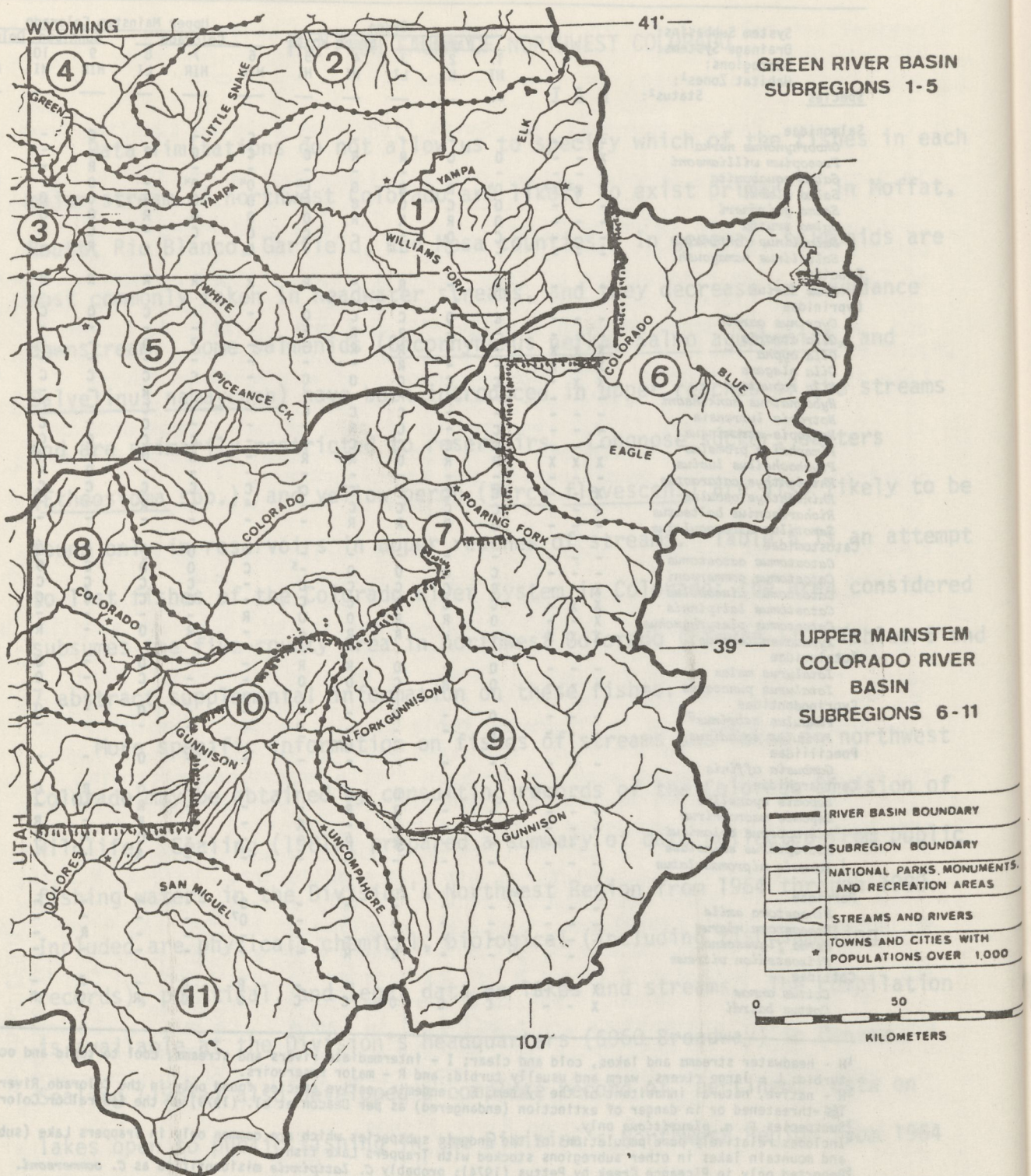

Figure 1. The Green River and Upper Mainstem Colorado river basins in western Colorado divided into 11 drainage-based subregions. The northwestern counties of Moffat, Routt, Rio Blanco, Garfield, and Mesa are outlined in the upper left half of the map. Modified from Snyder (1981).

Table 6. Numbers of fish families and species in the Green and Upper Mainstem Colorado (Grand) river basins.

	Sub-basin		Elevational zone			Green sub-basin			Grand sub-basin		
	Green	Grand	< 1.5 km	1.5-2.0 km	> 2.0 km	< 1.5 km	1.5-2.0 km	> 2.0 km	< 1.5 km	1.5-2.0 km	> 2.0 km
Number of Families											
Native to basin	4	4	2	4	4	2	4	4	2	4	4
Introduced	10	10	11	11	7	7	9	4	9	5	4
Native & Introduced	11	11	11	12	8	7	10	5	9	6	5
Number of Species[1]											
Native to basin	12	12	9	11	9	9	10	8	7	10	9
Introduced	32	31	27	36	29	17	29	15	21	11	13
Native & Introduced	44	43	36	47	38	26	39	23	28	21	22

[1] For convenience, the native and introduced subspecific forms of *Salmo clarki* are treated in the tallies as separate species. The two subspecific forms of *Rhinichthys osculus*, both native, are treated as one species.

Table 7. Important fishes of northwest Colorado with general habitat requirements, trophic characteristics and legal status.

		Legal Status								
		Federal	State	S/N	Lentic	Lotic	Thermal Guild	Adult Food Guild	Turbidity Tolerance	High Velocity Tolerance
Native Fishes										
Salmonidae										
Salmo clarki pleuriticus	Colo. R. cutthroat trout		T	N	+	+	CD	IP	-	+
Prosopium williamsoni	mountain whitefish				+	+	CW/CD	I	-	+
Cyprinidae										
Gila cypha	humpback chub	E	E	N	-	+	WW	I	+	+
Gila elegans	bonytail	E	E*	N		+	WW	I	+	+
Gila robusta	roundtail chub			N	-	+	WW	IP	+	+
Ptychocheilus lucius	Colorado squawfish	E	E	N	-	+	WW	P	+	+
Rhinichthys osculus	speckled dace			N	-	+	CW	I	0	-
Catostomidae										
Catostomus discobolus	bluehead sucker			N	0	+	WW/CW	0	-	+
Catostomus latipinnis	flannelmouth sucker			N	+	+	WW	0	+	+
Catostomus platyrhynchus	mountain sucker			N	0	+	CD/CW	0	-	+
Xyrauchen texanus	razorback sucker		E	N	0	+	WW	0	+	+
Cottidae										
Cottus bairdi	mottled sculpin			N	-	+	CD/CW	I	0	+
Cottus beldingi	Paiute sculpin			N	-	+	CD/CW	I	0	+
Introduced Species										
Salmonidae										
Oncorhynchus nerka	kokanee			S	+	-	CD	Z	-	+
Salmo gairdneri	rainbow trout			S	+	+	CD/CW	I	-	+
Salmo trutta	brown trout			S	+	+	CD/CW	IP	-	+
Salvelinus fontinalis	brook trout			S	+	+	CD	I	-	+
Salvelinus namaycush	lake trout			S	+	-	CD	P	-	0

Salvelinus fontinalis	brook trout	S	+	+	CD/CW	IP	-	+
Salvelinus namaycush	lake trout	S	+	-	CD	P	-	0

Table 7. Continued

		Legal Status Federal	State	S/N	Lentic	Lotic	Thermal Guild	Adult Food Guild	Turbidity Tolerance	High Velocity Tolerance
Esocidae										
Esox lucius	northern pike			S	+	+	CW/WW	P	0	0
Cyprinidae										
Cyprinus carpio	common carp			S	+	+	WW	O	+	-
Notropis lutrensis	red shiner			N	0	+	WW	I	+	0
Notropis stramineus	sand shiner			N	-	+	WW	I	0	-
Pimephales promelas	fathead minnow			N	+	+	WW	O	+	0
Richardsonius balteatus	redside shiner			N	+	+	CC/WW	I	0	-
Catostomidae										
Catostomus catostomus	longnose sucker			N	+	+	CD/CW	OD	-	+
Catostomus commersoni	white sucker			N	+	+	CW/WW	OD	-	+
Ictaluridae										
Ictalurus punctatus	channel catfish			S	+	+	WW	O	+	-
Cyprinodontidae										
Fundulus zebrinus	plains killifish			N	-	+	WW	I	+	-
Centrarchidae										
Lepomis cyanellus	green sunfish			S	+	+	WW/CW	IP	0	-

*probably extirpated from the state of Colorado

Y=yes
N=no
T=threatened
E=endangered

S=sport
N=nonsport
+=favorable
-=deliterious
O=neutral

P=piscivore
I=insectivore
O=omnivore
Z=planktivore
D=detritivore

Primary habitat/secondary (max. summer temp., C)

CD=cold water (<20 C)
CW=cool water (20 - 24 C)
WW=warmwater (>24 C)

example: WW/CW primarily found in warmwater habitats but also found in cool waters.

physicochemical and biological (including fish sampling records) parameters, stocking, creel census, mapping, water rights, and management plans. This compilation and earlier records on microfiche are also available at Division headquarters.

Reports by Bennett (1982) and Tully et al. (1982) provide details on stocking, angler use, angler catch, species composition of angler's catch, and some information regarding the Division of Wildlife's management activities on the important fishery waters of northwest Colorado. Wiltzius (1981) compiled data on introduction dates and places and on state and federal stocking of fishes in Colorado to 1978. Fishing regulations for the state of Colorado are issued by the Division of Wildlife (e.g., "1983-84 Fishing Season Information"); new "gold medal" waters include reaches of Upper Colorado River System streams (Kochman 1983).

The Ecological Services Section of the Colorado Division of Wildlife is developing a computerized system of information retrieval on fishes by geographical areas. Use of this Colorado Stream Data Bank was described by Weber (1983). Lake data and summaries of collecting permit and creel census reports are also being computerized by geographical area. Data from the Division's Colorado squawfish and humpback chub monitoring program are also being computerized and will be compatible with the MANAGE system of the U.S. Fish and Wildlife Service.

Weber (1983) listed other sources of information on Colorado streams, including Cope's (1977) index, Division Federal Aid reports, and other agency documents (Colorado Department of Health, Environmental Protection Agency, etc.). Galat and Haynes (1983) prepared an annotated bibliography of the Upper Colorado River Drainage; other bibliographies are mentioned elsewhere

in this report, and our report contains an annotated bibliography (p. 173ff.).

In the remainder of this section, fishes of northwest Colorado are discussed individually according to their status as warmwater or coldwater sport, native or non-native non-sport, and threatened or endangered species.

Non-Native Warmwater Sport Fishes of Northwest Colorado

In comparison to angler use of coldwater fisheries, the warmwater sport fisheries of northwest Colorado are rather insignificant, but some are of local importance. Locations of these include Rifle Gap Reservoir, Garfield County; Rio Blanco Lake, Rio Blanco County; and the Colorado River and Lower Yampa River of Mesa and Moffat counties, respectively.

The most ubiquitous warmwater sport fish is the channel catfish. It is abundant in deep, low-velocity sections of the Lower Yampa, White, and Colorado rivers. Warmwater impoundments have various combinations of black bullhead, largemouth bass, smallmouth bass, black and white crappie, bluegill, green sunfish, walleye, and northern pike. Except for the northern pike, these warmwater sport fish, typical of impoundments, are incidental in river environments. None of the warmwater sport fish species of northwest Colorado is native.

Following are brief discussions of the warmwater sport fishes of northwest Colorado. Major references used in preparation of these summaries were Beckman (1952), Baxter and Simon (1970), Everhart and Seaman (1971), Scott and Crossman (1973), Lee et al. (1980), Sealing (1981a), Wiltzius (1981), and Tyus, Burdick et al. (1982).

ICTALURIDAE

Channel catfish

The channel catfish, Ictalurus punctatus, is native to the east-slope Arkansas and Platte rivers in Colorado; it was introduced to the west-slope Colorado and Gunnison rivers in 1898 (Beckman 1952; Wiltzius 1981). The channel catfish has become well established in the lower portions of the Colorado and Yampa rivers in Colorado (Tyus, Burdick et al. 1982).

Natural reproduction evidenced by collections of young of year (YOY) is occurring in the Lower Colorado River below Grand Junction and in the Lower Yampa River in Yampa Canyon in Colorado (Wick et al. 1981). YOY channel catfish have also been collected in drift nets in the Lower Colorado and Yampa rivers by the Colorado Division of Wildlife and U.S. Fish and Wildlife Service (Robert Muth and Darrel Snyder, unpubl. data; pers. commun., CSU Larval Fish Laboratory). YOY channel catfish have also been collected in the Lower White River in Utah (Randy Radant, pers. commun., Utah Division of Wildlife Resources). Tyus, Burdick et al. (1982) listed the channel catfish as rare in the Green and White rivers in northwest Colorado, incidental in the Gunnison River, and common in the Lower Dolores River.

The channel catfish has potential as an important game fish in western Colorado rivers. Creel census surveys pertaining to the large rivers are being intensified by the Colorado Division of Wildlife. In 1982, the Lower Colorado River Angler Census indicated that, although fishing pressure appeared to be light, anglers caught catfish in good numbers with a catch-per-angler-hour of 0.40.

Although channel catfish have been stocked in several west-slope reservoirs, they prefer large rivers and can tolerate turbid habitats. In streams, adults rest in pools and under submerged logs and rocks during the day and move into shallow water and current at night to feed (Baxter and Simon 1970; Scott and Crossman 1973). On the Colorado and Yampa rivers, YOY catfish have been seined along sandy shorelines and in backwaters off the main river (Wick et al. 1981). Tyus, Burdick et al. (1982) listed preferred adult habitat in the Upper Colorado River System as deep pools, eddies, shorelines and runs over silt, gravel and boulder substrates and backwaters with silt and sand substrate. Migratory movement of channel catfish in rivers was discussed by Scott and Crossman (1973).

Channel catfish spawn in late spring or summer when temperatures reach 23.9-29.5 C; 26.7 C is the apparent optimum (Scott and Crossman 1973). Spawning sites include undercut banks, under logs, and rock ledges. Eggs are deposited in a gelatinous mass and are guarded by the male (Beckman 1952). Newly hatched larvae have large yolk sacs and remain on the bottom for 2-5 days before swimming to the surface to feed (Scott and Crossman 1973). Jacobi and Jacobi (1982) noted that YOY feed on most foods ranging from small particulates to large invertebrates (primarily Diptera, Coleoptera, and Hemiptera). Young catfish have been seen frequently feeding on the surface on the Lower Yampa and Green rivers in the Upper Colorado River System (USFWS and CDOW personnel, pers. comm.). As adults, channel catfish are omnivorous, feeding on algae, plants, terrestrial insects, dead fish, and garbage. In streams, larger fish are quite predaceous and probably compete for food with all other bottom feeders and some predatory species in their habitat (Baxter and Simon 1970, Scott and Crossman 1973).

Carlson et al. (1979) found that 17 specimens collected in the fall from the Yampa River near Lily Park had consumed only filamentous green algae and epilithic diatoms.

Future studies on channel catfish might be valuable to provide better understanding of their reproductive life history in Colorado's big rivers. Studies might also include investigation of their ecological interrelationships with other game species and endangered fishes in western Colorado rivers.

ESOCIDAE

Northern pike

The northern pike, Esox lucius, was first introduced to Colorado's western slope in 1962 at Vallecito Reservoir near Durango (Wiltzius 1981). Northern pike were stocked in reservoirs on the Upper Colorado River System in Williams Fork Reservoir (1973 and 1976) and in Rio Blanco Lake on the White River in 1976 (Sealing 1981a). It is also thought that pike were introduced into Elkhead Reservoir near Craig; however, no records of the Colorado Division of Wildlife indicate stocking there, nor were any pike reported in creel census data from Elkhead Reservoir. Pike were reported in creel census data from Rio Blanco Lake in 1975 and Williams Fork Reservoir in 1974, 1976, 1978 and 1979 (Sealing 1981a). Tyus, Burdick et al. (1982) listed northern pike as incidental in the Colorado, Gunnison, Green and White rivers and rare in the Yampa River. Colorado Division of Wildlife personnel captured a northern pike weighing 20 lbs. from the Gunnison River below Redlands Dam in 1979, and several pike in the 5-9 lb. range in the Yampa River from 1979 to 1981 (Wick et al. 1981). During March and April

electrofishing and gill net surveys in 1982, two yearling pike (300 mm long) were captured on the Yampa River at Lily Park and Morgan Gulch along with several large (4-10 lb.) adults (Wick, pers. commun.).

The occurrence of yearling northern pike and increasing incidence of adult captures suggests establishment of a northern pike fishery in the Yampa River. Fishermen have become increasingly successful in catching pike from the river. Several pike were reportedly taken at the mouth of Lay Creek by a local angler of Maybell, Colorado. Fishermen have also reported YOY northern pike near Milner and Hayden, Colorado (Charlie Brown, pers. commun., Colorado Division of Wildlife DWM, Sunbeam). Miller, Archer, Tyus and McNatt (1982) reported YOY pike in their 1981 collections on the Yampa River. Western Outdoor Magazine has mentioned the good northern pike fishing on the Yampa River. The origin of northern pike in the Yampa is presently unclear, but the case for an established, reproducing population is gaining strength, and a self-sustaining sport fishery may be developing.

The northern pike spawns shortly after ice melts in April to early May in water temperatures at 4.4-11.1 C. Spawning usually occurs during daylight hours in heavily vegetated floodplains of rivers, marshes, and bays of larger lakes. Eggs are scattered at random; they are demersal and very adhesive. Approximately 30,000 eggs are laid per female, but high mortality (95-99.8%) is suffered because of fluctuating water levels and predation.

Young feed on zooplankton and immature aquatic insects for 7-10 days after hatching. Small fish then enter their diets; at a length of 50 mm, fish assume predominance in diets. Adult pike are considered omnivorous, but predominately carnivores which eat virtually any living vertebrate

available within an edible size range. Optimum food size is generally one-third to one-half the size of the pike (Scott and Crossman 1973).

Tyus, Burdick et al. (1982) listed preferred habitat of pike in the Upper Colorado River System as pools in dam tailraces, riverine pools and inundated gravel pits over silt/gravel, rubble/sand substrates and shallow vegetated areas of lakes. Scott and Crossman (1973) stated that, in general, northern pike occur in shallower water in spring and fall but move to deeper cooler water at the height of summer temperatures. Some extensive movement (spawning migrations) occurs in the spring with congregations of fish at lake tributary streams. In general, pike are fairly sedentary. They establish territories where cover and food are adequate. Some fall movement has also been noted by Scott and Crossman (1973). Colorado Division of Wildlife personnel tagged three large pike in a single pool at the base of Cross Mountain Canyon on the Yampa River in August 1980. In October of the same year, two of the fish were recaptured in the same pool (Wick et al. 1981).

More intensive creel census information is needed on the Yampa River and other western rivers to determine the extent of pike fishing and angler success. Continued monitoring of fish populations with emphasis on pike should be considered. Studies of northern pike competition with and predation on other game and endangered fishes should be conducted.

CENTRARCHIDAE

Largemouth bass

The largemouth bass, Micropterus salmoides (Lacepede), was introduced to Colorado's east slope waters in 1878 (Everhart and Seaman

1971). In 1895, 500 largemouth bass were stocked in both the Lower Gunnison and Colorado rivers. In 1910, several thousand were stocked in the Yampa River near Craig (Wiltzius 1981). Tyus, Burdick et al. (1982) listed the largemouth bass as rare in the Colorado River and incidental in the Gunnison, Dolores, and Yampa rivers. The best largemouth bass fishing and greatest abundance of largemouth bass in northwest Colorado occur in the numerous small impoundments along the main rivers.

The largemouth bass usually spawns in June and July in Colorado when water temperatures range from 16-19 C. Largemouth males prepare a nest in vegetation beds. Females may spawn with several males on different nests. Eggs are deposited in nest depressions and are adhesive. Males guard the nests and fan the eggs (Beckman 1952, Scott and Crossman 1973). Young largemouth bass feed primarily on plankton and small insects. The diet of older fish includes fish, crayfish, frogs and insects (Beckman 1952). Lynn R. Kaeding (pers. commun., U.S. Fish and Wildlife Service) observed that a high percentage of largemouth bass collected from four Colorado River backwaters in 1982 had preyed upon tagged Colorado squawfish fingerlings.

Tyus, Burdick et al. (1982) listed preferred habitat as clear, quiet waters with aquatic macrophytes and littoral zones of reservoirs. Largemouth bass appear better adapted to Colorado's warmwater, sparsely vegetated reservoirs than smallmouth bass (Everhart and Seaman 1971). Catch results indicate that the largemouth bass has not adapted well to the river environments of Colorado. Young fish and few adults are collected. Young may enter rivers when impoundments along rivers are flooded. High turbidity in northwest Colorado rivers is probably a limiting factor.

Smallmouth bass

Smallmouth bass, Micropterus dolomieui, have been stocked in the Colorado River Drainage on limited occasions since 1951 (Everhart and Seaman 1971). Tyus, Burdick et al. (1982) considered the species rare in the Green River and incidental in the Gunnison, Colorado, and Yampa rivers of northwest Colorado. The smallmouth bass has reproductive and feeding habits similar to those of the largemouth bass. However, smallmouth bass prefer gravel and sand spawning substrates, spawn at slightly cooler temperatures, and build larger nests. Smallmouth bass appear better adapted to larger, deeper, and cooler reservoirs than largemouth bass (Beckman 1952). Tyus, Burdick et al. (1982) listed preferred habitat as clear, fast-flowing streams and flowing pools with gravel/rubble substrate. Turbidity probably is a limiting factor in northwest Colorado. Beckman (1952) stated that few waters in Colorado are suited to smallmouth bass; thus, it may never be an important species for the angler. However, certain sections of the middle Yampa and Gunnison rivers appear suitable for smallmouth bass, given reduced turbidity.

Black and white crappie

The black crappie, Pomoxis nigromaculatus (Lesueur), was introduced in Colorado along with the white crappie in 1882 and (since no distinction was made between the two species) into western Colorado in 1944. They occur in a few reservoirs on the western slope (Everhart and Seaman 1971). Tyus, Burdick et al. (1982) reported black crappie as rare in the Colorado, Gunnison, and Dolores rivers. The black crappie is distinguished from the white crappie by irregular dark mottlings on its silvery-olive-colored

sides, as opposed to the eight or nine dark vertical bands on the white crappie. Black crappie usually have seven or eight dorsal fin spines, as opposed to six on white crappie. Spawning and food habits are similar to those of white crappie. Black crappie prefer clear, weedy lakes; this habitat may be limited in northwest Colorado.

The white crappie, Pomoxis annularis Rafinesque, was first introduced into Colorado east-slope waters in 1882. It was introduced into some Yampa River backwaters on the west slope in 1944 (Wiltzius 1981). The white crappie is now present in only a few reservoirs in western Colorado (Everhart and Seaman 1971). Tyus, Burdick et al. (1982) did not report white crappie in northwest Colorado rivers.

Spawning occurs in late spring to early summer when temperatures are 14-23 C and is most active at 16-20 C. Nest areas (300 mm in diameter) are cleaned by aggressive territorial males over a variety of bottom types in 200-970 mm of water (Scott and Crossman 1973). Spawning sites are usually located near brush piles, stumps or rock outcroppings (Everhart and Seaman 1971). After spawning, males guard the nests. Young crappies seek heavy cover, while adults tend to frequent the edges of submerged and aquatic vegetation. Food of young is largely zooplankton; this fish progresses to feeding on insects and finally to fish as adults. White crappie are reported to be more tolerant of warmer and turbid waters than their close relative, the black crappie.

PERCIDAE

Walleye

The walleye, Stizostedion vitreum (Mitchill), was first introduced into Sterling Reservoir in Colorado in 1949. It was introduced into western Colorado in Harts Basin Reservoir of the Gunnison Drainage in 1950 (Wiltzius 1981). Walleye are now in numerous reservoirs including waters in the South Platte, Arkansas, Rio Grande and Colorado River drainage basins (Everhart and Seaman 1971). Tyus, Burdick et al. (1982) listed the walleye as rare in the Green River and incidental in the Yampa River.

Walleye spawning occurs in the spring shortly after ice-out over a temperature range of 5.6-11.1 C. Spawning grounds in rivers are rocky areas in white water below falls and dams or boulder to course-gravel shoals of lakes (Scott and Crossman 1973). In Colorado, walleye frequently spawn along rip-rapped banks and dams in reservoirs. Spawning usually occurs in less than 2 m of water at night (Beckman 1952, Everhart and Seaman 1971). No nests are built; eggs are broadcast and fall into crevices in the substrate. In Colorado, walleye populations are maintained by a management program of stocking fry resulting from eggs taken from wild stock and hatched and reared in hatcheries. Walleye take a wide variety of food including crayfish, frogs, snails, insects and fish. Adult diets consist mostly of fish when available.

Walleye usually prefer lakes to rivers and usually do best where they can range widely, as in larger bodies of water (Baxter and Simon 1970). Tyus, Burdick et al. (1982) listed preferred habitat as large streams, rivers and lakes in moderately deep water.

Scott and Crossman (1973) stated that walleye are tolerant of a great range of environmental conditions, but they appear to reach greatest abundance in large, shallow, turbid lakes. Walleye also thrive in clear lakes, but a special layer of their eye (tapetum lucidum) is extremely sensitive to bright daylight; therefore, feeding is restricted to twilight or dark periods. Northern pike may be the walleye's most important predator and competitor where they are sympatric. The walleye, because of the angling quality and excellent eating it provides, is a most desirable sport fish. However, it is best known from Colorado's reservoirs and has not become well established as a west-slope sport fish.

Coldwater Sport Fishes of Northwest Colorado

Most of the angling intensity in the Colorado River Basin of Colorado is directed at salmonid fish species generally found in rivers, lakes, and reservoirs at elevations of more than 1,700 m.

The Colorado Wildlife Commission has adopted a wild trout management policy. Certain waters with good environmental quality and capable of sustained natural reproduction have been designated as "wild trout waters" and will be managed without stocking of hatchery fish. Some waters capable of producing large trout are designated as "gold medal waters." The objective of a gold medal fishery is to have at least 20 percent of trout over 8 in long be 14 in or greater in size. Five of the eight presently designated Colorado gold medal waters are in the Colorado River Basin (Kochman 1983). One of these, the Lower Roaring Fork River, Garfield County, occurs in the geographic area emphasized in Consortium reports.

A "Colorado Fishing Map" was published and distributed by the Division of Wildlife in 1982. This map depicts gold medal and wild trout waters designated to date and other noteworthy sport-fish waters. A "Stream and Lake Evaluation Map for Colorado" was jointly published in 1979 by the Division of Wildlife, the Environmental Protection Agency, and the U.S. Fish and Wildlife Service. This map color-codes the relative significance of fishery resources into four categories: major, high priority, moderate, and limited.

Some of the important coldwater sport fishery resources in the Consortium's area of emphasis include Steamboat and Pearl lakes, Routt County; Lake Avery and the Upper White River, Rio Blanco County; Trappers Lake and sections of the Colorado and Roaring Fork rivers, Garfield County; and numerous lakes on the Grand Mesa, Mesa County.

Of all the salmonid fish species common to northwest Colorado, only the cutthroat trout and mountain whitefish are native. All other salmonid species have been introduced.

The rainbow trout is most intensively propagated in hatcheries and stocked into public waters (Beckman 1952). Because of the massive stocking program carried out by the Division of Wildlife, the rainbow trout is the major sport fish of northwest Colorado and the state as a whole. Excellent populations of self-sustaining wild rainbow trout are also found in some rivers such as the Upper Colorado, Upper Gunnison, Roaring Fork and Fryingpan rivers.

If coldwater sport fisheries of northwest Colorado were entirely dependent on natural reproduction, the rainbow trout would be of much lesser significance in the angler's catch. It would likely be exceeded by brown

trout and brook trout. The brown trout is well adapted to maintain populations in the medium to larger rivers (fourth to seventh order) at lower elevations (1,500-2,200 m), and the brook trout is particularly adapted to smaller, first- to third-order streams at higher elevations (2,200-3,200 m). Lake trout and kokanee salmon, Oncorhynchus nerka, are restricted to a relatively few large lakes and reservoirs containing large volumes of cold water.

The mountain whitefish is native to the White and Yampa rivers and has been successfully introduced into the Roaring Fork River. The whitefish typically coexists with brown trout and rainbow trout. In general, it is not highly regarded as a sport fish by most trout anglers but, because of its good quality as a food fish, it is esteemed by some local anglers.

Following are brief summaries of the biology of northwest Colorado's important salmonid species. Key references used in this section included Beckman (1952), Sigler and Miller (1963), Baxter and Simon (1970), Lee et al. (1980), Everhart and Seaman (1971), Scott and Crossman (1973), and Wiltzius (1981).

SALMONIDAE

Mountain whitefish

The mountain whitefish (Prosopium williamsoni) was first described by Girard in 1856 from the Deschutes River in Oregon (Daily 1971). It can be distinguished from trout and salmon by its large scales, weak teeth, and small mouth. The mountain whitefish has a widespread distribution in western North America; it is a native of the Green River Drainage but not of the Colorado River proper (Joseph et al. 1977). Daily (1971) reported that

mountain whitefish mature in their second to fourth year and spawn from October to December in gravel and rubble of streams. Eggs hatch in 1-5 months, depending on water temperature. Mountain whitefish early life history was described by Stalnaker and Siefert (1974).

Growth of mountain whitefish varies considerably among habitat types; food and temperature significantly influence growth rate. Several age-and-growth studies were reviewed by Daily (1971). Pettit and Wallace (1975) reported greater growth of young fish in lower reaches and of older fish in upper reaches of the North Fork Clearwater River in Idaho. Carlson et al. (1979) found that mountain whitefish grew slowly after their first year of life in the Yampa River in Colorado.

Mountain whitefish in streams feed predominantly on aquatic insects (Daily 1971, Joseph et al. 1977). Pontius and Parker (1973) reported opportunistic feeding on drift and from the bottom by mountain whitefish in the Snake River in Grand Teton National Park, Wyoming. Larger fish were more generalized feeders and used a greater size range of prey than smaller fish. Carlson et al. (1979) found that mountain whitefish in the Yampa River fed primarily on chironomid and simuliid larvae and pupae.

Pettit and Wallace (1975) reported that, in Idaho, native whitefish showed repeat homing to upstream areas in late spring and early summer, remained in upper stream reaches until spawning (November), and moved back to overwinter in deeper pools of the lower river. Mountain whitefish prefer pool and meadow areas of cool streams where water depths exceed 0.9 m (Daily 1971). Joseph et al. (1977) stated that their preferred habitat is open, slow run areas of cool tributary streams of the Upper Colorado River Basin, that their upper distribution limits may overlap distribution of brown and

rainbow trouts, and that they may occur at temperatures of 24 to 27 C below trout waters. In the past, the mountain whitefish was probably a dominant fish in transition areas (between trout and sucker zones) in the Green River sub-basin (Joseph et al. 1977).

Rainbow trout

The rainbow trout, Salmo gairdneri (Richardson), was introduced statewide into Colorado in 1882 (Everhart and Seaman 1971, Wiltzius 1981). The first group of fishes introduced was likely a subspecies called the coast rainbow trout, Salmo gairdneri irideus (Gibbons), from California. In 1951, an inland form of the kamloops rainbow trout, Salmo gairdneri kamloops (Jordan), was introduced into Granby Reservoir and a few other mountain reservoirs (Beckman 1952). Scott and Crossman (1973) provided additional references and a good discussion of the many subspecies of rainbow trout. The rainbow trout usually spawns in smaller tributary streams of rivers or inlet or outlet streams of lakes from March to August, most often from mid-April to late June. Their preferred spawning substrate is a bed of fine gravel in a riffle above a pool (Scott and Crossman 1973). Females dig nests (redds) and bury their eggs in the gravel. Spawning temperature is usually 10.0-15.5 C. Hatching and development times are quite variable depending upon water temperature and habitat; eggs hatch in 4-7 weeks, and yolk sac absorption and free swimming of young occur after an additional 3-7 days.

The food of rainbow trout includes planktonic and larger crustaceans, insects, snails, leeches, fish eggs, and fish. Food preferences usually shift from plankton to fishes (if available) as the fish grows. However,

rainbow trout have done well on invertebrates alone when fishes were not available for food (Scott and Crossman 1973). The preferred habitat of stream-dwelling rainbow trout is small to moderately large, shallow rivers of the pool-riffle type with moderate flow and gravel bottoms. Preferred habitat of lake-dwelling rainbow trout is usually moderately deep to deep, cool lakes with adequate shoal areas and vegetation for abundant food production (Scott and Crossman 1973). Rainbow trout prefer temperatures in the 10-16 C range but do well in temperatures up to 21 C and can tolerate 27 C temperatures for brief periods (Beckman 1952, Everhart and Seaman 1971).

Brown trout

The brown trout, Salmo trutta (Linnaeus), also called German brown or Loch Leven brown trout, originated in Europe and was first introduced privately to Colorado's east-slope in 1886 and into west-slope waters in 1888 (Wiltzius 1981).

The brown trout can be distinguished from other trout by red spots interspersed with black spots on its generally brownish sides. The lateral spots are often ringed with white or yellow (Beckman 1952).

Brown trout spawn in the fall, normally in October, when streams are usually low and clear and provide a stable environment for reproduction (Everhart and Seaman 1971). Spawning temperatures reported by Scott and Crossman (1973) were 6.7-8.9 C. The female digs a redd in gravel and covers the fertilized eggs. Young trout usually emerge from the gravel in the spring prior to peak runoff periods. Free-swimming young are able to withstand considerable turbidity; this contributes to their natural reproductive success in Colorado (Everhart and Seaman 1971). Scott and

Crossman (1973) reported that the optimum temperature range for brown trout was 18.3-23.9 C, higher than that of brook and rainbow trout. Brown trout are thought to do best in slower-moving waters and lower reaches of trout streams, but that view was questioned by Scott and Crossman (1973). Brown trout are carnivorous; food items include aquatic and terrestrial insects and their larvae, crustaceans, crayfish, mollusks, salamanders, frogs, rodents, and a wide variety of fishes. Brown trout over 12 in long eat predominantly fishes and crayfish. Larger brown trout generally feed late in the evening or after dark (Scott and Crossman 1973).

The brown trout is the most difficult trout to catch (Beckman 1952, Davis 1982). Because of this and its ability to reproduce successfully, it may become a more important part of Colorado's fisheries in unstocked wild trout streams in the future.

Brook trout

The brook trout, Salvelinus fontinalis (Mitchill), is native to the eastern part of North America. It was introduced into eastern Colorado privately in 1874 and stocked by the state into western Colorado streams in 1882 (Wiltzius 1981). The brook trout is distinguished in appearance by mottled gray markings on an olive-green to green body and numerous red and yellow spots bordered in blue circles on its sides. The anterior margins of its pectoral, pelvic, anal, and caudal fins are edged in white bordered by a black stripe behind (Beckman 1952). Brook trout are fall spawners and usually spawn in October. Spawning habitat includes gravel beds in the shallows of headwater streams or gravelly shallows of lakes in areas of spring upwelling. Gravelly shallows of headwater streams with strong

springwater flow are particularly favored (Scott and Crossman 1973). Females dig redds, and fertilized eggs are covered with gravel. Preferred temperatures range from 12.8-19 C within a tolerated range of 0.5-25 C. Brook trout may be found at lower elevations but flourish at 3,000-4,000 m (Everhart and Seaman 1971). Scott and Crossman (1973) listed preferred habitat as clear, cool, well-oxygenated streams and lakes and indicated that brook trout tend to seek cooler temepratures in lakes when surface temperatures warm to 20 C. In streams, they may move downstream to larger bodies of water or into lakes.

Brook trout are carnivorous and eat a wide variety of foods including aquatic insect larvae, terrestrial insects, worms, leeches, crustaceans (cladocerans, amphipods, decapods), spiders, mollusks (clams and snails), many fishes (including young brook trout and brook trout eggs, minnows, sticklebacks, and sculpins), frogs, salamanders, snakes, and small mammals.

The average size of brook trout in Colorado is quite small; however, fish weighing 2-3 lbs. may be occasionally caught. The state record brook trout is 8 lbs. The eating quality of brook trout is exceptionally good.

Native Non-Endangered Non-Sport Fishes of Northwest Colorado

Following are brief introductions to the native non-sport fishes of northwest Colorado that are not threatened or endangered. Preparation of these summaries was greatly facilitated by the bibliographies of Ecology Consultants, Inc. (1977) and Wydoski et al. (1980) and by the species

accounts of Joseph et al (1977). These species, with the exception of Cottus annae, were also considered by Lee et al. (1980). Common and scientific names used generally follow Robins et al. (1980). Wiltzius (1978) reviewed historic distribution of these fishes.

CYPRINIDAE

Roundtail chub

The roundtail chub, Gila robusta, was first described by Baird and Girard (1853a). Systematics of this and closely related species were reviewed by Smith, Miller and Sable (1979). A single subspecies (G. r. robusta) exists only in the Upper Colorado River Basin, but three other subspecies have been recognized in the Lower Basin (Rinne 1976). The roundtail chub and the bonytail were considered subspecies of Gila robusta from 1914 to 1970 (Rinne 1976), and older literature should be interpreted with caution because roundtail chub were often erroneously referred to as "squawfish" or "bonytail chub" (Joseph et al. 1977). Roundtail chub lack the nuchal hump of humpback chub, have thicker caudal peduncles than either the humpback chub or bonytail, and typically have nine dorsal and anal fin rays (Behnke and Benson 1983). Adults typically attain a standard length of 250 to 350 mm (Lee et al. 1980). Young specimens are often confused with Colorado squawfish; however, they lack the black spot at the base of the tail seen in squawfish up to about 10 in (25.4 cm) long. The roundtail chub was considered the dominant native carnivore of tributaries in the Colorado River Basin by Holden and Stalnaker (1975a). Some reductions in numbers and distribution occurred after the 1960s. Joseph et al. (1977) considered it common in warm intermediate-zone streams of the

Basin (except in the San Juan and its tributaries below Navajo Dam) and in upper reaches of lower zones in the Colorado and Green rivers. Tyus, Burdick et al. (1982) listed it as abundant in the Yampa and Lower Gunnison rivers; common in the Lower White, Colorado, and Dolores rivers; and rare in the Green River.

Vanicek and Kramer (1969) reported that roundtail chub spawn at temperatures of 65 F (18 C) or higher. Carlson et al. (1979) found that they spawned from early May into mid-June in the Yampa and into mid-July in the White River in Colorado. Young are important as food for other species (Miller 1965). Larval development was described by Snyder (1981) and continues to be studied by the Larval Fish Laboratory at Colorado State University. Roundtail chub may reach total lengths of 500 to 600 mm in large rivers but typically mature at total lengths of 150 to 200 mm in smaller tributaries (Joseph et al. 1977). Vanicek and Kramer (1969) presented age-and-growth data, which are subject to some question because they considered young (under 200 mm total length) G. robusta and G. elegans as one species. They indicated, however, that bonytail grew faster than roundtail chub (Vanicek and Kramer 1969). Vanicek and Kramer (1969) reported that roundtail chub feed on terrestrial and aquatic insects, and large adults may consume fish and floating plant debris. Jacobi and Jacobi (1982) noted that YOY and juveniles were opportunistic feeders on most invertebrate food items. Roundtail chub have been collected from a wide variety of habitats (Holden and Stalnaker 1975a), but a preference for moving water has been noted (Carlson et al. 1979). Tyus, Burdick et al. (1982) listed their preferred habitat as large river channels in association

with boulders or overhanging cliffs and in riffles, shallow runs, or eddy-run interfaces.

The roundtail chub was listed by Miller (1972) as one of the threatened fishes of the United States. It is not now considered either threatened or endangered.

Speckled dace

The speckled dace, Rhinichthys osculus, was first described by Girard (1856). Its taxonomy was reviewed by Hubbs et al. (1974). It is one of the most abundant and widespread minnows of the western United States (Miller 1965). Its variability is responsible for considerable confusion in its taxonomy. Most speckled dace in the Upper Colorado River Basin are of the subspecies R. o. yarrowi. This is a small minnow with an elongate, fusiform body, rounded fins, a small inferior to subterminal mouth, and small scales with radii in all fields. Hybrids between R. osculus and Richardsonius balteatus (redside shiner) are common. These hybrids were analyzed by Smith (1973) and found in the Yampa River by Carlson et al. (1979). Speckled dace are abundant in small streams in the mountains, less common in larger streams, and rare below the mountains (Joseph et al. 1977). There is no apparent difference in the historical and present distribution and abundance of speckled dace, except that they may now be less abundant in altered habitat below large dams (Joseph et al. 1977). Tyus, Burdick et al. (1982) listed speckled dace as abundant (although their distribution map indicated that they were only common) in the Yampa and White rivers and in sections of the Mainstem Colorado, Gunnison, and Dolores rivers but rare in the Green and Lower Colorado rivers in northwest Colorado.

Speckled dace biology has not been intensively studied in the Upper Colorado River Basin (Baxter and Simon 1970). John (1963) described spawning in R. osculus in mountain streams in Arizona, where photoperiod was suspected to regulate the reproductive period. Eggs were deposited by females under rocks in "nests" cleared of silt and plants by males. Collected eggs hatched (in the laboratory) at 18-19 C in 6 days. Snyder (1981) described larval development. Speckled dace usually grow to 2 to 3 in (5 to 7.6 cm) in length; they are valued as baitfish and are important as food for trout and other predatory fishes (Miller 1965). Jacobi and Jacobi (1982) stated that adults fed primarily on Ephemeroptera. Speckled dace were collected in most habitats by Holden and Stalnaker (1975a), but they were typically associated with small riffles or areas of current. Carlson et al. (1979) reported almost equal numbers of young and juveniles in moving water, pools, backwaters, and quiet waters near shore. Tyus, Burdick et al. (1982) listed preferred habitat as shallow, swift runs and riffles with gravel substrates.

The Kendall Warm Springs dace, Rhinichthys osculus thermalis, was described by Hubbs and Kuhne (1937). It is found only in Kendall Warm Springs along the Green River in Sublette County, Wyoming. This subspecies was listed as endangered by Miller (1972) and of special concern by Deacon et al. (1979). It is on the federal list of endangered species because of its restricted habitat and the possibility of the population being destroyed by pollution of the spring (Behnke and Benson 1983).

CATOSTOMIDAE

Bluehead sucker

The bluehead sucker, Catostomus discobolus, was originally described and named by Cope (1872) from the Green River, Wyoming (Baxter and Simon 1970, Lee et al. 1980). Nomenclature and synonymy of this species were discussed by Smith (1966). Some (Minckley 1973, Holden and Wick 1982) still consider it a member of the genus Pantosteus. Bluehead sucker and mountain sucker have a lateral notch on each side of their lips and a distinct cartilaginous biting edge on the jaw inside their lips. In contrast to the related mountain sucker, the bluehead has a narrower caudal peduncle, fewer scales, and pigmentation between the caudal fin rays. Bluehead sucker also grow to a much large size than mountain sucker. Wide- and narrow-peduncled forms (and intergrades) of the bluehead sucker occur in the Upper Colorado River Basin (Joseph et al. 1977). Prewitt (1977) collected more narrow-peduncled types at downstream areas on the Yampa River. Hybrids occur between bluehead sucker and flannelmouth and white sucker; they are discussed in greater detail in our flannelmouth sucker review (below). Holden and Stalnaker (1975a) noted no difference in historic and recent distribution of bluehead sucker. Tyus, Burdick et al. (1982) listed this species as common in all major northwest Colorado streams except the Green and White rivers, in which it was rare.

Joseph et al. (1977) suggested that bluehead sucker spawn at temperatures of 15-18 C. Andreasen and Barnes (1975) observed spawning from May through July in the Weber River, Utah. Carlson et al. (1979) reported spawning from mid-May to September in the Yampa River and from early May to late July in the White River in 1976 and 1977. Representative larval stages

were illustrated by Snyder (1981). Bluehead sucker, the largest of the "mountain" (subgenus Pantosteus) suckers may grow to 18 in (46 cm) in length (Baxter and Simon 1970). They feed on algae as adults (Taba et al. 1965, Carlson et al. 1979) and on seston as young (Jacobi and Jacobi 1982). Bluehead sucker were usually collected by Holden and Stalnaker (1975a) over rocky substrates and were common in riffles over cobble and small boulders in other areas. Young occupy slower waters such as backwaters and eddies (Joseph et al. 1977). Their preferred habitat is deep riffles and shallow runs over gravel/cobble substrate (Tyus, Burdick et al. 1982).

Flannelmouth sucker

The flannelmouth sucker, Catostomus latipinnis, was first described by Baird and Girard (1853b) and named Acomus latipinnis. It is distinguished by fleshy lips without a lateral notch, small scales, and a narrow caudal peduncle. Flannelmouth sucker are endemic in the Colorado River System and are known to hybridize with bluehead (Hubbs, Hubbs, and Johnson 1943, Hubbs and Hubbs 1947), white and razorback sucker (Hubbs and Miller 1953, Holden and Stalnaker 1975a, McAda and Wydoski 1980). Hybrids between flannelmouth sucker and white or bluehead suckers were collected and studied by Prewitt (1977); morphometric, meristic and electrophoretic analyses demonstrated hybrid intermediacy and supported the theory that hybrid suckers in the White and Yampa rivers cannot reproduce. The flannelmouth sucker was historically found in intermediate and lower zones of the Upper Colorado Basin (Joseph et al. 1977). Present distribution is similar to past distribution except that flannelmouth sucker are less abundant or absent in large reservoirs. This sucker is often the most

abundant fish collected in intermediate zones of Upper Colorado River Basin streams (Miller 1965, Holden and Stalnaker 1975a, Joseph et al. 1977, Carlson et al. 1979). Tyus, Burdick et al. (1982) listed it as abundant in the lower reaches of most major northwest Colorado streams and less abundant in the Green River and upstream reaches of the Yampa, White, Colorado, Gunnison and Dolores rivers.

Flannelmouth sucker spawn in late spring when water temperatures reach about 13 C (Joseph et al. 1977). Carlson et al. (1979) reported spawning from April into July (on the White River) or August (on the Yampa) in Colorado. Snyder (1981) described larval stages. Carlson et al. (1979) reported relatively slow growth of flannelmouth sucker after their first 3 years of life. Little age-and-growth data is available. Flannelmouth sucker reach a length of 2 feet (0.6 m) and weights of 1 to 5 lbs. (0.45 to 0.9 kg) (Miller 1965). Minckley (1973) indicated that flannelmouth sucker are omnivorous; Taba et al. (1965) found mainly bottom materials in Colorado River flannelmouth sucker stomachs. Carlson et al. (1979) reported that they fed primarily on algae and associated organisms. Jacobi and Jacobi (1982) reported that YOY fed predominantly on invertebrates.

Flannelmouth sucker have been caught in a variety of habitats (Holden and Stalnaker 1975a) but prefer shallower water with sand/cobble substrate and velocities under 4 fps (Carlson et al. 1979). Miller (1965) stated that young swarm in quiet marginal waters of swift-flowing streams in shallower water than is preferred by adults. Tyus, Burdick et al. (1982) listed preferred habitat as runs, shorelines and eddies of mainstream rivers.

Mountain sucker

The mountain sucker, Catostomus platyrhynchus, was constituted from three previously-recognized species (Pantosteus platyrhynchus, P. jordani, and P. lahontani) by Smith (1966). The mountain sucker can be distinguished from bluehead sucker by its deeper caudal peduncle and the lack of pigment in interspaces of its caudal fin rays. Mountain sucker hybridize with white and bluehead sucker (Smith 1966). This sucker was listed by Tyus, Burdick et al. (1982) as rare in the Green River and in headwaters of the Yampa and White rivers in Colorado. Mountain sucker are replaced by bluehead sucker in warmer, larger streams of the Green River System (Joseph et al. 1977).

Mountain sucker spawn in late spring and early summer; breeding sites and spawning behavior have not been described (Baxter and Simon 1970). Hauser (1969) observed most spawning in late June and early July in southwestern Montana. Males matured at age 4 years and females at age 5 years. Snyder (1981) described larval stages of mountain sucker. Adults grow to at least 8 in (20.3 cm) in length. Hauser (1969) studied the growth history of mountain sucker in Montana streams. Food of mountain sucker consists of algae scraped from rocks by the cartilaginous sheaths on their jaws (Baxter and Simon 1970). Hauser (1969) stated that diatoms and other algae were important food items. Mountain sucker are generally found over rubble bottoms in moderate to swift current of small streams (Joseph et al. 1977). Tyus, Burdick et al. (1982) stated that they prefer cool, clear streams with gravel/cobble substrate.

COTTIDAE

Mottled sculpin

The mottled sculpin, Cottus bairdi, is abundant in eastern North America, absent from most of the Great Plains region, and again present in the upper part of the Missouri river and in the Snake-Columbia and Colorado basins (Miller 1965). It is restricted to, but widely distributed in, the upper part of the Colorado River Basin in Wyoming, Colorado, and Utah. Its systematics were reviewed by Bailey and Bond (1963), but it is in need of comprehensive systematic study. Tyus, Burdick et al. (1982) listed the mottled sculpin as common in portions of the Green, Yampa, White, Upper Colorado and Upper Gunnison rivers in northwest Colorado. It apparently does not occur in the lower reaches of the White, Gunnison, and Colorado rivers in Colorado or in the Dolores River.

Mottled sculpin become sexually mature at 2 or 3 years of age. Spawning occurs between February and June at water temperatures of 45-48 F (7-9 C), according to Baxter and Simon (1970). Nests are apparently scooped out below rocks by males. Carlson et al. (1979) stated that the spawning season of mottled sculpins was late April to late June in the Yampa River and early May to mid-June in the White River in Colorado. Bailey (1952) observed spawning in June; males prepared and attended nests to remove dead eggs and debris. Simon and Brown (1943) described spawning of the "Bonneville" mottled sculpin in spring creeks near Jackson, Wyoming. Spawning occurred from late February to late May at an elevation of about 6,200 feet (1,890 m). Zarbock (1952) and Bailey (1952) studied growth (by otolith, vertebral and length-frequency analyses). Adult mottled sculpin may grow to 4 to 6 in (10 to 15 cm) in length; their food is aquatic

insects, crustaceans, and some small fishes (Baxter and Simon 1970). Bailey (1952) found that Diptera and Trichoptera dominated diets of mottled sculpin in Montana. Zarbock (1952) noted similar food habits in the Logan River, Utah. Holden and Stalnaker (1975a) reported that the mottled sculpin is a cool-water species, and they collected it only in Echo Park at the confluence of the Green and Yampa rivers. Bailey (1952) and Carlson et al. (1979) found mottled sculpin in very swift waters over boulder, large cobble, or rubble substrates. Young typically inhabit quiet waters (Bailey 1952). Tyus, Burdick et al. (1982) stated that preferred habitat is riffles and deeps runs with gravel/rubble/boulder substrate.

Eagle sculpin

The eagle sculpin, Cottus annae, and Cottus bairdi tubulatus were synonymized with C. beldingi by Bailey and Bond (1963). University of Michigan Museum of Zoology personnel are investigating the systematics of this group. C. annae is very rare in the Colorado and Gunnison rivers in northwest Colorado and should be considered for inclusion on state and federal threatened or endangered species lists. Beckman (1952) stated that the eagle sculpin may attain a length of 6 in (15 cm), breeds late April through July, and feeds principally in aquatic insect larvae, small fish and crustaceans. He noted its occurrence in small rapid streams at high elevations.

Non-Native Non-Endangered Non-Sport Fishes of Northwest Colorado

The following information is presented to direct readers to synopses on biology of non-sport fishes of northwest Colorado which are neither native nor rare and to describe their abundance, distribution, and preferred habitats. Scientific and common names are from Robins et al. (1980). Historic distribution of most of these fishes was reviewed by Wiltzius (1978). Tyus, Burdick et al. (1982) considered associations among fish species of the Upper Colorado River System.

CYPRINIDAE

Carp

The carp, Cyprinus carpio, was discussed by Beckman (1952), Sigler and Miller (1963), Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980). Snyder (1981) described its larval development. Tyus, Burdick et al. (1982) listed carp as common in the Green and Lower Yampa rivers, rare in the Lower White River, and abundant in the Colorado, Gunnison, and Dolores rivers in northwest Colorado. Its preferred habitats are runs, eddies, gravel pits and backwaters in moderate-to-deep water of low velocity with silt/sand/boulder substrates (Tyus, Burdick et al. 1982). Irrigation flow returns are also commonly occupied.

Utah chub

Gila atraria were considered by Sigler and Miller (1963), Baxter and Simon (1970), and Lee et al. (1980). Snyder (1981) described the larval development of Utah chub. Tyus, Burdick et al. (1982) described it as rare in the Green River and incidental in the Yampa River in northwest Colorado.

It is not known to occur in other major streams in northwest Colorado. Preferred habitats are littoral and pelagic zones of reservoirs (Tyus, Burdick et al. 1982).

Brassy minnow

Brassy minnow, Hybognathus hankinsoni, were discussed by Beckman (1952), Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980). Snyder (1981) illustrated larval stages. Tyus, Burdick et al. (1982) described brassy minnow as incidental in the Lower Colorado River in western Colorado. Preferred habitats are small, sluggish, weedy streams with sand, gravel, or mud bottom overlain by organic sediment (Tyus, Burdick et al. 1982).

Red shiner

Notropis lutrensis were considered by Baxter and Simon (1970) and Lee et al. (1980). Jacobi and Jacobi (1982) reported that YOY and adult red shiner consumed most major invertebrate food items and some plant microfragments and seston. Snyder (1981) described its larval development. The species was listed by Tyus, Burdick et al. (1982) as abundant to rare in the Green River, common in the Lower Yampa, Gunnison and Dolores rivers and throughout the White River, and abundant in the Lower Colorado River in northwest Colorado. Preferred habitats are backwaters, side channels, or inundated gravel pits with silt/sand/gravel substrates (Tyus, Burdick et al. 1982). Shorelines with emergent vegetation are also frequented.

Sand shiner

Notropis stramineus were discussed by Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980). Jacobi and Jacobi (1982) stated that adults were a dominant plant and invertebrate macrofragment consumer. Snyder (1981) described larval stages of the sand shiner. Tyus, Burdick et al. (1982) considered the species common in the Yampa River and rare in the Colorado and Dolores rivers. Preferred habitats are shallow runs and backwaters with silt/sand substrate (Tyus, Burdick et al. 1982).

Fathead minnow

Pimephales promelas were discussed by Beckman (1952), Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980). Jacobi and Jacobi (1982) indicated that YOY and adults fed on seston, macrofragments, and invertebrates; young consumed more invertebrates. Snyder (1981) illustrated selected larval stages. Tyus, Burdick et al (1982) reported that fathead minnow were common in all major rivers of northwest Colorado except the Upper Yampa and Middle White rivers, in which they were rare. Preferred habitats are backwaters and pools with silt/sand substrate (Tyus, Burdick et al. 1982).

Longnose dace

Rhinichthys cataractae were considered by Beckman (1952), Sigler and Miller (1963), Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980). Snyder (1981) illustrated larval stages. Tyus, Burdick et al. (1982) did not report longnose dace in northwest Colorado, but they are known from the Gunnison River (Wiltzius 1978). This species prefers

riffles and swift water in streams or littoral zones in reservoirs (Tyus, Burdick et al. 1982).

Redside shiner

Redside shiner, Richardsonius balteatus, were considered by Sigler and Miller (1963), Scott and Crossman (1973), and Lee et al. (1980). Hybrids with speckled dace occur in northwest Colorado. Haynes, Muth, and Wycoff (1982) reported an extension of the range of the redside shiner to the Upper Mainstem Colorado River. Tyus, Burdick et al. (1982) reported redside shiner as rare in the Green River, common to rare in the lower and middle reaches of the Yampa River, and incidental in the Colorado River in northwest Colorado. Carlson et al. (1979) discussed the possible role of redside shiner as competitors with or predators on young Colorado squawfish. Their research indicated that smaller redside shiner were rather non-selective, opportunistic feeders, and they noted only rare ingestion of larval fishes. Snyder (1981) described larval stages of redside shiner. Its preferred habitats are backwaters and pools with slow current in streams and littoral zones in reservoirs (Tyus, Burdick et al. 1982).

Creek chub

Creek chub, Semotilus atromaculatus, were included in works by Beckman (1952), Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980). Larval stages were illustrated by Snyder (1981). Tyus, Burdick et al. (1982) listed the creek chub as rare in the Green and Yampa rivers and incidental in the Colorado River in northwest Colorado. Riffles,

runs, and pools with rubble/cobble substrate are its preferred habitats (Tyus, Burdick et al. 1982).

CATOSTOMIDAE

Longnose sucker

The longnose sucker, Catostomus catostomus, was considered by Beckman (1952), Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980). Snyder (1981) illustrated larval stages. Tyus, Burdick et al. (1982) reported that the species does not occur in northwest Colorado, but it does occur in the Upper Gunnison River east of the five-county area considered in this report (Wiltzius 1978). This species prefers clear, cold waters of reservoirs (Tyus, Burdick et al. 1982).

White sucker

Catostomus commersoni, the white sucker, was discussed by Beckman (1952), Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980). Larval stages were illustrated by Snyder (1981). Tyus, Burdick et al. (1982) listed this species as rare in the Green, Colorado, and Gunnison rivers and common in middle reaches of the Yampa River in northwest Colorado. It has not been reported from the White or Dolores rivers. Preferred habitats are deep riffles and runs over gravel/cobble substrate (Tyus, Burdick et al. 1982).

ICTALURIDAE

Black bullhead

The black bullhead, Ictalurus melas, was considered by Beckman (1952), Sigler and Miller (1963), Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980). Tyus, Burdick et al. (1982) considered the species rare in the Green River and lower reaches of the Colorado River in northwest Colorado and incidental in the Yampa and White rivers. Preferred habitats are backwaters and inundated gravel pits with silt/gravel substrates (Tyus, Burdick et al. 1982).

CYPRINODONTIDAE

Plains topminnow

The plains topminnow, Fundulus sciadicus, was included in work of Beckman (1952), Baxter and Simon (1970), and Lee et al. (1980). Tyus, Burdick et al. (1982) considered it an incidental species found only in the White River in northwest Colorado. Preferred habitats are pools and backwaters in small- to medium-sized clear streams with moderate to rapid current and sandy/rocky substrates (Tyus, Burdick et al. 1982).

Plains killifish

Fundulus zebrinus, the plains killifish, was discussed by Beckman (1952) and Baxter and Simon (1970) (as Fundulus kansae) and by Sigler and Miller (1963) and Lee et al. (1980). Fundulus kansae (plains killifish) and Fundulus zebrinus (Rio Grande killifish) were considered conspecific by Robins et al. (1980); F. zebrinus is the senior synonym. Tyus, Burdick et al. (1982) listed Rio Grande killifish (sic) as

incidental in middle reaches of the Yampa River and lower reaches of the Colorado River in northwest Colorado. This species prefers shallow backwaters with silt/sand substrates (Tyus, Burdick et al. 1982).

POECILIIDAE

Mosquitofish

Gambusia affinis, the mosquitofish, was considered by Beckman (1952), Sigler and Miller (1963), and Lee et al. (1980). Tyus, Burdick et al. (1982) stated that it is incidental in the lower reaches of the White River and in the Colorado River above Grand Junction in northwest Colorado. Mosquitofish prefer vegetated ponds, drainage ditches, backwaters and oxbows with little or no current (Tyus, Burdick et al. 1982).

CENTRARCHIDAE

Green sunfish

The green sunfish, Lepomis cyanellus, was discussed by Beckman (1952), Sigler and Miller (1963), Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980). Tyus, Burdick et al. (1982) listed it as incidental in the Lower Yampa and White rivers, rare in the Colorado River, and incidental in the Gunnison and Dolores rivers in northwest Colorado. Green sunfish prefer slow-moving streams or the shelter of weeds in warmwater lakes or reservoirs (Tyus, Burdick et al. 1982). L. Kaeding (pers. commun.) observed that green sunfish collected in 1982 from four Colorado River backwaters occasionally had consumed tagged Colorado squawfish fingerlings.

Bluegill

Lepomis macrochirus, the bluegill, was considered by Beckman (1952), Sigler and Miller (1963), Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980). Tyus, Burdick et al. (1982) considered the species incidental in the Green and Colorado rivers in northwest Colorado. It prefers shallow, warm lakes, ponds, or slow-flowing streams with abundant aquatic vegetation (Tyus, Burdick et al. 1982).

PERCIDAE

Iowa and johnny darters

Etheostoma exile (Iowa darter) and E. nigrum (johnny darter) occur in reservoirs in the upper reaches of the Colorado River Drainage outside the five-county area considered in this document. Fishes obviously have access to downstream areas in drainages in which they occur, and these species have access to the Colorado River in northwest Colorado. Therefore, they should be considered as potential current or future inhabitants of northwest Colorado streams. These fishes were considered by Beckman (1952), Baxter and Simon (1970), Scott and Crossman (1973), and Lee et al. (1980).

The johnny darter is listed as threatened in Colorado and is, therefore, considered a non-game species (Colorado Division of Wildlife 1983).

Federal and State Endangered or Threatened Species

Colorado River Cutthroat Trout, *Salmo clarki pleuriticus*

Status

State Threatened

Distribution

The Colorado River cutthroat trout once had a wide distribution in the Upper Colorado River Basin. Its original range extended from the uppermost sources of the Green and Colorado rivers to the San Juan River Drainage in the east and to the Dirty Devil River in the western part of the basin. The native range included parts of Wyoming, Colorado, Utah, New Mexico, and Arizona (San Juan Drainage of Chukas Mountains along New Mexican border). The Colorado River cutthroat trout has been virtually eliminated throughout its once great range and a relatively few pure populations now exist mainly in remote, isolated headwater streams. An exception is Trappers Lake, Garfield County, which still maintains a substantial population of essentially pure native cutthroat trout despite many introductions of non-native trouts (Behnke and Benson 1983). Tables 8 and 9 list cutthroat trout collections made by the Division of Wildlife's Nongame Program in 1980 and 1981. These tables consist of collections of Colorado cutthroat trout, *Salmo clarki pleuriticus*, made in 1980 and 1981 by Colorado Division of Wildlife Endangered Wildlife Investigations (Grand Junction). Purity grades are assigned on the basis of the taxonomic characters of the sample in relation to the degree of hybrid influence apparent. Grades A (pure), B (essentially pure), and C (good representatives, but some hybrid influence

Table 8. Character analysis of 1980 collections of Colorado River Cutthroat trout (Salmo clarki pleuriticus) from the Upper Colorado Drainage in Colorado. (See pp. 67 and 72 for additional explanation.)

Locality	Gillrakers	Scales above lat. line and lat. series	Basibranchial teeth	Pyloric caeca	Purity Grade	Comments
Yampa Drainage Lost Dog Creek N=10 T10N R84W S24	18-21(19.1)	35-42 (39.0) 135-193(160.7)	4 w/0 teeth 6 w/2-3 (2.5)	32-55(41.3)	C	Hybrid characteristics.
Porcupine Lake N=10 T8N R83W S33	18-21(19.6)	40-46 (43.7) 155-186(174.3)	1-23 (7.8)	37-44(39.8)	B	Probable mixture Yellowstone and Trappers L. stocks.
Luna Lake N=11 T8N R83W S21, 28	18-22(20.0)	43-50 (46.3) 171-208(190.0)	1 w/0 teeth 10 w/1-7 (4.3)	36-44(40.9)	B+	Spotting variable, spots large.
Lake Diana N=11 T10N R83W S4	16-21(18.9)	39-47 (42.6) 166-199(182.6)	10-25(15.1)	35-55(45.8)	B	Definite Yellowstone influence. Perhaps stocking from Haypress L. origin.
Lake of the Crags N=10 T8N R83W S21	18-22(19.6)	39-46 (42.3) 169-200(183.9)	3-43(15.4)	38-46(41.5)	B-	Spotting erratic, indicates diverse parentage, probably Yellowstone and Trappers Lake stocks mixed.
Mandall Creek N=14 T 1N R87W S13	18-20(19.1)	41-53 (46.3) 161-198(178.8)	1-10 (4.4)	29-48(39.1)	B+	Spotting variability indicates hybrid influence.
White River Drainage Fawn Creek N=12 T1N R90W S7	19-22(20.4)	45-52 (47.3) 178-202(189.4)	1 w/0 teeth 11 w/1-8(3.4)	30-46(37.4)	A-	Relatively uniform, typical pleuriticus spotting.
Lost Creek N=9 T1N R90W S15	18-21(19.3)	41-52(47.8) 132-200(178.4)	3 w/0 teeth 6 w/2-11(5.7)	32-62(40.6)	C	Hybrid spotting.
Little Skinny Fish Lake N=10 T1N R87W S19	18-21(19.1)	40-50 (43.6) 175-199(187.1)	3 w/0 teeth 7w/1-11(4.1)	30-44(36.6)	B	Predominantly pleuriticus, large spots, some slight non-native influence.
Hahn Creek N=14 T2N R90W S34	18-22(19.2)	43-49 (46.7) 173-204(186.7)	1 w/0 teeth 13 w/1-6(3.5)	32-44(37.1)	A-	Relatively uniform, typical pleuriticus spotting.

Table 8. continued

Locality	Gillrakers	Scales above lat. line and lat. series	Basibranchial teeth	Pyloric caeca	Purity Grade	Comments
Colorado River Drainage Trib-to Eagle River Indian Creek N=15 T4S R81W S23	18-21(19.6)	39-47 (43.5) 176-206(192.8)	5 w/0 teeth 10 w/1-6(2.8)	33-46(39.4)	B+	Basibranchial teeth indicate hybrid influence, but spotting influence is uniform. Spots relatively large.
Pitkin Creek N=10 T5S R80W S1	19-21(20.0)	42-54 (47.9) 165-201(181.4)	3-19(10.1)	33-48(40.4)	B	Considerable variation in spotting.
Carter Lake N=15 T8S R82W S10	--	--	3 w/0 teeth 12 w/1-4(2.5)	--	C	Obvious rainbow hybrid spotting.
Nolan Creek N-5 T6S R83W S25	16-20(17.6)	45-49(47.0) 194-205(198.0)	1 w/0 teeth 4 w/2-6 (4.2)	32-41(34.6)	A(?)	Meristic characters ideal pleuriticus but spotting lacks uniformity.
Abrams Creek N=9 T 5S R84W S20	16-19(17.3)	44-56 (49.8) 180-211(198.2)	2-7 (4.1)	37-57(45.2)	A-	Uniform, typical pleuriticus spotting pattern.
Miller Creek N=10 T5S R79W S20	18-21(19.1)	42-54 (48.9) 182-215(198.9)	2-14(9.1)	26-42(37.0)	A(?)	Spots more evenly distributed over body, similar to Trappers Lake stock.
Polk Creek N=11 T5S R79W S28	17-21(18.9)	39-48 (43.7) 159-186(172.8)	1 w/0 teeth	26-48(38.1)	B+	Hybrid influence in spotting pattern.
Hat Creek N=10 T6S R83W S27	16-22(19.3)	42-52 (48.8) 171-206(191.8)	2-16(9.4)	29-46(36.9)	A(?)	Spotting variation, some specimens typical pleuriticus, some typical of stomias.
Trib. to Roaring Fork Frying Pan Lakes #2 & 3 N=13 elev. 11,000 ft.	18-21(19.3)	41-51 (45.6) 184-214(195.5)	3-14 (9.3)	36-48(41.4)	A-	Relatively large, but somewhat uniform spotting. May be natural variability.

Table 8. continued

Locality	Gillrakers	Scales above lat. line and lat. series	Basibranchial teeth	Pyloric caeca	Purity Grade	Comments
Lost Trail Creek N=6 T11S R87W S19	18-21(19.2)	44-50 (48) 174-198(191.5)	1 w/0 teeth 5 w/1-11(4.4)	27-43(33.2)	A-	Some inconsistency in spotting
Nickelson Creek N=8 T9S R87W S36	18-21(19.1)	40-52(45.9) 173-212(192.1)	2-10(6-13)	26-42(33.4)	A-	Meristic characters typical pleuriticus but considerable variation in spotting
Trib. to Colorado River Deadman Gulch N=10 T1N R83W S5	18-22(19.8)	38-51 (44.6) 172-198(184.8)	2 w/0 teeth 8 w/1-12(3.2)	33-52(41.0)	B+	Some rainbow hybrid influence, but generally uniform pleuriticus spotting.
East Fork Red Dirt Crk. N=10 T2S R86W S28	17-20(18.8)	40-52 (47.3) 159-203(189.8)	5 w/0 teeth 5 w1/7(3.6)	26-46(38.2)	B-	Spotting is definitely cutthroat with some large spots and pleuriticus spotting.
West Fork Red Dirt Crk. N=10 T2S R86W S34	17-22(19.5)	46-51 (47.8) 171-219(190.5)	3 w/0 teeth 7 w/1-16(5.7)	33-52(42.4)	B-	Some rainbow hybrid influence in teeth and ceaca, but 7 specimens with typical pleuriticus spotting.
East Meadow Creek N=10 T4S R81W S11	19-22(19.6)	48-59 (54.6) 198-223(207.8)	4-12 (7.3)	27-39(35.6)	A+	Uniform, typical pleuriticus spotting.
Possum Creek N=10 T5S R89W S20	15-21(19.0)	35-45 (42.1) 166-200(186.7)	1 w/0 teeth 9 w/2-16(5.8)	32-66(43.2)	C	Obvious rainbow hybrid spotting.
Mitchell Creek N=10 between barrier falls above Glenwood Hatchery T5S R89W S27	16-20(18.4)	44-50 (48.1) 179-205(194.0)	5-15(8.1)	32-38(34.8)	A+	Typical pleuriticus spotting.
Hack Lake N=10 T3S R87W S3	18-21(19.4)	42-56 (47.0) 167-190(181.8)	2-18(9.8)	28-42(33.8)	A(?)	Large, sparse spotting, lower anterior spotting.
Trib. to Blue River Corral Creek N=11 T6S R79W S15	17-20(19.3)	40-49 (45.3) 172-214(188.3)	3-12(6.9)	36-51(43.3)	A-	Although caeca count somewhat high, spotting pattern

Table 9. 1981 Collections of S. c. pleuriticus (See pp. 67 and 72 for additional explanation).

Blue River Drainage	County	Location			Purity Grade
N. Fk. Elliot Crk.	Summit	T2S	R80W	S21	B
Cataract Crk.	Summit	T3S	R80W	S21	B+
Lake 10794	Summit	T3S	R80W	S16	B+
N. Fk. Swan R.	Summit	T6S	R76W	S19	A-
Spruce Crk.	Summit	T5S	R78W	S23	B
Parachute Crk. Drainage					
Northwater Crk.	Garfield	T5S	R94W	S18	A
Trappers Crk.	Garfield	T5S	R94W	S7	C
JQS Gulch	Garfield	T5S	R91W	S23	A+
E. Fk. Parachute	Garfield	T5S	R94W	S33	C+
E. Mid. Fk. Parachute	Garfield	T5S	R95W	S14	C
Colorado R. Tributaries					
N. Fk. Wallace Crk.	Mesa	T8S	R95W	S20	D
Bobtail Crk.	Grand	T3S	R76W	S33	A+
Roaring Fk. Crk.	Grand	T2N	R75W	S12	C
Columbine Crk.	Grand	T3N	R75W	S35	B
Arapaho Crk.	Grand	T1N	R74W	S16	B
Little Green Crk.	Routt	T4N	R83W	S24	A-
Big Park Crk.	Grand	T1N	R82W	S28	C
Yampa R. Drainage					
First Crk.	Routt	T9N	R87W	S21	B-
Fraser R. Drainage					
S. Fk. Ranch Crk.	Grand	T1S	R75W	S35	A
Roaring Fork R. Drainage					
Cattle Crk.	Eagle	T7S	R86W	S15	A+
Express Crk.	Pitkin	T12S	R84W	S27	B+
Difficult Crk.	Pitkin	T11S	R84W	S27	B
Crystal R. Drainage					
Avalanche L.	Pitkin	T10S	R87W	S34	B
Yule Crk.	Pitkin	T12S	R87W	S18	C+
Mid. Fk. Thompson Crk.	Pitkin	T9S	R88W	S3	C+
N. Fk. Thompson Crk.	Pitkin	T8S	R89W	S28	B

apparent) are classified as S. c. pleuriticus because the genotypes contain considerably more pleuriticus influence than that of any other taxon. A D grade indicates the hybrids are predominantly rainbow trout.

Table 8 is reproduced from Lytle and Wagner (1981), and Table 9 is reproduced from Wagner and Chapal (1982). Some notable Grade A populations of S. c. pleuriticus in the Consortium's area of emphasis occur in Northwater Creek and JQS Gulch of the Parachute Creek Drainage, Garfield County.

Causes of Decline

The introduction of non-native trouts is the major factor leading to the near demise of the native cutthroat trout. Widespread stocking of non-native trouts began about 100 years ago in Colorado. The eastern brook trout, Salvelinus fontinalis, was the first non-native trout to be propagated and introduced into Colorado, followed by the rainbow trout, Salmo gairdneri, and later (1890s) by the brown trout, Salmo trutta.

The rainbow trout hybridized with the native cutthroat trout. The hybrid is fertile and hybrid populations soon were common. Most of the "wild" rainbow trout populations in Colorado still retain evidence of some native cutthroat trout heredity as can be observed by close examination. Brown trout do not hybridize with cutthroat trout but have replaced cutthroat trout in the medium-size and larger rivers. Brook trout, which also do not hybridize with cutthroat trout, have replaced the latter in smaller tributary

Early hatchery practices mixed different subspecies of cutthroat trout together under the category of "black-spotted" or "native" trout, and this contributed to the rapid disappearance of pure populations of S. c.

pleuriticus. Fortunately, the cutthroat trout native to Trappers Lake have resisted replacement and hybridization from non-native trouts. Over the years (until the mid-1950s), large numbers of non-native trouts were stocked into Trappers Lake including cutthroat trout from Yellowstone Lake, Wyoming (S. c. bouvieri), yet the present population of cutthroat trout in Trappers Lake is an excellent example of S. c. pleuriticus. Snyder and Tanner (1960) identified both native trout (S. c. pleuriticus) and Yellowstone Lake cutthroat trout (S. c. bouvieri) from Trappers Lake during their study in 1958 and 1959. It is doubtful that large numbers of Yellowstone cutthroat trout would disappear in 20 years without leaving a trace of hybrid influence in the present cutthroat trout of Trappers Lake. Perhaps the identifications made by Snyder and Tanner were incorrect due to different degrees of sexual maturity in the fish they examined.

Biology

Cutthroat trout spawn in the spring when water temperatures reach about 7 C. Females construct a nest in clean gravel. Clean, well-oxygenated water ($\geq$ 5 ppm O_2) is necessary for successful reproduction. The eggs require about 30 to 35 days to hatch at temperatures of about 10 C. After hatching, the young spend 10 to 15 days in the nest while the yolk sac is absorbed. In watersheds with accelerated erosion, fine sediment transported in the current can greatly reduce spawning success. The sediment fills the interstitial spaces in the gravel nest, blocking the free circulation of

water and oxygen to the developing eggs and may trap hatched young in the nest. In streams subjected to increased sediment loads from accelerated erosion, brown trout and brook trout may be favored because they spawn in the fall when flows are low and sediment transport is greatly reduced in streams.

Behnke and Zarn (1976), Behnke (1979, 1981), and Behnke and Benson (1983) are sources of additional information on S. c. pleuriticus.

Critical Areas

The most significant population of Colorado River cutthroat trout occurs in Trappers Lake. It is by far the most abundant population of this subspecies, the only natural population existing in a large lake, and the annual source of about one million eggs used in the Division of Wildlife's propagation program. Trappers Lake and its native trout are relatively secure. The lake is in the Flattops Wilderness Area of the White River National Forest, and the Colorado Division of Wildlife has designated Trappers Lake as a "wild trout" fishery with restrictive angling regulations.

Because of the abundance of S. c. pleuriticus in Trappers Lake and the effective propagation program of the Division of Wildlife, whereby many mountain lakes of northwest Colorado are annually stocked with Trappers Lake fish, it might be argued that there is no need for great concern to be expressed for the preservation of the few remnant stream populations. A successful restoration program for a rare and declining species or subspecies, however, is dependent on the preservation of as much of the remnant genetic diversity as possible (Ryman 1982), preferably in a number of different natural populations. In this light, the

small populations isolated in headwater streams assume a considerably greater significance than they would on mere numbers alone.

The two Grade A populations in the Parachute Creek Drainage, Northwater and JQS Gulch, in the midst of the oil shale region, call for special attention if they are to be preserved., The preservation or enhancement of some other stream populations will depend on watershed conditions and correction of accelerated erosion.

Research and Management

Up to one million S. c. pleuriticus are hatched from Trappers Lake eggs each year and stocked in mountain lakes where natural reproduction of trout is lacking. The Nongame Section of the Division of Wildlife has recognized the significance of preserving a range of genetic diversity for the recovery of an endangered or threatened species. The first step in a program to preserve genetic diversity is to find where pure populations still exist. During 1979, 1980, 1981, and 1982, the emphasis of studies on Colorado River cutthroat trout has been given to documenting the occurrence of the subspecies in northwest Colorado. To date, about 600 specimens of cutthroat-like trout have been examined from 55 waters (Lytle and Wagner 1981, Wagner and Chapal 1982). Nineteen Grade A populations have been identified. In the Consortium's area of emphasis, Grade A populations of S. c. pleuriticus have been found in Northwater Creek and JQS Gulch of the Parachute Creek Drainage, Mitchell Creek (a tributary to the Colorado River near Glenwood Springs), Hack Lake tributary to Sweetwater Creek, all in Garfield County, and in Hahn and Fawn creeks of the White River Drainage,

Rio Blanco County. The Hack Lake trout were introduced from Trappers Lake (Clee Sealing, pers. commun., Colorado Division of Wildlife).

Colorado Squawfish, Ptychocheilus lucius

Status

Federal and State Endangered

Distribution

Originally, Colorado squawfish occurred in all large, warm rivers of the Colorado River Basin; this included the mainstems of the Colorado and Green rivers and large tributaries such as the Gila, San Juan, Gunnison, White and Yampa rivers (Behnke and Benson 1983). The squawfish has been eliminated from the lower basin below Lake Powell. In the upper basin, squawfish occur in the Colorado River from Lake Powell to about 200 river miles (RM) (320 km) upstream into Mesa County. In the Green River, squawfish are found from the confluence with the Colorado to the confluence with the Yampa, about 340 RM (545 km), and occur in the Yampa River to above Juniper Canyon (about 160 km of the Yampa River) in Moffat County. In the White River, squawfish have been taken upstream to the confluence with Piceance Creek; this comprises about 70 km of the White River in Rio Blanco County. Squawfish occur in the lower 30 to 40 km of the Gunnison River. Collections of newly hatched or YOY squawfish from 1979 through 1982 have verified successful reproduction in the Colorado River (from about state line to Clifton, Mesa County) and in the Lower Yampa River of Dinosaur National Monument (Miller, Kaeding, and Tyus 1983).

Causes of Decline

The synthesis of opinion as expressed by Holden and Stalnaker (1975), Miller, Tyus, and Carlson (1982), and Behnke and Benson (1983) is that large dams have converted hundreds of kilometers of large river environment into reservoirs, cold-water releases from the dams create unsuitable temperatures for considerable distances below the dams, and this has played the major role in the decline of the squawfish. Non-native fishes must also certainly have a negative impact on young squawfish, particularly during their first year of life when they are vulnerable to predation and food competition (Miller, Kaeding, and Tyus 1983).

Biology

Studies by the U.S. Fish and Wildlife Service from 1979 through 1982 (Miller, Archer, Tyus, and Harper 1982; Miller, Kaeding, and Tyus 1983; Miller, Tyus, and Kaeding 1983) and by the Colorado Division of Wildlife from 1977 through 1982 (Wick et al. 1979; Haynes, Muth, Skiba and Wycoff 1982) have contributed much to a better understanding of squawfish biology.

The Colorado squawfish is a warm-water species. This thermal preference may be particularly important for survival of YOY squawfish. Temperatures of 22 C or higher during the first weeks after hatching may be important for increasing the survival of young. Laboratory tests revealed young squawfish mainly selected temperatures from 24 to 28 C with final preferred temperatures estimated at 24.6 to 25.5 C (Bulkley et al. 1982).

As the largest species in the minnow family in North America, the Colorado squawfish evolved as the top carnivore of the Colorado River fish

fauna. Of the non-native fishes, the northern pike, Esox lucius, is most similar in feeding habits and could be a competitor for food with adult squawfish as pike become more abundant. Presently, adult squawfish appear to ha reasonably adequate food supply. Although the maximum weights of squawfish taken in recent years (6-7 kg) are only a fraction of the historically reported maximum weights of 25 to 40 kg (Behnke and Benson 1983), the adult specimens captured are generally in good condition. Limited reproductive success, evidently, is the key factor governing the low level of squawfish abundance. From observation of radio-tagged squawfish it appears that only a relatively few sites in the upper basin have the proper combination of depth, velocity, and substrate to be utilized by squawfish for spawning (Miller, Valentine, and Tyus 1982). Adult squawfish are highly mobile. Spawning migrations of over 100 km are apparently common. In 1982 a radio-tagged, sexually mature, squawfish moved up the Colorado River from Lake Powell to near Clifton, Colorado, a distance of about 350 km, and a squawfish in the Green River had a monitored movement (upstream and downstream and into the Yampa River) of 480 km (Miller, Kaeding, and Tyus 1983; Miller, Tyus, and Kaeding 1983). In northwest Colorado, squawfish spawning has been documented (by finding concentrations of fish in spawning condition and later in the summer finding YOY squawfish below the suspected spawning site) for the Colorado River above and below Grand Junction and in the lower 30 km of the Yampa River in Dinosaur National Monument. YOY squawfish have been collected from both of these areas of the Colorado and Yampa rivers from 1979 through 1982 (Miller, Tyus, and Kaeding 1983).

For the years 1979-1981, by far the most YOY squawfish were found in 1980 (about 10 times or more per unit of sampling effort than in 1979 or

1981). This indication of greater squawfish spawning success in 1980 was particularly true of the Colorado River. A comparison of U.S. Geological Survey flow and temperature data from 1979-1981 recorded in the Colorado River at the state line was made (personal study for Consortium report) to gain some insight into the factors influencing squawfish spawning success.

Flows in 1979 were higher than normal. July and August flows were about 50% above the long-term average for these months. The 1980 flows in July and August (squawfish spawning and YOY rearing time) approximated the long-term average flows for these months. The higher 1979 flows maintained water temperatures significantly below the 1980 temperatures of July and August. In 1979, 23 days in July and August reached or exceeded a maximum temperature of 22 C. The cumulative degree-days in excess of 22 C (the total accumulation of maximum temperature units above 22 C) was 36 in 1979. In 1980, 58 days in July and August reached or exceeded a maximum water temperature of 22 C, and the cumulative degree-days in excess of 22 C was 165. There is a suggestion in this comparison that an optimum thermal regime is a significant influence upon timing of squawfish spawning, and that July and August flows much in excess of average flows may depress temperatures and negatively affect larval Colorado squawfish survival.

The year 1981 was a below-normal-flow year, and spawning success was poor based on YOY collections. Larval squawfish must find sheltered backwater habitat soon after spawning. The "optimum" flows for squawfish spawning success will likely be those that are sufficiently high to maintain habitat in nursery sites but low enough to avoid depressing water temperatures during early life history stages. This "optimum" range of flows is not known.

Critical Areas

For northwest Colorado, the Colorado River from the state line to Clifton, Mesa County, and the Lower Yampa River, Moffat County, are the most significant areas because these are the only sites where squawfish are known to spawn. The Yampa River above Dinosaur National Monument to above Juniper Canyon, the White River to its confluence with Piceance Creek, and the Lower 40 km of the Gunnison River are apparently important to adult squawfish primarily for feeding.

Research and Management

A great amount of effort has been expended on squawfish studies in recent years by federal and state agencies. It is obvious, however, that more work is necessary before scientifically sound recommendations can be made regarding flows to optimize spawning success in the Colorado River. Squawfish are relatively easily spawned and raised in hatchery raceways (Hamman 1981). Artificial propagation and rearing for stocking to supplement natural reproduction and increase the number of 1- and 2-year-old fish will be an important aspect of the early phase of efforts to increase squawfish abundance. On 5 October 1982, about 30,000 YOY squawfish from 35 to 85 mm, raised at the Dexter, New Mexico, National Fish Hatchery, were stocked into six backwater habitats along the Colorado River between Clifton, Colorado, and the Black Rocks section of the river (Miller, Archer, Tyus and Harper 1982). These hatchery-reared fish all contained a

magnetic tag implanted in their snouts so that they could be distinguished from naturally spawned fish and their movements followed in the future. Subsequent sampling of habitats where the young squawfish were stocked revealed a high incidence of predation by largemouth bass and green sunfish in those sites where these species occurred (Miller, Tyus, and Kaeding 1983).

Humpback Chub, Gila cypha

Status

Federal and State Endangered

Distribution

The original range of the humpback chub was probably similar to that of the Colorado squawfish, but its distribution was characterized by highly localized populations associated with deepwater canyon areas.

In Colorado, the greatest concentration of humpback chub occurs in the Colorado River in the Black Rocks area of Ruby Canyon near the Colorado-Utah state line, Mesa County. Humpback chub are also common in the Colorado River in Westwater Canyon, Utah, about 20 km below Black Rocks. The only other known concentration of humpback chub occurs in the lower few miles of the Little Colorado River in the Lower Colorado River Basin. The humpback chub has also been found in the Green River and in the Lower Yampa River, to Cross Mountain Canyon, Moffat County (Behnke and Benson 1983).

Causes of Decline

The primary habitat of humpback chub, the deepwater canyon areas of the Mainstem Colorado River, has been largely converted to large reservoirs and the coldwater release from Lake Powell makes the Colorado River in the Grand Canyon unsuitable for the species.

Biology

U.S. Fish and Wildlife Service sponsored studies have produced much new information on the biology of the humpback chub (Beleau and Bartosz 1982, Bulkley et al. 1982, Hamman 1982, Kaeding and Zimmerman 1982, Miller et al. 1982, Valdez et al. 1982).

Evidence of spawning in the Black Rocks area of the Colorado River indicated spawning occurred in early June 1980 and in May of 1981 at temperatures of about 15 to 18 C. In the Little Colorado River, spawning probably occurs in April and May at temperatures of 19-20 C. At various test temperatures, the best hatch of eggs occurred at 20 C and best survival of larvae at 26 C. Eggs hatch in 3 days at 26 C but take 8 to 10 days to hatch at 16 C. The preferred temperature of humpback chub was variable among the individuals tested but the final preferred temperature was estimated to be 24 C (Bulkley et al. 1982, Hamman 1982).

Humpback chub are predominantly insectivores. In the Colorado River at Black Rocks, mayflies (Ephemeroptera) were important in the diet. Blackfly and gnat larvae (families Simuliidae and Chironomidae) made up the bulk of the diet in the Little Colorado River (Jacobi and Jacobi 1982).

Tagging studies revealed only limited movement of humpback chub. Of 218 fish tagged in Westwater Canyon and Black Rocks, 16 were subsequently

recaptured. Most moved less than 1 km. The greatest movement was by one chub that moved from Westwater Canyon to Black Rocks, a distance of about 20 km. In the Little Colorado River 32 tagged fish were recaptured from 1 day to 16 months after release. Of these, 13 were recaptured within 0.3 km of the original capture and 19 moved an average of 3.8 km with a maximum distance of 17.1 km (Valdez, Mangan, Smith, and Nilson 1982).

Radio-tagged chub in Black Rocks preferred to inhabit low velocity areas of less than 0.1 m per second velocity. They moved into deeper sections of the river during midday and in the middle of the night (Valdez, Mangan, Smith, and Nilson 1982).

In tests with salinity (total dissolved solids or TDS) concentrations and organic and inorganic toxicants, humpback chub showed no avoidance response to the highest salinity levels tested, 11,600 parts per million, and were more resistant to most toxicants in acute toxicity tests than non-native fishes such as channel catfish and fathead minnow (Beleau and Bartosz 1982, Bulkley et al. 1982).

Hybridization evidently occurs between humpback chub and roundtail chub in the Colorado River as indicated by frequent specimens of intermediate morphology found in Ruby Canyon. Most chubs in the Black Rocks area of Ruby Canyon can presumably be identified as humpback chub or roundtail chub by external appearance; thus, it can be assumed that past and present environmental conditions favor maintenance of the separation of niches of the two species. About 100 km upstream from Black Rocks in the Colorado River in DeBeque Canyon, a hybrid population exists that is predominantly of roundtail chub heredity according to data given by Valdez and Clemmer (1982).

Critical Areas

In northwest Colorado, perhaps the most critical site for humpback chub is the Colorado River in Ruby Canyon, near the state line in Mesa County. The maintenance of proper flow and temperature regimes in this area will be emphasized by the U.S. Fish and Wildlife Service during Endangered Species Act consultation for water projects that may impact flows or temperatures. The problem for recommending good or optimum flows for humpback chub is that there are no data correlating population abundance, year-class strength or degree of hybridization to past flow and temperature regimes.

Humpback chub occur in the Lower Yampa River of Moffat County, but no particular site is known to contain a high density population comparable to that in the Colorado River at Black Rocks.

Research and Management

The goal of the U.S. Fish and Wildlife Service as expressed in the Humpback Chub Recovery Plan (U.S. Fish and Wildlife Service 1982b) is to "Restore and maintain a minimum of five self-sustaining humpback chub populations in the Colorado River System by 1990." In December 1981, 7300 YOY humpback chub were stocked into the Colorado River in Cataract Canyon, Utah, about 15 to 25 km above the inlet to Lake Powell (Valdez, Mangan, Smith, and Nilson 1982).

Bonytail, *Gila elegans*

Status

Federal and State Endangered

Distribution

Historically, the names bonytail and roundtail (*G. robusta*) were used interchangeably for *Gila elegans* and *G. robusta*, thus accurate documentation of the precise range of *G. elegans* was not made before the rapid decline of the species. All available evidence indicates that the original distribution of the bonytail was essentially similar to that of the Colorado squawfish, in the main channels of the larger rivers in the entire Colorado River Basin. The present occurrence of bonytail is apparently restricted to Lake Mohave and to Lake Havasu in the Lower Colorado River Basin. Fish sampling in the Upper Colorado River Basin by the U.S. Fish and Wildlife Service from 1979 through 1982 yielded only one fish resembling *G. elegans*. Collections of *Gila* sp. were made from the Coal Creek rapids area of the Green River in Gray Canyon, Utah. Some of these chubs exhibited features of bonytail. Of 19 specimens critically examined, 1 was tentatively identified as a bonytail, 5 were identified as humpback chub, 4 as roundtail chub, 5 as roundtail x humpback hybrids, 1 as humpback x bonytail hybrid, and 3 as unknown (Tyus, McAda, and Burdick 1982). Considering the extensive collections of fishes made in the Upper Colorado River Basin in recent years by the U.S. Fish and Wildlife Service, the Colorado Division of Wildlife, and consulting firms, it is highly improbable that a viable population of bonytail remains undetected. The remnants of

the G. elegans genotype in the upper basin evidently are being absorbed into G. cypha and G. robusta by hybridization.

The official position of the U.S. Fish and Wildlife Service concerning the distribution of G. elegans was given in the biological opinion for the White River, Utah, dam project (Feb. 24, 1982, from Regional Director, USFWS, Denver, to BLM State Director, Salt Lake City), which concludes: "The only recognized pure population of bonytail chub occurs in Lake Mohave, Arizona."

Causes of Decline

The bonytail was abundant in the Green River until the closure of Flaming Gorge Dam in 1962. It rapidly declined thereafter. The plight of the bonytail is attributed to changes in flow and temperature regimes, but, as Behnke and Benson (1983) pointed out, there are many unresolved questions concerning the precise cause or causes of the rapid disappearance of this species.

Biology

The genetic relationships between G. elegans, G. cypha, and G. robusta are close. The three species have been experimentally hybridized with no indication of reduced egg viability among hybrid combinations (Hamman 1981). Hybridization may have led to loss of bonytail in the upper basin, but the degree of success of this hybridization may have been related to changing environmental conditions that negatively impacted the bonytail niche.

Bonytail originating from Lake Mohave and propagated at the Willow Beach, Arizona, National Fish Hatchery were supplied to Utah State University for tests of environmental preferences. Water temperatures of 20 and 26 C resulted in the best hatch of eggs. Young bonytail selected a wide range of preferred temperatures, but the final or ultimate preferred temperature was estimated at 24.2 C, similar to those of humpback chub and razorback sucker (Bulkley et al. 1982).

One major biological difference between humpback chub and bonytail is in their relative fecundity. On an average, bonytail females produce more eggs per unit of body weight than do humback chub females. Five bonytail females weighing from 956 g to 1.5 kg spawned from 5,850 to 37,700 eggs for an average relative fecundity of 21,514 eggs per kg of body weight (range from 6,120 to 32,783 eggs per kg). Eight humpback chub females weighing 350 to 690 g had relative fecundities from 868 to 10,102 eggs per kg of body weight (mean of 5262) according to Hamman (1982).

Rosenfeld (1982) studied roundtail chub, bonytail, and humpack chub chromosomes. All species have 25 pairs of chromosomes for a diploid number of 50. Bonytail and humpback chub were found to differ from roundtail chub in the morphology of one pair of chromosomes. In general, however, differences in the chromosomes of the three Gila species are less than differences found within some species (such as rainbow trout, Salmo gairdneri, or cutthroat trout, S. clarki).

Critical Areas

None concerning northwest Colorado at present.

Research and Management

The studies sponsored by the U.S. Fish and Wildlife Service, cited earlier in this chapter, are attempts to piece together basic biological data on G. elegans as a basis for preservation and recovery of the species. Bonytail were propagated at the Willow Beach National Fish Hatchery and are currently being propagated by the Dexter, New Mexico, National Fish Hatchery, which is now devoted to the propagation of endangered, threatened and rare fishes of the Southwest. In November 1981, 42,000 bonytail were stocked into Lake Mohave to supplement the present population (Johnson and Rinne 1982).

A draft recovery plan for G. elegans calls for an attempt to re-establish bonytail in the Green River by stocking 100,000 fish per year for 5 years. Unless the environmental conditions that adversely affected the bonytail in the Green River can be modified, it is likely that any attempt to establish a viable self-sustaining population will prove futile (Behnke and Benson 1983).

Razaorback Sucker, Xyrauchen texanus

Status

State Endangered

Distribution

Distribution of the razorback sucker is similar to that of Colorado squawfish in all large river sections of the basin from Wyoming to Mexico. Four years of fish sampling by the Colorado River Fishery Project (1979-1982) of the U.S. Fish and Wildlife Service and 6 years of sampling by the Colorado Division of Wildlife's Nongame Wildlife Program (1977-1982)

have taken fewer razorback sucker than squawfish, and all razorback sucker collected have been adult fish with no indication of successful reproduction by this species in recent years (Haynes, Muth, Skiba, and Wycoff 1982; Miller, Valentine, and Tyus 1982). (But see pp. 91-92 for circumstantial evidence of reproduction.)

Razorback sucker have been sporadically taken in the Colorado River above and below Grand Junction, Mesa County, and in the Colorado River above the Highline Dam between DeBeque and Rifle, Mesa and Garfield counties (Valdez, Mangan, Smith, and Nilson 1982).

They are occasionally found in the Green River and Lower Yampa River (to Cross Mountain Canyon) of Moffat County (Miller, Valentine, and Tyus 1982). The only record of razorback sucker in the Gunnison River during the past several years consists of one specimen collected in 1981 at river mile 55, Delta County (Valdez, Mangan, McInerns, and Smith 1982).

Causes of Decline

Although changes in the historical flow and temperature regimes must have had a severe impact on the razorback sucker, predation on eggs and young by non-native fishes is also a probable cause of the great decline of the species. The flannelmouth sucker, Catostomus latipinnis, a native species.historically sharing the "big river sucker niche" with the razorback, is still abundant. The flannelmouth sucker, however, is not dependent on backwater lagoon-type of habitat for reproduction. The degree of dependency of razorback sucker on large backwater or limnetic-type of habitat is not known, but the circumstantial evidence of finding aggregations of razorback sucker in slack-water and off-channel ponded sites during their spawning period, and actual observations of spawning in lower

basin reservoirs, suggest a connection between reproduction and suitable backwater or pond-type environments (Behnke and Benson 1983).

Biology

Razorback sucker probably spawn earlier than the Colorado squawfish or humpback chub. In nature, spawning has been reported to occur at water temperatures from 12 to 20 C. At the Willow Beach National Fish Hatchery, razorback sucker from Lake Mohave were introduced into a small pond, and spawning activity began after 12 days and extended from early February to late March in water of about 10 to 16 C (Inslee 1982). Razorback sucker spawn on gravel-rocky substrates where current velocity is low. After hatching, for about 2 weeks, larval razorback sucker are incapable of swimming and are vulnerable to predation and suffocation by sediments. No young were found from spawning in the Willow Beach Hatchery pond, evidently because the larvae were trapped in silt.

The earlier and probably more protracted spawning of razorback sucker than for Colordo squawfish and humpback chub is likely an evolutionary adaptation for spawning during the runoff period (which is naturally highly variable in timing, magnitude, and duration), when high water floods backwater areas and creates lagoon-type habitats. Most such habitat presently inhabited by razorback suckers during the spawning season are man-made--impoundments, gravel excavation sites, etc. These artificial environments typically host an abundance of non-native fishes, especially bass, sunfish, catfish, and carp which are effective predators on the eggs and young of razorback sucker. Linda Ulmer, California Department of Fish and Game, presented a paper at the 1981 Desert Fishes Council meeting which

reported direct observation of predation by non-native fishes on razorback sucker eggs in Senator Wash Reservoir, California.

Despite extensive spawning by razorback sucker in Senator Wash Reservoir, not a single young sucker has been found; evidently the predators are completely effective in suppressing population increase. Recruitment occurs from adult razorback sucker moving into the reservoir from the Colorado River. From this evidence, the major cause of the great decline in razorback sucker can probably, at present, most reasonably be attributed to the fact that their preferred spawning habitat is also the preferred habitat of non-native fishes that are effective predators on eggs and larvae.

Results of studies of tagged fish indicate razorback sucker may move considerable distances. A fish tagged in May 1975 in the Green River near the confluence with the Yampa (river mile 345) was recaptured in July 1980 in the Green River at RM 216--206 km downstream. In the spring, spawning congregations appear in the Green River at the mouth of Ashley Creek (RM 299) and at the mouth of the Yampa River. In the Colorado River, sexually mature razorback sucker move into the Walter Walker pond and the Clifton gravel pond near Grand Junction (Wick et al. 1982).

The razorback sucker is the only endangered or threatened big-river species documented from above the Highline Dam in the Colorado River (Valdez, Mangan, Smith, and Nilson 1982). Because the dam is a barrier to upstream movement of fishes, it must be assumed that the razorback sucker found in the DeBeque area of the river are an isolated population. The ability of the razorback sucker to successfully spawn at lower temperatures than the squawfish is a probable reason why the razorback sucker has

maintained a population above the Highline Dam while squawfish have disappeared from this section of the river.

Critical Areas

The most critical area for the preservation of the razorback sucker--a site where reproduction is successful--has yet to be found. The DeBeque area of the Colorado River is significant because it represents the most upstream limit of the species in the Colorado River. The Lower Yampa River represents the most upstream limit in the entire Colorado River Basin. The off-channel ponds around the Grand Junction area are attractive spawning habitats for razorback sucker, but the abundance of non-native fishes probably completely eliminates any spawn and young produced.

Research and Management

The obvious key to the recovery of the razorback sucker is to create spawning and nursery habitats free of non-native fishes. This might be accomplished by construction of sites that fill at high flows and drain during low flows to avoid permanently ponded areas that are so attractive to sunfish, bass, and carp (Valdez, Mangan, Smith, and Nilson 1982). Also, ponds completely isolated from the river could be used to introduce mature razorback sucker for spawning and rearing of young, which could then be released into the river at an advanced stage. Until workable natural solutions are found to enhance abundance of the species, artificial propagation is being undertaken. Large numbers of razorback sucker have been raised at the Dexter, New Mexico, National Fish Hatchery. In 1981 and 1982 they were stocked into the Salt, Verde, and Gila rivers of Arizona, and

introductions are planned for the San Juan River, New Mexico (Johnson and Rinne 1982).

MITIGATION AND NORTHWEST COLORADO

Mitigation may be defined as the reduction of wildlife resource losses to a project through the use of loss-prevention measures and offsetting losses through the use of other structural and nonstructural measures (Krulitz 1979). It can be argued that mitigation has three aspects: 1) disaster modification, which involves attempts to salvage whatever is possible from a project over which there is little control; 2) compensatory, in which habitat lost is compensated for (if a project requires 500 hectares of habitat in one place, project supporters must come up with 500 hectares of similar habitat elsewhere); and 3) preventing damage from occurring in the first place (Yarn 1979). Before mitigation plans can be derived, one must elucidate the potential impacts and their magnitudes, including direct and indirect effects, and gain a thorough knowledge of the system, including its fauna and flora. Two important aspects involved in understanding potentially impacted aquatic ecosystems are classification and inventory of habitat and biota.

The major energy-related impacts to fish and wildlife resources of northwest Colorado include energy-minerals development and processing activities, water and transportation development, and secondary impacts created by the aforementioned. Changes in grazing and other agricultural land uses may also have important impacts on aquatic ecosystems. Impacts on aquatic systems may be essentially reduced to three major physical/chemical disruptions: 1) habitat destruction, 2) alteration of stream flows, and 3) pollution loading. These three categories have been and will continue to be the areas where mitigation attempts are focused.

Mining, which includes extraction, processing and transportation of mineral resources, will concentrate on coal, natural gas, oil-shale, uranium, deep water, and precious metals in northwest Colorado. The extraction and refinement of oil-shale is especially water-consumptive (Streeter et al. 1979) and potentially toxic to aquatic organisms (Turnbull et al. 1954, Fox et al. 1982, Nystrom and Post 1982, Dickson et al. 1983). Many publications are available for assessing impacts on surface coal mining, including U.S.E.P.A. (1973), Honkala (1974), U.S. Fish and Wildlife Service (1977a; 1977b; 1978a; 1978c; 1979a; 1980a; 1980b; 1980d), Mason (1978), U.S. Forest Service (1980a), Burroughs and Scott (1982), and Packer et al. (1982). The U.S. Fish and Wildlife Service (1980f) and Yamamoto (1982) addressed the impacts of uranium mining and mill tailing on aquatic resources. A guide for reclaiming small tailing ponds and dumps was published by the U.S. Forest Service (1979). Impact prediction associated with steam electric power plants was discussed by the U.S. Fish and Wildlife Service (1978b,c). Thurston et al. (1979) and Johnson and Finley (1980) provided information concerning toxicity of byproducts from energy development on fish and aquatic invertebrates.

Water development ranges from large dam and reservoir projects to small hydroelectric and channelization projects. The growth of northwest Colorado will create the need for water projects for irrigation, power, flood control and other consumptive uses of water, with potential impacts on the large, highly mobile riverine fishes of the Colorado River Basin. Changes in land use with increased population, mining and milling activities may also cause changes in livestock grazing practices in northwest Colorado, leading to increased riparian habitat degradation and siltation (Platts 1982).

Secondary impacts from changes in land use in northwest Colorado may include increased water pollution (domestic and industrial), increased air pollution (from automobile and truck emissions, coal-fired electric plants, etc.), and increased siltation and erosion due to timber operations, land clearing, and mining. Human impacts will increase the demand for domestic water and sewage plants, thereby increasing the potential for flow reductions in the natural ecosystem. Fishing pressure will increase with higher population concentrations and a decrease in publicly accessible waters, with the potential for rapid degradation of available fisheries unless mitigation measures are taken. Land development, including boom towns with few zoning regulations, decreases the quality and quantity of wildlife habitat and often destroys riparian habitat and stream banks.

With regard to energy-related impacts on the fishes of northwest Colorado, a major concern has been threatened or endangered species. However, the traditional concept of mitigation appears at odds with the Endangered Species Act (ESA) (Lambertson 1982). Section 7 of the ESA specifically guarantees a higher level of protection than that associated with mitigation. 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 of the act. Section 7 is applied to prevent jeopardy, not merely to reduce or mitigate jeopardy. Behnke (1982), Lambertson (1982), and Prewitt and Stalnaker (1982) have discussed this problem. Some aquatic impacts such as change in amount or timing of flows and blockage of access to habitat could be compensated for by mitigations involving careful control of storage and release patterns at critical periods, provision of fish ladders, etc.

Spofford et al. (1980) considered energy development in the Upper Colorado River Basin. The goals of their report were generally to 1) explore some methodologies available for assessing economic, demographic, and environmental impacts of energy development; 2) assess some impacts of energy development on fish and wildlife in the Upper Colorado River Basin; 3) assess some economic impacts of energy development; 4) identify and explore some trade-offs involved with the development of energy resources in the upper basin; and 5) delineate some research needs associated with improving the state of the art in assessing impacts, particularly with respect to fish and wildlife-related impacts. Chapters of particular importance included an overview of the physical and ecological aspects of the upper basin. A range of general research needs was presented. These are important for understanding the consequences to fish and wildlife of energy development activities in the Upper Colorado River Basin. Another chapter specifically addressed potential impacts of alterations of stream flow and water quality on fish and macroinvertebrates. The fish fauna was described, with examples of changes that have already resulted from construction of impoundments and of problems that may result from increased demand for sport fishing in the region. Other chapters described impacts of habitat alterations on threatened or endangered fishes, political and legal institutions affecting uses of land and water of the upper basin, and a method for predicting impacts of surface coal mining on trout populations of the Yampa River Basin.

Miller, Tyus and Carlson (1982) edited a publication on the present and future status of fishes of the Upper Colorado River Basin based on a symposium presented at the 1981 annual meeting of the American Fisheries

Society. Objectives of this symposium were to 1) present basic information about threatened or endangered fishes, 2) identify critical needs for recovery and maintenance of rare or endangered fishes, 3) emphasize life history and status of rare or endangered fishes, and 4) consider past and future impacts on fishes due to development activities. Distribution, abundance, life history and status of fish species were discussed, with emphasis on threatened or endangered fishes. Mitigation of impacts on these fishes was also discussed.

Adams and Lamarra (1983) edited a book on aquatic resource management of the Colorado River ecosystem. A variety of topics was presented, including water policy and major diversions, energy impacts, oil shale development, ecology and management of the watershed and riparian habitats, fisheries, salinity problems, sedimentation, eutrophication, fish depletion, and water augmentation. Two chapters dealt with an ecosystem approach to management of the aquatic resources in the Yampa River Basin and the White River Basin. Monitoring of processes related to primary production, decomposition, etc., rather than fish populations, was recommended. However, there is some doubt that monitoring primary production, detritus, organic particulate matter, etc., will yield directly useful information for predicting impacts on fish from energy-development activities. Alternatively, changes in flows and water quality have important impacts that can be monitored directly without regard to their influence on basic ecosystem processes; e.g., monitoring of primary production has little to do with loss of spawning habitat for rare fishes.

The accuracy of impact predictions and mitigation recommendations for aquatic systems will be strongly dependent on the adequacy of underlying classification and inventory procedures that are used to describe aquatic wildlife resources. Therefore, an attempt is made in the following pages to present a concise listing of databases, procedures, methods and models that might prove useful in classifying and inventorying, as well as evaluating, predicting, and mitigating energy-related impacts on the fishes and fisheries of northwest Colorado.

A) Classification, Inventory and Database Management Systems

1) Method: Land Use/Land Cover Classification System-LULC (U.S. Geological Survey)
Reference: Anderson et al. (1976)
Approach: Classification system, inventory system
Output: Map (planned)
Overview: LULC proposed that a map of the United States be created using remote sensor data. Five major categories were developed for aquatic habitats: streams and canals, lakes, reservoirs, bays and estuaries, and wetlands.

2) Method: River Reach File (U.S. Environmental Protection Agency)
References: U.S. Fish and Wildlife Service (1980g), Olson et al. (1981)
Approach: Database, inventory
Output: Computerized database system

Overview: The River Reach File will be a computerized catalogue based on the hydrological features of the United States. It is designed to organize and analyze water resources data (water quality, toxic substances, flows, fisheries, aquatic life) for over 60,000 stream reaches. It will cross-reference and facilitate access to STORET and WATSTORE. The system is not yet available for public use.

3) Method: Unnamed stream classification system (Maryland Department of Natural Resources)

Reference: Van Deusen (1953)

Approach: Classification

Output: Stream classification system

Overview: The system classifies Maryland stream reaches based primarily on characteristic fish species. Whether this system would work in northwest Colorado needs to be tested.

4) Method: RUN WILD (U.S. Forest Service)

References: Patton (1978), Lehmkuhl and Patton (1982)

Approach: Database, inventory, literature review

Output: Computerized database for vertebrate species and associated habitat factors

Overview: RUN WILD is a computer program written in conversational mode to allow the user to list factors in the environment that are associated with 721 vertebrate species in Arizona and New Mexico. A management file provides information on species distribution, protective status, key habitat

factors, and food and cover requirements. References for each species are contained in a separate file. Developed for the southwest United States, RUN WILD can be modified for other geographical areas (Patton 1978). This system, like many others, takes a species-by-species approach, ignoring species interactions. RUN WILD III has been expanded to 875 species and subspecies; it uses the System 2000 database management system.

5) Method: Hydrologic Units (U.S. Water Resources Council)

References: U.S. Geological Survey (1974), U.S. Water Resources Council (1977), U.S. Fish and Wildlife Service (1982a)

Approach: Classification system, maps

Output: Maps and codes for streams and rivers

Overview: The hydrologic unit maps for Colorado and water codes result from a hierarchical system based on the region (major drainage), subregion (subdrainage), accounting unit, and cataloging unit. For northwest Colorado, the system provides an orderly way of storing fish and habitat data from the Upper Colorado River Basin. Within northwest Colorado, all streams and rivers are in region 14 (the Upper Colorado) and in subregions 01 (Upper Colorado), 02 (Gunnison-Uncompahgre river drainages), 03 (Dolores River Drainage), 04 (Green River Drainage), 05 (White-Yampa Drainage), or 06 (Green River below confluence with Yampa River).

6) Method: Stream and Lake Evaluation Map (U.S. Fish and Wildlife Service, Colorado Division of Wildlife, U.S. Environmental Protection Agency)

References: U.S. Fish and Wildlife Service (1978g), U.S. Fish and Wildlife Service (1979b), Short (1981)

Approach: Classification system, map, fishery evaluation system

Output: Maps and value classes for river reaches and large lakes and reservoirs

Overview: These maps rate the streams, rivers, major lakes, and major reservoirs of Colorado using codes and value classes based on fishery value, wild and scenic river potential, and concerns for endangered and threatened fishes. In northwest Colorado, sections of the White, Colorado, Yampa and Gunnison rivers are rated as high-priority fishery resources, while the Upper Colorado, Eagle, Fryingpan, Crystal, Gunnison, Roaring Fork, North Fork of White, Upper Yampa, Williams Fork, Blue River and Elk Creek are given Value Class I because they are major fishing streams. Class I ratings are given to Trappers Lake, Northwater Creek, White River, Yampa River, Green River, Colorado River, and Lower Gunnison River because of the presence of threatened and endangered fishes. This classification scheme, although flawed for some individual waters, provides an easy way for developers to identify potential fish-development conflicts in northwest Colorado.

7) Method: Montana Stream Classification System (Montana Department of Fish and Game)

Reference: Stream Classification Committee (1965)

Approach: Classification system

Outputs: Streams classified by their sport fishery values

Overview: The Montana Stream Classification System evaluates streams and river reaches on the basis of the value of the sport fishery. Five classes are listed, with Class I reserved for streams of national or statewide importance and Class V for streams of restricted local value or not yet classified. Degree of access, aesthetics, fishing pressure, and fishery productivity were considered in the value ratings.

8) Method: Streams of National Significance for Fish and Wildlife (U.S. Water Resources Council)

Reference: U.S. Water Resources Council (1977)

Approach: Classification system

Output: Map

Overview: U.S. riverine habitats are classified by national significance for fish, wildlife and endangered species. Criteria include 1) supports endangered or threatened species, 2) proposed wild and scenic river, 3) enacted wild and scenic river, 4) riverine habitat within the National Wildlife Refuge System, 5) supports a nationally important sport fishery (many nonresident fishermen), 6) produces a

nationally important commercial inland fishery, and 7) produces a significant anadromous fishery resource.

9) Method: Michigan Stream Classification System (Michigan Department of Natural Resources)

Reference: Michigan Department of Natural Resources (1967)

Approach: Classification system

Output: Streams evaluated by standard method based on fishery potential

Overview: Michigan streams are divided into two major types based on thermal guilds of fishes, trout streams, and warmwater streams. Within each of these are subtypes (mainstream and feeder streams). Each stream is described as either top quality or second quality. Classification criteria are fish species composition (salmonids versus warmwater game fishes), population sizes, stream width, significant anadromous fishery, and degree of stream zone development.

10) Method: Bailey's Stream Classification System

Reference: Bailey et al. (1974)

Approach: Classification system

Output: Streams evaluated in West Virginia based on trout fishery potential and aesthetics

Overview: Five classes of streams are developed, with Class 5 as coldwater fisheries of multi-state importance and Class 1 as streams unsuited for salmonids. In decreasing order of

importance, the factors considered in this evaluation are aesthetics, access, fishing use, and fish productivity. Each factor was rated from 1 to 5 and then weighted according to its importance for sustaining a salmonid fishery. After each factor was rated and weighted, scores were summed and the stream classified.

11) Method: ECOCLASS (U.S. Forest Service)

Reference: Carleton et al. (1976)

Approach: Classification system

Output: Hierarchical classification of terrestrial and aquatic ecosystems

Overview: ECOCLASS was designed to classify ecosystems, including lentic and lotic aquatic systems, in a hierarchical manner. Streams are first divided by stream order and then grouped by gradient, pool-riffle ratio, inflow, and flood plains. Other data to be collected include fish species composition, fish population size, stocking records, type and abundance of aquatic macroinvertebrates, catch records, type and abundance of aquatic vegetation, substrate composition, stream discharge, flow patterns, and water temperature.

12) Method: National Wetland Inventory Classification System (U.S. Fish and Wildlife Service)

References: Cowardin (1978), Cowardin et al. (1979)

Approach: Classification system

Output: A national system for classification of all wetlands and inland waters

Overview: The proposed system classifies all wetlands, riverine, and lacustrine habitats in the U.S. Riverine systems are divided into tidal, lower perennial, upper perennial, and intermittent subsystems. Riverine subsystems are further divided into classes based on substrate type and flooding regimes. Special modifiers may also be added to these hierarchical codes. The lacustrine system is subdivided into littoral and limnetic subsystems. Classes are based on substrate type and dominant aquatic vegetation (if present). Photos of typical aquatic habitat types are included to help users correctly classify their systems.

13) Method: Stream Continuum Theory

References: Cummins (1975), Vannote et al. (1980)

Approach: Classification system

Output: Stream classification based on stream order, physical attributes, and energy inputs

Overview: Lotic waters are divided into three groups based on stream order (1-3, 4-6, and 7-12). Stream size, heterotrophy versus autotrophy, allochthonous versus autochthonous organic matter inputs, light regime, water temperature, and substrate composition are associated with these three groups.

14) Method: Large-scale Aerial Color Photographs Evaluation (U.S. Forest Service)

Reference: Greentree and Aldrich (1976)

Approach: Classification system; inventory system

Output: Aerial color photographs, trout stream inventory and habitat evaluation

Overview: Large-scale aerial color photographs are used to evaluate trout habitat. The interpreter is able to discern form, shape, and color of instream and streambank features, including substrate type, water depth, bank height, and riparian vegetation.

15) Method: Alluvial River Channel Classification System (U.S. Geological Survey)

Reference: Schumm (1963)

Approach: Classification system

Output: Streams classified by sediment load

Overview: Streams are classified by sediment load characteristics, and nine subclasses are developed using channel stability and sediment transport models.

16) Method: Stream Order Classification System

Reference: Horton (1945)

Approach: Classification system

Output: Streams and rivers classified by stream order

Overview: Horton (1945) developed ideas of stream order often used in modern aquatic ecosystem classifications (fingertip streams or unbranched tributaries are considered first order streams, second order streams only have first order tributaries, third order streams receive second or first and second order streams, etc.).

17) Method: Idaho's Stream Classification System (Idaho Fish and Game Department)

Reference: Idaho Fish and Game Department (1968)

Approach: Classification system

Outputs: Map, salmonid fisheries classification

Overview: Idaho Fish and Game Department (1968) designed a classification system for Idaho streams based on salmonid fishery values. Five factors (aesthetics, availability, use, productivity, and size) are considered, and five classes are established. The streams with highest ratings, Class 1 streams, have anadromous fishes, endangered or unique fishes, or vital spawning habitat for an important fishery. Class 4 streams are lowest ranked, and Class 5 are unclassified.

18) Method: Colorado Stream Data Bank (Colorado Division of Wildlife)

Reference: Weber (1983)

Approach: Computer database system, inventory system

Output: Computer-based catalogue of stream surveys of Colorado

Overview: The Colorado Division of Wildlife is developing a publicly accessible computer database based on survey information for over 3,600 streams in Colorado, with emphasis on sport fisheries. Computer sorts of the data bank will be possible by one or more criteria, including geographic location, fish species, flow rate, size, political boundaries, fishery value, water quality, or drainage.

19) Method: Procedure for Describing Fish and Wildlife (Colorado Division of Wildlife, U.S. Fish and Wildlife Service)

References: Mason et al. (1979), DuBrock et al. (1982)

Approach: Computer database system, literature review

Output: Database of vertebrate species of Colorado

Overview: Modified from the procedures for Pennsylvania (Mason et al. 1979). DuBrock et al. (1982) have designed a computer database for describing fishes and other vertebrates of Colorado which will be maintained and updated by the Colorado Division of Wildlife (Ecological Services Section) and made accessible to the public. This system is a species-by-species account, including biotic, abiotic, political, and distributional information (historical, resident, seasonal, and general occurrence by county and by USFWS, NPS, BLM, USFS, and CDOW administrative units), hydrologic units, ecoregion and potential natural vegetation systems, lat:long, 7 1/2 quads, section-township-range, river mile, and EPA River Reach System. Habitat associations are by the Land Cover

Classification and National Wetland Inventory systems. Feeding, breeding, high value habitat interrelations, limiting environmental factors, environmental requirements by life stage, life history information and management practices are provided for each species. Although database manipulations may allow the user to artificially cross species "boundaries", the system does not treat fishes or other vertebrates at the interactive community level.

20) Method: Colorado Fish Distribution Project (Colorado Division of Wildlife)

References: Galat and Haynes (1981, 1983)

Approach: Computer database system, literature review

Output: Database of Colorado fishes for each major drainage and annotated bibliography

Overview: Completed so far in this massive, dual computer-oriented and manual database system are the Rio Grande, San Juan, and Colorado drainages of Colorado. One hundred forty-four references are provided for the Colorado River Drainage. Fishes included are endangered, threatened, nongame and game species. Many of the references have been overlooked previously (e.g., those from early sporting magazines such as Forest and Stream and American Angler, Colorado Division of Wildlife unpublished creel censuses, stocking, scientific collecting permit and stream and lake survey records, and Colorado Division of Wildlife in-house

reports). The computer system, when completed, will be available to public users.

21) Method: Stonefly Classification System

Reference: Knight and Gaufin (1967)

Approach: Classification system

Output: Classification of the Gunnison River Drainage

Overview: Five divisions are used for classifying the Gunnison River Drainage on the basis of its plecopeteran fauna: 1) temporary or snow-melt streams; 2) small, stony streams (high = 3,000+ ft, low = below 3,000 ft); 3) stony rivers; 4) constant rivers; and 5) sluggish rivers.

22) Method: Lotic Habitat Classification

References: Pennak (1971, 1978)

Approach: Classification system

Output: Classification system of lotic habitats useful worldwide

Overview: At the first stage, streams are divided into two groups: distinctive lotic habitats which have relatively homogeneous and constant features, and indistinctive habitats which are highly variable and defy practical classification. Spring brooks, tundra brooks, mountain trout streams, sand streams and rivers of the Great Plains, medium to large silted rivers, sewage pollution reaches, and irrigation ditches are the types of distinctive habitats. Indistinctive lotic habitats include

intermittent streams, desert streams, agricultural streams, meadow brooks, and canals. To classify these indistinctive waters, 13 physical and chemical criteria are suggested.

23) Method: MANAGE (U.S. Fish and Wildlife Service)

Reference: Shumate et al. (1981)

Approach: Computer database system

Outputs: Database of streams, lakes, fishes, and water quality

Overview: This is the user guide to the U.S. Fish and Wildlife Service's MANAGE database management system, which is being used extensively by federal and state natural resource agencies. Includes species characteristics, biological surveys, map indexes, wetland inventories, bibliographies, water quality monitoring data, and "issue tree" analysis.

24) Method: Channel Stability Evaluation System (U.S. Forest Service)

Reference: Pfankuch (1975)

Approach: Classification, inventory, and evaluation system

Output: Evaluation of stream channel stability

Overview: This inventory and evaluation system was designed for the U.S. Forest Service to allow measurement of management success. Channel stability is evaluated using bank stability, debris jam potential, and channel bottom information. The resistance capacity of mountain stream channels to detachment of bed and bank materials and the capacity of streams to adjust and recover from potential

changes in flow or increases in sediment production are also addressed.

25) Method: Geomorphic Characteristics in Aquatic Ecosystem Classification (U.S. Forest Service)

References: Platts (1974, 1979a, 1979b), Swanston et al. (1977)

Approach: Classification system

Output: Evaluation of salmonid fisheries by physical habitat in Idaho and Alaska

Overview: Geomorphic characteristics of landform were measured and related to streams and salmonid fisheries. Swanston et al. (1977) measured 21 quantitative geomorphic variables and used discriminant function analysis to classify very poor and very good watersheds. Platts (1979a) used four land-type associations: glaciated, cryric, fluvial, and depositional. The advantages of these approaches are that they allow stream classification and fishery evaluation with minimal field data based on information from aerial photographs, topographic and geologic maps.

26) Method: Idaho Natural Area Classification System (Idaho Water Resources Research Institute)

References: Rabe and Savage (1977), Savage and Rabe (1979)

Approach: Classification system

Output: Streams are classified by stream order, characteristic flows, gradients, and substrate type. Extensive fish,

invertebrate, and macrophyte collections are used as modifiers and to indicate different associations for each permanent stream type.

27) Method: Ecological Classification System (Ontario Fishery Research Laboratory)

Reference: Ricker (1934)

Approach: Classification system

Output: Ecological classification of Ontario streams

Overview: Creeks and rivers are distinguished by flow volume and width. Subcategories of creeks are spring creeks and drainage creeks. Spring creeks are further broken down into four subtypes by substrate, discharge, vegetation and other biota, and water hardness.

28) Method: Modified Horton System

References: Strahler (1957), Horton (1945)

Approach: Classification system

Output: Streams classified by stream order

Overview: Strahler (1957) modified the classification of Horton (1945) based on stream order (small, fingertip tributaries are first order streams; when first order streams join, a second order stream is formed; a third order stream forms at the confluence of second order streams, etc.).

29) Method: National Site Classification System - Aquatic (U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S. Bureau of Land Management, U.S. Soil Conservation Service, U.S. Forest Service)

Reference: Terrell et al. (1980)

Approach: Classification system

Output: Classification of the riverine systems of the United States

Overview: Five categories (tidal, lower perennial, upper perennial, intermittent, and ephemeral) defined on the basis of water permanence, gradient, water velocity, substrate, and extent of floodplain development are used to divide the riverine systems of the U.S. A variety of chemical and physical characteristics form the criteria for the lowest level of classification.

30) Method: WATSTORE (U.S. Geological Survey)

Reference: U.S. Geological Survey (1975)

Approach: Computer database management system

Output: Storage and retrieval system for hydrological data

Overview: WATSTORE is the U.S. Geological Survey's computer-assisted database management system for handling hydrological data of the United States.

31) Method: STORET (U.S. Environmental Protection Agency, U.S. Federal Water Pollution Control Administration)

References: Green (1964), DuBois (1966)

Approach: Computer database system

Output: Two subsystems for database management of water quality information

Overview: STORET I (streams and rivers) and II (open water bodies) are designed for handling water quality data for the United States.

32) Method: Ecoregions (U.S. Forest Service)

References: Bailey (1980, 1982)

Approach: Classification system

Output: Hierarchical ecoregion maps

Overview: Maps are created which permit planning at the national level and still allow for recognition of regional differences based on climate, vegetation, and landforms. The maps attempt to systematically divide the U.S. and the world into ecosystem regions. Inventory data could be organized into these ecoregions, resulting in better organization and easier retrieval. The U.S. Forest Service used the 1976 map in the RARE II process. The U.S. Fish and Wildlife Service used the ecoregion maps as an aid in the National Wetlands Inventory. One problem with this method when dealing with large aquatic ecosystems is that the ecoregion maps divide many river basins into many parts on the basis of terrestrial criteria.

33) Method: National Reservoir Research Program (U.S. Fish and Wildlife Service)

Reference: Aggus and Bivini (1982)

Approach: Computer database system

Output: Database for all reservoirs larger than 500 surface acres in the U.S. It includes physical, chemical, fish composition, sport fishery harvest, and climatic information.

34) Method: Watershed Rehabilitation Evaluation System (National Park Service)

Reference: Heede (1981)

Approach: Classification and evaluation system

Output: Ranking of gully networks for treatment priority

Overview: Analysis of gully networks and subsequent ranking for treatment priority leads to highest rehabilitation benefit-cost ratio. Ranking is suggested as a stepwise process consisting of determining stream order, number of tributaries, and stages of development. Developmental stages are interpreted in terms of present and expected future erosion rates.

35) Method: Resource Evaluation Techniques-RET (U.S. Forest Service)

References: U.S. Forest Service (1980b), Hawkes et al. (1983), Joyce et al. (1983)

Approach: Computer database system, multiresource inventory system, literature review

Output: National assessment and appraisal of fish and wildlife resources

Overview: In accordance with the Forest and Rangelands Renewable Resources Planning Act (RPA) of 1974, the U.S. Forest Service is developing procedures for national assessments and inventories of our nation's natural resources so that multiresource management with trade-offs can be achieved. Aquatic ecosystems are treated as entities but are also considered in the interaction with management of other resources, including timber, water, recreation, wilderness, and range. A database is being formed for the National Forest System to store its updated inventories of aquatic ecosystem resources so that multilevel management decisions can be made ranging from site to national levels. The ecological analyses will be accompanied by economic trade-off analyses.

36) Method: Natural Area Classification System

Reference: Radford (1978)

Approach: Classification and inventory system, literature review, computer database management system

Output: Hierarchical classification of areas important to national heritage

Overview: This system attempts to standardize inventories and storage and retrieval of information on natural areas, vegetation, floras, rare species, endangered species, and threatened

species. The files in the database are vegetation (biotic communities), climate, soils, geology, hydrology, topography, hydrography, and physiography. These titles or themes are independent but interacting components that comprise the ecosystems, biomes, and natural areas of this open, dynamic classification system.

37) Method: Balanced Ecogeographical Information System (Nature Conservancy)

References: Jenkins (1978), Moyseenko et al. (1978)

Approach: Inventory, classification, and evaluation system, computer database management system

Output: The Nature Conservancy's Heritage Programs database

Overview: The Nature Conservancy, through its State Natural Heritage Programs, is developing a balanced information system for systematizing and managing data on certain biological species, habitats, communities and geographical features. Manual filing structures are "balanced" with computerized methods for inventorying, recording, mapping, and managing data. The computer programs are in 12 modules which can be applied flexibly according to the user's needs. Automated map generation is an important feature.

38) Method: Geographical Information Systems-GIS (U.S. Fish and Wildlife Service)

Reference: Wilcott and Gates (1978)

Approach: Computer database management system, mapping, inventory system

Output: Maps of soils, vegetation, wildlife, habitat, and hydrologic basins; computer-assisted data storage and retrieval; statistical analyses

Overview: The U.S. Fish and Wildlife Service is developing a GIS to aid planners and land managers in handling large datasets of habitat, species, and natural resources information that are organized geographically. Maps are generated by specific queries as well as statistical analyses of data.

39) Method: Aquatic Habitat Inventory and Display System (U.S. Forest Service)

Reference: Collotzi and Dunham (1978)

Approach: Classification system, inventory system, computer database management system

Output: Habitat rating for aquatic ecosystems

Overview: This systematic and uniform approach to the inventory and display of aquatic habitats was developed by the U.S. Forest Service (Intermountain Region). A final "percent of optimum" is calculated from the average of four habitat component ratings: pool measure, a rating of pool and riffle habitat; pool structure, a rating of pool quality; stream bottom, the percent of gravel and rubble bottom; and stream environment, a streambank vegetative cover rating.

40) Method: Morpho-edaphic Index-MEI

References: Ryder (1965), Ryder et al. (1974), Cole (1978)

Approach: Classification system, evaluation system

Output: Graphics and tables grouping lakes based on MEI and prediction of fish yields

Overview: MEI, based on mean depth and total dissolved solids (TDS), is used to classify lakes and reservoirs into groups. However, there appear to be some regional limitations of the system; therefore, interregion comparisons should be avoided. Problems in water bodies with extremes in salinity, pH, and free CO_2 are discussed by Cole (1978).

41) Method: Missouri System (Missouri Department of Conservation)

Reference: Fry and Pflieger (1978)

Approach: Inventory, classification, and evaluation system

Output: Numerical evaluation of aquatic habitat

Overview: The Missouri Department of Conservation is developing a method for numerical evaluation of aquatic habitats that emphasizes relatively scarce habitats for maintaining fishery resources. Scarcity units may also be used in impact and mitigation analyses. The habitat classification system will be based on indicator fish communities. Indicator fish communities are common fish associations that characterize particular suites of environmental conditions that enable the user to avoid numerous, expensive habitat measurements.

42) Method: Wildlife/Fish Habitat Relationships System-WFHR (U.S. Forest Service, California Department of Fish and Game, The Nature Conservancy)

Reference: Grenfell et al. (1982)

Approach: Database management, inventory and evaluation system

Outputs: Distribution maps, species-habitat relationship models, species narratives, California Natural Diversity Data Base

Overview: To aid in land and resource management decisions, the California Department of Fish and Game, U.S. Forest Service, and The Nature Conservancy developed the WFHR system. Fish habitat capabilities and predicted consequences of land and resource management alternatives on fishery resources are provided. The database for all California vertebrates and their habitats has improved standardization and uniformity in wildlife and fish habitat inventory, classification, and evaluation. Applicability of this system to northwest Colorado should be tested.

B) Evaluation, Prediction and Mitigation Methodologies

Two recent papers discuss evaluation and prediction methods for aquatic ecosystems in more detail. Schuytema (1982) summarized and compared approximately 30 aquatic habitat assessment techniques. These techniques are classified according to categories such as impact assessment, inventory and general description, salmonid or non-salmonid streams, particular fish species orientation, channel stability, transect, and biotic indices.

More recently, Fausch and Parsons (1983) reviewed models that predict standing crop of stream fish from measurable habitat variables. Models are grouped according to the types of independent variables found to be significant during model development: 1) only geomorphic and watershed variables, 2) only microhabitat variables, and 3) a combination of all three variable types. Fausch and Parsons concluded that statistical inference has often been minimized or overlooked. Two areas neglected are testing of models and reporting standard error of regression coefficients.

Platts, Megahan, and Minshall (1983) attempted to standardize the way physical and biological attributes are measured and quantified in streams. They discussed some of the environmental parameters that best measure and describe conditions existing in aquatic ecosystems. In particular, they present the precision and an estimation of the accuracy that can be expected when measuring many of these conditions.

1) Method: Adaptive Environmental Assessment-AEA (U.S. Fish and Wildlife Service)

Reference: Holling (1978)

Approach: Evaluation, prediction, and mitigation

Output: Variable, depending on needs

Overview: Coordination, synthesis, and analysis are the greatest strengths of adaptive assessment methodology, which uses workshops, quantitative tools such as simulation models, and reports to bring people and ideas together. AEA involves an interdisciplinary approach to solving ecological problems. At the core of the methodology is an

intensive 5-day workshop involving a team of four or five experienced simulation modelers and a group of 15 to 20 specialists. The workshop focuses on construction of a quantitative simulation model of the system under study. Development of the simulation model forces specialists to view their areas of interest in the context of the whole system, and it allows ecological knowledge to be incorporated with economic and social concerns at the beginning of the analysis rather than at the end of the design process. Simulation models require unambiguous information. Specialists are thus forced to be explicit about their assumptions. This objectivity exposes critical conceptual uncertainties about the behavior of the system and identifies research needs.

2) Method: Habitat Suitability Index Models-HSI (U.S. Fish and Wildlife Service)

References: Weber (1979), Schamberger et al. (1982)

Approach: Literature review, database, impact analysis

Output: A numerical index of habitat suitability on a 0-1 scale for each variable measured and the entire habitat

Overview: HSI forms an integral part of the habitat evaluation procedures (HEP) of the U.S. Fish and Wildlife Service. The models serve as a concise literature review and database for species-specific habitat data. Suitability index (SI) graphs are provided for each model variable and

are rated on a scale from 0.0 to 1.0, with 1.0 being optimal habitat with respect to that habitat variable. The SIs are then combined into a species HSI model with different models provided for riverine and lacustrine conditions.

3) Method: Cluster Analysis-CA

Reference: Dixon et al. (1981)

Approach: Evaluation and prediction

Output: Dendrograms showing groups or clusters of associated species or habitat types depending upon specific techniques.

Overview: CA is a computer-oriented, multivariate statistical technique that can be used to detect patterns in data. Clustering by case, variables or blocks of data is possible with BMDP computer packages (Dixon and Brown 1979). CA allows for integration of biological interactions and physical-chemical habitats to help explain fish community patterns. Species associations or habitat types may form the building blocks of a hierarchical clustering technique. A graphic based on these calculations, referred to as a dendrogram, trellis diagram, or tree diagram, helps in identification of clusters with biological relevance and in unusual cases of particularly significant river reaches. We have explored the possibility of application of CA as a predictive tool for locating areas of successful or

potential reproductive habitat for Colorado River rare fishes. With the proper microhabitat information, one could also refine species preference curves used in other mitigation systems (HEP, HES, Instream Flow Methodologies) with this technique. The results of CA and other multivariate analyses should be considered indicative of true biological relationships but not as an absolute statement, and the computer should be viewed as assistance to sound thinking, not as a substitute.

5)

4) Method: Factor Analysis-FA

Reference: Poole (1971)

Approach: Evaluation and prediction

Output: Associations of parameters with newly formulated (underlying) factors

Overview: FA is a computer-oriented, multivariate statistical technique that produces predictive equations and identifies underlying factors causing variance of species associations or population levels. Consequently, only those variables that have a significant effect on the output are included in models. This method can also predict future consequences. For example, a key variable in the model can be evaluated while other factors are assumed to remain constant. One can then estimate probable values of this key variable and enter them into the simulation. This capability increases the reality of the model. One drawback of this approach is that it

requires tremendous amounts of field work to sample species populations.

5) Method: Habitat Evaluation Procedures-HEP (U.S. Fish and Wildlife Service)

References: U.S. Fish and Wildlife Service (1980c), Terrell et al. (1982)

Approach: Evaluation, prediction, mitigation

Output: Units of habitat quality

Overview: HEP is a method used to document the quality and quantity of available habitat in selected wildlife species. HEP provides information for the development of two types of wildlife habitat comparisons: 1) the relative value of different areas at some point in time, and 2) the relative value of some area at future points in time. One assumption is that habitat can be described by a habitat suitability index (HSI). This index is multiplied by area to yield habitat units. The basic HEP methodology uses this simple relationship to provide ecological data for comparison of impacts over time of alternative project plans to species, species groups, species life stages, cover types, etc. The HSI, then, is a critical part of the HEP methodology. An important aspect of HEP is its capability to quantify the noneconomic value of fish and wildlife resources by measuring impacts and formulating mitigation measures on a biological basis rather than solely on a use

basis. HEP requires the exercise of judgement by an expert to 1) determine the quality of habitat being lost and the management needed to replace the habitat, 2) identify acceptable substitute habitats when exact replacement is not possible, and 3) measure variables and parameters used to aggregate the measurements into an index. Also, the following analytical assumptions are not always met: 1) habitat value can be quantified. 2) habitat suitability can be determined by measuring physical and chemical parameters of the habitat, 3) habitat can be evaluated by assessing the suitability of that habitat for selected species, and 4) habitat quality and quantity are directly related to potential animal numbers.

6) Method: Habitat Evaluation System-HES (U.S. Army Corps of Engineers)

Reference: U.S. Army Corps of Engineers (1980)

Approach: Prediction, mitigation, evaluation

Output: Units of habitat quality

Overview: HES is a system for evaluating the environmental impacts of water resources development projects, using a habitat approach. It evaluates quality of different habitat types (e.g., lakes, streams) and compares relative environmental impacts which can be expected to result from alternative plans for water resources development and other activities. Utilizing six variables (fish species associations,

sinuosity index, total dissolved solids, turbidity, chemical type, benthic diversity), HES determines the quality of a habitat type by developing functional curves which relate habitat quality to quantitative characteristics of the habitat. Habitat size and quality are combined to assess project impacts. HES describes habitat quality for a broad range of species rather than for individuals or groups of species. However, the use of general habitat characteristics that are indicative of habitat quality for fish as a whole may not be appropriate for the needs of northwest Colorado because of the concern for endangered or threatened species in that region.

7) Method: Habitat Quality Index (HQI)

References: Binns and Eiserman (1979a,b)

Approach: Evaluation, prediction, mitigation

Output: Units of habitat quality

Overview: A habitat quality index (HQI) was developed to quantify fluvial trout habitat in Wyoming. Ease of measurement was among the criteria used originally to select 22 attributes characterizing fluvial trout habitat. The relationship between habitat attributes and trout standing crop is then explored with multiple regression analysis. This indicates certain attributes linearly related to trout standing crop, which are then used to develop a predictive HQI model. The value of a trout habitat unit (HU) is determined using the

linear relationship between HQI score and trout standing crop.

The most important feature of HQI is that it provides objective and quantitative evaluations of trout fishery resources in non-monetary terms. HQI also appears to have value for use in mitigation evaluation where there is potential for loss in the trout fishery from human activities.

8) Method: Human Use and Economic Evaluation-HUEE (U.S. Fish and Wildlife Service)

Reference: U.S. Fish and Wildlife Service (1980e)

Approach: Evaluation, prediction, mitigation

Output: Use, worth, and value of habitat

Overview: HUEE provides a means for estimating the extent of human uses of wildlife and dollar values of these uses. The procedures were developed and are intended for use in conjunction with HEP (Habitat Evaluation Procedures). When conducting a monetary evaluation, a specialist (economist or recreation planner) is needed. Data produced in an HUEE analysis are used primarily to compare effects of proposed actions on human uses of wildlife. The procedure produces four outputs: average annual use, average annual worth, present worth, and average annual equivalent value. The procedure is also capable of considering externalities (secondary effects of man's use).

9) Method: Index of Biotic Integrity

Reference: Karr (1981)

Approach: Evaluation

Output: A single number, used in a rating system

Overview: The index of biotic integrity is a procedure for monitoring water resources by using fishes. The contention is that, by carefully monitoring fishes, one can rapidly assess the health (biotic integrity) of a local water source. The use of fishes in this regard has several advantages over monitoring of other taxa. The index incorporates 12 fish community parameters separated into two major categories: ecological factors, and species composition and richness. The final product is a number than can be placed into one of several discrete classes (excellent, good, etc.) to evaluate fish communities. Several assumptions are apparent in calculating the index and in collecting fish data. Since the index was derived for midwestern streams, the parameters utilized must be revised for application to other geographic areas. Where biotic integrity appears impaired, a more complex monitoring program is necessary to search for the causative agent(s). For a review of fish as indicators of biological integrity, see Hocutt (1981).

10) Method: Instream Flow Techniques (U.S. Fish and Wildlife Service)

References: Bovee (1981), Bovee (1982), Orth and Maughan (1982)

Approach: Evaluation, prediction, mitigation

Output: Habitat in units of weighted usable area (WUA)

Overview: A series of instream flow models has been developed to produce probability-of-use or preference (selectivity, usability) curves for various environmental parameters for different fish life history stages such as spawning, incubation, juvenile, and adult. Cross sections of a representative reach of river are divided into cells, and weighted usable areas (WUA) are computed in relation to habitat quality for various life stages. The computer model predicts changes in WUA from flows above or below that at which measurements were taken. Theoretically, the method has an advantage over other commonly used methods: it is species-specific and considers all major aspects of life history.

The probability-of-use curves are fixed, two-dimensional figures; hence, they do not account for the fact that boundaries of a species niche are elastic and subject to change, especially in the presence of another species. In addition, the method does not measure certain aspec microhabitat, e.g., the 10 to 15% of the total habitat where fis spend 95% of their time. This is caused by use of average velocities from measurements taken throughout the water column.

11) Method: Land and Water Impact Analysis (U.S. Fish and Wildlife Service)

Reference: Porter et al. (1979)

Approach: Evaluation, prediction

Output: Units of habitat quality

Overview: The Yampa River Basin is the study area. Tools and methods described included a computerized Geographic Information System (GIS), conflict mapping, ranking of project impacts, and prediction of fish habitat changes resulting from multiple water developments. The GIS allows manipulation and analysis of mapped information that would be impractical manually. Mapped wildlife data are composited to determine habitat values of land units in the study area. Proposed locations of coal and water development are overlaid on composited wildlife maps to identify potential conflicts. A method is devised to quantify and compare relative impacts of different development scenarios on wildlife. Finally, a reservoir-stream flow analysis is suggested to predict changes in stream fisheries habitat resulting from proposed resource developments.

12) Method: Multivariate Statistical Analysis

Reference: U.S. Forest Service (1981)

Approach: Evaluation and prediction

Outputs: Various, depending on specific techniques

Overview: The commonly recognized multidimensional nature of wildlife habitat has led to rapidly increasing use of multivariate

statistical techniques such as discriminant function analysis, principal components analysis, factor analysis, and canonical correlation in studies of wildlife habitat. These methods have been applied in studies of habitat selection and resource partitioning, ordination of habitats and simulation of habitat change, and development of habitat inventory systems. Although multivariate methods are somewhat complex mathematically, they may be employed with little difficulty if one has access to a computer. Such convenience tempts researchers to employ sophisticated analytical techniques but overlook important statistical assumptions, experimental design, and biological interpretation. With these temptations in mind, a meeting was organized to discuss multivariate methods and their applications to studies of wildlife habitats. This meeting resulted in a publication (U.S. Forest Service 1981) which effectively discusses techniques employed, their applications, and new approaches to analysis and interpretation.

13) Method: Predicting Trout Abundance

Reference: Burton and Wesche (1974)

Approach: Evaluation and prediction

Output: Standing crop of trout stream

Overview: The objectives of this methodology are two-fold: 1) to determine the significance of flow duration values at

yearly and seasonal intervals, estimate standing crop of trout, and relate significant results to suitable minimum streamflow recommendations for trout based on average daily flow; and 2) to determine, through statistical analysis, significant watershed parameters related to standing crop estimates of trout and develop from these an index of potential trout productivity. Four parameters are considered to be significantly related to potential productivity: watershed area, basin area, mean drainage basin elevation, and total drainage basin stream length.

14) Method: Quantitative Geomorphic Approach (U.S. Forest Service)
Reference: Swanston et al. (1977)
Approach: Evaluation and prediction
Output: Qualitative estimate of potential production
Overview: Twenty-one quantitative geomorphic variables were measured from photos and topographic and geologic maps of 18 watersheds identified as either exceptionally good or exceptionally poor pink and chum salmon producers. Intermediate-quality streams are not categorized. Each variable is tested for its ability to differentiate between good and poor producers. A discriminant function model is constructed which uses eight of the original 21 variables to produce a value which allows a particular stream to be categorized as good or poor salmon-producing habitat. The approach requires minimal field investigation.

15) Method: Reservoir and Stream Habitat Improvements Handbook

Reference: Nelson et al. (1978)

Approach: Mitigation

Output: Literature review

Overview: This handbook documents successful and potentially successful habitat and population improvement measures accompanying water resource development projects. The projects of primary interest are dams and reservoirs in the western U.S., including diversion dams and canals. Measures considered involve structural and operational features as well as habitat modifications. Improvement measures are discussed with reference to purposes, illustrations, limitations, performance, and cost. This is basically a handbook that can guide planners in choosing mitigation methods once a loss has resulted or is suspected. It should be used as a guide for selecting efficient measures to recommend to administrators, biologists, and engineers associated with fish and game and water resource development agencies.

16) Method: Prediction of Habitat Quality and Fish Species Occurrence in Reservoirs (U.S. Fish and Wildlife Service)

Reference: McConnell et al. (1982)

Approach: Evaluation, prediction, mitigation

Output: Predicted species richness

Overview: The technique of pattern recognition can be used to evaluate suitability of a proposed reservoir for different species and to compare outcomes of alternative construction plans. A five-digit number is developed with each digit representing an aggregate of habitat attributes. The aggregate attributes are temperature, mineral turbidity, structure, severity of water level fluctuation, and occurrence of shallow, protected coves. Values ranging from one to three for each of the digits represent one of the aggregate attributes. The output is a list of species of fish that should exist in the reservoir at some unspecified time during the life of the reservoir.

The technique appears to have great potential as a screening tool in early stages of the reservoir planning process. It could be expanded to include additional species; this would improve its utility. The system should be useful in determining losses relative to benefits, trade-offs, and potential mitigation measures in reservoir projects.

17) Method: Systems Approach to Ecological Baseline Studies Manual

Reference: States et al. (1978)

Approach: Evaluation and prediction

Output: See overview; also contains an extensive literature review

Overview: This manual attempts to define and standardize a holistic approach to ecological baseline studies for energy

development projects in the western U.S. The premises are that 1) there are serious deficiencies in the present process of gathering information on social and environmental systems, and 2) the decision processes and time frames for energy developments are often not designed for properly incorporating results of ecological or other socio-environmental baseline studies. Theoretical and applied materials are separated in the manual. The first chapter presents an argument for a new viewpoint that can serve as a basis for generating better ecological baseline studies. Remaining chapters present a detailed, step-by-step approach recommended for designing better ecological baseline studies. Because baseline studies are both site-specific and project-specific, the process addresses a general case and provides specific examples of how to apply the techniques. It remains for each project team to adapt and apply the specific needs of a given project with resourcefulness, creativity, and expertise.

18) Method: Manual of Stream Channelization Impacts on Fish and Wildlife

Reference: Simpson et al. (1982)

Approach: Evaluation, prediction, mitigation

Output: Literature review

Overview: This manual contains a synthesis of information on physical and chemical effects of stream channelization on stream and

riparian environments and biological impacts of these effects on fish and wildlife resources. Available information on channelization is summarized to provide the user with an overview and analysis of key studies regarding impacts of channelization that can be used in assessing channelization projects.

19) Method: Stream Simulation and Assessment Model

Reference: Grenney and Kraszewski (1981)

Approach: Evaluation, prediction, mitigation

Output: Varies, depending on needs

Overview: The purpose of this report is to describe the mathematical model used to introduce water quality aspects into the Instream Flow Group's Incremental Methodology. The model is designed to asnwer the following management questions: 1) Assuming that source loads remain unchanged, how are concentrations changed by altering flows? 2) Assuming that flows remain unchanged, how are concentrations changed by altering loads? A combination of 1) and 2) is also considered. The following information is also provided: 1) mathematical concepts involved in modeling water quality in stream environments, 2) a description of the computer model which incorporates these concepts, 3) a user's guide to developing input required by the computer model, and 4) a specific application of the computer model to the Yampa River in Colorado.

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Taxonomy of a transplanted population of Colorado River cutthroat trout.

Hamman, R. L. 1981. Spawning and culture of Colorado squawfish in raceways. Prog. Fish-Cult. 43:173-177.

As part of the Colorado squawfish recovery plan, hatchery spawning and culture techniques have been developed at the U.S. Fish and Wildlife Service National Fish Hatchery at Willow Beach, Arizona. Captive fish spawned naturally in raceways. Also, hatchery-reared squawfish were hand-stripped and the eggs artificially fertilized. Incubation times were 90-121h at

20-24 C and 145-180h at 12-13 C. Fry, 6-7.5 mm at hatching, grew to lengths of 42-50mm by day 107.

Hamman, R. L. 1981. Hybridization of three species of chub in a hatchery. Prog. Fish-Cult. 43:140-141.

Roundtail chub, Gila robusta, humpback chub, G. cypha, and bonytail, G. elegans, were hybridized with each other at Willow Beach National Fish Hatchery. The three hybrid crosses exhibited no loss of fertility, indicating close genetic relationships of the three species.

Hamman, R. L. 1982. Induced spawning and culture of bonytail chub. Prog. Fish-Cult. 44:201-203.

The U.S. Fish and Wildlife Service's hatchery program at Willow Beach, Arizona now includes techniques for culturing and hatchery spawning of the bonytail.

Hamman, R. L. 1982. Spawning and culture of humpback chub. Prog. Fish-Cult. 44:213-216.

Advances in hatchery spawning and culture of the humpback chub, Gila cypha, are presented by Hamman of the U.S. Fish and Wildlife Service National Fish Hatchery, Willow Beach, Arizona.

Harper, V. C., and H. M. Tyus. 1981. White River fishes study. Trans. Bonneville Chapter Am. Fish. Soc.

Not available for review.

Haynes, C. M. 1980. Saving Colorado's big-river fish. Colo. Outdoors 29:26-29.

The status and distribution of the Colorado squawfish, humpback chub, bonytail, and razorback sucker are described in laymen's terms.

Haynes, C. M. (in press). Lordosis in Gila, Yampa River, Colorado. Proc. Desert Fish. Counc. (presented at 1981 meeting).

Lordosis, abnormal dorsoventral curvature of the spine, was found in 360 of 3,497 (10.3%) young-of-year (YOY) Gila chubs in 1980 and in 667 of 4,032 (16.5%) YOY chubs examined in 1981 from the Yampa River. Environmental contaminants, including pesticides, are suspected causes.

Haynes, C. M., and R. T. Muth. 1982. Identification of habitat requirements and limiting factors for Colorado squawfish and humpback chubs. Endangered Wildl. Invest. Rep. Proj. SE-3-4, Work Plan 1, Job 1. Colo. Div. Wildl., Fort Collins.

Progress report on habitat investigations for Colorado squawfish and humpback chub, including larval stages.

Haynes, C. M., R. T. Muth, and L. C. Wycoff. 1982. Range extension for redside shiner, Richardsonius balteatus, in the Upper Colorado River. Southwest. Nat. 27:223.

This is the first record of redside shiner from the Colorado River (taken about 10 mi. below Loma). The redside shiner has long been a dominant species in the Upper Green River.

Haynes, C. M., T. A. Lytle, E. J. Wick, and R. T. Muth. (in press). Larval Colorado squawfish (Ptychocheilus lucius) in the Upper Colorado River Basin, Colorado, 1979-1981. Southwest. Nat.

Estimation of spawning times from larval and young-of-year developmental stages. Larval collections indicate good spawning conditions in the Colorado River in the high flow years 1979 and 1980, but poor spawning success in the low flow year 1981.

Hibbert, A. R. 1979. Managing vegetation to increase flow in the Colorado River Basin. U.S. Forest Serv. Gen. Tech. Rep. RM-66, Fort Collins, Colo. 27pp.

The potential for increasing water yield for the Colorado River Basin is discussed, and treatments are postulated to achieve these increases by managing vegetation and snow.

Hickman, T. J., and T. A. Lytle. 1979. Colorado River cutthroat trout inventory. Job Prog. Rep. SE-3-2, Work Plan 1, Job 5, Colo. Div. Wildl., Grand Junction.

Progress report for restoration of the threatened Colorado River cutthroat trout, including purity ratings of sample populations.

Holden, P. B. 1977. A study of the habitat use and movement of rare fishes in the Green River from Jensen to Green River, Utah, August and September 1977. PR-B-1 to U.S. Fish Wildl. Serv. Bio/West, Logan, Utah. 58pp.

Holden, P. B. 1977. A study of the habitat use and movement of the rare fishes in the Green River, Utah, August and September 1977. Final Rep. PR-13-1 for U.S. Fish Wildl. Serv. Bio/West, Logan, Utah. 65pp.

Distribution and movements of endemic, rare fishes of the Green River are reported.

Holden, P. B. 1980. Ecology of riverine fishes in regulated stream systems with emphasis on the Colorado River. Pages 57-74 in Ward, J. V., and J. A. Stanford, eds. The ecology of regulated streams. Plenum Publ. Corp., New York.

Using the Colorado River System as an example of a regulated stream in which most native fishes are obligate riverine species, the author describes the history of flow regulation, native "large river" fishes, and factors that have led to their decline. Included in this combination of factors are low flows, abundant exotic competitors, predators, long-term habitat changes, water quality changes, and preimpoundment eradication programs.

Holden, P. B. 1980. Correlation between Yampa River stream flow patterns and spawning success of the endangered Colorado River squawfish. PR-31-1 to Nat'l Park Serv. Bio/West, Logan, Utah.

Historical review of squawfish reproductive success and flow regimes.

Holden, P. B., and D. A. Selby. 1978. A study to determine spawning requirements of Colorado squawfish. PR-17-1, U.S. Fish Wildl. Serv., Fort Collins, Colo. 29pp.

Reports the first (unsuccessful) attempt to use radio-telemetry to track spawning squawfish.

Holden, P. B., and D. A. Selby. 1979. An aquatic biology survey of the White River (Colorado) to assess potential impacts of a proposed water withdrawal system. PR-21-1, Burns and McDonnell, Kansas City, Mo.

Baseline information on potential impacts of water withdrawals and pollution by a proposed coal mine near Rangely, Colorado.

Holden, P. B., and D. A. Selby. 1979. Aquatic biology report for the Moon Lake Project. PR-21-1 to Burns and McDonnell, Kansas City, Mo. Bio/West, Logan Utah. In three sections: 40pp., 35pp., 9pp.

More than 22,000 fishes were collected in a 35-km section of the Green River below Jensen, Utah. Collections indicated poor squawfish spawning success in 1977 (low flow year) and good success in 1978 and 1979. The most significant aspect of this work was finding 1,288 young-of-year squawfish in a backwater of the Green River in the Horseshoe Bend area in August-September 1979.

Holden, P. B., and L. W. Crist. 1979-1981. Documentation of changes in the macroinvertebrate and fish populations in the Green River due to inlet modification of Flaming Gorge Dam. Bio/West, Logan, Utah.

A series of two annual reports and a final report to the Bureau of Reclamation on invertebrate and fish sampling in the Green River from Jensen, Utah, upstream to 8 mi. below Flaming Gorge Dam. No dramatic changes in invertebrate species in comparison to previous studies were

found. Only a few species of native fishes occur in the Green River above the mouth of the Yampa River.

Holden, P. B., T. M. Twedt, and C. Richards. 1980. An investigation of the benthic, planktonic, and drift communities and associated physical components of the San Juan River, New Mexico and Utah. PR-20-1 to U.S. Water and Power Resour. Serv., Amarillo, Texas. Bio/West, Logan, Utah. 129pp.

Limnological investigations of the San Juan River of the Upper Colorado River System are described in terms of biological and physical/chemical components.

Holland, W. E. 1975. Mixing oil and water: The effect of prevailing water law doctrines on oil shale development. Denver Law J. 52:657-694.

Provides fishery managers with basic insights into legal problems of oil shale development related to protecting fish habitat and water flows.

Hoope, R. A., and L. M. Finnell. 1979. Aquatic studies on Fryingpan River, Colorado; 1969-1979. Bur. Sport Fish Wildl., Div. River Basin Studies. 12pp. (mimeogr.)

Distribution and game fish survey of non-native salmonids in the Fryingpan River, including fishery recommendations.

Hughes, R. M. 1981. The plains killifish, Fundulus zebrinus (Cyprinodontidae), in the Colorado River Basin of western North America. Southwest. Nat. 26:321-324.

A short note reviewing past and present distribution of the introduced plains killifish in the Colorado River System, including habitat preferences and new site records.

Jeppson, P. 1957. The control of squawfish by use of dynamite, spot treatment and reduction of lake levels. Prog. Fish-Cult. 19:168-171.

Outlines effective means of eradicating squawfish, once considered a "rough" fish. Some of the methods and their manner of action indicate critical habitat factors necessary for squawfish survival.

Johannes, R. E., and P. A. Larkin. 1961. Competition for food between redside shiners (Richardsonius balteatus) and rainbow trout (Salmo gairdneri) in two British Columbia lakes. J. Fish. Res. Board Can. 18:203-220.

Pertains to the introduction and establishment of redside shiners in northwest Colorado, and how they may interact with native Colorado River Basin fishes and introduced game fishes.

Johnson, J. E., and J. N. Rinne. 1982. The Endangered Species Act and Southwest fisheries. Fisheries 7:2-8.

Reviews the Endangered Species Act and summarizes actions taken for recovery of some southwestern endangered and rare species.

Joseph, T. W. 1978. Capture locations of rare fish in the Upper Colorado River System. U.S. Fish Wildl. Serv. FWS/OBS-78/32, Fort Collins, Colo. 44pp.

This report is a summary of distributional information for Colorado cutthroat trout, Kendall Warm Springs dace, Colorado squawfish, razorback sucker, bonytail, and humpback chub for Colorado, Utah, Wyoming, and New Mexico. Thirty-nine maps are provided with keys by species and state. A numbered bibliography corresponds to site collections.

Joseph, T. W., J. A. Sinning, R. J. Behnke, and P. B. Holden. 1977. An indexed annotated bibliography of the endangered and threatened fishes of the Upper Colorado River System. U.S. Fish Wildl. Serv. FWS/OBS-77/61, Fort Collins, Colo. 169pp.

An annotated bibliography of Upper Colorado River Basin native fishes, including many references for northwest Colorado. Emphasized are publications dealing with the limiting factors, habitat alterations, and numerous environmental factors associated with these threatened or endangered fishes.

Klein, W. D., and L. M. Finnell. 1969. Comparative study of coho salmon introductions in Parvin Lake and Granby Reservoir, Colorado, U.S.A. Prog. Fish-Cult. 31:99-108.

Coho salmon were introduced into Granby Reservoir in northwest Colorado and Parvin Lake on the East Slope. Cohos appeared to provide a better fishery in the larger, fluctuating Granby Reservoir.

Knight, A. W., and A. R. Gaufin. 1967. Stream type selection and associations of stoneflies (Plecoptera) in a Colorado River drainage system. J. Kans. Entomol. Soc. 40:347-352.

A stream classification system based on species composition of stoneflies.

Lamarra, V., and J. Carter. The assessment of energy related impacts within the Upper Colorado River Basin. Unpublished manuscript. 49pp. (mimeo)

This paper appraises environmental impacts of oil shale development on the "complete" aquatic ecosystem, including primary production, macroinvertebrates, fishes, and food webs of the White River. No evidence is given for predictive capabilities of "structure and function" ecosystem studies, especially at the threatened or endangered fishes level of management.

Langlois, D. 1977. Status of the razorback sucker and bonytail chub in western Colorado. Colo. Div. Wildl., Denver. 12pp. (mimeo)

The status and distribution of two native Colorado River System fishes; includes northwest Colorado waters as well as the rest of the Upper Colorado River Basin.

Lanigan, S. H., and C. R. Berry, Jr. 1979. Distribution of fishes in the White River, Utah. Final Report, U.S. Bur. Land Manage., Utah State Off., Salt Lake City. 84pp.

Lanigan, S. H., and C. R. Berry, Jr. 1981. Distribution of fishes in the White River, Utah. Southwest. Nat. 26:389-393.

A fish survey of the White River, Utah, was conducted during summers of 1978 and 1979 to determine abundance and distribution of endemic and

non-native fishes during and after spring runoff. Habitat preferences for native fishes are described. This was the first documented collection of adult squawfish in the Utah section of the White River. However, no evidence of successful squawfish reproduction was found in this study. The 1979 and 1981 publications by these authors are very similar.

Larkin, P. A., and S. B. Smith. 1954. Some effects of introduction of the redside shiner on the Kamloops trout in Paul Lake, British Columbia. Trans. Am. Fish. Soc. 83:161-176.

May give some insight into ecological effects of the introduced redside shiner on native northwest Colorado fishes and introduced rainbow and brown trouts.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. N.C. State Mus. Nat. Hist. and U.S. Fish Wildl. Serv., Raleigh, N.C. 854pp.

Species accounts of fish distribution in North American, including northwest Colorado; map distributions (both native and introduced), life history data, general habitat preferences, status, legal classification, and systematics are presented. The distribution map for the humpback chub, Gila cypha, lacks collection sites on the Yampa River above its confluence with the Green River and sites on the Green River reported by Joseph (1978).

Matthews, W. J., and L. G. Hill. 1979. Influence of physio-chemical factors on habitat selection by red shiners, Notropis lutrensis (Pisces: Cyprinidae). Copeia 1:70-81.

Habitat selection by red shiners, especially with regard to flow patterns, may provide information on their habitat use in northwest Colorado.

McAda, C. W., C. Berry, and C. Phillips. 1980. Distribution of fishes in the San Rafael River System of Upper Colorado River Basin. Southwest. Nat. 25:41-50.

Records finding of a young squawfish in the San Rafael River.

McAda, C. W., and R. S. Wydoski. 1980. The razorback sucker, Xyrauchen texanus, in the Upper Colorado River Basin, 1974-1976. U.S. Fish Wildl. Serv. Tech. Pap. 99. 15pp.

Discusses possible spawning areas of razorback sucker in the Colorado River near Grand Junction and at the mouth of the Yampa River. Age, growth, and fecundity data are presented.

Middletown, W. H. 1969. Hybridization and distribution of catostomid fishes in Blue Mesa Reservoir and the Upper Gunnison River Drainage. M.S. Thesis, West. State Coll. of Colo., Gunnison. 121pp.

The distribution and hybridization of suckers, native and non-native, are described from the Curacanti Storage Project on the Gunnison River.

Miller, W. H., D. L. Archer, H. M. Tyus, and K. C. Harper. 1982. White River fishes study, Final Rep. Colo. River Fish. Proj., U.S. Fish Wildl. Serv., Salt Lake City, Utah. 58pp.

The final report of the Colorado River Fishery Project on fishes of the White River includes data on habitat use, distribution, movements of rare native fishes, and fish community composition information (including non-natives). Limnological data for the White River are also given.

Spawning aggregations occurred near Clifton, Colorado, when river flows were receding and water temperatures were near 20 C.

Miller, W. H., D. Archer, H. M. Tyus, and R. M. McNatt. 1982. Yampa River fishes study. Final Rep. Colo. River Fish. Proj., Salt Lake City, Utah. 24pp.

The final report on the fishes of the Yampa River by the Colorado River Fishery Project discusses instream flow needs, habitat use, and fish distribution.

Miller, W. H., H. M. Tyus, and C. A. Carlson, eds. 1982. Fishes of the Upper Colorado River System: present and future. West. Div., Am. Fish. Soc., Bethesda, Md. 131pp.

Edited proceedings of a symposium on Upper Colorado River fishes held at the 1981 annual meeting of the American Fisheries Society in Albuquerque, New Mexico.

Chapters include: Review of selected literature on the Upper Colorado River System and its fishes; Fishes of the Upper Colorado River System: Political and resource considerations; Fishes of the Upper Colorado River

Basin: Distribution, abundance and status; New impacts by man in the Upper Colorado River Basin; Mitigation of aquatic endangered species habitat losses in the Upper Colorado River Basin: Feasibility and applications; Mitigation and section 7 on the Upper Colorado River: Providing water for endangered fishes in the Upper Colorado River System; Realities and illusions of endangered species preservations; Colorado River Fishes Recovery Team; Life history and prospects for recovery of Colorado squawfish; Life history and prospects for recovery of the humpback and bonytail chub; Life history and prospects for recovery of the razorback sucker; Concerns about the status and protection of endemic fishes, especially threatened and endangered species; Synthesis of a panel discussion.

This symposium and its proceedings represent the culmination of intensive research from the 1970s and early 1980s by the Colorado Division of Wildlife, U.S. Fish and Wildlife Service, Utah Division of Wildlife Resources, Utah State University, and Colorado State University on fishery resources of the Upper Colorado River System. New data on four endemic fishes are presented.

Miller, W. H, H. M. Tyus, and L. R. Kaeding. 1983. Colorado River fishes monitoring project. First Annu. Rep., U.S. Fish Wildl. Serv., Colo. River Fish Proj., Salt Lake City, Utah. 23pp. (mimeo)

Objectives were to use radiotelemetry to expand information on distribution and movement of adult Colorado squawfish to and from spawning site locations including Lake Powell and the headwaters of the Gunnison, Colorado, and Green rivers; to verify flow requirements of adult Colorado

squawfish in relation to spawning success and survival of larval Colorado squawfish; and to determine the effects of flow fluctuation at Flaming Gorge Dam on survival and rearing of young-of-the-year and juvenile Colorado squawfish.

Miller, W. H., J. J. Valentine, D. L. Archer, H. M. Tyus, R. H. Valdez, and L. Kaeding. 1982. Colorado River Fishery Project. Part 1, Summary Report. U.S. Fish Wildl. Serv., Salt Lake City, Utah. 35pp.

Movements and distributions of Colorado River endemic fishes.

Miller, W. H., J. J. Valentine, and H. M. Tyus. 1980. Colorado River fisheries investigations 1979, Progress report. Colo. River Fish. Proj., U.S. Fish Wildl. Serv., Salt Lake City, Utah. 66pp.

Field and hatchery-laboratory studies on the squawfish are presented, including: spawning requirements, young-of-the-year and adult habitat preferences, migrations and movements, interspecific competition, culturing technology, tolerance to physico-chemical conditions, and experiments on acute toxicology to heavy metals.

Miller, W. H., L. R. Kaeding, and H. M. Tyus. 1983. Windy-Gap fishes study. First annu. Rep., Colo. River Fish. Proj., U.S. Fish Wildl. Serv., Salt Lake City, Utah. 39pp. (mimeogr.).

Objectives were to determine survival factors of young-of-the-year Colorado squawfish and humpback chub, locate and describe spawning and rearing habitat for squawfish and humpback chub in the Grand Junction, Colorado area, modify river backwaters and gravel pits between DeBeque

Canyon and the mouth of the Green River to enhance endangered fish survival, and assess movements within the Colorado River System by squawfish and humpback chub using radiotelemetry. However, none of this report was found to relate to the Windy-Gap project; it is very similar to the study by Miller, Tyus, and Kaeding (1983).

Minckley, W. L. 1982. Trophic interrelations among introduced fishes in the Lower Colorado River, southwestern United States. Calif. Fish and Game 68:78-89.

Discusses major food sources for fishes and probable areas of competition between native and introduced species in the highly altered environment of the lower basin.

Musker, B. 1981. Results of a fish aging study for the U.S. Fish and Wildlife Service, Salt Lake City, Utah. U.S. Fish Wildl. Serv., Salt Lake City, Utah. 3pp.

An attempt was made to estimate ages of Gila species and Colorado squawfish. The results, reportedly poor, were not presented in the final report of the Colorado River Fishery Project.

Narayanan, R., and D. R. Franklin. 1983. An evaluation of water conservation techniques in the Upper Colorado River Basin. Water Resour. Planning Ser. UWRL/P-82/07, Utah Water Res. Lab., Logan.

Future energy development in the Upper Colorado River Basin (oil shale, natural gas, crude oil, and tar sands) will compete with agriculture for the limited supply of water by bidding up the price of water. Agriculture is

the predominant water-consuming industry of the basin, accounting for 90 percent of total depletions. An economic model was developed to identify which water conservation measures in the agricultural and energy sectors are economically efficient, select the technological process which optimally allocates water from a special point of view, and determine the total cost to the economy of the public sector. Investment in water was found to be greater than the cost of various conservation programs when costs associated with salinity were also considered.

Nicolas, S. J. 1979. Fisheries problems associated with development on the Colorado River. Calif. Fish and Game Dep., Inland Fish. Endang. Species Program, Special Publ. 79-4:1-18.

Federally endangered fishes and their conflicts with water and energy development are addressed in a basin-wide approach.

Nystrom, R. R., and G. Post. 1982. Chronic effects of ammonia-stripped oil shale retort water on fishes, birds, and mammals. Bull. Environ. Contam. Toxic. 28:271-276.

Fingerling rainbow trout were exposed to various concentrations of oil shale retort water from which most of the ammonia had been removed. Concentrations of 125 and 250 ppm caused high mortality.

Ohmart, R. D., W. O. Deason, and C. Burke. 1977. A riparian case history: The Colorado River. Pages 35-47 in Johnson, R. R., and D. A. Jones, eds. Importance, preservation, and management of riparian habitat: A symposium. U.S. Forest Serv. Gen. Tech. Rep. RM-43, Fort Collins, Colo.

Discusses the decline of cottonwood communities on the Lower Colorado River and how historic change in the riparian community of the Colorado River can be used to demonstrate changes in aquatic habitat and predict future impacts of flow changes, agricultural channelization projects, and dam construction.

Paulson, L. J., and J. R. Baker. 1980. Nutrient interactions among reservoirs on the Colorado River. Pages 1647-1656 in Symposium on surface water impoundments. ASCE, Minneapolis, Minn.

Not available for review at press time.

Perry, E. 1978. Rivers of Colorado, ten easy river trips in the mountains, canyons, and plains of Colorado. National Organization for River Sports. 60pp.

With an environmentalist slant, Perry presents general descriptions, brief history, hazards, fish and wildlife species, flows, gauging station access, and ratings of the difficulty (by river mile) for each river section described. Environmental controversies, such as the Cross Mountain-Juniper Project, are also described as they pertain to the rivers. For the uninitiated, invaluable help for planning field schedules includes river guides for an 85.6-km stretch of the Yampa River near Craig, 42.8km of the Colorado River including Horsethief and Ruby Canyons, 75.6km of the Colorado River near Rifle through DeBeque Canyon, 55.8km of the Dolores River above Gateway and 46.2km of the Gunnison River below Delta.

Pettus, D. 1974. Inventory and impact analysis of fishes, Piceance Creek Basin, Rio Blanco and Garfield Counties, Colorado. Thorne Ecol. Inst., Boulder, Colo.

Impact analysis of fishes of the Piceance Creek Basin with respect to oil shale development, including information on the state-threatened Colorado River cutthroat trout, Salmo clarki pleuriticus.

Prewitt, C. G. 1977. Catostomid fishes of the Yampa and White rivers, Colorado. M.S. Thesis, Colo. State Univ., Fort Collins.

Only native suckers were found in the White River, but the non-native white sucker is common in the Upper Yampa River, where hybridization with native flannelmouth sucker occurs, especially in disturbed habitat (channelized river sections).

Prewitt, C. G., B. A. Caldwell, and W. H. Miller. 1982. Completion report, Yampa-White physical habitat study. Colo. River Fish. Proj., U.S. Fish Wildl. Serv., Fort Collins, Colo. 24pp.

Suitability curves are constructed for flow, depth, and temperature for different life stages of Colorado squawfish and then evaluated using incremental methodology to derive weighted usable area and recommended minimum flows for the White and Yampa rivers. The suitability curve for depth for adult Colorado squawfish seems biologically unrealistic, even if it is based on real but limited data. Optimum habitat, suitability of 1.0, is given as 4 ft deep with a decline in suitability (from 0.4 to 0.0) from 5 to 10 ft in depth. The questionable validity of this curve makes analyses which use it highly suspect. There is also inconsistency at the Maybell

site on the Yampa River. The spawning habitat value there is predicted to be quite high based in part on the water depth suitability curve, although habitat for young-of-the-year and adults is judged to be very low (unsuitable, in fact). Although Maybell has been predicted to be a perfect spawning site, extensive sampling through many studies has never turned up evidence of squawfish reproduction there.

Prewitt, C. G., and C. A. Carlson. 1981. An evaluation of four instream flow methodologies. U.S. Bur. Land Manage. Biol. Sci. Ser. 2, Denver, Colo. 65pp.

Four instream flow methodologies are contrasted for selected reaches of the Yampa and White Rivers in Colorado. Use of the weighted usable area approach allowed simulation of flow reductions and their effects on channel catfish and Colorado squawfish.

Proceedings International Society of Petroleum Industry Biologists Symposium. 1982. Land and water issues related to energy development: Denver, Colorado, Sept. 22-25, 1981. Ann Arbor Publ., Ann Arbor, Mich.

Conflicts between agricultural use of water and land and energy development in the West, including northwest Colorado.

Reed, E. B. 1975. Limnological characteristics of strip-mine ponds in northwestern Colorado, U.S.A. Veh. Int. Verein. Limnol. 19:356-865.

Rainbow trout were living in an excavation pit resulting from strip-mining. Limnology of two ponds is described with recommendations for establishing sport fisheries.

Roberts, E. H., and R. W. Dana. 1982. Comparison of three types of remote sensing data for mapping in Grand County Colorado. Pages 801-804 in Brann, T. B., L. O. House and H. G. Lund, eds. In-place resource inventories: Principles and practices. Proceedings of a national workshop, Orono, Maine, 9-14 August, 1981. Soc. Am. For., Washington, D.C.

Digital data from microdensitometer color separation of color infrared aerial photographs and landsat data, both classified for wildlife cover maps using spectral clustering techniques, are compared with maps from intense photointerpretation utilizing ground reference material. Film response calibration techniques are employed, and normalization techniques for lens falloff, illumination variations, and topographic effects are described.

Robins, C. R. et al. 1980. A list of common and scientific names of fishes from the United States and Canada. Am. Fish. Soc. Special Publ. 12, Bethesda, Md. 174pp.

The official reference list of currently accepted names of fishes of the U.S. and Canada. Included is change from humpback to razorback sucker as the common name for Xyrauchen texanus.

Rosenfeld, J. J. 1982. Cytogenetic investigation of the Colorado River Gila complex. Report submitted to U.S. Fish. Wildl. Serv., Salt Lake City, Utah.

The karyotypes of G. cypha (from Colorado River in Black Rocks area, Colorado, and Little Colorado River, Arizona), G. elegans (Lake Mohave), and G. robusta (Gunnison River) were compared. The modal diploid number of 50 chromosomes was found for all three species. G. cypha and G.

elegans appear to differ from G. robusta in the position of the centromere on one pair of chromosomes. The centromere position on this pair is submetacentric (unequal arm lengths) in G. cypha and G. elegans and metacentric (equal arms) in G. robusta.

Smith, G. R., and R. K. Koehn. 1971. Phenetic and cladistic studies of biochemical and morphological characteristics of Catostomus. Systematic Zool. 20:282-297.

Systematic studies of catostomids including Catostomus discobolus, C. latipinnis, C. platyrhynchus, C. catostomus and C. commersoni found in the Upper Colorado River System.

Smith, G. R., R. R. Miller, and W. D. Sable. 1979. Species relationships among fishes of the genus Gila in the Upper Colorado River Drainage. Pages 613-623 in R. N. Lin, ed. Proceedings of the First Conference on Scientific Research in the National Parks, U.S. Nat'l Park Serv. Trans. Proc. Ser. 5.

Objectives of the study were to determine the validity and relationships of the roundtail chub, bonytail, and humpback chub and to find characteristics useful for identifying young and adult Gila robust, G. elegans and G. cypha and possible hybrids. Very few intermediates or "intergrade" specimens were found in the Green River.

Snyder, D. E. 1981. Contributions to a guide to the cypriniform fish larvae of the Upper Colorado River System in Colorado. U.S. Bur. Land Manage. Biol. Sci. Ser. 3, Denver, Colo. 81pp.

A guide to the minnow and sucker species of the Upper Colorado River System. Includes sections on terminology, key characteristics, anatomy of fish eggs and larvae, and a key for larval identification.

Spofford, W. O., A. L. Parker, and A. V. Kneese, eds. 1980. Energy development in the Southwest, problems of water, fish, and wildlife in the Upper Colorado River Basin. Resour. for the Future, Res. Pap. R-18. (2 vol.), Washington, D.C.

This two-volume work contains several chapters by different authors covering aspects of the biotic and abiotic components of the basin, potential energy development scenarios, and possible impacts on flow, water quality, fish, and wildlife.

Stanford, J. A., and J. V. Ward. (in press). The Colorado: North America's desert river. In B. R. Davies and K. F. Walker, eds. Ecology of river systems. Monogr. Biologicae, Dr. W. Junk, The Hague, The Netherlands.

Summarizes geological history, physical-chemical data, and biota of the Colorado River. Reviews impacts of man's regulation of the river in relation to changes in fish fauna.

Stoneburner, D. L. (in press). Observations on the ecology of Colorado squawfish (Ptychocheilus lucius) in the Yampa River, Colorado.

Nat'l Park Serv., Water Resour. Field Support Lab. Tech. Rep., Fort Collins, Colo.

Not available for review at press time.

Stuber, R. J. 1979. An evaluation of two strains of rainbow trout in Dillon Reservoir, Colorado. M.S. Thesis, Colo. State Univ., Fort Collins.

Growth, survival rates, and harvest statistics were compared for the strains of rainbow trout in Dillon Reservoir. Competition between kokanee and fingerling rainbow trout for zooplankton is suggested.

Swanson, G. A. (coordinator). 1979. The mitigation symposium: A national workshop on mitigating losses of fish and wildlife habitats. July 16-20, 1979, Colorado State University, Fort Collins, Colorado, U.S.A. U.S. For. Serv. Gen. Tech. Rep. RM-65, Fort Collins, Colo. 684pp.

Proceedings of a national symposium on mitigation of fish and wildlife habitat, including sections on the Endangered Species Act, energy-fish conflicts in the West, water development-fish conflicts, impact assessment procedures, power projects-fish conflicts, and the mitigation process as viewed by various federal and state natural resources agencies.

Thorne Ecological Institute. 1975. Wildlife and oil shale, a problem analysis and research program. U.S. Fish Wildl. Serv., Vol. I. 112pp.

Conflicts between wildlife and oil shale development and possible mitigation are discussed.

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Three hundred seventy lakes of the Flat Tops Wilderness Area in northwest Colorado are sensitive to acidification if precipitation in the region becomes as acidic as that of the Northeast. Alkalinity values as low as 70 eq l^{-1} (micro equivalents per liter) occur in the higher-altitude lakes.

Twedt, T. M., and P. B. Holden. 1980. The development of the habitat suitability curves and estimation of available habitat for Colorado squawfish in the San Juan River, New Mexico and Utah. PR-46-1 submitted to U.S. Water and Power Resour. Serv. Bio/West, Inc., Logan, Utah. 26pp.

U.S. Fish and Wildlife Service's incremental instream flow methodology used to assess habitat essential for squawfish reproductive success in the San Juan River as a significant area for successful squawfish reproduction.

Tyus, H. M., E. J. Wick, and D. L. Skates. 1982. A spawning migration of Colorado squawfish (Ptychocheilus lucius) in the Yampa and Green rivers, Colorado and Utah, 1981. Proc. Desert Fish. Counc. 8 (in press).

Tracking with radiotransmitters permitted study of Colorado squawfish movements in the Yampa and Green rivers. Eight fish were followed to spawning areas in the Lower Yampa River.

U.S. Fish and Wildlife Service. 1979. Stream and lake evaluation map state of Colorado. U.S. Fish Wildl. Serv., Salt Lake City, Utah. (map)

This updated map classifies streams, rivers, major lakes and reservoirs of the state of Colorado by wild and scenic river status,

endangered/threatened species, major fishing streams, major fishing reservoirs, and high-priority, moderate and limited fishery resources. Water bodies are color-coded by value class with Value Class I status reserved for streams and rivers with documented occurrence of state or federally listed endangered or threatened fishes. In northwest Colorado, the Yampa River, White River, Northwater Creek, Trappers Lake, Gunnison River, Green River, and Colorado River are included in Class I. The upper portions of these drainages are classified as major fishing streams. The evaluation system is superimposed on the base map of Colorado with hydrologic units included.

U.S. Fish and Wildlife Service, various authors. 1982. Final reports of Colorado River Fishery Project to Bureau of Reclamation. Colo. River Fish Proj., U.S. Fish Wildl. Serv., Salt Lake City, Utah.

The results of investigations in 1979-1981 are presented as follows: Part 1, summary report; Part 2, field studies: 1)Green River, 2) Colorado River, Lake Powell to Rifle, 3) Life history of humpback chub in Little Colorado River, 4) Tributary studies--Dolores and Gunnison rivers; Part 3, contract studies: 1) IFG study of physical-chemical habitat conditions on the Green and Colorado rivers in Colorado and Utah; 2) Spawning behavior, habitat selection, and early life history of northern squawfish with inferences to Colorado squawfish; 3) Culture of endangered Colorado River fishes--a. induced spawning and culture of humpback chub and bonytail chub hybrids, b. spawning and culture of Colorado squawfish in a raceway environment, c. spawning of razorback suckers, d. spawning and culture of humpback chub, e. spawning and culture of bonytail chub; 4) Disease survey of Colorado

River fishes; 5) Tolerance and preference of Colorado River endangered fishes to selected habitat parameters; 6) Acute toxicity of selected chemicals, data base; 7) Movement and feeding of adult striped bass, Colorado River inlet, Lake Powell, 1980-1981; 8) Movements of Colorado squawfish in the Colorado River inlet of Lake Powell; 9) Fish stomach content analysis. Ancillary reports have been prepared on the White River for the Bureau of Land Management and on the Yampa River for the National Park Service.

These reports are the most comprehensive data base on endangered fishes in the Upper Colorado River Basin and will form the basis for U.S. Fish and Wildlife Service preparation of a conservation plan designed for preservation and recovery of squawfish and humpback chub.

U.S. Forest Service 1982. Wildlife user guide for mining and reclamation. U.S. For. Serv. Gen Tech. Rep. INT-126, Ogden, Utah. 77pp.

This user guide for wildlife managers covers the biologist's role in mineral area management, legal framework, land-management planning, phases of mining, guidelines for evaluating impacts of mining on wildlife, mitigation measures, and opportunities for wildlife management.

U.S. Geological Survey. 1974. Hydrological unit map 1974, state of Colorado. U.S. Geol. Survey. (map)

This map divides the state of Colorado into hydrologic units on an hierarchical scale that includes region (based on major drainages), subregion (based on subdrainages), accounting unit, and cataloging unit. Political subdivisions using state and county codes are also given. In

northwest Colorado, all waters are in the Upper Colorado region (14), with subregions corresponding to the White-Yampa (05), Green (04), Colorado (01), and Gunnison (02) basins.

U.S. National Park Service. 1979. Draft Wild and Scenic River study and draft environmental statement, Green and Yampa rivers. U.S. Nat'l Park Serv., Washington, D.C.

Draft ES recommending 91 mi. of the Green River and 47 mi. of the Yampa River for inclusion into the Wild and Scenic River System. Dam proposals were evaluated, and recommendations for no federal licenses were made.

U.S. Water and Power Resources Service. 1981. Colorado-Big Thompson Windy Gap Projects, Colorado, Final Environmental Statement. U.S. Water Power Resour. Serv., Denver, Colo. Irregular pagination.

Includes brief discussion of potential impacts to endangered fishes from flow depletions resulting from transbasin diversions.

Utah State Division of Water Resources. 1977. White River Dam and Reservoir. Project summary document. Utah Div. Water Resour., Salt Lake City. 11pp.

The White River Project of Utah is described, including possible impacts on the wide-ranging, rare Colorado River fishes found in the Upper Colorado River Basin.

Valdez, R. A. 1981. Status of the distribution and taxonomy of Gila cypha in the Upper Colorado River. Proc. Desert Fish. Counc. 12:53-60.

The humpback chub recovery plan, identifying five areas of the Colorado River which Gila cypha inhabits, including four in northwestern Colorado from Black Rocks to Palisade, Colorado (80km).

Walburg, C. H., J. F. Novotny, K. E. Jacobs, T. M. Campbell, and W. D. Swink. 1980. Water quality, macroinvertebrates and fisheries in tail waters and streams - an annotated bibliography. Nat'l Reservoirs Res. Program, U.S. Fish Wildl. Serv. Contract Rep. to U.S. Army Eng. Waterways Exp. Station, Vicksburg, Miss. 199pp.

A synthesis and summary of the vast literature on the downstream influence of impoundments.

Walburg, C. H., J. F. Novotny, K. D. Jacobs, W. D. Swink, J. M. Campbell, J. Nestler, and G. E. Saul. 1981. Effects of reservoir releases on the tailwater ecology: A literature review. U.S. Army Eng. Waterways Exp. Station. Tech. Rep. E-81-12, Vicksburg, Miss. 216pp.

Review of the often-contradictory literature describing the effects of reservoir releases on tailwater-environment biota. Contrasts natural streams with tailwaters from warmwater and coldwater impoundments.

Ward, J. V., H. J. Zimmerman, and L. D. Cline. (in press). Lotic zoobenthos of the Colorado River System. In B. R. Davies and K. R. Walker, eds. Ecology of river systems. Mongr. Biologicae, Dr. W. Junk, The Hague, The Netherlands.

The most comprehensive and complete synthesis of information on the invertebrate fauna of the entire Colorado River Basin with emphasis on an ecosystem interpretation.

Weisel, G. F., and H. W. Newman. 1951. Breeding habitats, development and early life history of Richardsonius balteatus, a northwestern minnow. Copeia 3:187-194.

Describes the early life history and spawning behavior of the redside shiner in its native habitat.

Wick, E. J., C. M. Haynes, T. A. Lytle, and D. E. Snyder. 1979. The Colorado Division of Wildlife's Colorado squawfish and humpack chub trend zone monitoring program. Proc. Desert Fish. Counc. 11:100 (abstract only).

Sampling strategies, techniques, and preliminary results in a study designed to determine habitat preferences of early life stages and reproductive success of Colorado squawfish, humpback chub and razorback sucker. Reproductive success was indicated by young squawfish and humpback chub collected near Black Rocks and Ruby Canyon areas of the Colorado River.

Wick, E. J., T. A. Lytle, and C. M. Haynes. 1981. Colorado squawfish and humpback chub population and habitat monitoring. Fed. Aid Endangered Wildl. Program Rep. SE-3-3. Colo. Div. Wildl., Denver. 156pp.

Contains detailed data on fish collections, species, and habitat associations on a section-by-section basis for the Colorado, Yampa, White, and Gunnison Rivers for 1979 and 1980. In 1979, 486 individual collections contained 49,371 fishes. In 1980, 63,061 fishes were identified from 485 collections. Numerous young-of-the-year squawfish were found in the Colorado and Yampa Rivers in 1980.

Wiltzius, W. J. 1983. Historic fish cultural and stocking compendium for Colorado, 1872-1978. Colo. Div. Wildl., Fort Collins. 254pp. (mimeo)

This massive research paper lists Colorado's earliest known fish hatcheries, culturists, fish commissioner reports, introduction dates, federal egg collection stations, and annual stocking summaries for various fishes by state and federal agencies. Many unusual early references are provided.

Woodling, J. 1980. Game fish of Colorado: An identification guide for sport fish commonly caught in Colorado. Colo. Div. Wildl. DOW-M-125-80, Denver. 40pp.

Popular account of the gamefish and protected fishes of Colorado. Color photos of live fish accompany general habitat descriptions and life history information for each species or subspecies described. Of particular interest are the Colorado River cutthroat trout, mountain whitefish, rainbow trout, brook trout, lake trout, kokanee salmon, northern pike, and channel catfish.

Wydoski, R. S., K. Gilbert, K. Seethaeler, C. W. McAda, and J. A. Wydoski. 1980. Annotated bibliography for aquatic resource management of the Upper Colorado River ecosystem. U.S. Fish Wildl. Serv. Resource. Publ. 135. 186 pp.

An extensive annotated bibliography containing 1,109 references with indexed keywords. Current to 1979.

GLOSSARY

Acre-foot - a measure of water volume; that amount which covers one acre to a depth of one foot; one acre-foot is 1,233.49 m^3.

Benthic - refers to organisms living in or on the bottom of a body of water.

Biomass - total weight of a particular species or of all organisms in a particular habitat.

Biota - all living organisms in a region.

Demersal - living on or near the bottom of a body of water.

Detritivore - organism that ingests detritus.

Detritus - fine particulate debris of organic or inorganic origin.

Drift net - gear used to sample stream drift (organisms transported by the current).

Ecology - study of the interrelations between living organisms and their environment.

Electrofishing - collection of fishes by stunning with an electric current.

Endangered, Federal - a species listed by the Secretary of the U.S. Department of the Interior as endangered (in immediate jeopardy of becoming extinct) in the U.S.

Endangered, State - a species listed by the Colorado Wildlife Commission as endangered (in immediate jeopardy of becoming extinct) in Colorado.

Endemic - organisms geographically restricted to one area or drainage basin; e.g., the humpback chub is endemic to the Colorado River Basin.

Extirpated - a species which no longer exists in some part of its historical habitat but is not extinct.

Fyke net - cylindrical fish trap used to sample stream fishes; fish are trapped in a crib.

Genotype - genetic composition.

Gill net - a passive net used to collect fish; specimens are entangled in the net upon colliding with it.

Gold medal waters - waters managed by the Colorado Division of Wildlife to provide anglers an opportunity to catch large trout. Special regulations are in effect.

Guild - a group of species whose resource requirements are very similar, e.g., thermal guild, feeding guild, reproductive guild.

Habitat - place where a particular organism lives.

Hypervolume - an n-dimensional space defined by many niche dimensions; an abstract concept because we cannot visualize a space with more than three dimensions.

In-sutu - in its natural or original position.

Juvenile fish - a stage in development occurring after fins have fully formed but before onset of sexual maturity.

Lacustrine - related to or living in lakes.

Larval fish - a stage in development between times of hatching and full fin differentiation.

Lentic - refers to standing (non-flowing) bodies of water.

Limnology - study of the physical, chemical and biological conditions in fresh waters.

Lotic - refers to flowing-water habitats.

Macrophyte - macroscopic or large forms of vegetation.

MANAGE system - U.S. Fish and Wildlife Service's database management system for biological surveys, bibliographies, map indexes, and water quality data.

Mayfly - a member of the insect order Ephemeroptera; aquatic nymphs are often important fish foods.

Native - species that occur naturally in a given drainage basin; not introduced by man.

Niche - the functional role of an organism; the set of conditions under which an organism exists is its "realized" niche which, e.g., includes its feeding and breeding niches.

Non-native - introduced species including transplants from other drainage basins and from other countries (exotic).

Nuchal - pertaining to the nape of the neck.

Nursery - habitat in which young fish feed and grow.

Otoliths - calcareous concretions in the inner ears of fishes; sometimes used in age determination.

Peduncle - a stalk-like structure as at the base of a fish's tail (caudal) fin.

Piscivore - organism that feeds on fishes.

Pools - the deeper, slowly flowing reaches of a stream in which the substrate is usually soft.

Production (productivity) - the rate at which (fish) biomass is elaborated.

Radiotelemetry (radio tracking) - refers to affixing radio transmitters on or in organisms and using the radio signals to trace movements.

Reach - a sample section of a river or stream including representative habitats such as pools, runs and riffles.

Recruitment - the rate at which new individuals are added to a population.

Redd - spawning area of trout or salmon; usually a cleared depression in bottom gravel.

Riffles - the shallow, fast-flowing, hard-bottomed reaches of a stream.

Ripe - refers to fish (in reproductive condition) from which eggs or milt are flowing.

River mile - distance in miles upstream from an established baseline (usually the river's mouth).

Run - a stream reach that occurs between pools and riffles; deep, fast-flowing water with non-turbulent surface.

Seine - a net used to actively collect fishes; collected specimens are encircled as the net is pulled.

Seston - all living and dead suspended microscopic particulate matter in aquatic habitats.

STORET - U.S. Environmental Protection Agency subsystems for database management of water quality information (STORET I for streams and rivers and STORET II for open water bodies).

Stream order - ranking system related to size; increases as streams of the same order merge from headwaters downstream to large river systems.

Synonymy - a chronological list of scientific names that have been applied to a taxon.

Tailwater (tailrace) - channel or stream below a dam.

Taxon - taxonomic unit or category of organisms.

Taxonomy - the classification of plants and animals.

Taxonomic character - a character used for classification; e.g., number of scales, fin rays, body shape, etc.

Threatened, Federal - a species listed by the U.S. Secretary of the Interior as threatened (in danger of becoming endangered) in the U.S.

Threatened, State - a species listed by the Colorado Wildlife Commission as threatened (in danger of becoming endangered) in Colorado.

Trophic level - refers to the position occupied by an organism in a food web.

Turbidity - cloudiness of water caused by the presence of suspended matter.

Water quality - a term used to describe the chemical, physical and biological characteristics of water with respect to its suitability for a particular use.

WATSTORE - U.S. Geological Survey's computer-assisted database for handling the hydrological data of the United States.

Wild trout fishery - refers to a fishery based on resident trout where hatchery trout have not been stocked.

Year class - fish of a given species which hatched in a given year's cohort.

Young-of-the-year - fish in their first calendar year of life after hatching; synonymous with age group 0 (zero).

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