

Chapter 8 Fish Fauna

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INTRODUCTION

The Rio Grande was recently classified as one of the most endangered or imperiled rivers in North America (American Rivers 1993). Originating in southwestern Colorado, it passes through New Mexico and forms the international boundary between the United States (Texas) and Mexico. In its 2,000+ kilometer course to the Gulf of Mexico it passes through several major impoundments, is used in numerous irrigation diversion dams, and sustains massive groundwater pumping of its aquifer, especially in major metropolitan areas.

This paper addresses the fish fauna of only the Middle Rio Grande Basin. This reach is demarcated at the upstream boundary by the confluence of the Rio Grande and Rio Chama near Española, New Mexico, with the downstream boundary at the headwaters of Elephant Butte Reservoir (fig. 1). Two major mainstream Rio Grande reservoirs, Elephant Butte and Cochiti, were completed in 1916 and 1975, respectively. Within this river-reach lie three major mainstream diversion structures that divert water into 1,280 km of levees, drains, and canals between the town of Algodones and the Bosque del Apache National Wildlife Refuge near Socorro. Two of these diversion dams, Isleta and San Acacia, have the capability under low flow conditions to divert all water from the Rio Grande, thereby potentially eliminating all surface flow from a 177 km reach of river between Isleta and Elephant Butte Reservoir.

In addition to the Rio Chama, two major Rio Grande tributaries drain upper elevation, forested lands of north central New Mexico. The Jemez River enters the Rio Grande from the west just upstream of Bernalillo and the Santa Fe River just below Cochiti Reservoir. Lands drained by these tributaries are primarily under United States Forest Service adminis-

tration and management. Historically, these landscapes were under the moderate influences of the American Indian tribes. However, commencing with the Spanish explorations and evidenced today by the extant Land Grant holdings, human influences have increased markedly since the 1500s. Diversion of surface flow and alteration of streams and rivers coincided with agricultural development and were the beginning of successive modifications to historic stream courses and flows that continue now. Riparian vegetation, especially cottonwood (*Populus*), has declined dramatically with changes in flow (Howe and Knopf 1991). In addition, nonnative plants such as tamarisk and Russian olive have invaded and become a large component of the riparian vegetation.

GENERAL STATUS

Historic collections of fishes by Cope and Yarrow (1875) and Dr. W.J. Koster (former Curator of Fishes, University of New Mexico) provided documentation of a relatively diverse and a largely endemic Middle Rio Grande Basin fish fauna (table 1). Many native species disappeared from the northern portion of the mainstream Middle Rio Grande Basin by the early 1960s. The last collection of two mainstream cyprinids, speckled chub (*Macrhybopsis aestivalis*) and Rio Grande bluntnose shiner (*Notropis simus simus*), was in 1964 just downstream of the present location of Cochiti Dam (Bestgen and Plantania 1988, 1989, 1990; Platania and Bestgen 1988). Rio Grande silvery minnow (*Hybognathus amarus*) is the only endemic short-lived mainstream cyprinid that survives in the Rio Grande in New Mexico (Bestgen and Platania 1991; Cook et al. 1992).

Based on our determinations, of the 45 native and nonnative species of fishes reported in the Middle Rio Grande Basin, only 17 (38 percent) are native and

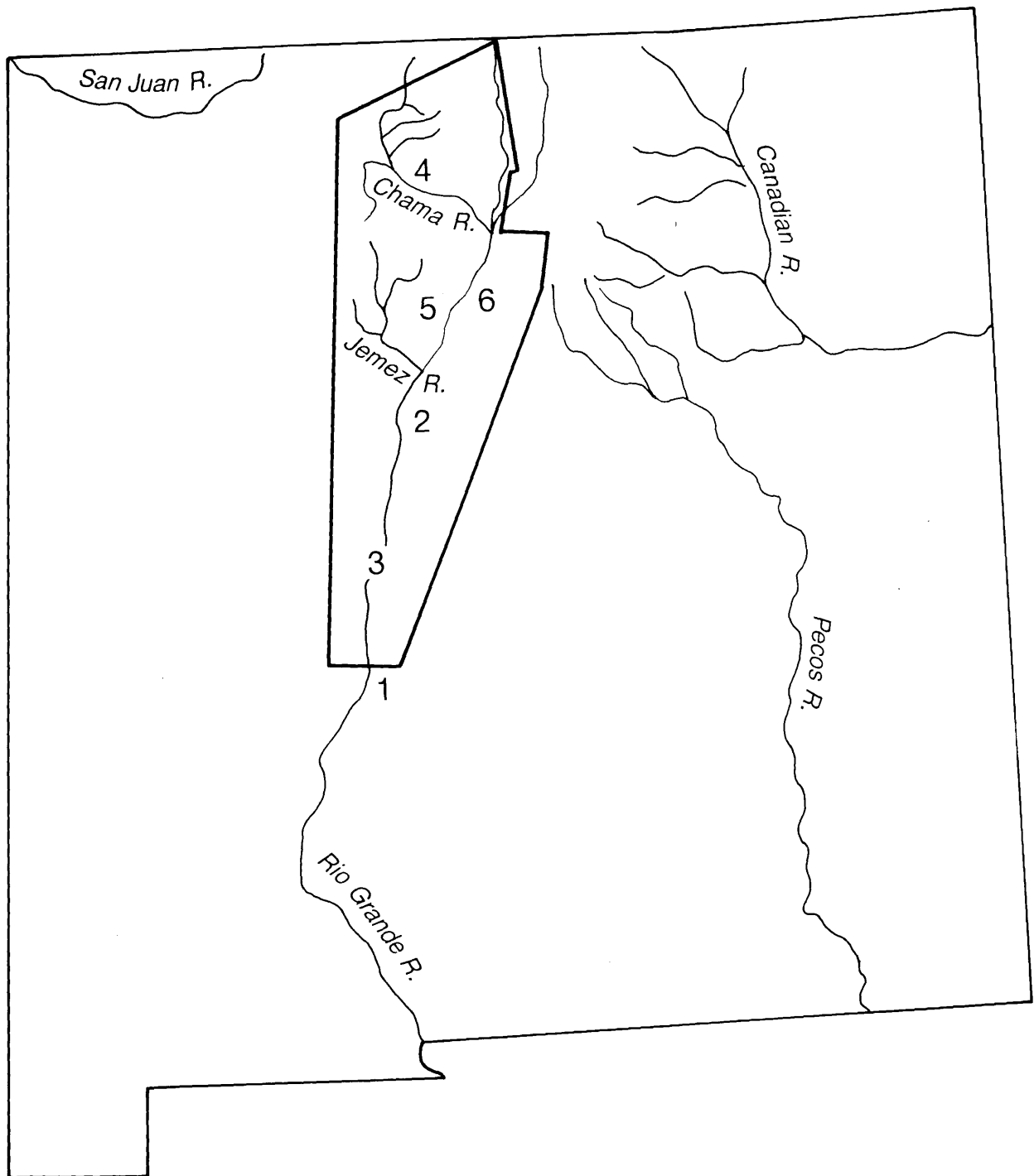


Figure 1.—Hydrologic map of New Mexico indicating the reach of the Rio Grande referred to as the "Middle Rio Grande." Elephant Butte Reservoir (1), Metropolitan area of Albuquerque (2), Santa Fe River (3), Chama River (4), Jemez River (5), and Cochiti Reservoir (6) are indicated.

Table 1.—List of Middle Rio Grande (New Mexico) fishes and their residence status. N = native; I = introduced; En = endemic. Platania determinations are considered to be the most complete and up to date.

Taxa	Middle Rio Grande ^a	Smith and Miller ^b	Sublette et al. ^c	Taxa	Middle Rio Grande ^a	Smith and Miller ^b	Sublette et al. ^c
Acipenseridae				<i>Ameiurus natalis</i>	I	—	I
<i>Scaphirhynchus platyrhynchus</i>	N	N	N	(yellow bullhead)			
(shovelnose sturgeon)				<i>Ictalurus furcatus</i>	N	N	N
Anguillidae				(blue catfish)			
<i>Anguilla rostrata</i>	N	N	N	<i>Ictalurus punctatus</i>	I	—	I
(American eel)				(channel catfish)			
Clupeidae				<i>Pylodictis olivaris</i>	I	—	I
<i>Dorosoma cepedianum</i>	I	—	N	(flathead catfish)			
(gizzard shad)				Salmonidae			
<i>Dorosoma petenense</i>	I	—	I	<i>Oncorhynchus clarki virginalis</i>	En	En	En
(threadfin shad)				(Rio Grande cutthroat trout)			
Cyprinidae				<i>Oncorhynchus mykiss</i>	I	—	—
<i>Camptostoma anomalum</i>	I	—	I	(rainbow trout)			
(central stoneroller)				<i>Salmo trutta</i>	I	—	—
<i>Carassius auratus</i>	I	—	—	(brown trout)			
(goldfish)				<i>Salvelinus fontinalis</i>	I	—	—
<i>Cyprinella lutrensis</i>	N	N	N	(brook trout)			
(red shiner)				Cyprinodontidae			
<i>Cyprinus carpio</i>	I	—	I	<i>Lucania parva</i>	I	—	I
(common carp)				(rainwater killifish)			
<i>Dionda espicopa</i>	I	—	N	Poeciliidae			
(roundnose minnow)				<i>Gambusia affinis</i>	I	—	N
<i>Gila pandora</i>	En	En	En	(western mosquitofish)			
(Rio Grande chub)				Percichthyidae			
<i>Hybognathus amarus</i>	En	En	En	<i>Morone chrysops</i>	I	—	I
(Rio Grande silvery minnow)				(white bass)			
<i>Macrhybopsis aestivalis</i>	N	N	N	Centrarchidae			
(speckled chub)				<i>Lepomis cyanellus</i>	I	—	I
<i>Notemigonus crysoleucas</i>	I	—	—	(green sunfish)			
(golden shiner)				<i>Lepomis gulosus</i>	I	—	I
<i>Notropis jemezianus</i>	En	En	En	(warmouth)			
(Rio Grande shiner)				<i>Lepomis macrochirus</i>	I	—	N
<i>Notropis orca</i>	En	En	En	(bluegill)			
(phantom shiner)				<i>Lepomis megalotis</i>	I	—	I
<i>Notropis simus simus</i>	En	En	En	(longear sunfish)			
(bluntnose shiner)				<i>Micropterus dolomieu</i>	I	—	I
<i>Pimephales promelas</i>	N	N	N	(smallmouth bass)			
(fathead minnow)				<i>Micropterus salmoides</i>	I	—	I
<i>Platygobio gracilis</i>	N	N	N	(largemouth bass)			
(flathead chub)				<i>Pomoxis annularis</i>	I	—	I
<i>Rhinichthys cataractae</i>	N	N	N	(white crappie)			
(longnose dace)				<i>Pomoxis nigromaculatus</i>	I	—	I
Catostomidae				(black crappie)			
<i>Carpiodes carpio</i>	N	N	N	Percidae			
(river carpsucker)				<i>Perca flavescens</i>	I	—	I
<i>Catostomus commersoni</i>	I	—	I	(yellow perch)			
(white sucker)				<i>Stizostedion vitreum</i>	I	—	I
<i>Catostomus (Pantosteus) plebeius</i>	N	N	N	(walleye)			
(Rio Grande sucker)							
<i>Ictiobus bubalus</i>	N	—	N	Number of native species	17	16	21
(smallmouth buffalo)				Number of endemic taxa	6	6	6
Ictaluridae				Number of introduced species	28	—	22
<i>Ameiurus melas</i>	I	—	I	Total number of species	45	—	43
(black bullhead)							

^aDetermination by Platania (1993).

^bDetermination based on Smith and Miller (1986); introduced species not reported.

^cDetermination reported by Sublette et al. (1990).

6 (13 percent) are endemic (table 1) (Platania 1991a, 1991b, 1993; Lang and Altenback 1994; Propst et al. 1987). Sublette et al. (1990) suggested four additional species (gizzard shad, *Dorosoma cepedianum*; roundnose minnow, *Dionda episcopa*; western mosquitofish, *Gambusia affinis*; and bluegill, *Lepomis macrochirus*) were native to this river system. Lee et al. (1980), however, suggested roundnose minnow and bluegill were introduced into the Middle Rio Grande Basin.

We have a more conservative estimate of the number of native fish species and recognize 17 confirmed native species. Of the native species, five have been extirpated from the Middle Rio Grande and two are extinct (table 2). Among the surviving species, the Rio Grande silvery minnow is federally and state listed as endangered (USDI 1993, 1994; New Mexico State Game Commission 1984) and the Rio Grande shiner (*Notropis jemezianus*) is a federal "notice of review" species (USDI 1991). Rio Grande cutthroat trout, *Oncorhynchus clarki virginalis*, the most southerly occurring of the cutthroat trout complex (Behnke 1992), is one of the species addressed in a U.S. Forest Service regional habitat conservation assessment (Rinne 1995c; Young 1995). Bluntnose and phantom shiners (*Notropis orca*) are listed as endangered by the State of New Mexico (Chernoff et al. 1982; New Mexico State Game Commission 1987). In summary, over 40 percent of the native species of the Middle Rio Grande have been eliminated from this reach of river.

Rio Grande cutthroat trout was listed as a Forest Service sensitive species and a "management indicator species" (Stefferdud 1988). The American Fisheries Society listed the subspecies as "protected" (Johnson 1987) and of "special concern" (Williams et al. 1989). Stefferud (1988) has provided the most recent review and description of the management of this cutthroat trout subspecies. In New Mexico, Rio Grande cutthroat trout is considered a sport species and subjected to State Game Commission regulations.

The New Mexico Department of Game and Fish has the legislative mandate to "preserve the natural diversity and distribution patterns of the State's native ichthyofauna" (New Mexico Wildlife Conservation Act 1974). Under this directive, the state has the dual objectives of maintaining Rio Grande cutthroat trout while ensuring that its populations are not diminished to the point of special regulations. The state's program is coordinated with the Forest Service's land and resource management plans (U.S.

Forest Service 1986, 1987). The National Forests, through best management practices, monitor water quality in cutthroat trout streams to meet state water quality standards. Also, the New Mexico Department of Game and Fish initiated a broodstock program in 1987 that is currently being refined (Cowley 1993). Both the New Mexico Department of Game and Fish and the Colorado Division of Wildlife have draft management plans for Rio Grande cutthroat trout (Colorado Division of Wildlife 1992; Stumpff 1992).

As of 1992, 77 populations of Rio Grande cutthroat trout were thought to occur in northern New Mexico in its historic range (Stumpff 1992). Of these, 42 were designated pure populations based on morphometric, meristic, and genetic analyses. The other 35 populations displayed some degree of hybridization with rainbow trout. In Colorado, 39 populations exist, 34 of which are pure. The 20-year effort to accurately document the distribution of Rio Grande cutthroat continues at present. During summer 1994, six new populations of potentially pure Rio Grande cutthroat trout were found through cooperative efforts of the U.S. Forest Service and New Mexico State University.

THREATS TO NATIVE FISH FAUNA

Impacts on Low Elevation, Mainstream Reaches

The principal threats to the remaining Middle Rio Grande fish fauna are water diversion and pumping for municipalities. Annual discharge is generally highest during spring runoff between March and June. By comparison, the period of lowest discharge is from July to October and coincides with peak irrigation demand. During these months the need for irrigation water, combined with the potential lack of precipitation and resulting streamflow, may result in loss of surface flow and drying of extensive reaches of the mainstream river channel. For example, flow in the Rio Grande downstream of Isleta Diversion Dam is mainly the result of significant summer monsoon convectional storms, and is supplemented by unpredictable irrigation return flow. Sustained flow in this river reach sometimes returns only following the termination of irrigation at the end of October. Further, water diversion has been (and continues to be) a factor in reducing both water quantity and quality in upper elevation tributary streams and rivers at the northern extent of the Middle Rio Grande (Rinne, 1995c).

The sporadic and cyclic desiccation and re-wetting of the mainstream Rio Grande channel severely impacts habitat availability, life cycles, and population levels of fishes throughout the Middle Rio Grande. During low-flow periods, fish are often trapped in pools where they may more readily fall prey to in-

troduced game fishes (table 1). Even in absence of predation, fish trapped in intermittent pools may ultimately succumb due to declining water quality prior to re-connection of sustained flows. Fish appear to have a tendency to move upstream during periods of low-flow thereby concentrating populations

Table 2.—Residence (i.e., geographic distribution in the Middle Rio Grande), relative abundance, and legal status of native fishes of the Middle Rio Grande, New Mexico.

Taxa	Residence ^a	Population ^b	Federal ^c	NM ^d
Acipenseridae				
<i>Scaphirhynchus platyrhynchus</i> (shovelnose sturgeon)	N	Exr	—	—
Anguillidae				
<i>Anguilla rostrata</i> (American eel)	N	Exr	—	—
Cyprinidae				
<i>Cyprinella lutrensis</i> (red shiner)	N	C	—	—
<i>Gila pandora</i> (Rio Grande chub)	En	R	—	—
<i>Hybognathus amarus</i> (Rio Grande silvery minnow)	En	R	End	2
<i>Macrhybopsis aestivalis</i> (speckled chub)	N	Exr	—	—
<i>Notropis jemezianus</i> (Rio Grande shiner)	En	Exr	NOR2	—
<i>Notropis orca</i> (phantom shiner)	En	Ext	—	1
<i>Notropis simus simus</i> (bluntnose shiner)	En	Ext	—	—
<i>Pimephales promelas</i> (fathead minnow)	N	C	—	—
<i>Platygobio gracilis</i> (flathead chub)	N	C	—	—
<i>Rhinichthys cataractae</i> (longnose dace)	N	C	—	—
Catostomidae				
<i>Carpiodes carpio</i> (river carpsucker)	N	C	—	—
<i>Catostomus (Pantosteus) plebeius</i> (Rio Grande sucker)	N	R	—	—
<i>Ictiobus bubalus</i> (smallmouth buffalo)	N	R	—	—
Ictaluridae				
<i>Ictalurus furcatus</i> (blue catfish)	N	Exr	—	—
Salmonidae				
<i>Oncorhynchus clarki virginalis</i> (Rio Grande cutthroat trout)	En	R	—	—
Number of native species	17			
Number of extirpated taxa	5	29.4%		
Number of extinct taxa	2	11.8%		
Number of eliminated taxa	7	41.2%		

^aN = native, I = introduced, En = endemic.

^bExr = extirpated from the Middle Rio Grande in New Mexico, Ext = extinct, C = common, R = rare.

^cEnd = endangered, NOR = notice of review classification. Source: U.S. Department of the Interior (1993).

^d1 = Endangered Group 1 classification (endangered), 2 = Endangered Group 2 classification (threatened). Source: New Mexico Department of Game and Fish (1988).

below mainstream diversions. Below these areas, there is not only a greater probability of encountering predation, but also increased disease due to stress. Such concentration and crowding at the base of dams potentially increases the probability of the loss of a major portion of the native fish fauna during natural events such as de-oxygenation or human-caused activities such as spills of toxic materials.

In the mainstream Rio Grande, the number of introduced sport fishes is large (table 1); however, they are not currently considered the major reason for decline of the native species. Game species reach their greatest abundance immediately after cessation of spring runoff and decline in abundance throughout the summer during periods of reduced streamflow and potential loss of surface flow. Predatory species (particularly centrarchids and percichthyids) seem less tolerant than native species of harsh physical-chemical conditions such as decreasing water volumes of intermittent pools, increasing water temperatures, and lowering dissolved oxygen levels.

Of the 10 surviving native fishes of the Middle Rio Grande, five are rare or have relatively restricted distributions. Three of those five taxa (Rio Grande chub, *Gila pandora*; Rio Grande sucker, *Catostomus plebeius*; and Rio Grande cutthroat trout) were known to occur historically, but at unknown abundances, in the mainstream Rio Grande. They are now most abundant in upper elevations, in more cool to cold water tributaries (Koster 1957). The other two species (Rio Grande silvery minnow and smallmouth buffalo, *Ictiobus bubalus*, are warmwater fishes restricted to the mainstream Rio Grande.

Impacts on Upper-Elevation Tributary Rivers and Streams

Rio Grande cutthroat trout evolved with cypriniform (i.e., cyprinid and catostomid) species in middle to upper elevation (2,000–2,600 m) montane streams. It was once widespread in the upper Rio Grande and Canadian River basins of northern New Mexico and south-central Colorado, and in the headwaters of the Pecos Rivers, (Sublette et al. 1990; Behnke 1992). It may have occurred as far south as Chihuahua, Mexico (Behnke 1992). This fish, the only true native coldwater species in the Middle Rio Grande Basin, has been reported from only two mainstream localities downstream of Cochiti Reservoir.

Currently, Rio Grande cutthroat trout is restricted primarily to headwater tributaries within its native

range. Its southernmost distribution is Indian Creek on the Lincoln National Forest and Animas Creek on the Gila National Forest, in southern New Mexico. It ranges north to headwater tributaries of the Rio Grande in the San Juan and Rio Grande National Forests in southwestern Colorado. There are also a few lake and introduced populations (Colorado Division of Wildlife 1992; Stumpff 1992).

Probably the greatest impact on the Rio Grande cutthroat trout has been the introduction of nonnative salmonids, principally rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*) (Behnke 1980, 1992; Behnke and Zarn 1976; Sublette et al. 1990). Of these, rainbow trout, also a spring spawner, readily hybridizes with Rio Grande cutthroat trout. As suggested for other native southwestern trouts (Rinne 1985, 1988; Rinne et al. 1981), the other two salmonid species appear to compete with the Rio Grande cutthroat trout for food and space. Although extensive efforts have focused on the effect of hybridization with rainbow trout, the nature and extent of the effects of competition and predation by other introduced salmonids with native cutthroat trout have been unstudied.

No precise historical data are available on how many kilometers of stream once served as habitat for Rio Grande cutthroat trout. However, the distribution of this subspecies may have declined to only 5–7 percent of its historic range (Stumpff 1992). Because most stocks are now isolated in headwater habitats, gene flow among populations is virtually nonexistent. Winter habitat conditions, stream intermittency, deteriorating water quality conditions resulting from drought and water diversion, and the potential effects of the aftermath of wildfire (Propst et al. 1992) increase the probability of losing more Rio Grande cutthroat trout populations.

An apparently near equal impact is that of habitat degradation and loss. Domestic livestock grazing has occurred on lands surrounding the Middle Rio Grande Basin since the arrival of the Spanish expeditions (Scurlock 1986). By 1830, ranchers were annually herding hundreds of thousands of sheep to supply mining areas of northern New Mexico (Williams 1986). In 1860, 830,000 sheep were being grazed in northern New Mexico; by 1880, that number had increased to about four million.

Currently, livestock grazing is partially controlled by permit on National Forest lands. However, this land use potentially has a major impact on the habi-

tat of Rio Grande cutthroat trout (Behnke and Zarn 1976; Sublette et al. 1990; Behnke 1992). These impacts include trampling of streambanks and removal of streamside vegetation (Platts 1978, 1979, 1981, 1982, 1991). Both undercut banks and streambank vegetation serve as resting and hiding cover for trout (Boussu 1954; Meehan et al. 1991). Loss of streamside vegetation facilitates the elevation of stream temperatures in the summer (Brown and Krygier 1970) and the development of anchor ice in winter. Nevertheless, neither the effects nor extent of grazing on the trout habitat requirements of Rio Grande cutthroat trout have been specifically studied.

Timber harvesting also may affect cutthroat trout habitat through the loss of streamside vegetation and large woody material (Sedell et al. 1991) but these potential impacts also remain undocumented in southwestern streams. Removal of vegetation affects surface runoff and stream hydrographs, and in turn trout habitat and populations (Chamberlin et al. 1991).

Irrigation diversions accompanying the immigration of early settlers into northern New Mexico (Scurlock 1986; Sayles and Williams 1986) resulted in the loss of streams that very likely provided Rio Grande cutthroat trout habitat (Sublette et al. 1990). This dewatering, as an impact on cutthroat populations, has not been studied either.

Cutthroat trout are known for their characteristic low aggression (Nilsson and Northcote 1981), ease of being caught (Behnke 1980), and low vagility (Heggens et al. 1991). Behnke (1992) suggested that brown trout dominated the Rio Chiquito near Taos, New Mexico, because the Rio Grande cutthroat were easier for anglers to catch. However, detailed information on the effects of angling on Rio Grande cutthroat trout are not available.

Introduced species, principally rainbow trout and brown trout and white sucker (*Catostomus commersoni*), to tributary streams may have an even greater impact on the cutthroat trout than does reductions in habitat quantity or quality (Rinne, 1995c). The habitat of the Rio Grande cutthroat has become fragmented because of loss of stream connectivity resulting from the loss of streamflow and habitat quality progressing downstream. The remaining suitable habitats for the Rio Grande native trout appear also suitable for introduced salmonids. Rainbow and brown trout have been either observed or demonstrated to have a detrimental impact on two other native southwestern trouts, Gila trout (*Oncorhynchus gilae*) and Apache trout (*Oncorhynchus apache*) when

they co-occur (Rinne 1985; Rinne and Minckley 1985; Rinne 1988; Rinne 1991a, 1991b; Rinne and Minckley 1991). Hybridization, competition for food and space, and direct predation probably reduce or extirpate local populations and distributions.

Rio Grande sucker co-occur in upper elevation streams with Rio Grande cutthroat trout and Rio Grande chub (*Gila pandora*). White sucker, which is native in New Mexico to the Pecos and Canadian River drainages, has been widely established throughout the New Mexico portion of the Rio Grande (Sublette et al. 1990) where it readily hybridizes with the Rio Grande sucker. The Rio Grande sucker still occurs in many montane tributaries of the Middle Rio Grande (Rinne, 1995b). However, because the Rio Grande sucker was nearly extirpated in the headwaters of the Rio Grande in Colorado, the distributional patterns and interaction mechanisms of the two congeners must be monitored.

The endemic Rio Grande chub is widely distributed throughout the Rio Grande Basin in New Mexico and Colorado and is the most abundant member of the two cypriniform fishes (Sublette et al. 1990; Rinne, 1995a). The Rio Grande sucker is known from only one population in the headwaters in Colorado and has disappeared from several historic localities in northern New Mexico. Habitat degradation competition with the introduced white sucker is most frequently cited as the reason for the decline of the Rio Grande sucker (Sublette et al. 1990).

RESEARCH NEEDS

Warmwater Species

Rio Grande silvery minnow, the last remaining endemic mainstream Middle Rio Grande cyprinid, was recently accorded federal endangered status (U.S. Department of the Interior 1994). This fish historically occurred from near Abiquiu, New Mexico, to the Gulf of Mexico. It now occurs only in about 5 percent of its former range—a reach of stream restricted to the Middle Rio Grande between Cochiti Dam and Elephant Butte Reservoir. Long-term studies designed to determine the species' life history attributes, habitat associations, and relative abundances were initiated in 1987. Additional research activities on reproductive biology and the early life-history of the Rio Grande silvery minnow were initiated in summer 1994.

Cold Water Species

Based on available information, Rinne (1995c) suggested that the following areas of research should be pursued (not listed in order of importance):

1. Distribution and genetic analyses of populations.
2. Habitat (spawning, rearing, over-wintering) evaluation.
3. Effects of introduced salmonids.
4. Basic life history (reproduction, age-growth, production, parasites and diseases, food) delineation.
5. Response of this subspecies to land management activities.
6. Fish-habitat relationships.

Research efforts should be closely meshed and integrated with management plans of the U.S. Forest Service and the management plan for the Middle Rio Grande Basin. Information from the above six areas will facilitate management activities to restore this rare native trout to its former range and abundance. Further, researchers should be opportunistic and proactive in synchronizing research efforts with those of the New Mexico Game and Fish Department and the University of New Mexico.

Extensive efforts have been expended in surveying streams to locate populations of Rio Grande cutthroat trout and determining their genetic purity. A priority should be to continue these efforts. It is critical to know the size and distribution of the resource across the landscape before it can be either properly managed or effectively researched.

The remaining areas of research (i.e., 2–6 above) should be pursued both by cooperative efforts with management agencies and by initiating new independent research efforts. First, the basic life history attributes of the subspecies should be determined. Secondly, the spawning, rearing, feeding, and resting (cover) habitat requirements need to be delineated. The relationships of the subspecies and its habitat also need to be investigated. Simultaneously to this effort should be the study of the effects of land management practices on these life history components. Great efforts should be made to conduct this research in the concept of “ecosystem,” or the newly adopted “ecology-based multiple use management” philosophy in Region 3 (U.S. Forest Service 1992).

Finally, research needs to be conducted on whether and how introduced salmonids (principally brown

and rainbow trout) limit Rio Grande cutthroat trout populations. In addition, interactions of the Rio Grande cutthroat trout with the other members of the native fish community should be investigated.

REFERENCES

- American Rivers. 1993. The nation's ten most endangered rivers and fifteen most threatened rivers for 1993. American Rivers, Washington, D.C. 51 p.
- Behnke, R.J. 1980. Report on collections of cutthroat trout from north-central New Mexico. Report to New Mexico Department of Game and Fish. 19 p.
- Behnke, R.J. 1992. Native trout of western North America. American Fisheries Society Monograph 6.
- Behnke, R.J.; Zarn, M. 1976. Biology and management of threatened and endangered western trout. Gen. Tech. Rep. RM-28. Ft. Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station.
- Bestgen, K.R.; Platania, S.P. 1988. The status of bluntnose and phantom shiner in the Rio Grande drainage of New Mexico. Report to New Mexico Department of Game and Fish, Santa Fe, NM. 91 p.
- Bestgen, K.R.; Platania, S.P. 1989. Inventory and microhabitat association of fishes of the Middle Rio Grande, New Mexico: Year I Progress report: Survey of the fishes and their habitats in the middle Rio Grande and in the low-flow conveyance canal. Report to the New Mexico Department of Game and Fish (Contract 516.6-74-23) and U.S. Bureau of Reclamation (Intergovernmental Agreement 8-AG-53-06920). 36 p.
- Bestgen, K.R.; Platania, S.P. 1990. Extirpation and notes on the life history of *Notropis simus simus* and *Notropis orca* (Cypriniformes: Cyprinidae) from the Rio Grande, New Mexico. Occ. Pap. Museum of Southwestern Biology. 6: 1–8.
- Bestgen, K.R.; Platania, S.P. 1991. Status and conservation of the Rio Grande silvery minnow, *Hybognathus amarus*. Southwestern Naturalist. 36(2): 225–232.
- Boussu, M.F. 1954. Relationship between trout populations and cover on a small stream. Journal of Wildlife Management. 18: 229–239.
- Brown, G.W.; Krygier, J.T. 1970. Effects of clear-cutting on stream temperature. Water Resources Research. 6: 1133–1139.
- Chamberlin, T.W.; Harr, R.D.; Everest, F.H. 1991. Timber harvesting, silviculture, and watershed processes. 181–206 pp. In: Meehan, W.R., ed. Influences

- of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Spec. Publ. 19, Bethesda, MD.
- Chernoff, B.; Miller, R.R.; Gilbert, C.R. 1982. *Notropis orca* and *Notropis simus*, cyprinid fishes from the American Southwest, with description of a new subspecies. Occ. Pap. Mus. of Zoology, Univ. of Michigan. 698: 1-49.
- Colorado Division of Wildlife. 1992. Rio Grande cutthroat trout management plan. Denver, CO.
- Cook, J.A.; Bestgen, K.R.; Propst, D.L.; Yates, T.L. 1992. Allozymic divergence and systematics of the Rio Grande silvery minnow, *Hybognathus amarus* (Teleostei: Cyprinidae). Copeia. 1992: 36-44.
- Cope, E.D.; Yarrow, H.C. 1875. Report upon the collections of fishes made in portions of Nevada, Utah, California, Colorado, New Mexico, and Arizona, during 1871, 1872, 1873, and 1874. Report of the Geographic and Geologic Exploration Survey West of the 100th Meridian (Wheeler Survey). 5(6): 637-700.
- Cowley, D.E. 1993. Strategies for development and maintenance of a hatchery broodstock of Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*). Report to New Mexico Game and Fish Department (Prof. Serv. Contract 94-516-34), figures and tables. 41 p.
- Crawford, C.S.; Culley, A.C.; Lutheuser, R.; Sifuentes, M.S.; White, L.H.; Wilber, J.P. 1993. Middle Rio Grande ecosystem: bosque biological management plan. U.S. Fish and Wildlife Service Report. 291 p.
- Hatch, M.D. 1985. Native fishes of the Major Drainages east of the Continental Divide, New Mexico. Eastern New Mexico University, Portales, New Mexico. M.S. Thesis. 85 p.
- Heggens, J.; Northcote, T.G.; Peter, A. 1991. Spatial stability of cutthroat trout (*Oncorhynchus clarki*) in a small, coastal stream. Can J. Fish. Aquat. Sci. 48: 757-762.
- Howe, W. H.; Knopf, F.L. 1991. On the imminent decline of Rio Grande cottonwoods in central New Mexico. Southwestern Naturalist. 36(2): 218-224.
- Johnson, J.E. 1987. Protected fishes of the United States and Canada. American Fisheries Society, Bethesda, MD.
- Koster, W.J. 1957. Guide to the fishes of New Mexico. Univ. New Mexico Press, Albuquerque, NM. 116 p.
- Lang, B.K.; Altenbach, C.S. 1994. Ichthyofauna of the Middle Rio Grande Conservancy District irrigation system: Cochiti Dam to Elephant Butte State Park, July-August 1993. Report to U.S. Bureau of Reclamation, Albuquerque Projects Office, Albuquerque, NM. 87 p.
- Lee, D.S.; Gilbert, C.R.; Hocutt, C.H.; Jenkins, R.E.; McAllister, D.E.; Stauffer Jr. J.R. 1980. Atlas of North American Freshwater Fishes. North Carolina State Museum of Natural History, Raleigh, NC. 852 p.
- Meehan, W.R., ed. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Spec. Publ. 19: 1-751.
- New Mexico Department of Game and Fish. 1987. Operation Plan: Management of New Mexico Aquatic Wildlife. Santa Fe, NM. 188 p.
- New Mexico Department of Game and Fish. 1988. Handbook of species endangered in New Mexico. Santa Fe, NM.
- Nilsson, N.A.; Northcote, T.G. 1981. Rainbow trout (*Salmo gairdneri*) and cutthroat trout (*S. clarki*) interactions in coastal British Columbia lakes. Can J. Fish. Aquat. Sci. 38: 1228-1246.
- Platania, S.P. 1991a. Fishes of the Rio Chama and upper Rio Grande, New Mexico, with preliminary comments on their longitudinal distribution. Southwestern Naturalist. 36(2): 186-193.
- Platania, S.P. 1991b. Interim report of the middle Rio Grande Fishes Project: Inventory and Habitat Associations of the fishes of the Middle Rio Grande, New Mexico. Survey of the fishes in the Upper reach of the Middle Rio Grande. Report to the New Mexico Department of Game and Fish (contract 516.6-74-23) and U.S. Bureau of Reclamation (co-operative agreement O-FC-40-08870).
- Platania, S.P. 1993. The fishes of the Rio Grande between Velarde and Elephant Butte Reservoir and their habitat associations. Report to the New Mexico Department of Game and Fish (contract 516.6-74-23) and U.S. Bureau of Reclamation (co-operative agreement O-FC-40-08870). 188 p.
- Platania, S.P.; Bestgen, K.R. 1988. A survey of the fishes in a 8 km reach of the Rio Grande below Cochiti Dam, July, 1988. Report to the U.S. Army Corps of Engineers, Albuquerque District. Albuquerque, NM. 23 p.
- Platts, W.S. 1978. Livestock interactions with fish and their environments: A symposium summary. Calif.-Nevada Wildl. Trans. 1978: 92-96.
- Platts, W.S. 1979. Livestock grazing and riparian-stream ecosystems: An overview. In: O.B. Cope, ed. Grazing and riparian-stream ecosystems: A forum. Trout Unlimited, Inc: 39-45.
- Platts, W.S. 1981. Effects of sheep grazing on a riparian-stream environment. U.S. Department of Agriculture

- ture, Forest Service, Res. Note INT-307: 1-6. Ogden, UT: U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station.
- Platts, W.S. 1982. Livestock and riparian fishery interactions: what are the facts? Trans. N. A. Wildl. and Nat. Res. Conf. 47: 507-515.
- Platts, W.S. 1991. Livestock grazing. In: Meehan, W.R., ed. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Spec. Publ. 19., Bethesda, MD. 389-424.
- Propst, D.L.; Burton, G.L.; Pridgeon, B.H. 1987. Fishes of the Rio Grande between Elephant Butte and Caballo Reservoirs, New Mexico. Southwestern Naturalist. 32(3): 408-411.
- Propst, D.L.; Stefferud, J.A.; Turner, P.R. 1992. Conservation and status of Gila trout. Southwestern Naturalist. 37: 117-125.
- Rinne, J.N. 1985. Livestock grazing effects on southwestern streams: A complex research problem. In: Johnson, R.R. et al., tech eds. Proceedings First North American Riparian Conference. Riparian ecosystems and their management: reconciling and conflicting uses. Gen. Tech. Rep. RM-120. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station: 295-299.
- Rinne, J.N. 1988. Grazing effects on stream habitat and fishes: research design considerations. North American Journal Fisheries Management. 8(2): 240-247.
- Rinne, J.N. 1991a. Apache trout. In: Stoltz, J., ed. Trouts in North America. Stackpole Books, Harrisburg, PA. 178-183.
- Rinne, J.N. 1991b. Gila trout. In: Stoltz, J., ed. Trouts in North America. Stackpole Books, Harrisburg, PA. 274-279.
- Rinne, J.N. 1995a. Reproductive biology of the Rio Grande chub, *Gila pandora* Teleostomi: (Cypriniformes) in a montane stream, New Mexico. Southwestern Naturalist. 40(1): 107-110.
- Rinne, J.N. 1995b. Reproductive biology of the Rio Grande sucker, *Catostomus plebeius*, Teleostomi: (Cypriniformes) in a montane stream, New Mexico. Southwestern Naturalist. 40(2): 237-241.
- Rinne, J.N. 1995c. Rio Grande cutthroat trout, pp. 24-27. In: Young, M. L., tech. ed. Conservation assessment for inland cutthroat trout. Gen. Tech. Rep. RM-GTR-256. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station. 61 p.
- Rinne, J.N.; Minckley, W.L. 1985. Patterns of variation and distribution in Apache trout (*Salmo apache*) relative to co-occurrence with introduced salmonids. Copeia. 1985(2): 285-292.
- Rinne, J.N.; Minckley, W.L. 1991. Native fishes of arid lands: a dwindling resource of the desert Southwest. Gen. Tech. Rep. RM-206. Ft. Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station..
- Rinne, J.N.; Minckley, W.L. Hansen, J.N. 1981. Chemical treatment of Ord Creek, Apache County, Arizona, to re-establish Arizona trout. Arizona-New Mexico Academy of Sciences. 16: 74-78.
- Sayles S.; Williams, J.L. 1986. Land Grants. In: Williams, J.L., ed. New Mexico in Maps, 2nd Edition. Univ. New Mexico Press, Albuquerque, NM. 105-107.
- Scurlock, D. 1986. Settlement and Missions. In: Williams, J.L., ed. New Mexico in Maps, 2nd Edition. University of New Mexico, Albuquerque, NM. 92-94.
- Sedell, J.R.; Leone, F.N.; Duval, W.S. 1991. Water transportation and storage of logs. In: Meehan, W.R., ed. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Spec. Publ. 19, Bethesda, MD. 325-368.
- Smith, M.L.; Miller, R.R. 1986. The evolution of the Rio Grande Basin as inferred from its fish fauna. In: Hocutt, C.H., and Wiley, E.O., eds. Zoogeography of North American Freshwater Fishes. John Wiley and Sons, New York. 866 p.
- Stefferd, J.A. 1988. Rio Grande cutthroat trout management in New Mexico. In: Gresswell, R.E., ed. Status and management of interior stocks of cutthroat trout. American Fisheries Society, Bethesda, MD.
- Stumpff, W.K. 1992. Stabilization of native trout populations. Fed. Aid Rep. F-22-R-33: 1-20.
- Sublette, J.E.; Hatch, M.D.; Sublette, M. 1990. The fishes of New Mexico. University of New Mexico Press, Albuquerque. NM. 393 p.
- U.S. Department of Interior. 1991. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species, proposed rule. Fed. Reg. 58(38): 58804-58836.
- U.S. Department of Interior. 1993. Endangered and threatened wildlife and plants; Proposed rule to list the Rio Grande silvery minnow as endangered, with critical habitat. Fed. Reg. 58(38): 11821-11828.
- U.S. Department of Interior. 1994. Endangered and threatened wildlife and plants: Final rule to list the Rio Grande silvery minnow as an endangered species. Fed. Reg. 59(138): 36988-36995.

- U.S. Forest Service. 1986. Carson National Forest Plan. Taos, New Mexico.
- U.S. Forest Service. 1987. Santa Fe National Forest Plan. Santa Fe, NM.
- U.S. Forest Service. 1992. Ecology-based multiple use management. Albuquerque, NM.
- Williams, J. 1986. Ranching and conflicts. In: Williams, J.L., ed. New Mexico in Maps, 2nd. Univ. New Mexico Press, Albuquerque, NM. 12-122.
- Williams, J.E. et al. 1989. Fishes of North America endangered, threatened, or species of special concern: 1989. Fisheries (Bethesda). 14(6): 2-21.
- Young, M. L. 1995. Conservation assessment for inland cutthroat trout. Gen. Tech. Rep. RM-GTR-256. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station. 61 p.