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Kevin R. Bestgen

Steven P. Platania

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# Extirpation of *Notropis simus simus* (Cope) and *Notropis orca* Woolman (Pisces: Cyprinidae) from the Rio Grande in New Mexico, with Notes on Their Life History

KEVIN R. BESTGEN AND STEVEN P. PLATANIA

## Abstract

The Rio Grande bluntnose shiner, *Notropis simus simus*, and the phantom shiner, *Notropis orca*, once occupied warmwater reaches of the Rio Grande in New Mexico, but have not been collected there since 1964 and 1949, respectively. *Notropis s. simus* was widespread and common until 1950; *N. orca* was apparently never abundant. Our collections indicated that both forms are extirpated from New Mexico, and each may be extinct. Two other cyprinids, Rio Grande shiner, *Notropis jemezanus*, and speckled chub, *Hybopsis aestivalis*, also disappeared from the Rio Grande around 1949 and 1964, respectively. A fifth cyprinid, the Rio Grande silvery minnow, *Hybognathus amarus*, is presently reduced in distribution and abundance.

Irrigation withdrawals and mainstream dams altered natural discharge patterns of the Rio Grande prior to 1930 and probably reduced populations of this suite of mainstream fishes. Drought and increased water withdrawal after 1950 periodically dried extensive reaches of warmwater Rio Grande habitat and probably eliminated remaining small populations of the aforementioned species except *H. amarus*. Life history attributes of *N. s. simus*, and the distribution and habitat of all of the other extirpated forms do not indicate special requirements other than a flowing mainstream environment. Short-lived fishes that occupy exclusively mainstream riverine environments are especially susceptible to extirpation when flow regimes are altered.

## INTRODUCTION

The Rio Grande bluntnose shiner, *Notropis simus simus* (Cope), and the phantom shiner, *Notropis orca* Woolman, are two little-known, endemic species from the Rio Grande drainage whose taxonomy was only recently clarified (Chernoff et al. 1982). *Notropis s. simus* occurred historically in the Rio Grande from north-central New Mexico to El Paso, Texas, while *N. orca* was distributed from central New Mexico downstream throughout most of the mainstream Rio Grande to the Gulf of Mexico (Chernoff et al. 1982). The Rio Grande from El Paso downstream to its confluence with the Pecos River was not extensively sampled prior to the work by Hubbs et al. (1977), so little is known of the historic distribution and status of native fishes in that area.

Recent surveys in limited portions of the Rio Grande in New Mexico (Propst et al. 1987; Platania, in press; C.W. Painter, pers. comm.) indicated that the native fauna had declined. The lack of recent specimens led Chernoff et al. (1982)

to presume that *N. s. simus* and *N. orca* were extinct. Our charge was to determine if *N. orca* and *N. s. simus* still existed in the Rio Grande drainage in New Mexico and to identify probable reasons for decline of these species and other small cyprinids there. We discuss changes in historic flow patterns of the Rio Grande in New Mexico and provide notes on the life history of *N. s. simus* and *N. orca.*

## STUDY AREA

The Rio Grande originates in southern Colorado and flows south through New Mexico for approximately 750 km (U.S. Geological Survey 1889–1988). The Rio Chama empties into the Rio Grande in the vicinity of Española and is the only major tributary in New Mexico (Fig. 1). Elevation in the study area ranges from 3,962 m peaks in the Sangre de Cristo Mountains to about 1,219 m where the Rio Grande exits the state. Vegetation varies from spruce-fir communities at higher elevations to Chihuahuan desert-scrub associations at lower elevations (Brown 1982). Precipitation also varies with elevation but the Rio Grande flows mostly through an arid region with annual precipitation of <25 cm/year.

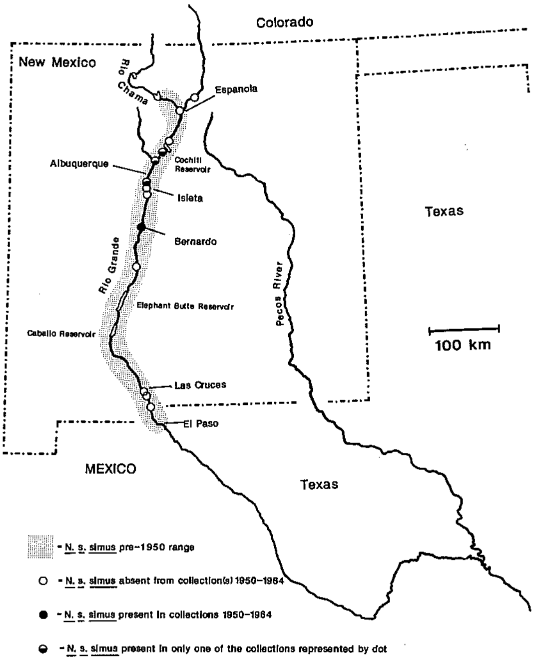

Figure 1. Rio Grande, New Mexico, study area and distribution of *Notropis simus simus*. Circles represent collection localities after 1950 (1–4 collections/locality, N = 24 total).

Aquatic habitats in the Rio Grande drainage in New Mexico exhibit a gradient from small, cold, high-elevation streams with large substrate particles and salmonid-dominated fish communities to downstream reaches that are 50–250 m wide, sandy, and support warmwater fish communities. The Rio Grande downstream of Albuquerque changes from a usually perennial system with mixed substrate types to an ephemeral, predominantly sand substrate, river. Diminished flows have contributed to extensive sand deposition in the Rio Grande. Habitat in warmwater reaches is mostly shallow runs <1 m deep; pools and riffles are less common. Just downstream from mainstream storage reservoirs, water is clear and cool, and substrate particles are large.

From Cochiti Reservoir downstream to Elephant Butte Reservoir, the Rio Grande is partially channelized, but it does meander in a somewhat natural fashion between levee banks. Downstream of Caballo Reservoir, the Rio Grande is highly modified and constricted to a single narrow channel. South of Albuquerque, the banks of the Rio Grande are lined with dense growths of non-native saltcedar, *Tamarix pentandra,* and Russian olive, *Eleagnus angustifolia;* few native Rio Grande Valley cottonwoods, *Populus fremontii,* remain. The deep root systems of non-native riparian tree species constrain flows within the banks which serves to further channelize the river.

Most streamflow derives from high elevation snowpack in north-central New Mexico and southern Colorado; summer thunderstorms and transmountain diversions from the San Juan River drainage provide additional flow. High flows follow snowpack melt in spring and low flows occur in late summer and fall during the irrigation season (Fig. 2). During our study, discharge was high throughout 1986 and most of 1988, and the Rio Grande was perennial throughout New Mexico. In 1987, discharge was also high through July, but by September, several dry reaches (10–15 km) were observed from Isleta to Elephant Butte Reservoir.

Flows are highly regulated as five mainstream reservoirs occur on the Rios Chama and Grande and numerous smaller irrigation diversion

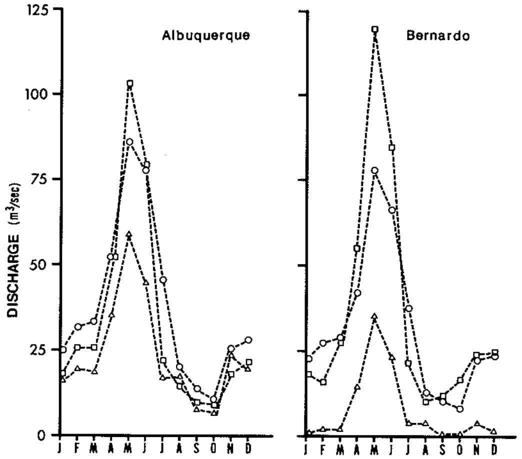

Figure 2. Mean monthly discharge of the Rio Grande at Albuquerque and downstream from Isleta at Bernardo. Squares represent 1940–1950, triangles 1951–1973, and circles 1974–1988 time periods.

dams occur throughout the drainage. A complex system of ditches, drains, and conveyance canals is maintained to provide extensive irrigated agriculture in the Rio Grande Valley. In the early 1950's, two conveyance canals were constructed along the Rio Grande from near Isleta downstream to Elephant Butte Reservoir. These canals were designed to carry all middle Rio Grande discharge <63 m$^3$/s to Elephant Butte Reservoir. Thus, flows bypass the mainstream during all but the highest flow periods. Conveyance canal operations were suspended in the mid-1970's; high flows in the Rio Grande and the rising level of Elephant Butte Reservoir has restricted recent use of these canals.

## METHODS

Collections were made from 1986 to 1988 primarily with small mesh (1.6–6.4 mm), 3–5 m long seines. A backpack electrofishing unit was occasionally used in small, clear, high-elevation streams. We attempted to collect in all available habitats (e.g., pools, riffles, runs, and backwaters) at each collection site. Specimens were fixed in 10% formalin, preserved in alcohol, and deposited at the University of New Mexico in the Division of Fishes, Museum of Southwestern Biology (MSB). Most fish >250 mm total length (TL) were identified, enumerated, and released.

We obtained data on historic fish distribution and abundance from the Fish Database of the New Mexico Department of Game and Fish (NMGF), from published and unpublished literature, and from museum specimens. Museum acronyms follow Leviton et al. (1985). Because *N. orca* was only recently recognized as distinct from *N. simus,* MSB collections of *N. s. simus* containing 68 specimens not examined by Chernoff et al. (1982) were re-analyzed for additional specimens of *N. orca* (MSB lots 1386, 1397, 1398, 1399, 1401, 1404, 1406, 1407, 1408, 1409, 1410, 2455, and 3628). Only small numbers of museum specimens of *N. s. simus* were available for analysis of reproductive and diet characteristics. Somatic body mass of each specimen used for reproductive studies was determined to the nearest 0.01 g after removal of gonads and the digestive tract. The ovaries of 16 *N. s. simus* from prespawning-season collections (MSB 1387b, N = 15, 9 June 1939; MSB 1405, N = 1, 19 June 1939) were examined. The gonosomatic index (GSI) was calculated as the ratio of ovary weight to somatic body mass. Eggs from a weighed subsample (15–42%) of the ovary were counted, and fecundity was calculated by proportion. The number of eggs in the largest size class ($\geq$0.70 mm diameter) of each subsample were counted separately. Clear, nucleated oocytes 0.05–0.13 mm in diameter were not considered in fecundity estimates but were counted in a single specimen. Eggs in a subsample from two specimens were measured and the diameters plotted on a histogram to delimit modes of developing eggs. Eggs were not uniformly round so diameters were measured as they were randomly encountered on the petri dish.

Age-growth characteristics were derived from histogram plots of standard lengths (SL) for large collections and ages were assigned according to separation between length modes. Separation of year-classes was verified by independent scale analysis. Fish are considered Age 0 from the time they hatch until January 1 of the following year. On that date they become Age I individuals and fish that were Age I become Age II.

Excised digestive tracts were measured, and gut length was calculated as a percentage of SL. Food items were identified and enumerated and the percent volume of each food type was visually estimated for each specimen.

## RESULTS

Collection sites were distributed from near the Colorado–New Mexico border in the Rios Chama and Grande downstream to the Texas–New Mexico border; canal habitats were occasionally sampled. A total of 203 collections was made, with as many as three made at localities of historic occurrence for *N. s. simus* and *N. orca*. Neither *N. s. simus* nor *N. orca* was taken, and we consider both forms extirpated from the Rio Grande in New Mexico. Speckled chub, *Hybopsis aestivalis* (Girard), and Rio Grande shiner, *Notropis jemezanus* (Cope), were not collected and are also presumed extinct in the study area. Shovelnose sturgeon, *Scaphirhynchus platorynchus* (Rafinesque), and American eel, *Anguilla rostrata* (Lesueur), are native to the study area, but are also considered extirpated (Koster 1957, Smith and Miller 1986, Propst et al. 1987).

We attempted to reconstruct patterns of depletion and dates of extirpation for mainstream Rio Grande cyprinid fishes from museum collections. The type collection of *N. s. simus* (lectotype, USNM 16982, N = 1, 1874; paralectotypes, USNM 227343, N = 69, 1874) at Otowi Bridge near Española, New Mexico, and two collections in the Rio Chama in 1949 (MSB 1398, N = 1; MSB 1400, N = 13) are the only known sites of occurrence for *N. s. simus* upstream of present-day Cochiti Reservoir. Collections indicate that *N. s. simus* was extirpated from the type locality by 1943. The fate of *N. s. simus* in the Rio Chama remains speculative. That population was peripheral, apparently small, and was probably extirpated around 1943 because of upstream dam construction on the Rio Chama.

Only 11 *N. s. simus* from five collections are known from the Rio Grande in New Mexico, downstream of Caballo Reservoir. The species was apparently extirpated from that reach by 1940.

*Notropis s. simus* was historically most abundant in the middle Rio Grande in New Mexico, from just upstream of Albuquerque downstream to Bernardo, a distance of about 95 km. The largest collections (MSB 1387b, N = 375, 1939; MSB 1403, N = 87, 1949; UMMZ 125064, N = 80, 1939) were taken in the Rio Grande near or at the Isleta Diversion Dam. All other collections in the Albuquerque–Bernardo reach (N = 19) are represented by 25 or fewer individuals. It appears as though *N. s. simus* was moderately abundant in the middle Rio Grande until at least 1949.

From 1950 to 1964, the 24 collections made within the historic range of *N. s. simus* indicated that its distribution and abundance had declined severely. In that period, 15 of those collections were made in the reach from Cochiti Reservoir downstream to Isleta, but only 11 *N. s. simus* were taken in four collections. The last specimen was collected in 1964 (TU 35683, N = 1) near Peña Blanca, New Mexico, just below present-day Cochiti Reservoir.

Historic collection records suggested that *N. s. simus* occupied mainstream habitats in the Rios Chama and Grande. Koster (1957) stated that *N. s. simus* was especially common below diversion dams. During our collections, and presumably when *N. s. simus* and *N. orca* were extant, scour below such structures removed fine substrate particles. This created a short reach of deeper habitat with gravel and cobble substrate, whereas, just up- and downstream, habitats were shallower and had sand substrata.

Our largest and most diverse collections came from below diversion dams when river flow was reduced. Rio Grande fishes apparently colonize habitat below diversion dams during low flows, as fish abundance below diversion dams is much greater than in downstream reaches with reduced flow. During higher flows, fish abundance below diversion dams appeared little different than just up- or downstream.

Occasional pre-1964 collections of one or a few *N. s. simus* from various canals and drainage ditches suggested that bluntnose shiners occupied habitats other than those in the mainstream. It was noteworthy, however, that only subadult and adult fish (>34 mm SL) were taken from such habitats.

Little else is known regarding specific habitat requirements of *N. simus*. Pecos bluntnose shiner, *N. s. pecosensis* Gilbert and Chernoff, were found in all available habitats in the Pecos River but adult fish occupied mostly mainstream runs (Hatch et al. 1985).

Reproductive data obtained from museum specimens of *N. s. simus* indicated that spawning was initiated from mid-June to mid-July following declines in spring runoff when water temperature was increasing. The restricted size ranges of Age 0 and Age I fish (Fig. 3) and the distinctly

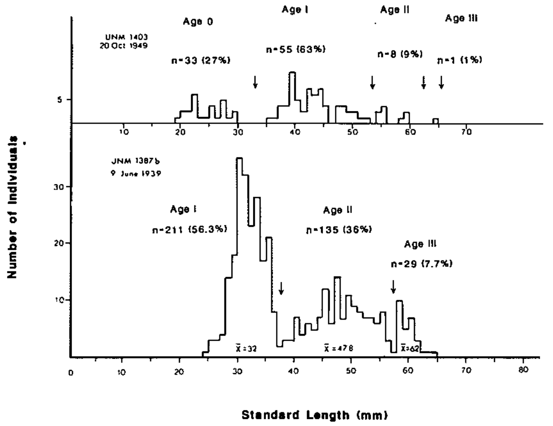

Figure 3. Length frequency histogram and age composition for two collections of *Notropis simus simus* from the Rio Grande, New Mexico.

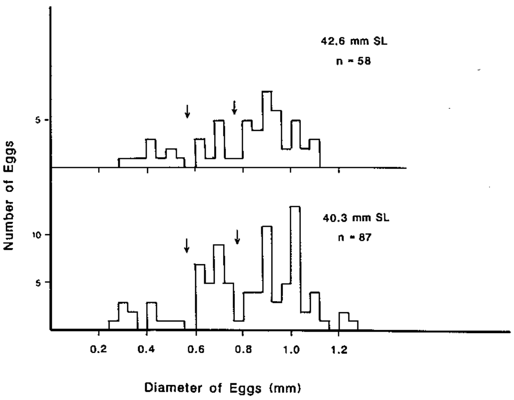

Figure 4. Frequency distribution of egg diameters from two *Notropis simus simus* from the Rio Grande, New Mexico.

separate modes between year-classes suggested a spawning season of 4–6 weeks. Occasional extended spawning may also have occurred. One of five adult females examined from a fall collection (MSB 1410, 14 September 1941) contained maturing eggs. Three small specimens (MSB 3638, x̄ = 15.8 mm SL, 14.1–17.6 mm SL) collected on 28 April 1956 in the middle Rio Grande were probably from spawns in late autumn of the previous year. Ripe ova found in specimens of *N. s. pecosensis* collected in September (Hatch et al. 1985) indicated extended spawning.

Maturity of female *N. s. simus* appeared to be dictated by size and age. Six Age I females (33–37 mm SL) were immature (GSI <2%), while 10 specimens ≥Age II and >40 mm SL all had large ovaries and maturing ova. Mean GSI for the 10 mature females was 31.2% (range = 17.5–43.2%).

The size of eggs in the ovaries of 10 ripe fish varied substantially. A histogram plot of the diameters of a random sample of developing eggs from two specimens (Fig. 4) indicated that as many as three distinct modes existed. The first mode consisted primarily of small, opaque to white eggs 0.25–0.56 mm, while the second mode was white to pale-yellow and 0.60–0.72 mm. The most mature third mode consisted of eggs 0.70–1.28 mm and were dark yellow-orange. Hatch et al. (1985) reported a similar size range for mature eggs from a single *N. s. pecosensis*.

Fecundity of female *N. s. simus* appeared related to body size. The correlation between SL and total (eggs ≥0.25 mm) fecundity [y = x̄(0.013) + 25.8; r = 0.91] was slightly higher than that for SL and fecundity of the largest (≥0.70 mm) eggs [y = x̄(0.018) + 31.3; r = 0.84]. Average total fecundity for seven Age II females (x̄ = 49.2 mm SL, 40.3–56.9 mm SL) was 1,883 eggs (1,298–2,831) while three Age III females (x̄ = 63.7 mm SL, 59.8–70.4 mm SL) contained an average of 2,721 eggs (2,331–3,090). The most mature mode of eggs represented an average of 57% (46–68%) of the total number of eggs counted in each of the 10 fish examined.

Numerous nucleated oocytes (0.05–0.13 mm) were present in all ovaries of *N. s. simus*. Eggs in this size class from a single 40.3 mm SL *N. s. simus* outnumbered all other yolked eggs by a factor of 1.4 (1,835 vs. 1,298), but it is not known if nucleated oocytes were eventually developed and spawned. Under optimal conditions, small, nucleated oocytes developed quickly and were eventually spawned by red shiner, *Cyprinella lutrensis* (Baird and Girard), but these fish spawned repeatedly over a period of several months (Gale 1986).

Histogram plots of two large collections of *N. s. simus* revealed distinct peaks and age classes. Independent analysis of scale annuli corroborated age-group designations derived from histograms for all but the oldest age class (Age IV). Populations were dominated by Age 0 and Age I fish, with older age classes making up a decreasing proportion of the population. If spring (prespawning, 9 June 1939) and fall (postspawning, 29 October 1949) collections are compared, it appears that few, if any, *N. s. simus* survive a fourth summer (Age III+). The largest female we examined was 70.4 mm SL (Age III+). We made no measurements on males. Chernoff et al. (1982) reported a maximum length of 65.2 mm for male *N. s. simus*.

Hatch et al. (1985) found that populations of *N. s. pecosensis* were composed primarily of Age 0 (77.5%) and Age I (18.5%) fish and that Age II specimens were rare (4%). They also reported that *N. s. pecosensis* attained a maximum length of 56.5 mm SL.

The digestive tracts of 15 adult *N. s. simus* were examined, 14 of which contained food. Gut length was short, averaging 82% of SL (73–97%), and the peritoneum was silvery; both traits suggested carnivorous habits. We found, however, that *N. s. simus* was quite omnivorous. By volume, invertebrates of terrestrial and aquatic origin comprised 48% of the diet. Terrestrial invertebrates found in 43% of the stomachs were mostly small, adult Diptera. Most aquatic invertebrates consumed by *N. s. simus* were either case-building larval Trichoptera or adult Coleoptera (Gyrinidae), but also included Ephemeroptera, Diptera, and Hemiptera (Corixidae).

Detritus, filamentous algae, seeds, and small woody debris were found in a majority (71%) of specimens examined and comprised half (52%) of the total stomach contents. The nutrient value of the plant material, detritus, and algae is unknown, but the large amounts found in stomach contents suggested purposeful ingestion. The microbial community associated with these food items may provide some nutrition.

*Notropis orca* was uncommon in the Rio Grande in New Mexico. Only three collections are known from the state (MSB 4139, N = 19; MSB 4140, N = 20; UMMZ 207688, N = 5) and all were made in 1939 in a 60 km reach of the middle Rio Grande from Isleta to Bernardo. In addition, two hybrids of *N. orca* × *N. s. simus* (MSB 4141, 1939; UMMZ 207689, 1940) are known from the same reach (Chernoff et al. 1982). No additional *N. orca* specimens were found in MSB collections of *N. s. simus* but an additional hybrid specimen (MSB 2455; C.R. Gilbert, pers. comm., tentative identification) was found indicating that extirpation may have occurred after 1949. The only known specimens from the El Paso area are the holotype and paratypes collected in 1891 (Chernoff et al. 1982). Two additional hybrids were also collected at that time.

We found a single *N. orca* in a mixed lot (TNHC 4545, 1953) of specimens collected from the Rio Grande in Big Bend National Park. This is the only record known for that species in the Rio Grande between El Paso and the mouth of the Pecos River. Trevino-Robinson (1959) reported *N. simus orca* (= *N. orca*) as abundant in the lower Rio Grande in Texas, downstream from the Pecos River confluence. This species has undergone a severe decline there; the last known collection of *N. orca* was made in Mexico in 1975 (Chernoff et al. 1982).

Specimens in the two largest New Mexico collections of *N. orca* had mean lengths of 53.1 mm SL (39.5–70.1 mm) and 61.8 mm SL (49.9–73.7 mm), respectively. This probably represented at least two and probably three year-classes (Age I-III) if life history parameters and maximum sizes were similar to those found for *N. s. simus*. No other life history data were recorded as specimens are rare.

*Hybopsis aestivalis* was widely distributed in the study area and like *N. s. simus*, occupied exclusively mainstream habitats. The last specimens of *H. aestivalis* known from the Rio Grande in New Mexico, were collected with the last *N. s. simus* at Peña Blanca (TU 35682, N = 7) and at Las Cruces (ASU 686, N = 5) in 1964. *Notropis jemezanus* was formerly widespread but generally uncommon in the Rio Grande, New Mexico. It was last collected in the middle Rio Grande near Isleta in 1949.

## DISCUSSION

A suite of four small cyprinids (*N. s. simus, N. orca, N. jemezanus, H. aestivalis*) that occupied exclusively mainstream habitat has been eliminated from the Rio Grande in New Mexico. The Rio Grande silvery minnow, *Hybognathus amarus*, is the only surviving endemic cyprinid that inhabits exclusively mainstream environments in the study area. Historic distribution and abundance patterns of *H. amarus* approximated that of *N. s. simus,* but it is now reduced to about 40% of its former range in the Rio Grande in New Mexico. The species still occurs from Albuquerque to Elephant Butte Reservoir, but our surveys indicate that the remaining habitat is threatened by continued water depletion.

Annual discharge of the Rio Grande at the Colorado–New Mexico border had declined by 1930, presumably because of increased upstream irrigation demand. Further reductions in streamflow were caused by construction of several mainstream reservoirs used to store irrigation water. The additive effects of water regulation and drought in the 1950's and early 1960's annually dried reaches of the Rio Grande downstream of present-day Cochiti Reservoir for as long as 2 months. Operation of the conveyance-canal water-delivery-system severely dewatered middle Rio Grande habitat during the documented declines of mainstream cyprinids. From 1951 to 1973, flows were especially low and in most years, the riverbed was dry during September and October.

It was perhaps not coincidental that the last *N. s. simus* was taken just downstream from the present-day Cochiti Reservoir area. That reach was relatively unregulated and had perennial flows prior to impoundment. If *N. s. simus* were present after the 1964 construction of Cochiti Reservoir, inundation of habitat, drying of downstream reaches during reservoir filling, and lowered water temperatures probably eliminated them. The fish assemblage below Cochiti Reservoir is presently dominated by coolwater species like longnose dace, *Rhinichthys cataractae* (Valenciennes), and white sucker, *Catostomus commersoni* (Lacepede).

Most of the native Rio Grande fishes that still occur in mainstream reaches fall into these three groups: 1) fishes that occupy perennial mainstream and tributary habitat at higher elevations [flathead chub, *Hybopsis gracilis* (Richardson), *R. cataractae,* Rio Grande chub, *Gila pandora* (Cope)], 2) fishes that are tolerant of standing water and degraded habitat conditions (*C. lutrensis,* fathead minnow, *Pimephales promelas* Rafinesque), or 3) fishes capable of occupying reservoir refugia [river carpsucker, *Carpiodes carpio* (Rafinesque); smallmouth buffalo, *Ictiobus bubalus* (Rafinesque); blue catfish, *Ictalurus furcatus* (Lesueur); and channel catfish, *I. punctatus* (Rafinesque)].

*Notropis s. pecosensis, H. aestivalis, N. jemezanus,* and most other native species, still occupy the Pecos River in eastern New Mexico, despite considerable alteration by human activity. Discharge in that stream has been dramatically altered by reservoir construction and irrigation withdrawals, and faunal composition has been changed by abundant introduced fish species (Hatch et al. 1985, Bestgen et al. 1989). Apparent differences between the Rio Grande and the Pecos River in New Mexico may explain differential survival of native species. In contrast with the Rio Grande, the Pecos River has spring seeps and limited tributary discharge to supplement flow, and irrigation demands of downstream users are sometimes met by delivering water down the river channel, thus maintaining a limited, albeit highly variable, habitat.

Short-lived Rio Grande cyprinids that were mainstream habitat specialists were especially susceptible to reduction and alteration of stream discharge. Patterns indicate that uncommon species with restricted ranges (*N. orca* and *N. jemezanus*) were extirpated first. When habitats were severely altered, even widespread and common species like *N. s. simus* and *H. aestivalis* were affected. These fishes were presumably unable to migrate to secure areas because of river desiccation, extreme distance, or habitat dissection due to dam construction and were unable to survive in reservoirs. Extreme dissection of mainstream riverine habitat may affect species whose life histories were primarily dependent upon tributary streams (Sheldon 1988). Recent high flows of the Rio Grande may be a result of a short-term increase in precipitation and water releases from Cochiti Reservoir. Plans to reinstitute use of the conveyance-canal system may once again dry the mainstream Rio Grande and reduce habitat for the remaining fish fauna.

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(USBR), and T.L. Yates (UNM) are appreciated. Several Pueblo Indian Governments permitted us to sample on their lands. C.R. Gilbert provided a tentative identification of a hybrid specimen. The comments and suggestions of D.L. Propst, J.P. Hubbard, R.R. Miller, R.E. Robino, N.J. Scott, and an anonymous reviewer improved the manuscript.

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Kevin R. Bestgen and Steven P. Platania, Department of Biology, Museum of Southwestern Biology, University of New Mexico, Albuquerque, New Mexico 87131. (Present address: K.R. Bestgen, Department of Fishery and Wildlife Biology and Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado 80523.)

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