In cooperation with the National Park Service

Status of Fish Communities in the Rio Grande, Big Bend National Park, Texas—Comparison Before and After Spring 2003 Period of Low Flow

Scientific Investigations Report 2005–5209

U.S. Department of the Interior
U.S. Geological Survey

Cover. Rio Grande upstream of Santa Elena Canyon (January 2002).

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By J. Bruce Moring

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Status of Fish Communities in the Rio Grande, Big Bend National Park, Texas—Comparison Before and After Spring 2003 Period of Low Flow

By J. Bruce Moring

Abstract

During 2003–04 the U.S. Geological Survey, in cooperation with the National Park Service, re-evaluated the status of fish communities in three reaches of the Rio Grande in Big Bend National Park that originally were evaluated when the three reaches were established for study in 1999. The objective was to determine whether there were measurable differences between 1999 and 2003–04 (referred to as 2004) fish community status that likely are attributable to a rare 58-day period of low flow (less than 1 cubic meter per second) in spring 2003 at the Johnson Ranch gaging station on the Rio Grande in Big Bend National Park. The total number of fish species collected at all three sites (Boquillas, Johnson Ranch, and Santa Elena) in 1999 was greater than in 2004. The number of fish species collected at the Boquillas site in 1999 (10) was twice that collected in 2004; the number of species collected at the Johnson Ranch site in 1999 (nine) was almost twice that collected in 2004 (five). In contrast, the numbers at the Santa Elena site were nearly the same, 15 species in 1999, 14 in 2004. Percent community similarity for the Boquillas site is 8.04, for the Johnson Ranch site, 6.65, and for the Santa Elena site, 47.6, which indicates considerably more similarity between the 1999 and 2004 fish communities at the Santa Elena site than for the Boquillas and Johnson Ranch sites. At the Boquillas and Johnson Ranch sites, the fish communities shifted from small minnow (Cyprinidae) dominated in 1999 to largely gar (Lepisosteidae) and catfish (Ictaluridae) dominated in 2004. In contrast, no such shift occurred at the Santa Elena site between 1999 and 2004. Differences in flow conditions between the two downstream sites and the Santa Elena site might account for the dissimilar findings. The findings of the study provide some evidence that the spring 2003 period of low flow affected fish communities, but the findings are not definitive as other factors such as increased salinity, algal toxins, bioavailable contaminants, and exotic species can affect fish populations and, ultimately, fish community structure.

Introduction

In 1999 the U.S. Geological Survey (USGS), in cooperation with the National Park Service (NPS), established five benchmark reaches on the Rio Grande in and near Big Bend National Park (BBNP) in western Texas for long-term monitoring of stream-habitat conditions, riparian vegetation, benthic macroinvertebrates, and fish communities (Moring, 2002). Three of the reaches are in BBNP (fig. 1). Fish communities in the newly established reaches were assessed in 1999. Flow averaged about 28 cubic meters per second at the International Boundary and Water Commission (IBWC) streamflow-gaging station Rio Grande at Johnson Ranch (IBWC site 08-3750.00) (Johnson Ranch gaging station), BBNP, during the 15 years 1990–2004; flow was less than 1 cubic meter per second for 58 consecutive days (March 16–May 12) in spring 2003 (International Boundary and Water Commission, 2005). Extended periods of no flow in a stream can negatively influence fish communities. During 2003–04 the USGS, again in cooperation with the NPS, re-evaluated the status of fish communities in the three reaches in BBNP. The objective was to determine whether there were measurable differences between the 1999 and the 2003–04 fish community status that likely are attributable to the spring 2003 period of low flow.

This report describes the methods used to assess community status and compares the findings of the 2003–04 assessment with those of the 1999 assessment. Comparisons focus on numbers of fish species in a community and similarity in community structure.

The Rio Grande drains about 600,000 square kilometers from headwaters in the San Juan Mountains of Colorado to its terminus at the Gulf of Mexico (fig. 1). Big Bend Ranch State Park borders 97 kilometers of the river upstream from BBNP. The NPS manages 386 kilometers of the Rio Grande including 190 kilometers in BBNP and another 196 kilometers of the Rio Grande Wild and Scenic River reach downstream from BBNP. The Canon de Santa Elena Floral and Faunal Protected Area

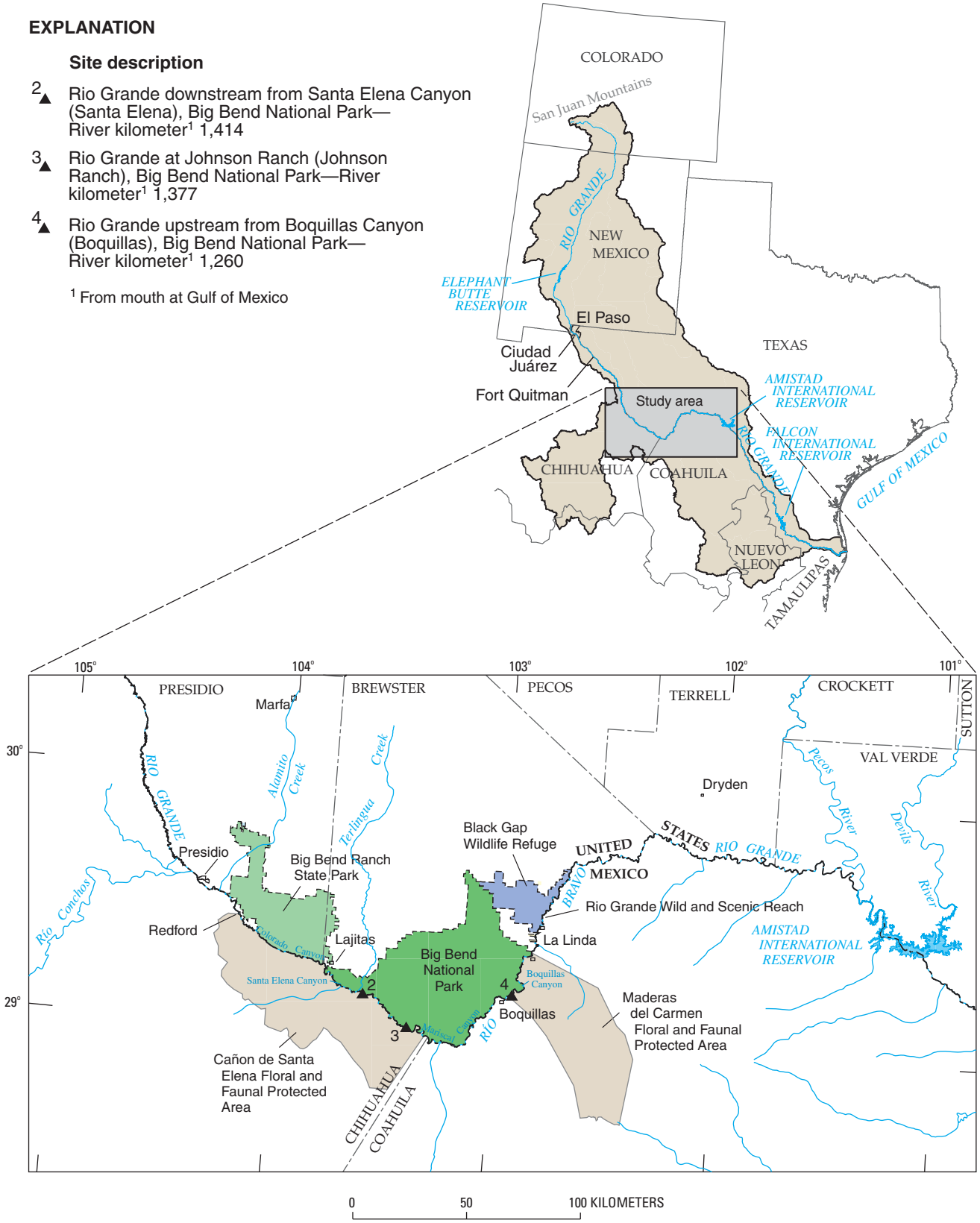

Figure 1. Fish community assessment sites on the Rio Grande in Big Bend National Park, Texas, 1999 and 2003–04 (modified from Moring, 2002).

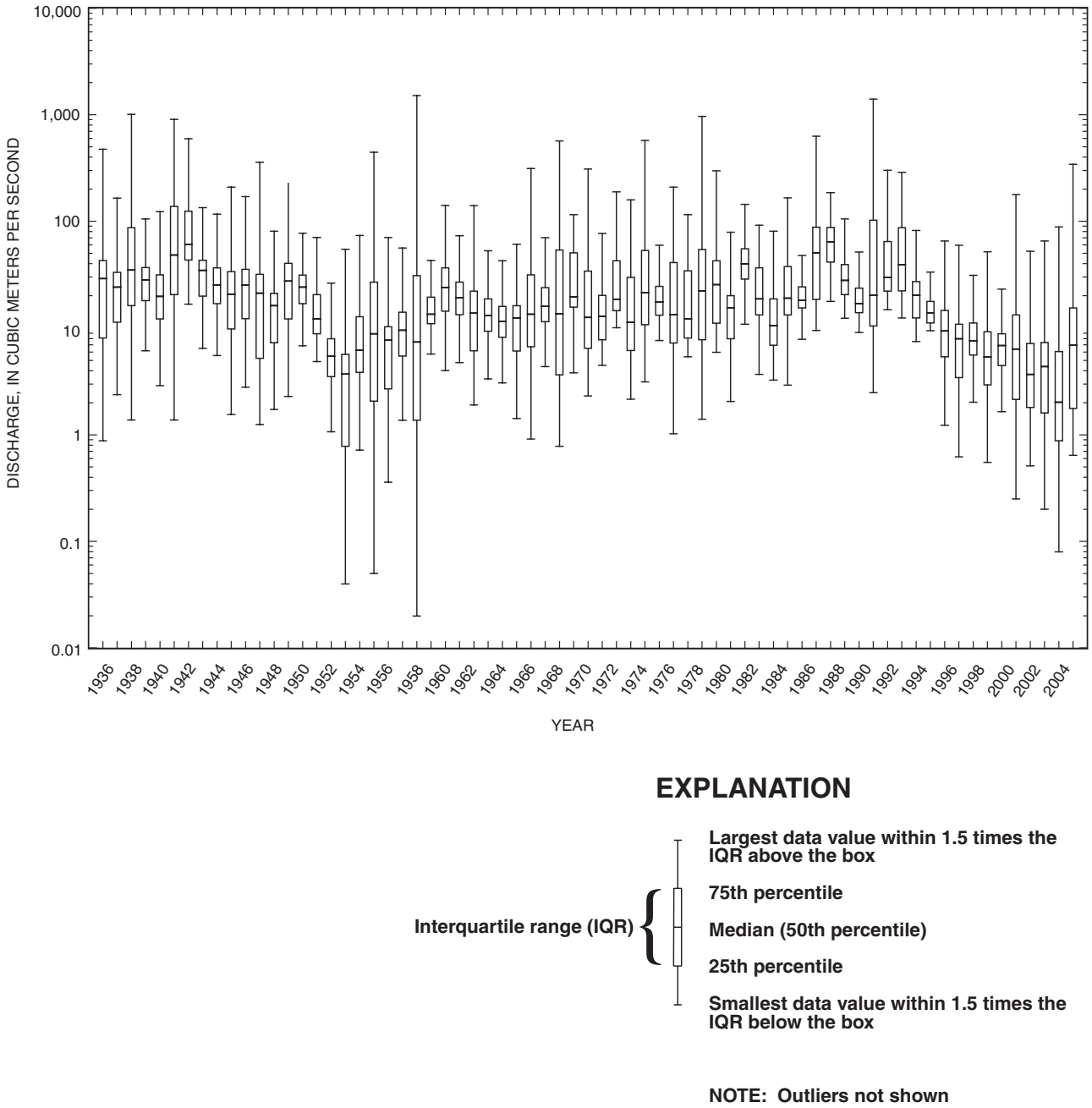

Figure 2. Boxplots showing distribution of daily mean discharge at International Boundary and Water Commission (IBWC) streamflow-gaging station Rio Grande at Johnson Ranch (IBWC site 08–3750.00), Big Bend National Park, Texas, 1936–2004.

borders the river for about 150 kilometers from near Redford, Texas, to the border of the Mexican States of Chihuahua and Coahuila. The Maderas del Carmen Floral and Faunal Protected Area borders the Rio Grande for about 40 kilometers from near Boquillas, Mexico, to just upstream from La Linda, Mexico. In all, about 483 river kilometers of the Rio Grande in the Big Bend region of Texas are bordered by public lands of the United States and Mexico.

Daily mean flow has been recorded at the Johnson Ranch gaging station since 1936 (fig. 2). The average daily mean flow for 1936–2004 was about 35 cubic meters per second, and the median was about 16 cubic meters per second. As noted, the average daily mean flow for the most recent 15 years of record (1990–2004) was about 28 cubic meters per second or about 20 percent less than the long-term average. Median flow for 1990–2004 was about 9.9 cubic meters per second or about 38 percent less than the long-term median. The 58-day period of low flow

in spring 2003 was the longest such period at the Johnson Ranch gaging station since the early- to mid-1950s. Drought in northern Mexico and southern Texas in the 1990s (Texas Water Development Board, [1998?]) likely was a primary cause of reduced flow in the Rio Grande during the latter period.

The Rio Grande and its tributaries represent the largest and most extensive freshwater aquatic ecosystem in the Chihuahuan Desert of southern New Mexico, southwestern Texas, and northern Mexico. Forty-four species of fish (table 1) have been identified historically in the Rio Grande and its tributaries from BBNP to the confluence of the Rio Grande with the Pecos River and Amistad International Reservoir (Garrett, 2002, table 1). Seven species are introduced, two are extinct, and five have been extirpated from this reach and its tributaries (Garrett, 2002). The freshwater drum, *Aplodinotus grunniens,* is listed as native to the region, although it might not be; it was introduced from the lower Rio Grande according to Smith and Miller (1986). Of the remaining native species, the blue sucker, Chihuahua shiner, and Mexican stoneroller are State-listed as threatened species, and the Rio Grande silvery minnow is State- and Federal-listed as an endangered species (Texas Parks and Wildlife Department, 2004).

Mean future extinction rates of 2.4 percent per decade have been estimated for North American freshwater fauna (Ricciardi and Rasmussen, 1999). Reductions in Chihuahuan Desert ichthyofauna have been noted (Edwards and Contreras-Balderas, 1991**;** Hubbs, 1990; and Stotz, 2000). Hubbs (1990) estimated that one-half of the native ichthyofauna of the Chihuahuan Desert are already extinct or threatened with extinction.

Many historical fish community surveys have been done in the reach of the Rio Grande in and near BBNP (Evermann and Kendall, 1894; Hubbs, 1940, 1958; Trevino-Robinson, 1959; Bestgen and Platania, 1988; Platania, 1990; Garrett, 1997, 2002; and Moring, 2002). However, only Garrett (2002) and Moring (2002) have addressed seasonal and inter-annual (Garrett, 2002) fish distribution and abundance in the reach from BBNP to the confluence with the Pecos River at Amistad International Reservoir.

Methods of Assessment

Methods of assessment in 1999 (Moring, 2002) and in 2003–04 were essentially the same. Of the five Rio Grande reaches (sites) in the Big Bend region originally established in 1999, the three in BBNP (fig. 1) were selected for re-study in 2003–04: site 4, Rio Grande upstream from Boquillas Canyon (Boquillas); site 3, Rio Grande at Johnson Ranch gaging station (Johnson Ranch); and site 2, Rio Grande downstream from Santa Elena Canyon (Santa Elena). River reaches were established on the basis of the occurrence and frequency of geomorphic channel units (Meador and others, 1993; Moring, 2002) so that each reach had at least two riffles and two runs over its length, and the reach length was at least 10 times the wetted channel width. Setting a minimum reach length of 20 times the wetted channel width, which is preferable (Leopold and others, 1964; Meador and others, 1993), would have been difficult because of the large channel widths and inaccessibility of the Rio Grande in BBNP. Reach boundaries were recorded as the latitude and longitude at the upstream and downstream boundaries on the high-bank terrace on the left (U.S.) bank.

The fish communities at the Boquillas, Johnson Ranch, and Santa Elena sites were each sampled once in early spring and late summer 1999 and again in late summer 2003 and early spring 2004. (Hereinafter, 2003 and 2004 sampling referred to as 2004 sampling.) A single pass through each reach was made with a barge or backpack electrofishing unit during each sampling event. Seining, gill netting, and fyke netting also were used in each reach to supplement electrofishing sampling. A minimum of six seine hauls were made in each reach using a 7.5- by 3.0-meter, 0.64-centimeter mesh-size bag seine or a 3.0- by 3.0-meter, 0.17-centimeter mesh-size common-sense minnow seine depending on depth and flow conditions. The electrofishing time in seconds and the number of seine hauls per seine type for each sampling were recorded so that catch-per-unit-effort (CPUE) by sampling-gear type could be computed. Computing CPUE for each reach helps to standardize the fish community data to allow for more appropriate between-reach comparisons. A 45- by 8-meter, 0.63-centimeter mesh-size experimental gill net and a 2.0- by 2.0-meter fyke net with 20-centimeter front panel were deployed overnight at each site in both 1999 and 2004.

All collected fish were identified to species, weighed to the nearest gram, and measured for standard and total lengths recorded to the nearest millimeter. The type, frequency, and location of external anomalies, such as lesions and fin erosion, were recorded. If individual fish could not be positively identified to species in the field, they were preserved in 10-percent phosphate-buffered formalin for identification or verification of identification later by USGS staff or by staff of The University of Texas Memorial Museum in Austin. Vouchered non-game specimens of selected species were deposited with Dr. Dean Hendrickson at The University of Texas Memorial Museum.

All field data were recorded on forms printed on waterproof paper. Field data were reviewed for accuracy and completeness before transfer into digital format. All data were keyed into an electronic spreadsheet and reviewed a second time for accuracy by comparison of digital data to original field data. All field and digital data are archived at the USGS Texas Water Science Center in Austin.

Fish Community Status Before and After Period of Low Flow

A cumulative total of 19 species of fish were collected among the three reaches in 1999 and 2004 (table 2). The blue catfish, *Ictalurus furcatus*, and the flathead catfish, *Pylodictis olivaris*, were the only species collected at all three sites during

Table 1. Historical fish species in the Rio Grande in and near Big Bend National Park, Texas (Garrett, 2002, table 1).

[Shading indicates presence or absence]

Family	Scientific name	Common name	Status	Present	Absent
Acipenseridae	*Scaphirhyncus platorynchus*	Shovelnose sturgeon	Native, extirpated		
Lepisosteidae	*Atractosteus spatula*	Alligator gar	Native, extirpated		
	Lepisosteus oculatus	Spotted gar	Native		
	Lepisosteus osseus	Longnose gar	Native		
Anguillidae	*Anguilla rostrata*	American eel	Native, extirpated		
Clupeidae	*Dorosoma cepedianum*	Gizzard shad	Native		
	Dorosoma petenense	Threadfin shad	Introduced		
Cyprinidae	*Campostoma ornatum*	Mexican stoneroller	Native		
	Cyprinella lutrensis	Red shiner	Native		
	Cyprinella lutrensis blairi	Blair's red shiner	Native, extirpated		
	Cyprinus carpio	Common carp	Introduced		
	Dionda episcopa	Roundnose minnow	Native		
	Hybognathus amarus	Rio Grande silvery minnow	Native, extirpated		
	Hybognathus placitus	Plains minnow	Native		
	Macrhybopsis aestivalis	Speckled chub	Native		
	Notropis braytoni	Tamaulipas shiner	Native		
	Notropis chihuahua	Chihuahua shiner	Native		
	Notropis jemezanus	Rio Grande shiner	Native		
	Notropis orca	Phantom shiner	Native, extinct		
	Notropis simus	Bluntnose shiner	Native, extinct		
	Pimphales promelas	Fathead minnow	Native		
	Pimphales vigilax	Bullhead minnow	Introduced		
	Rhinichthys cataractae	Longnose dace	Native		
Catostomidae	*Carpiodes carpio*	River carpsucker	Native		
	Cycleptus elongatus	Blue sucker	Native		
	Ictiobus bubalus	Smallmouth buffalo	Native		
	Scartomyzon austrinum	West Mexican redhorse	Native		
	Scartomyzon congestum	Gray redhorse	Native		
Characidae	*Astyanax mexicanus*	Mexican tetra	Native		
Ictaluridae	*Ictalurus furcatus*	Blue catfish	Native		
	Ictalurus lupus	Headwater catfish	Native		
	Ictalurus punctatus	Channel catfish	Native		
	Pylodictis olivaris	Flathead catfish	Native		
Cyprinodontidae	*Fundulus zebrinus*	Plains killifish	Introduced		
Poeciliidae	*Gambusia affinis*	Western mosquitofish	Native		
Atherinidae	*Menidia beryllina*	Inland silverside	Introduced		
Percichthyidae	*Morone chrysops*	White bass	Native		
Percidea	*Etheostoma grahami*	Rio Grande darter	Native		
Centrarchidae	*Lepomis cyanellus*	Green sunfish	Native		
	Lepomis gulosus	Warmouth	Introduced		
	Lepomis macrochirus	Bluegill	Native		
	Lepomis megalotis	Longear sunfish	Native		
	Lepomis microlophus	Redear sunfish	Introduced		
	Micropterus salmoides	Largemouth bass	Native		
Scianidae	*Aplodinotus grunniens*	Freshwater drum	Native		

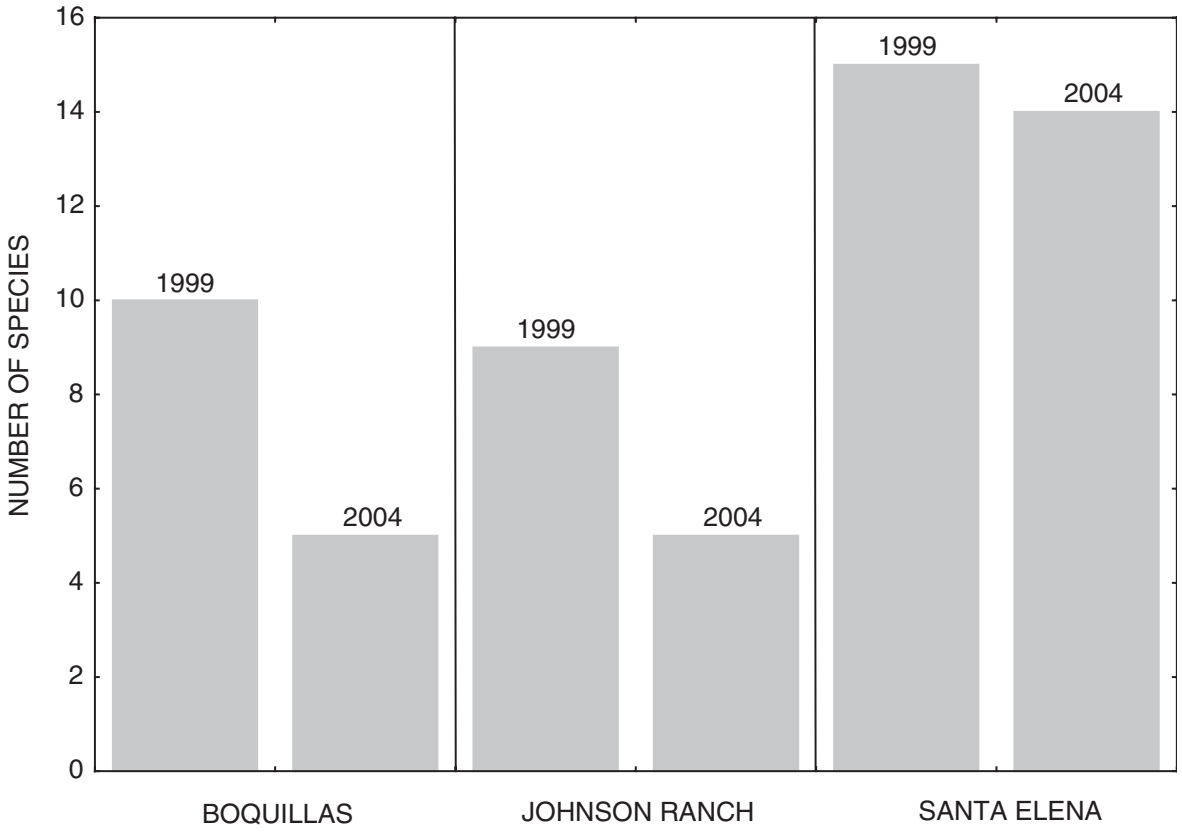

Figure 3. Number of fish species collected at three sites on the Rio Grande in Big Bend National Park, Texas, 1999 and 2004.

both surveys. The red shiner, *Cyprinella lutrensis*, was the most frequently collected species (151 individuals). The smallmouth buffalo, *Ictiobus bubalus*, and the western mosquitofish, *Gambusia affinis*, were the least frequently collected species in terms of both number of individuals (one each) and sites where found (one each). The greatest number of individual fish (282) and species (18) were collected at the Santa Elena site. The smallest number of individuals (151) and species (11) were collected at the Johnson Ranch site.

The total number of fish species collected in 1999 was greater than in 2004 for all three sites (fig. 3). The number of fish species collected at the Boquillas site in 1999 (10) was twice that collected in 2004; the number of species collected at the Johnson Ranch site in 1999 (nine) was almost twice that collected in 2004 (five). In contrast, the numbers at the Santa Elena site were nearly the same, 15 species in 1999, 14 in 2004.

The number of species collected can be influenced by the number of individuals collected, which can introduce bias into interpretations of data or biological metrics computed from the data (Ludwig and Reynolds, 1988). One way to deal with this bias is to standardize the number of species collected by dividing the number of species collected by the square root of the number of individuals collected (Menhinick, 1964). The result is Menhinick's species richness, a unitless metric for comparing numbers of species among sites. Standardizing the number of species to the number of individuals collected did not change the relative differences in species richness for any of the sites between 1999 and 2004 (fig. 4).

Percent community similarity (PS) is a commonly used metric to compare biological communities between sites or for a given site at different times (Brower and Zar, 1977). For this report, the metric was applied to indicate within-site differences before and after the period of no flow. PS is computed as the sum of the smallest relative abundance percentages of each species between sites or dates. For the Boquillas site, for example, common carp, blue catfish, and flathead catfish were the only species collected in both 1999 and 2004 (table 2). The smaller of the 1999 and 2004 relative abundance percentages for common carp is 0.84 ([1 individual/119 total individuals] x 100) for 1999; for blue catfish, 5.88 for 1999; and for flathead catfish, 1.32 for 2004. PS for the Boquillas site thus is the sum of the three percentages, 8.04. PS for the Johnson Ranch site, 6.65, is close to that of the Boquillas site and also relatively small; but PS for the Santa Elena site, 47.6, is about six and seven times larger, respectively, which indicates considerably more similarity between the 1999 and 2004 fish communities at the Santa Elena site than at the Boquillas and Johnson Ranch sites.

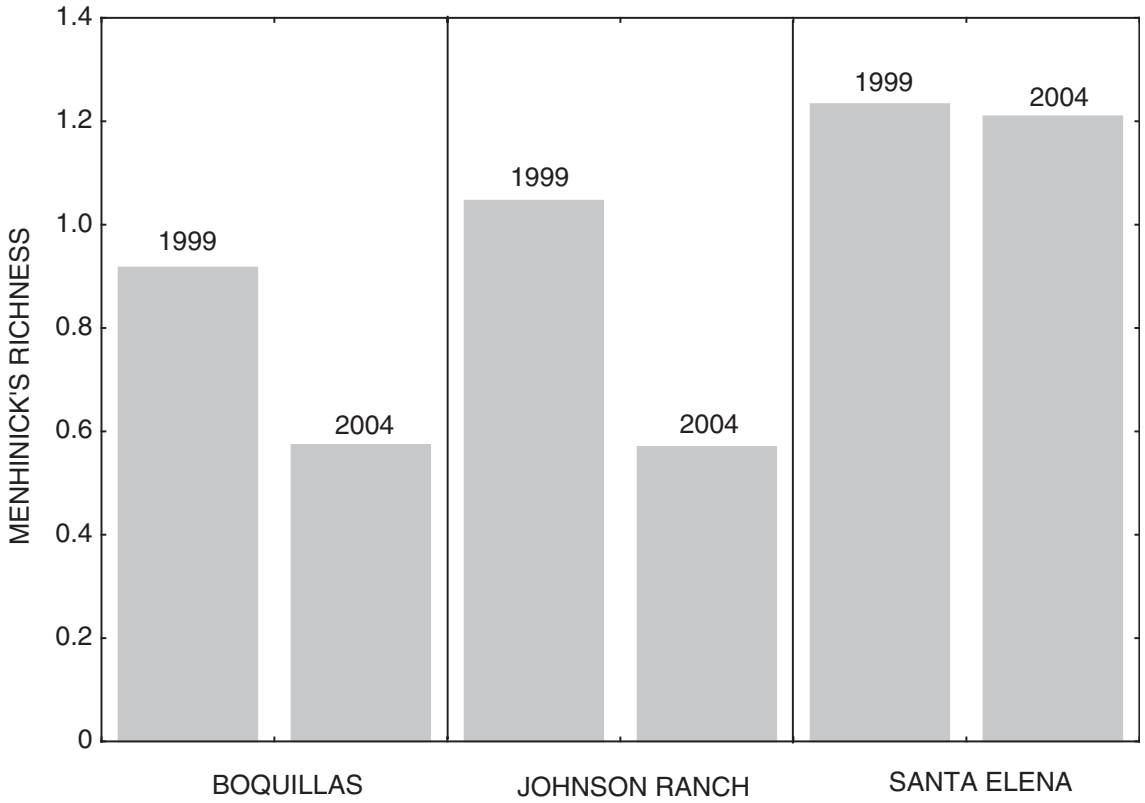

Figure 4. Menhinick's species richness for fish communities at three sites on the Rio Grande in Big Bend National Park, Texas, 1999 and 2004.

Organizing the fish community data by relative abundance of major families for 1999 and 2004 (fig. 5) also illustrates the within-site differences in fish community structure before and after the spring 2003 period of low flow. Cyprinidae, particularly red shiners and Tamaulipas shiners (table 2), dominated the fish communities at the Boquillas and Johnson Ranch sites in 1999. In contrast, the cyprinids were one of the least-common families represented in 2004 at both of these sites. Members of the families Lepisosteidae and Ictaluridae dominated the fish communities at these sites in 2004. In particular, longnose gar (Lepisosteidae) and blue catfish (Ictaluridae) were the most frequently collected species for these families (table 2). The longnose gar, a predator, is the most common fish species in the Rio Grande from El Paso to the confluence with the Devils River (Campbell, 1962). Consistent with the species richness and PS metrics for the Santa Elena site that indicate relative similarity, family relative abundance data from the Santa Elena site for 1999 and 2004 show relatively little difference. The difference in fish communities at this site between 1999 and 2004 was accounted for mostly by an increase in the number of blue catfish and channel catfish collected at Santa Elena in 2004.

When low-flow conditions occur in the warmer months of the year, related increases in water temperature and decreases in dissolved oxygen concentrations can adversely affect the fish community by causing an increase in physiological stress and mortality. In addition, a reduction in flow and stage can result in a decrease in the total area of available fish habitat, particularly in shallow rapids and riffles. A decrease in the available habitat can negatively influence the food resource base, fish dispersal and recruitment, and suitable spawning habitat for certain species or species assemblages. At the Boquillas and Johnson Ranch sites, the fish communities shifted from small minnow (Cyprinidae) dominated in 1999 to largely gar (Lepisosteidae) and catfish (Ictaluridae) dominated in 2004 (fig. 5, table 2). The lower dissolved oxygen concentrations and higher water temperatures that often occur with low-flow conditions might be better tolerated by gar and catfish than by many of the cyprinid or minnow species. Red shiners historically have been one of the most abundant cyprinid species in the Rio Grande in BBNP (Bestgen and Platania, 1988; Garrett, 1997, 2002; Moring, 2002). Red shiners and Tamaulipas shiners were present in relatively large numbers at the Boquillas and Johnson Ranch sites (and also river carpsuckers at Boquillas) in 1999, but none of the three species were collected at those sites in 2004. Longnose gar, three species of catfish, and freshwater drum were the only species collected at the Johnson Ranch site in 2004. Another indicator of the potential influence of the no-flow period involves the speckled chub species; this species

Table 2. Fish species, number of individuals, and percent community similarity for fish communities at three sites on the Rio Grande in Big Bend National Park, Texas, 1999 and 2004.

Scientific name	Common name	Boquillas		Johnson Ranch		Santa Elena	
		1999	2004	1999	2004	1999	2004
Lepisosteus osseus	Longnose gar		33		15	1	2
Dorosoma cepedianum	Gizzard shad	4					1
Cyprinella lutrensis	Red shiner	32		35		31	53
Cyprinus carpio	Common carp	1	3	2			
Macrhybopsis aestivalis	Speckled chub	11				31	4
Notropis braytoni	Tamaulipas shiner	32		25		31	15
Notropis jemezanus	Rio Grande shiner			4		31	
Rhinichthys cataractae	Longnose dace					5	11
Carpiodes carpio	River carpsucker	16		1		2	3
Cycleptus elongatus	Blue sucker	2				1	
Ictiobus bubalus	Smallmouth buffalo					1	
Astyanax mexicanus	Mexican tetra		9				2
Ictalurus furcatus	Blue catfish	7	30	1	15	1	15
Ictalurus punctatus	Channel catfish	8		2	42	1	18
Pylodictis olivaris	Flathead catfish	6	1	2	2	4	5
Fundulus zebrinus	Plains killifish			2		4	2
Gambusia affinis	Western mosquitofish					1	
Lepomis megalotis	Longear sunfish					3	2
Aplodinotus grunniens	Freshwater drum				3		1
Number of individuals		119	76	74	77	148	134
Number of species		10	5	9	5	15	14
Percent community similarity (PS)		8.04		6.65		47.6	

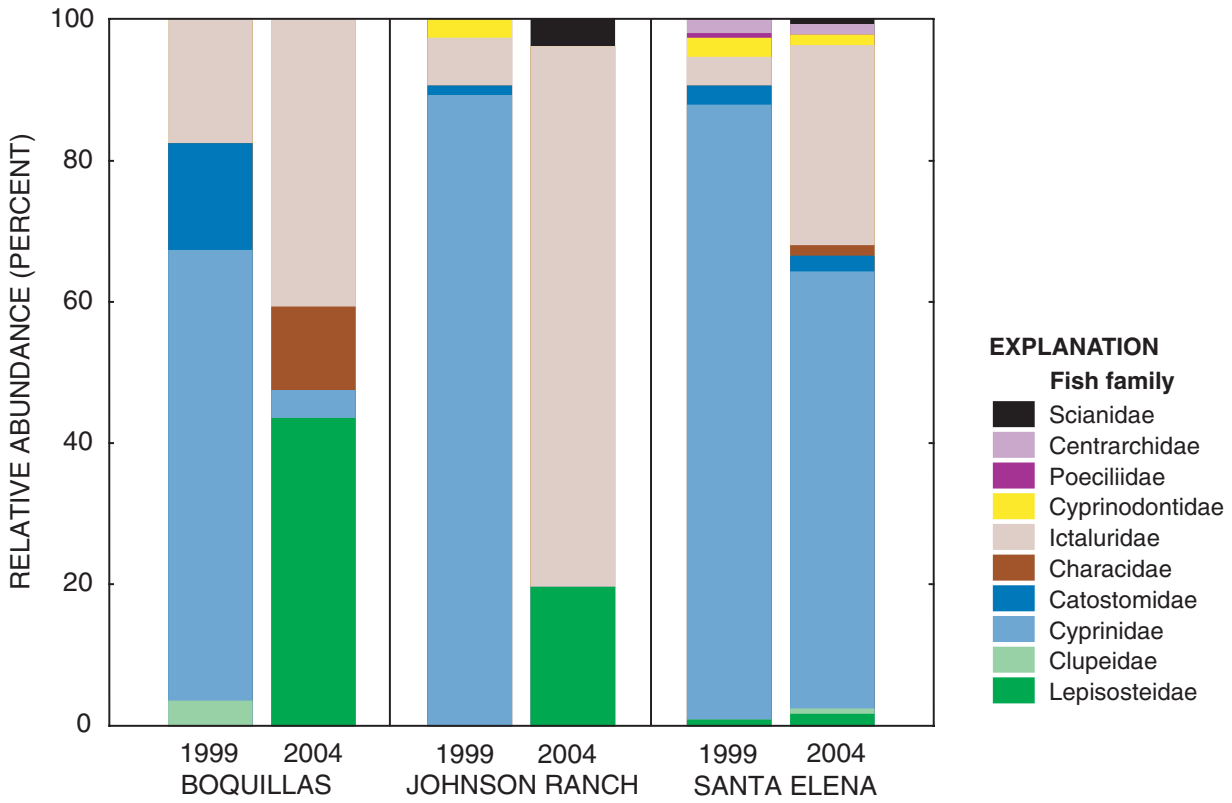

Figure 5. Relative abundance of major fish families at three sites on the Rio Grande in Big Bend National Park, Texas, 1999 and 2004.

was present at the Boquillas site (11 individuals) in 1999 but not in 2004. Speckled chub are rheophilous (current-loving) fish that are more common in the fast-moving waters of rapids or riffles where they feed and spawn.

In contrast to the findings at the two downstream sites, very similar fish communities were found at the Santa Elena site in 1999 and 2004. Differences in flow conditions between the downstream sites and the Santa Elena site might account for the dissimilar findings. The Santa Elena site is about 0.6 kilometer downstream from the confluence of the Rio Grande with Terlingua Creek. Staff-gage records from all three sites indicate that flows were greater and more sustained at this site in spring 2003 compared with those at the Boquillas and Johnson Ranch sites.

The findings of this study provide some evidence that the spring 2003 period of low flow affected fish communities, but the findings are not definitive. Other factors such as increased salinity, algal toxins, bioavailable contaminants, and exotic species can affect fish populations and, ultimately, fish community structure. More intensive seasonal and annual fish community surveys collocated with water-quality monitoring and assessment would be needed to better understand the variables that influence the fish community.

Summary

During 2003–04 the U.S. Geological Survey (USGS), in cooperation with the National Park Service (NPS), re-evaluated the status of fish communities in three reaches of the Rio Grande in Big Bend National Park (BBNP) that originally were evaluated when the reaches were established for study in 1999. The three reaches are among five benchmark reaches the USGS, in cooperation with the NPS, established and sampled in 1999 on the Rio Grande in the Big Bend region of western Texas to provide the NPS with data and information on stream-habitat conditions, riparian vegetation, benthic macroinvertebrates, and fish communities. The objective of the 2003–04 study was to determine whether there were measurable differences between 1999 and 2003–04 fish community status that likely are attributable to a 58-day period of low flow (less than 1 cubic meter per second) in spring 2003 at the Johnson Ranch gaging station on the Rio Grande in BBNP. Such a flow condition had not occurred there since the early- to mid-1950s.

The three BBNP reaches (sites) selected for re-study in 2003–04 are site 4, Rio Grande upstream from Boquillas Canyon (Boquillas); site 3, Rio Grande at Johnson Ranch gaging station (Johnson Ranch); and site 2, Rio Grande downstream from Santa Elena Canyon (Santa Elena). The fish communities

at the Boquillas, Johnson Ranch, and Santa Elena sites were each sampled once in early spring and late summer 1999 and again in late summer 2003 and early spring 2004 (2003 and 2004 sampling referred to as 2004 sampling).

A cumulative total of 19 species of fish were collected among the three reaches in 1999 and 2004. The total number of fish species collected in 1999 was greater than in 2004 for all three sites. At the Boquillas site twice the number of fish species were collected in 1999 (10) as in 2004, and at the Johnson Ranch site almost twice the number of species were collected in 1999 (nine) as in 2004 (five). In contrast, the numbers at the Santa Elena site were nearly the same, 15 species in 1999, 14 in 2004. An alternative metric for comparing numbers of species among sites that is free of potential bias introduced by the number of individuals of a species collected, Menhinick's species richness, showed similar relations among numbers of species collected at the sites for 1999 and 2004.

Percent community similarity (PS) is a commonly used metric to compare biological communities between sites or for a given site at different times, the latter application used for this report. PS for the Boquillas site is 8.04, for the Johnson Ranch site, 6.65, and for the Santa Elena site, 47.6. These results indicate considerably more similarity between the 1999 and 2004 fish communities at the Santa Elena site than at the Boquillas and Johnson Ranch sites.

At the Boquillas and Johnson Ranch sites, the fish communities shifted from small minnow (Cyprinidae) dominated in 1999 to largely gar (Lepisosteidae) and catfish (Ictaluridae) dominated in 2004. The lower dissolved oxygen concentrations and higher water temperatures that often occur with low-flow conditions might be better tolerated by gar and catfish than by many of the cyprinid or minnow species. Another indicator of the potential influence of the no-flow period involves the speckled chub species; this species was present at the Boquillas site (11 individuals) in 1999 but not in 2004. Speckled chub are rheophilous (current-loving) fish that are more common in the fast-moving waters of rapids or riffles where they feed and spawn.

In contrast to the findings at the Boquillas and Johnson Ranch sites, very similar fish communities were found at the Santa Elena site in 1999 and 2004. Differences in flow conditions between the two downstream sites and the Santa Elena site might account for the dissimilar findings. Staff-gage records from all three sites indicate that flows were greater and more sustained at the Santa Elena site in spring 2003 compared with those at the Boquillas and Johnson Ranch sites.

The findings of this study provide some evidence that the spring 2003 period of low flow affected fish communities, but the findings are not definitive. Other factors such as increased salinity, algal toxins, bioavailable contaminants, and exotic species can affect fish populations and, ultimately, fish community structure.

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