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Baseline Assessment of Instream and Riparian-Zone Biological Resources on the Rio Grande in and Near Big Bend National Park, Texas

Water-Resources Investigations Report 02–4106

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

Cover:

Rio Grande just downstream of Santa Elena Canyon in Big Bend National Park, August 1998 (photograph by Patrick O. Keefe, U.S. Geological Survey).

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U.S. GEOLOGICAL SURVEY
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ABBREVIATIONS

cm, centimeters
km, kilometers
L, liters
m, meters
m/s, meters per second
m^2, square meters
m^3/s, cubic meters per second
µm, micrometers
mg/L, milligrams per liter
mm, millimeters

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By J. Bruce Moring

Abstract

Five study sites, and a sampling reach within each site, were established on the Rio Grande in and near Big Bend National Park in 1999 to provide the National Park Service with data and information on the status of stream habitat, fish communities, and benthic macroinvertebrates. Differences in stream-habitat conditions and riparian vegetation reflect differences in surface geology among the five sampling reaches. In the most upstream reach, Colorado Canyon, where igneous rock predominates, streambed material is larger; and riparian vegetation is less diverse and not as dense as in the four other, mostly limestone reaches. Eighteen species of fish and a total of 474 individuals were collected among the five reaches; 348 of the 474 were minnows. The most fish species (15) were collected at the Santa Elena reach and the fewest species (9) at the Colorado Canyon and Johnson Ranch reaches. The fish community at Colorado Canyon was least like the fish communities at the four other reaches. Fish trophic structure reflected fish-community structure among the five reaches. Invertivores made up at least 60 percent of the trophic structure at all reaches except Colorado Canyon. Piscivores dominated the trophic structure at Colorado Canyon. At the four other reaches, piscivores were the smallest trophic group. Eighty percent of the benthic macroinvertebrate taxa collected were aquatic insects. Two species of blackfly were the most frequently collected invertebrate taxon. Net-spinning caddisflies were common at all reaches except Santa Elena. The aquatic-insect community at the Boquillas reach was least similar to the aquatic-insect community at the other reaches.

INTRODUCTION

The National Park Service (NPS) manages 386 km of the Rio Grande in West Texas, including 190 river kilometers in Big Bend National Park (BBNP) and another 196 km of the Rio Grande Wild and Scenic River downstream from the Park (fig. 1). The Texas Parks and Wildlife Department (TPWD) manages 97 km of the Rio Grande at Big Bend Ranch State Park adjacent to and upstream of BBNP. In Mexico, the Cañon de Santa Elena Floral and Faunal Protected Area borders about 220 km of the Rio Grande from Mulato, Mexico, to near the mouth of Mariscal Canyon. The Maderas del Carmen Floral and Faunal Protected Area borders about 40 km of the Rio Grande upstream of Boquillas Canyon to Boquillas, Mexico, at the downstream boundary of BBNP just upstream of La Linda, Mexico.

The North American Free Trade Agreement (NAFTA) of 1992 has resulted in increased population and industry upstream of BBNP in both the United States and Mexico. Ciudad Juárez, Chihuahua (pop. 1,200,000), across the Rio Grande from El Paso, Texas, has historically discharged untreated urban and industrial waste directly into the Rio Grande.

Dams and flow diversions in the Rio Grande Basin have reduced the annual flow volume of the river and altered the seasonality of flows, particularly peak flows from snowmelt from the mountains of southern Colorado and northern New Mexico (Schmidt and Everitt, 2000). Currently (2001), peak flows in the Rio Grande downstream of the confluence of the Río Conchos are about one-half what they were prior to 1915. For example, the maximum mean daily discharge with a 2-year recurrence interval was 217 m^3/s prior to 1915 and the construction of Elephant Butte Reservoir in New Mexico and 126 m^3/s after its construction (Schmidt and Everitt, 2000). The Río Conchos is the primary tributary to the Rio Grande upstream of BBNP

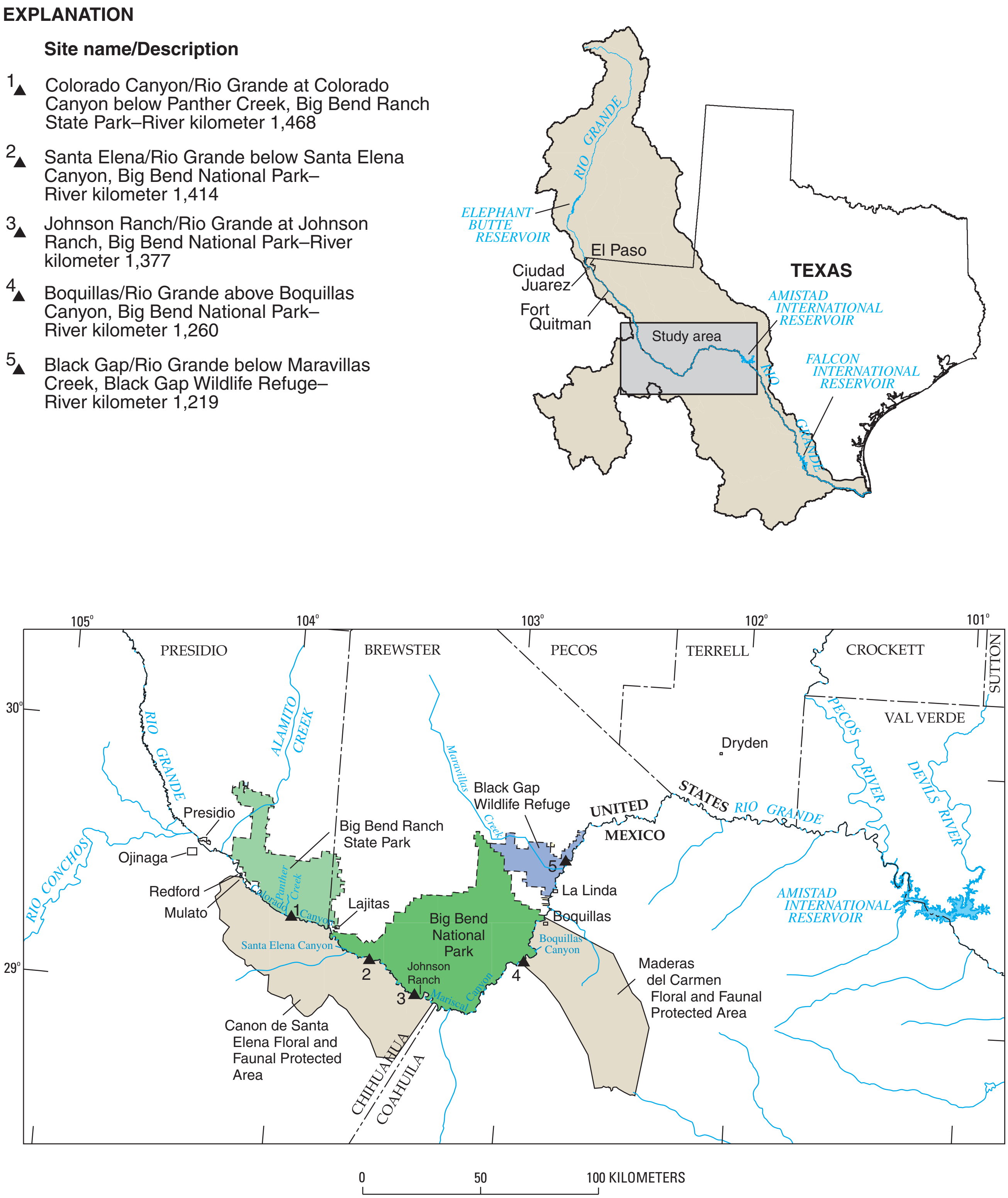

Figure 1. Baseline biological assessment sites in and near Big Bend National Park, Texas.

and accounts for almost one-half the entire Rio Grande drainage area in Mexico. In recent decades, the Río Conchos has contributed 85 percent of its pre-reservoir historical flow volumes through Big Bend Ranch State Park, BBNP, and the Rio Grande Wild and Scenic River (Saunders, 1987). Regulation on the Río Conchos has reduced total annual flow volumes and peak flows downstream in the Rio Grande and in BBNP.

In addition to historical changes in streamflows in the Rio Grande in the Big Bend region, several water-quality issues could be affecting the status and health of aquatic biota. First, salinity has increased at a rate of 15 to 18 mg/L per year downstream of the Río Conchos confluence with the Rio Grande (Miyamoto and others, 1995). At this rate, salinity could reach 1,000 mg/L early in the 21st century, about a 30-percent increase over average salinity levels in this reach of the Rio Grande in 1969. Second, concentrations of dissolved arsenic, copper, lead, and mercury in this reach of the Rio Grande have exceeded the U.S. Environmental Protection Agency (USEPA) chronic criteria for the protection of aquatic life (Miyamoto and others, 1995), and concentrations of metals in fish tissues have exceeded the 85th-percentile criterion established by the U.S. Fish and Wildlife Service (USFWS), which means that the concentrations were greater than 85 percent of the concentrations measured throughout the United States. Third, the State of Texas has listed segment 2306 of the Rio Grande, upstream of Amistad Reservoir, as not meeting aquatic-life use designation because of ambient toxicity of sediment and water that exceeds criteria for the protection of aquatic life (Texas Natural Resource Conservation Commission, 1999). Fourth, hydrophobic compounds such as the DDT breakdown product *p,p'*-DDE, the organophosphate pesticide chlorpyrifos, and several polycyclic aromatic hydrocarbons have been detected in the water (Moring, 1999) and probably occur in the streambed sediment of this reach of the Rio Grande. These hydrophobic compounds can bioaccumulate in the tissues of aquatic organisms to levels of concern and can accumulate in streambed sediments because of their tendency to adsorb to sediment particles and other particulates (Moring, 1999).

The Rio Grande represents the Chihuahuan Desert's most extensive aquatic and associated riparian environments. Aquatic-life inventories in the Rio Grande through the Big Bend region indicate that 4 of 36 known native fish species from the river and its tributaries in the Big Bend region have been extirpated, including the endangered Rio Grande silvery minnow (Platania, 1990). Of the remaining native species, the Big Bend gambusia is federally endangered, and the Rio Grande chub, blue sucker, blotched gambusia, Chihuahua shiner, Mexican stoneroller, proserpine shiner, Rio Grande darter, and Rio Grande shiner have been identified by the USFWS as species of concern. Thirty-two native fish species persist but compete with 11 non-native fish species, a number that has steadily increased in recent years. Several fish-community surveys have been done in the Rio Grande and its tributaries through the Big Bend region (Evermann and Kendall, 1894; Hubbs, 1940; Trevino-Robinson, 1959; Bestgen and Platania, 1988; Platania, 1990; Garrett, 1997; Allan, 1998). However, no study has been done in the last 5 to 10 years to quantify the occurrence and distribution of native fish species in the Big Bend region or to establish long-term benchmark reaches to assess the status and trends in fish communities over time.

The use of aquatic invertebrates, particularly insects, as indicators of aquatic ecosystem health is well known (Hilsenhoff, 1987; Reynoldson and Rosenberg, 1996). However, the NPS lacks distribution and abundance data on the majority of Rio Grande invertebrate taxa in BBNP. Aquatic invertebrates are integral to ecosystem health and are indicators of ecosystem disturbance that could be used to monitor effects of non-native species, pollution events, reduced streamflow, and other anthropogenic disturbances in the Big Bend region. No comprehensive characterization of Rio Grande aquatic invertebrate communities in the Big Bend region has been done, and nothing is in place to monitor changes in the invertebrate community in BBNP.

This study, conducted by the U.S. Geological Survey (USGS) in cooperation with the NPS, was designed to collect and interpret the essential data needed to effectively manage aquatic-life resources of the Rio Grande in reaches in and near BBNP—and to establish benchmark sites to assess the status and trends in stream habitat, fish communities, and benthic macroinvertebrates over time. The key findings from this study will be integrated into a comprehensive long-term water-quality assessment plan for the Rio Grande. The study was part of the Water Quality Partnership Program between the USGS and NPS.

The purpose of this report is to provide the NPS as well as policymakers, regulators, and non-governmental organizations in Texas and Mexico with baseline data and supporting interpretations on the occurrence and distribution of instream and riparian-zone biological resources of the Rio Grande in five reaches in and near BBNP. The report describes the field methods of assessment of stream habitat, fish communities, and benthic macroinvertebrates. Results based on statistical analyses and graphical comparisons are presented.

METHODS OF ASSESSMENT

Site Selection and Establishment

Potential study sites on the main stem of the Rio Grande were selected after map-based and aerial reconnaissance in December 1998 and January 1999. Five study sites were selected from the potential sites—one upstream of BBNP adjacent to Big Bend Ranch State Park, three in BBNP, and one downstream of the Park adjacent to Black Gap Wildlife Refuge (fig. 1). The sites, in downstream order, are Colorado Canyon at river kilometer 1,468, Santa Elena at river kilometer 1,414, Johnson Ranch at river kilometer 1,377, Boquillas at river kilometer 1,260, and Black Gap at river kilometer 1,219 (table 1). The five sites compose a synoptic network for assessment, and the three sites in BBNP also are benchmark sites for proposed long-term monitoring.

A sampling reach was selected at each site on the basis of the occurrence and frequency of geomorphic channel features. Reaches were selected in segments of the river where riffle-pool geomorphic sequences were common, and the channel had a classical meandering morphology (Leopold and others, 1964; Gordon and others, 1992). A meandering channel was selected for each reach to maximize the variability in streamflow velocities, depth, bed substrate, and in-channel structure over the shortest length of channel possible. Each reach had at least two each of the three geomorphic channel units: riffles, runs, or pools (Meador, Hupp, and others, 1993). Reach length varied from about 352 m at Santa Elena to about 726 m at Black Gap. Upstream and downstream boundaries for each reach were selected, and monuments were established to identify them by driving a 30- by 1.25-cm reinforcement-bar stake with an aluminum surveyor cap on top stamped with "USGS." Additional stakes and caps were driven into the ground to establish markers for each of four transects corresponding to the four geomorphic channel units in the reach. All monuments and markers were established on or above what was determined by on-site visual inspection to be the high-bank terrace on the U.S. bank. If a stake could not be driven, a chisel-square mark was made on the rock and painted blue to indicate a reach boundary monument or orange to indicate a transect marker. Coordinates were recorded for each monument and marker using a hand-held GPS unit with an accuracy of $\pm$3.0 m.

All of the transects were located in reference to a permanent marker that was georeferenced. Coordinates and a transect bearing and distance were recorded in reference to this marker. This permanent marking of each transect will allow subsequent investigators to return and make measurements and comparisons over time of all of the reach and transect-based measures.

Stream-Habitat Assessment

Synoptic assessments at each reach included the construction of a detailed planimetric reach map (figs. 2–6) to highlight channel features and reach shape and the characterization of channel and riparian-zone habitat features (Meador, Hupp, and others, 1993; and Moring and others, 1998), which include depths, velocities, and type, frequency, and extent of geomorphic channel units (riffles, runs and pools).

Several reach-based and within-reach, transect-based measures were taken (table 2). Four channel cross sections extending from the right bank (Mexican bank) high-bank terrace to the left bank (U.S. bank) high-bank terrace were selected in each reach corresponding to the four geomorphic channel units that were selected. Six or more transects per reach have been suggested (Cuffney and others, 1993). However, in this study, the selection of four cross sections in each reach was thought to be sufficient to characterize channel morphology and therefore variability in stream velocity, depth, and substrate types and distribution. In addition to noting the dominant and subdominant bed substrate, a 100-point "pebble count" (Goudie, 1981) was done in riffles in each reach to quantify the types and relative abundance of the coarser substrates such as gravel, cobble, and boulders.

A Sokia Leitz™ Set 4A laser-operated total station was used to survey all transects and the entire reach to produce many of the stream habitat measures and the planimetric maps. All survey data were stored on site in a datalogger that was electronically linked to the total station. The data were imported into an electronic spreadsheet and sorted, and computations were performed to determine linear reach length, curvilinear reach length, bank slope, bank height, channel width, and median depth (Moring and others, 1998).

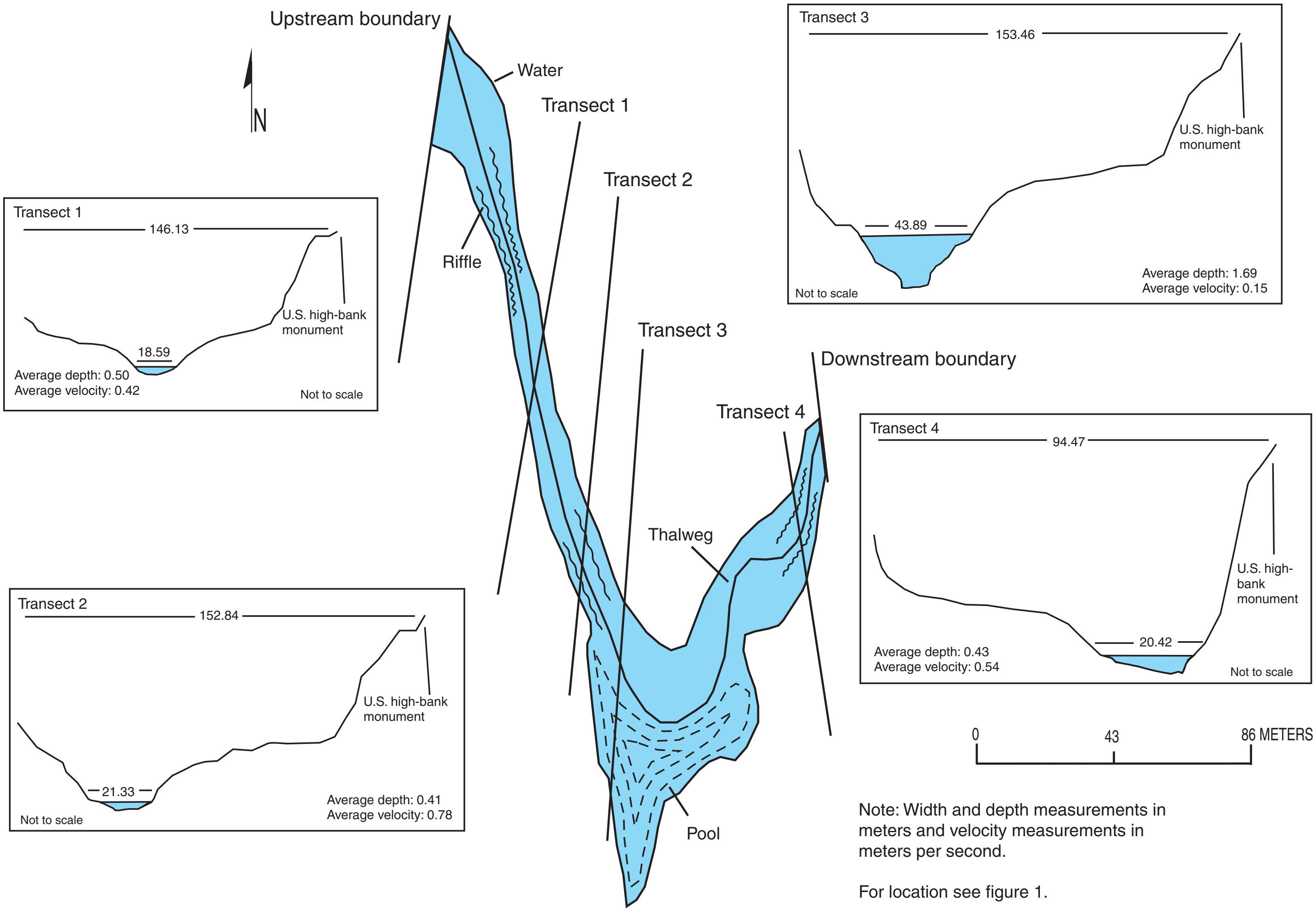

Figure 2. Planimetric reach map for Rio Grande above Colorado Canyon.

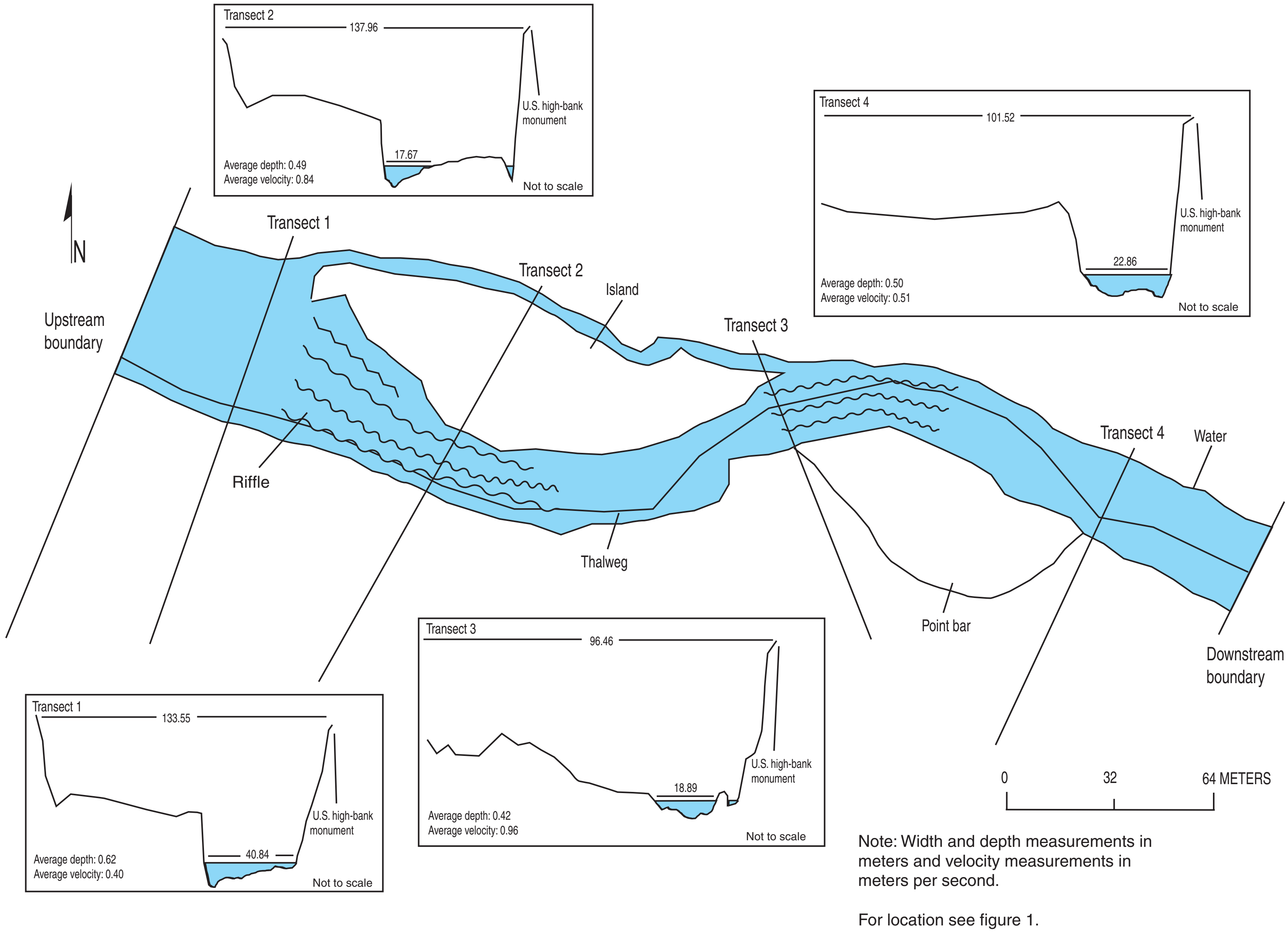

Figure 3. Planimetric reach map for Rio Grande below Santa Elena Canyon.

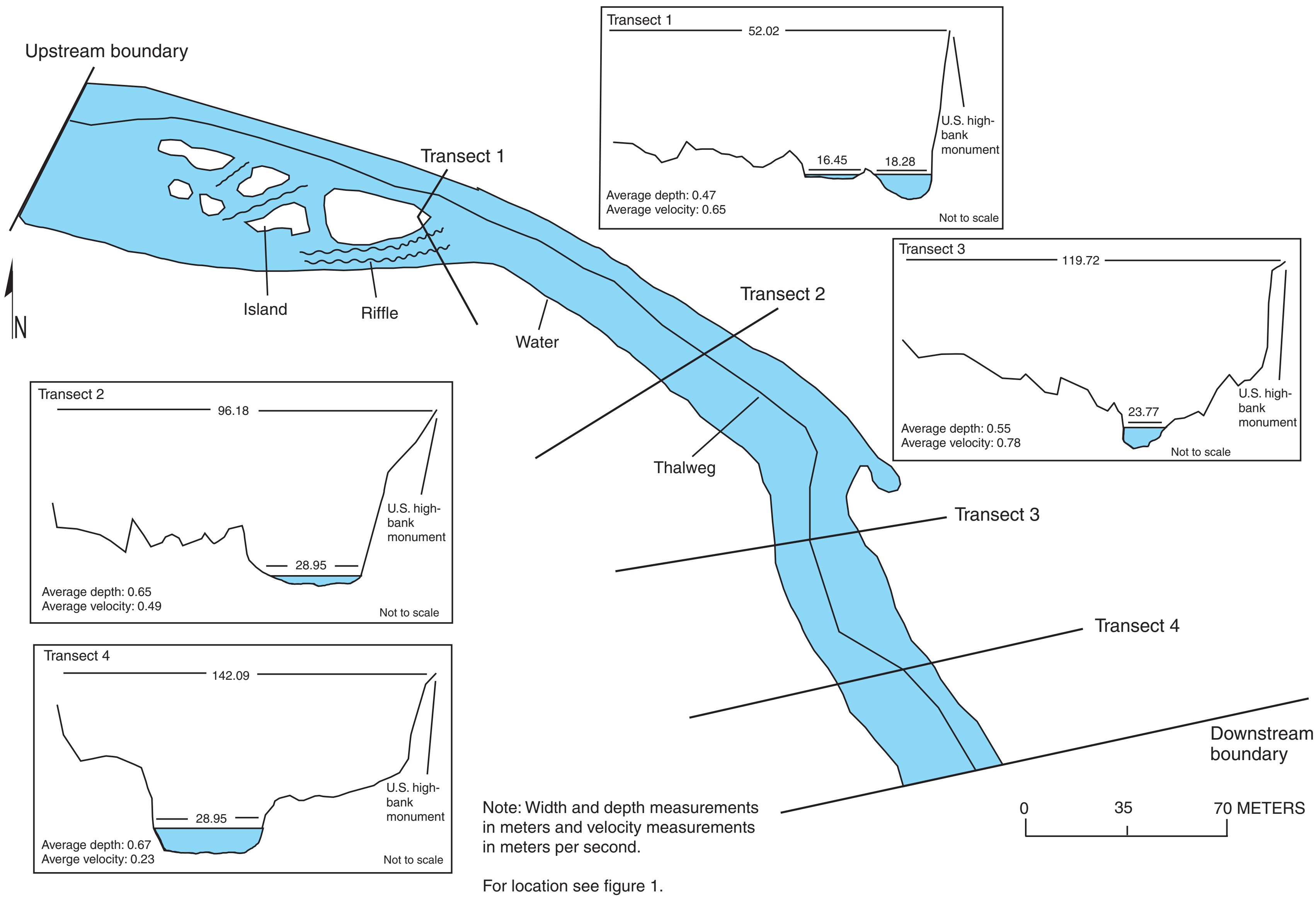

Figure 4. Planimetric reach map for Rio Grande at Johnson Ranch.

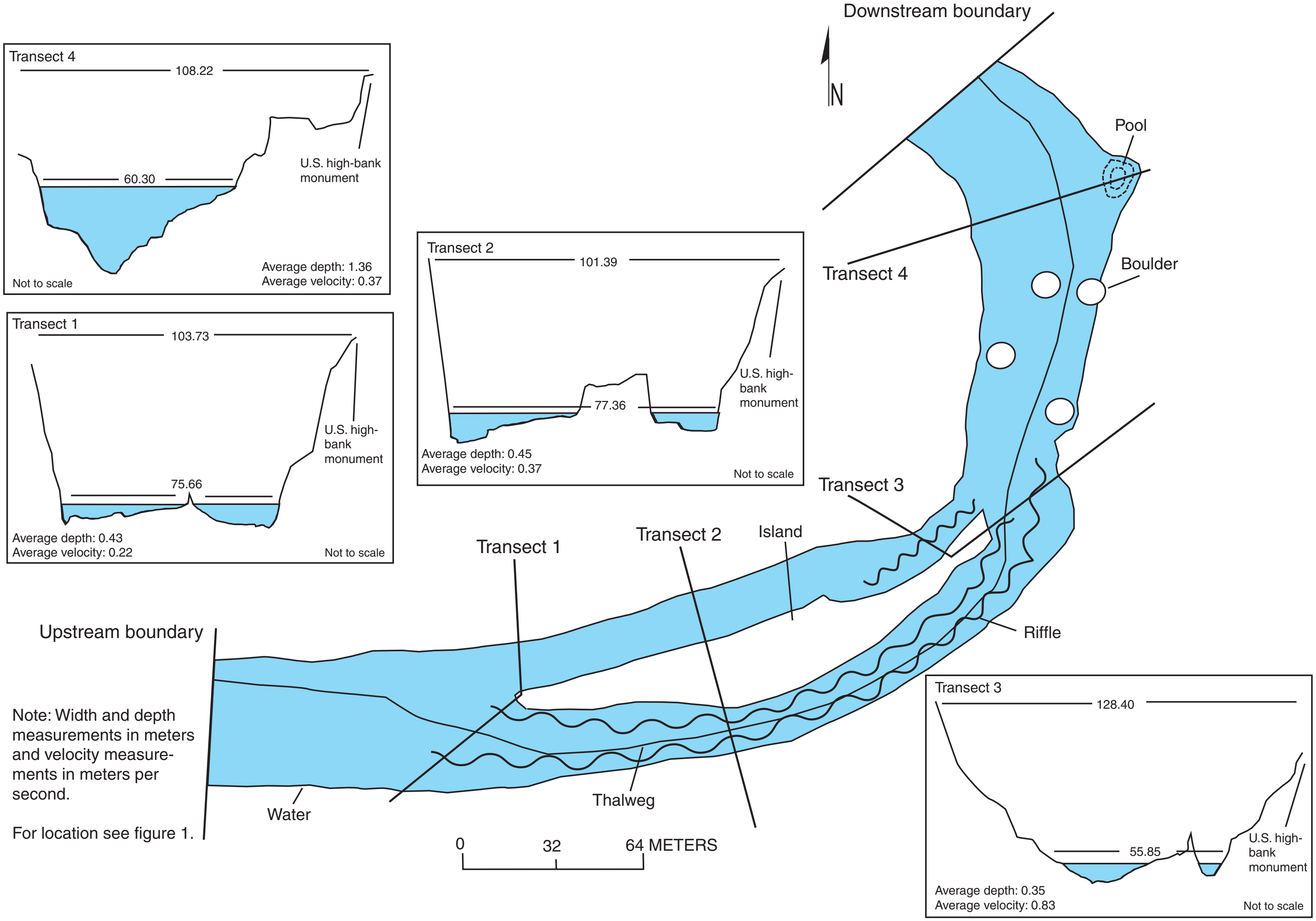

Figure 5. Planimetric reach map for Rio Grande above Boquillas Canyon.

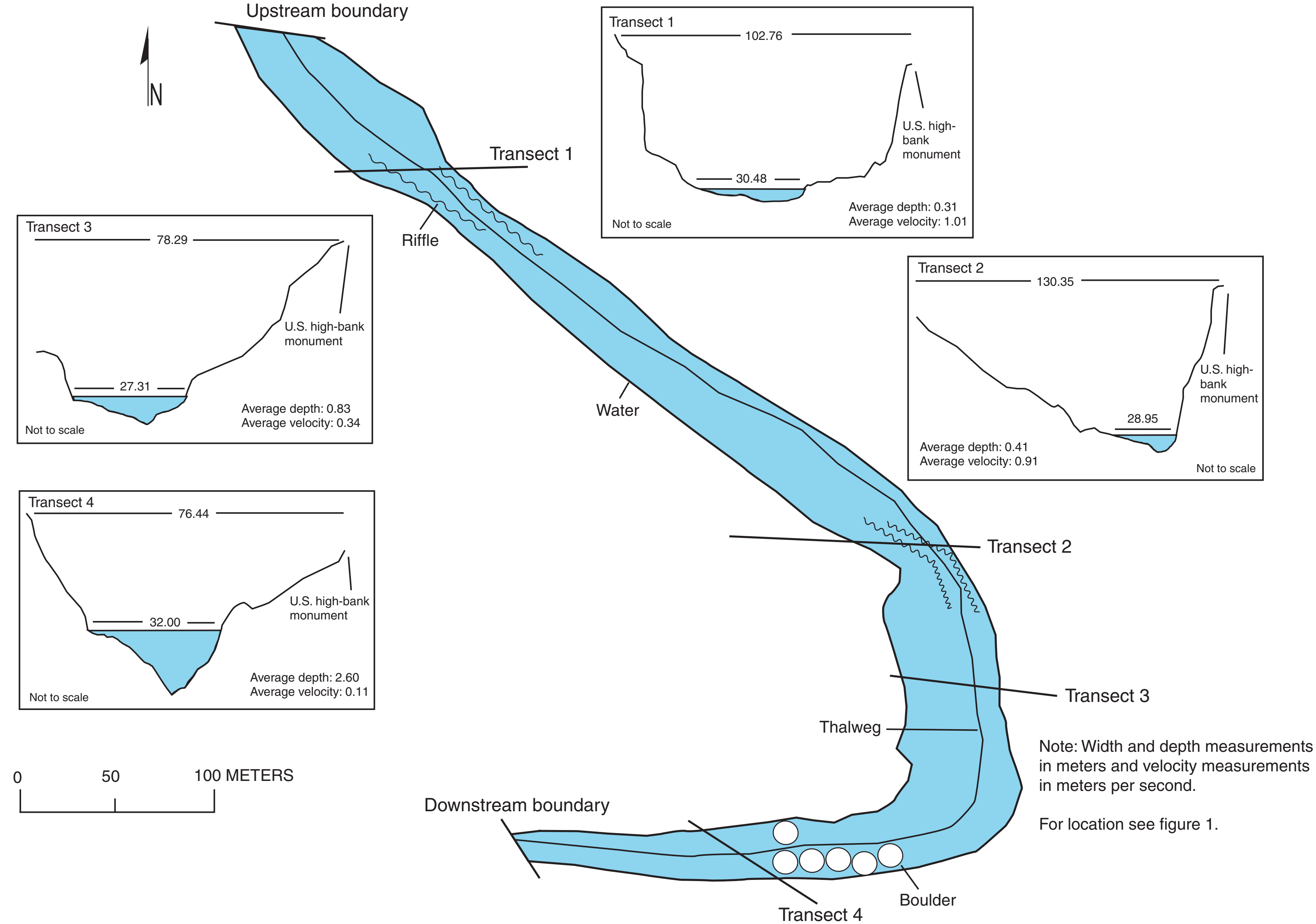

Figure 6. Planimetric reach map for Rio Grande below Maravillas Creek (Black Gap Wildlife Refuge).

Table 1. Name, location, and general description of U.S. Geological Survey Rio Grande bioassessment reaches in and near Big Bend National Park, Texas

[km, kilometers; --, not available]

Reach name	Reach location	River kilometer at upstream boundary	Coordinates for upstream boundary monument	Geomorphic channel unit coordinates for reach: Transect 1 monument	Transect 2 monument	Transect 3 monument	Transect 4 monument	Coordinates for downstream boundary monument
Colorado Canyon	1.6 km above “Big Hill” turnoff on U.S. 170	1,468	N 29°17'52.89" W 103°57'23.49"	Riffle N 29°17'52.68" W 103°57'18.74"	Riffle N 29°17'52.42" W 103°57'17.08"	Pool N 29°17'52.46" W 103°57'16.76"	Riffle N 29°17'51.61" W 103°57'11.28"	N 29°17'51.80" W 103°57'10.24"
Santa Elena	1.6 km below Terlingua Creek confluence at river take-out	1,414	N 29°09'20.38" W 103°35'54.88"	Run N 29°09'19.40" W 103°35'54.15"	Riffle N 29°09'17.60" W 103°35'52.66"	Riffle N 29°09'16.04" W 103°35'51.45"	Run N 29°09'13.18" W 103°35'48.77"	N 29°09'11.71" W 103°35'48.09"
Johnson Ranch	International Boundary and Water Commission gaging station near Johnson Ranch	1,377	N 29°02'05.10" W 103°23'22.47"	Riffle N 29°01'59.72" W 103°23'18.88"	Run N 29°02'01.12" W 103°23'16.04"	Riffle N 29°01'58.10" W 103°23'13.61"	Run N 29°01'56.24" W 103°23'12.12"	N 29°01'54.72" W 103°23'11.38"
Boquillas	1.6 km above mouth of Boquillas Canyon	1,260	N 29°11'30.80" W 102°55'14.87"	Riffle N 29°11'28.65" W 102°55'10.19"	Run N 29°11'28.32" W 102°55'08.02"	Riffle N 29°11'28.98" W 102°55'06.13"	Pool N 29°11'31.62" W 102°55'04.31"	N 29°11'32.37" W 102°55'04.34"
Black Gap	4.8 km below confluence of Maravillas Creek in Black Gap Wildlife Refuge	1,219	--	Riffle --	Riffle N 29°35'34.49" W 102°46'07.79"	Run N 29°35'38.24" W 102°46'09.11"	Pool N 29°35'45.43" W 102°46'06.82"	N 29°35'46.23" W 102°46'05.27"

Table 2. Stream-habitat measures for bioassessment reaches on the Rio Grande in and near Big Bend National Park, Texas

[m, meters; m/s, meter per second; mm, millimeters]

Habitat measure	Colorado Canyon	Santa Elena	Johnson Ranch	Boquillas	Black Gap
Linear reach length (m)	362.6	323.9	349.4	397.7	609.5
Curvilinear reach length (m)	487.6	352.5	403.7	593.1	726.6
Reach sinuosity	1.34	1.09	1.16	1.49	1.19
Reach slope	.0048	.0024	.0017	.0012	.0017
Median bank slope	.102	.079	.061	.072	.187
Median bank height (m)	20.4	18.0	19.9	15.7	22.8
Median high-bank channel width (m)	149.5	117.5	116.8	105.9	90.5
Median bank height to high-bank channel width ratio	.117	.042	.042	.047	.077
Median depth (m)	1.19	.503	.609	.548	.695
Median velocity (m/s)	.799	.587	.492	.309	.625
Median embeddedness of cobble (percent)	40	20	60	50	65
Dominant streambed substrate	boulder	cobble	cobble	cobble	cobble
Median canopy angle (degrees)	153	138	158	168	162
Median particle size (mm)	110.0	26.5	47.0	57.0	50.0
Median bank vegetation coverage (percent)	17.5	72.5	92.5	40.0	85.0

Fish-Community Assessment

The fish community at each reach was sampled once in early spring 1999 and once in late summer 1999. Samples were collected in different seasons to account for any seasonal sampling bias because of differences in fish recruitment and local distribution and to provide the most accurate information on species composition and relative abundance for each reach.

Various electrofishing and netting techniques were used to assess fish-community composition and structure (Meador, Cuffney, and Gurtz, 1993; Moring and others, 1998). Backpack and barge electrofishing equipment were used to sample fish at each reach. Two electrofishing passes per reach were made, and the time in seconds that the electrofishing unit was operating was recorded to monitor electrofishing sampling. A 7.5- by 3.0-m by 0.64-cm mesh seine was used to supplement electrofishing sampling, particularly in riffles, and at least one seine-haul was made in each type of geomorphic channel unit present in the reach.

All collected fish were identified to species. In addition, total and standard lengths in millimeters, total weight in grams, and the type, frequency, and location of any external anomalies such as lesions, tumors, or parasites were noted (Meador, Cuffney, and Gurtz, 1993). All minnows were fixed in 10-percent buffered formalin and returned to the USGS office in Austin, Tex., for verification of identification.

Benthic Macroinvertebrate Assessment

Benthic macroinvertebrate samples were collected at the five sampling reaches using reach-based compositing methods developed by the USGS National Water-Quality Assessment (NAWQA) Program (Cuffney and others, 1993; Moring and others, 1998). Two sample types, a richest targeted habitat (RTH) and a qualitative multihabitat (QMH), were collected at each reach in early March 1999. In addition to the NAWQA-style samples, a USEPA Rapid Bioassessment Method (Plafkin and others, 1989) traveling kick-seine sample was collected at each reach at the time the RTH samples were collected.

Five RTH samples were collected at each reach and composited. Each RTH sample was taken by selecting five sampling locations distributed between two or more riffles in the reach and placing a 0.25-m^2 sampling quadrat frame in the streambed at each location. A modified Surber sampling net with a 425-µm mesh net and a 425-µm attached plankton bucket was placed on the downstream end of the frame, and the streambed in the frame was disturbed for 60 seconds to dislodge benthic organisms into the net. The contents of the net and plankton bucket were rinsed into a 19-L bucket, processed through a 425-µm sieve to remove entrained organic and inorganic debris, and placed in a 1-L polypropylene jar and fixed with 10-percent buffered formalin (Cuffney and others, 1993).

A QMH sample was collected at each reach by using a 205-µm mesh d-frame net. Individual QMH samples were collected in multiple habitats at each reach and composited into the QMH sample. Contents of the d-frame net were placed in a 19-L bucket, field processed through a 205-µm mesh sieve, and placed in a 1-L polypropylene jar and fixed with 10-percent buffered formalin.

All benthic samples were shipped to a contract laboratory for identification and enumeration of taxa. If a sample contained 500 or fewer organisms, all the organisms in the sample were sorted, counted, and identified. If the sample contained more than 500 organisms, a 500-count subsampling routine was used (Lester, 1999). Most taxa, except for some midges and non-insect macroinvertebrates, were identified to genus. A reference collection with at least one specimen of each taxon identified was provided to the USGS by the contract laboratory.

Data Management and Analysis

All field data were recorded on forms printed on waterproof paper. All field data were checked for data-recording anomalies and consistency in units of measurement prior to transfer to digital format, then keyed into an electronic spreadsheet and reviewed for accuracy. Survey data were recorded in digital format in the field, printed and reviewed, and uploaded to an electronic spreadsheet pending map production and data analysis.

Selected stream-habitat measures (table 2) were compared among the five reaches. All quantitative transect-based stream-habitat measures (those for which medians are listed in table 2) were compared among reaches using a multisample median test (Zar, 1984). The objective of the test was to determine if the median measures differ significantly among the five reaches. The test indicates whether at least one median is significantly different but does not indicate which reach median is different. If the result of a median test indicated a significant difference, then a nonparametric Tukey-type multiple-comparison test (Zar, 1984) was used to determine which median (or medians) was different. The multiple-comparison test compares all possible combinations of reach medians and indicates which medians are similar or different from others. The tests were done and graphical comparisons were generated using a statistical software package (StatSoft, 1998).

All fish and benthic macroinvertebrate data were analyzed using an electronic spreadsheet to compute community metrics or were transferred to the statistical software package for statistical analysis and generation of graphical comparisons. In addition to the computation of summary statistics (means, medians, percentiles, maximums, and minimums), cluster analyses were done using abundance data to compare overall fish-community similarity and benthic aquatic-insect similarity among the five reaches. Cluster analysis is a statistical classification technique that places similar objects (reaches in this application) into groups or "clusters" (Ludwig and Reynolds, 1988).

RESULTS OF ASSESSMENT

Stream Habitat

Reach sinuosity, determined as the ratio of curvilinear reach length divided by linear reach length, varied from a minimum of 1.09 at Santa Elena to a maximum of 1.49 at Boquillas (fig. 7). Reach slope varied from a minimum of 0.0012 at Boquillas to a maximum of 0.0048 at Colorado Canyon (fig. 8). Sinuosity can be interpreted as the degree to which a channel meanders over a given distance of channel length. Presumably, the greater the sinuosity, the greater the variability in stream velocities, channel substrate types and sizes, and overall habitat variability and availability for aquatic life. The larger sinuosity of the Boquillas reach reflects the wider floodplain of the Rio Grande just upstream of Boquillas Canyon; whereas the smaller sinuosity of the Santa Elena reach might be influenced by confining canyon walls, at least on the Mexico side.

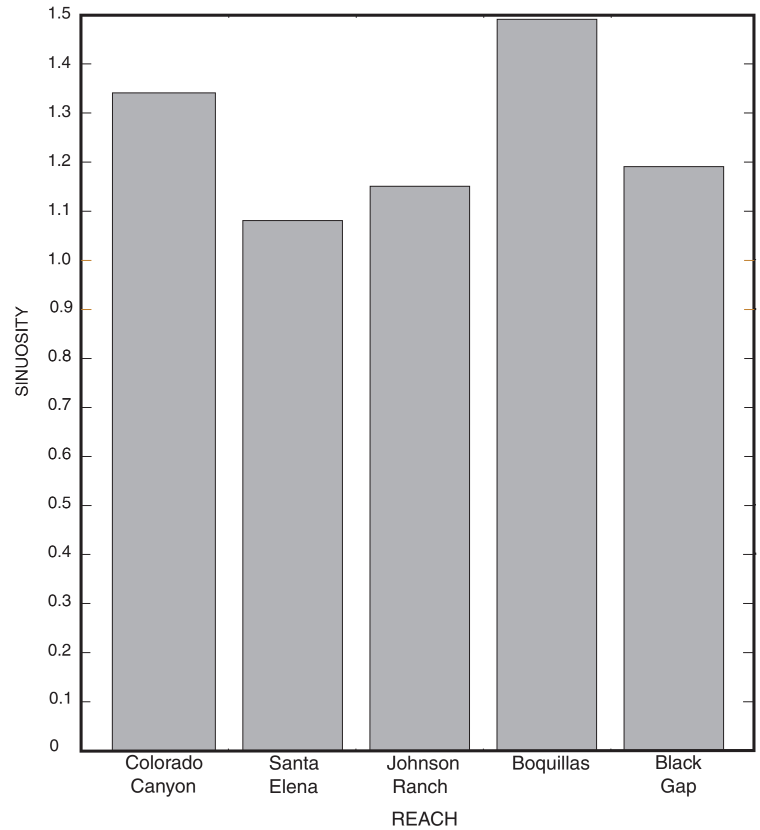

Figure 7. Reach sinuosity for five bioassessment reaches in and near Big Bend National Park, Texas.

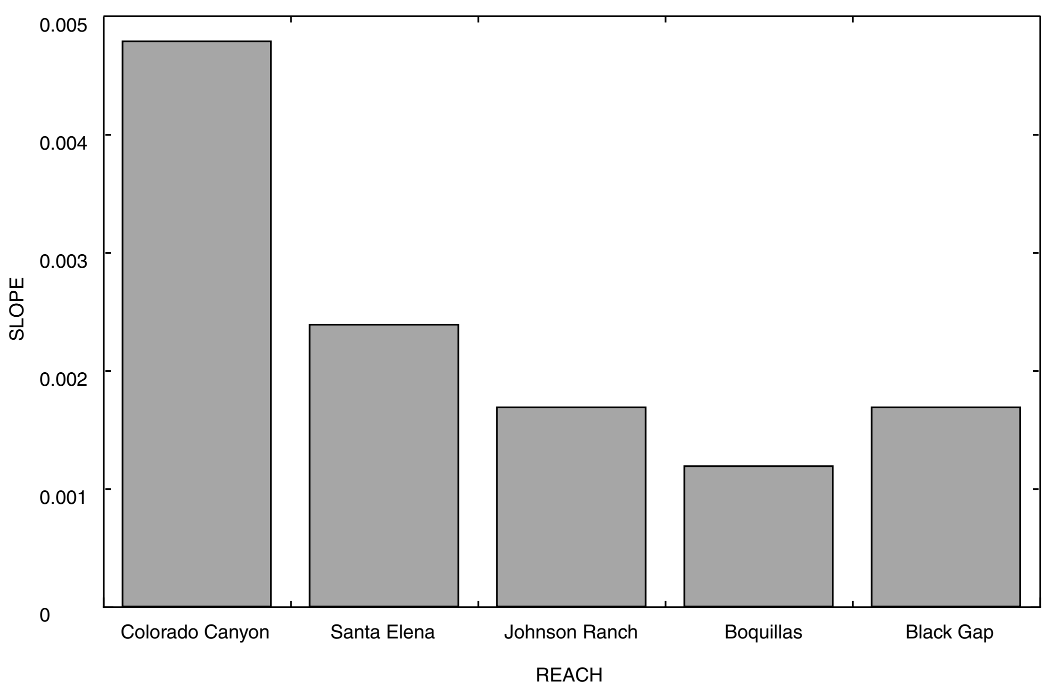

Figure 8. Reach slope for five bioassessment reaches in and near Big Bend National Park, Texas.

Stream velocity (χ^2 = 2.67, p = 0.61), bank height (χ^2 = 7.00, p = 0.14), and bank slope (median test statistic [χ^2] = 4.00, p-value = 0.41) were not significantly different among the five reaches (fig. 9). Too few data were available for statistical testing of high-bank channel width. Median bank slope was largest at Black Gap (0.187) and smallest at Johnson Ranch (0.061). Bank heights generally were larger at the Colorado Canyon and Black Gap reaches. Median high-bank channel widths ranged from 90.5 m at Black Gap to 149.5 m at Colorado Canyon. Median stream velocities were relatively uniform among all five reaches, less than 1 m/s. A maximum stream velocity of 3.25 m/s was recorded at Colorado Canyon in Panther Rapids at the upstream end of the study reach.

The bank height to high-bank channel width ratio was computed for each reach as a measure of channel incision. On the basis of the median test, this ratio was not the same among all reaches (χ^2 = 16.00, p = 0.003); thus the multiple comparison test was done. Channel incision ratio was significantly different at the 0.05 level between Colorado Canyon and Santa Elena and between Colorado Canyon and Johnson Ranch (fig. 10). The median incision ratio of 0.117 for Colorado Canyon was greater than the ratios for Santa Elena and Johnson Ranch by a factor of almost 3. The Colorado Canyon reach is bordered on both sides by the downstream end of Colorado Canyon. This confinement has created a narrow floodplain, a relatively high bank terrace, and the largest bank height to channel width ratio of the five reaches.

The percent embeddedness of cobble substrate was not the same among the five reaches (χ^2 = 18.02, p = 0.0012). Percent embeddedness was significantly different at the 0.05 level between the Santa Elena and Black Gap reaches (fig. 11). Median percent embeddedness varied from 20 percent at Santa Elena to 65 percent at Black Gap. Increased embeddedness might indicate a channel that is not in equilibrium with its floodplain because of increasing bed loads that are not being distributed downstream or into the adjacent floodplain. Embeddedness also can be interpreted as a measure of the extent of siltation in a reach and can affect organism dispersal, occlusion of respiratory membranes (such as gills), egg development, and hatch success.

Gravel and larger particle sizes were compared among the reaches. Particle size was not the same among the five reaches (χ^2 = 205.4, p = 0.0001). Median particle size for the Colorado Canyon reach and for the Santa Elena reach were significantly different at the 0.05 level from that for other reaches (fig. 12). Median particle size was not significantly different among the Johnson Ranch, Boquillas, and Black Gap reaches. The significantly different (larger) median particle size at Colorado Canyon is caused by the presence of more small cobbles or boulders of igneous rock. Igneous rock weathers more slowly than the limestone that characterizes the surficial geology of the four other reaches farther downstream. No apparent factor was responsible for the significantly different (smaller) median particle size at Santa Elena.

The density and composition of bank vegetation can influence bank stability, rates of bank erosion, and composition and rate of allochthonous input to a stream channel (Hynes, 1970). In addition, a number of exotic species of vegetation have encroached on BBNP and the surrounding region. Accounting for the occurrence and distribution of indigenous and non-indigenous species of riparian vegetation along the Rio Grande is important because the river can act as a major corridor of dispersal for exotics as well as native species.

The percent of the bank covered by rooted vegetation was not the same (fig. 13) among the reaches (χ^2 = 13.00, p = 0.01). Percent bank vegetation coverage was significantly different at the 0.05 level between Colorado Canyon and Johnson Ranch and between Johnson Ranch and Boquillas. Median percent coverage ranged from 17.5 percent at Colorado Canyon to 92.5 percent at Johnson Ranch. The Santa Elena, Johnson Ranch, and Black Gap reaches all had percent coverages from 1.8 to 5.3 times greater than those of Colorado Canyon and Boquillas. The banks at the Colorado Canyon reach were dominated by igneous rock, and vegetation was much more sparse on the Colorado Canyon banks than on the banks dominated by the more weathered limestone rocks at the four other reaches. Santa Elena, Johnson Ranch, and Black Gap all had bermuda grass covering much of the bank surface, which accounts for the higher percentage of bank vegetation coverage for these reaches.

The relative abundance of the dominant native and non-native species common to the banks of the Rio Grande varied among the five reaches (fig. 14). Of the native species, honey mesquite, groundseltree (*Baccharis* sp.*),* giant reed (*Arundo donax*), and common reed (*Phragmites australis)* were the most common. Like the common and giant reeds, groundseltree often was found in dense stands, possibly excluding seeding and germination by other species. The giant reed was more commonly encountered within and

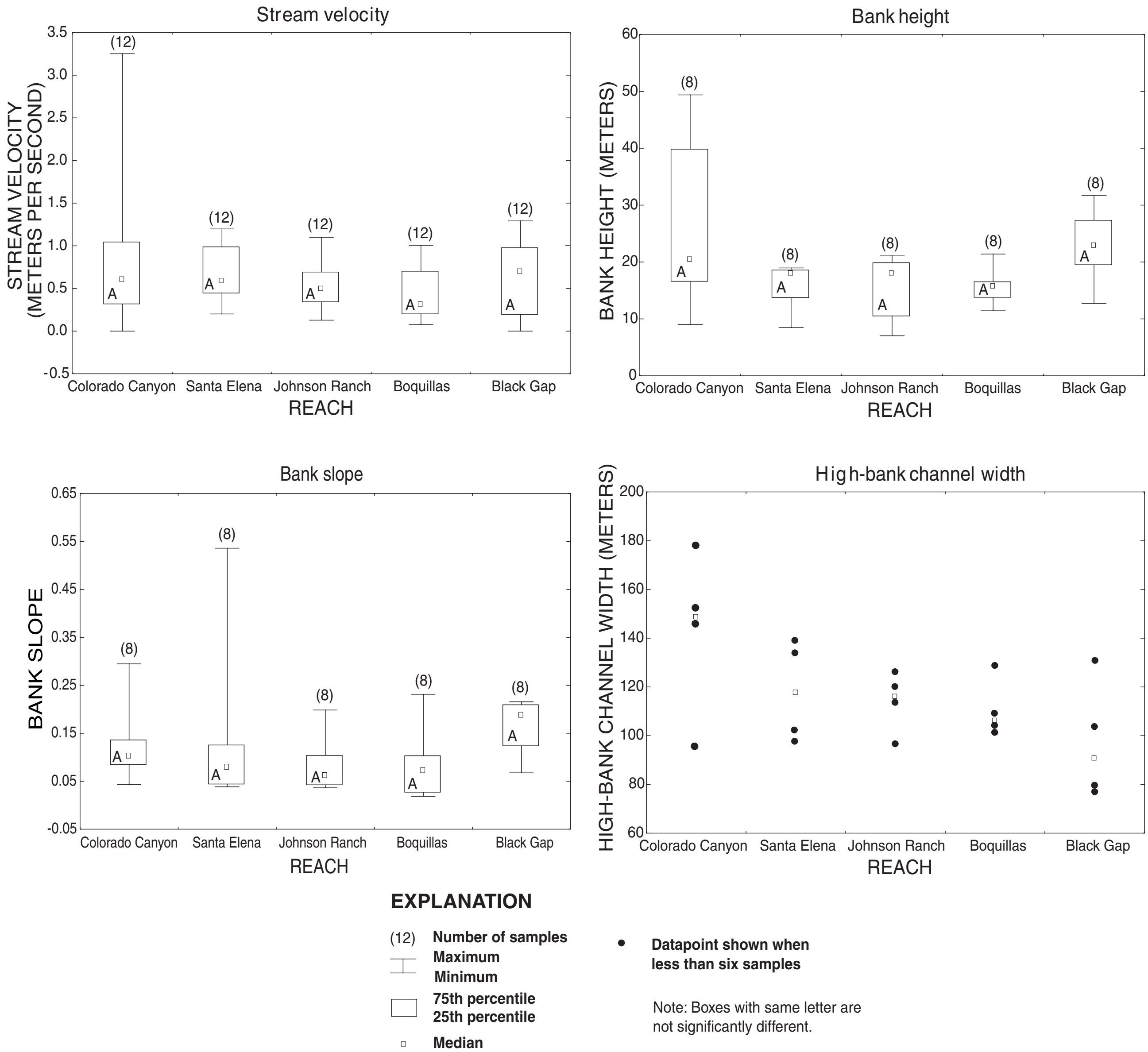

Figure 9. Streamflow velocity and selected stream-habitat measures for five bioassessment reaches in and near Big Bend National Park, Texas.

between the reaches than the common reed. Common reed was encountered only along the transects at the Colorado Canyon and Johnson Ranch reaches. The non-native species salt cedar (*Tamarisk* sp.) and bermuda grass (*Cynodon dactylon*) accounted for about 25 to 40 percent of the vegetation on the banks of the five reaches. Salt cedar was as much as 17 percent of the vegetation at Santa Elena and not present along the transects at Johnson Ranch. Bermuda grass ranged from a minimum of 16 percent at Boquillas and Black Gap to a maximum of 26 percent at Colorado Canyon. Where bermuda grass exists on the banks of the Rio Grande, it was usually the dominant herbaceous ground cover and, in some instances, covered the majority of the bank. This was most obvious on the U.S. bank at Johnson Ranch on both sides of several transects.

Fish Community

Eighteen species of fish were collected among the five reaches (table 3). A total of 474 fish were collected

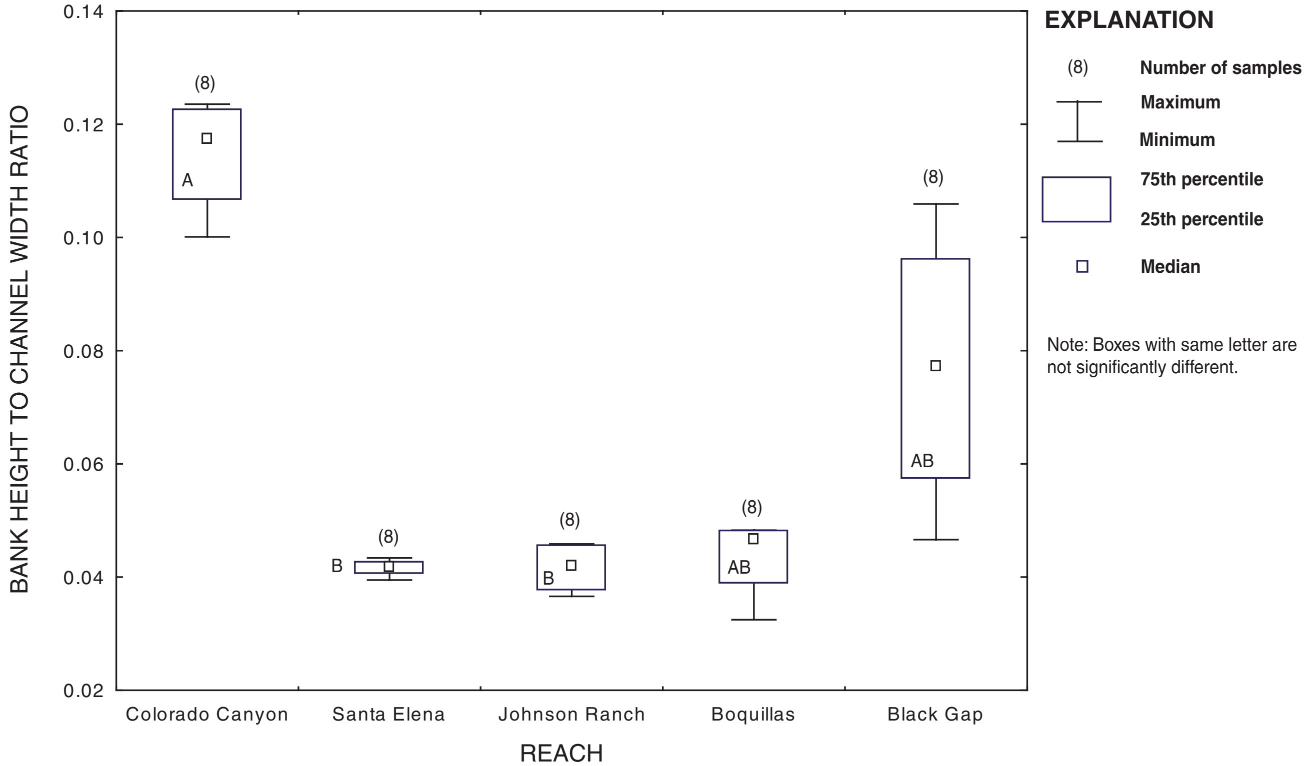

Figure 10. Bank height to channel width ratio for five bioassessment reaches in and near Big Bend National Park, Texas.

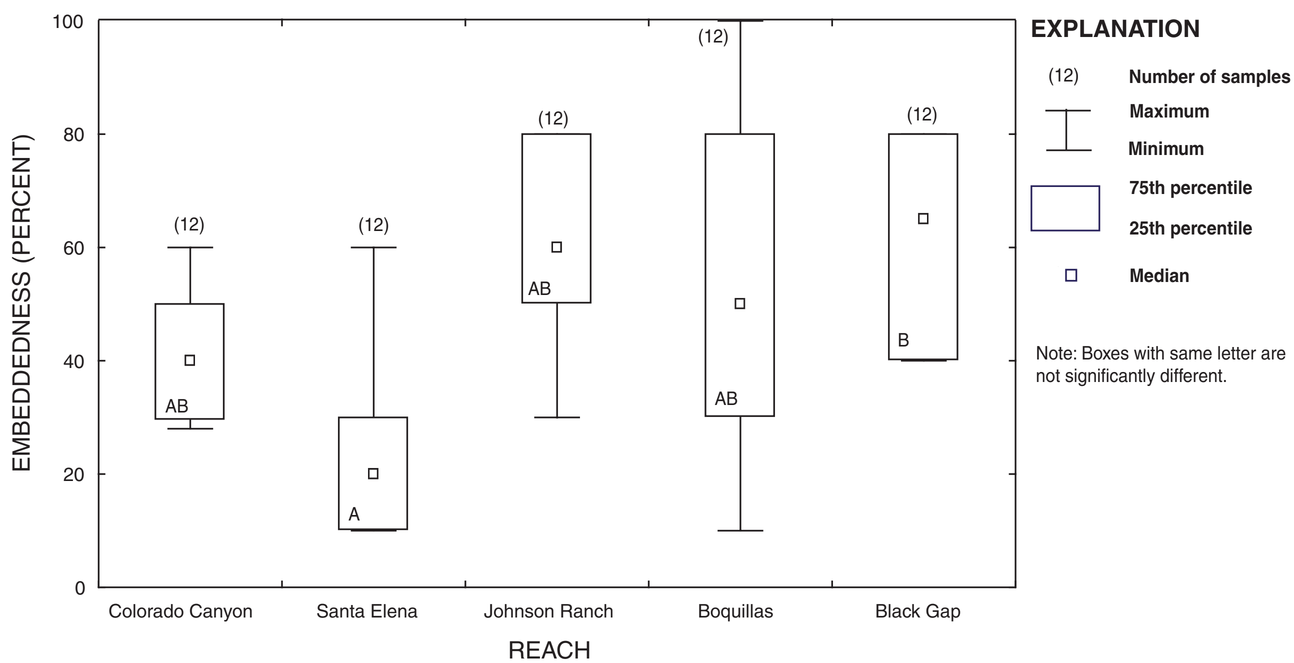

Figure 11. Embeddedness of cobble for five bioassessment reaches in and near Big Bend National Park, Texas.

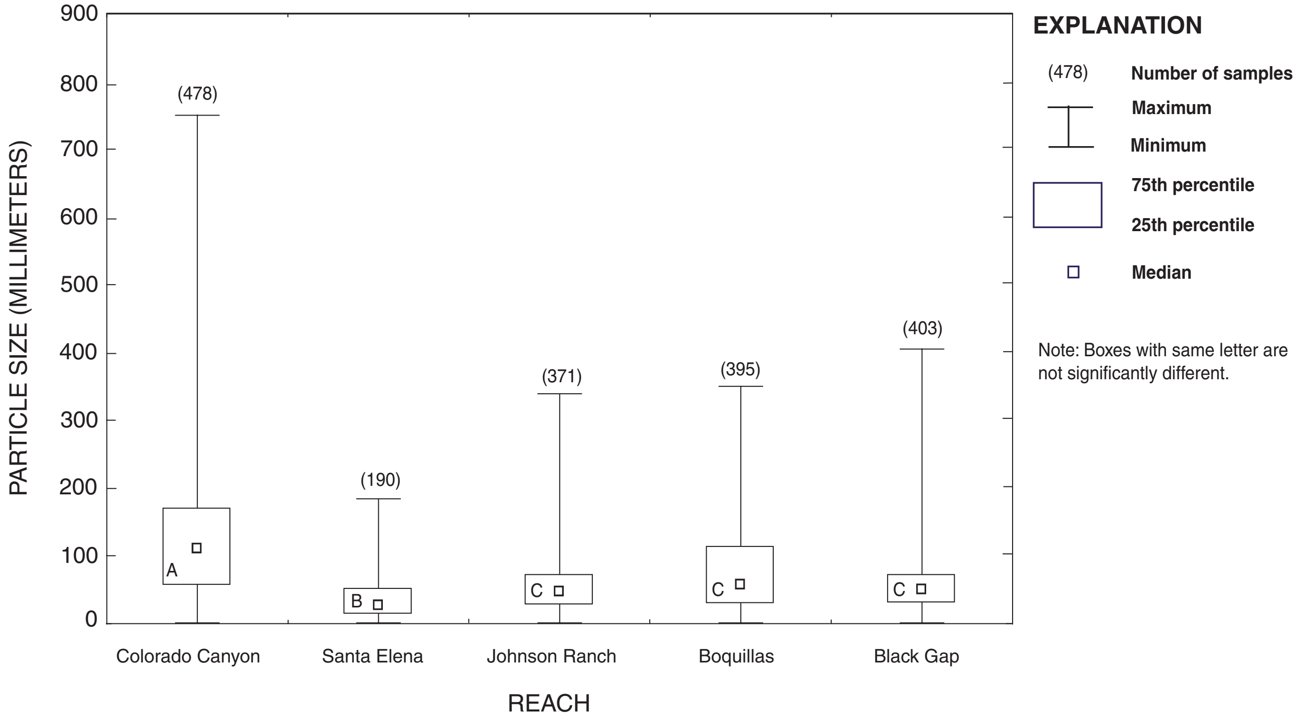

Figure 12. Gravel and larger particle size of bed material for five bioassessment reaches in and near Big Bend National Park, Texas.

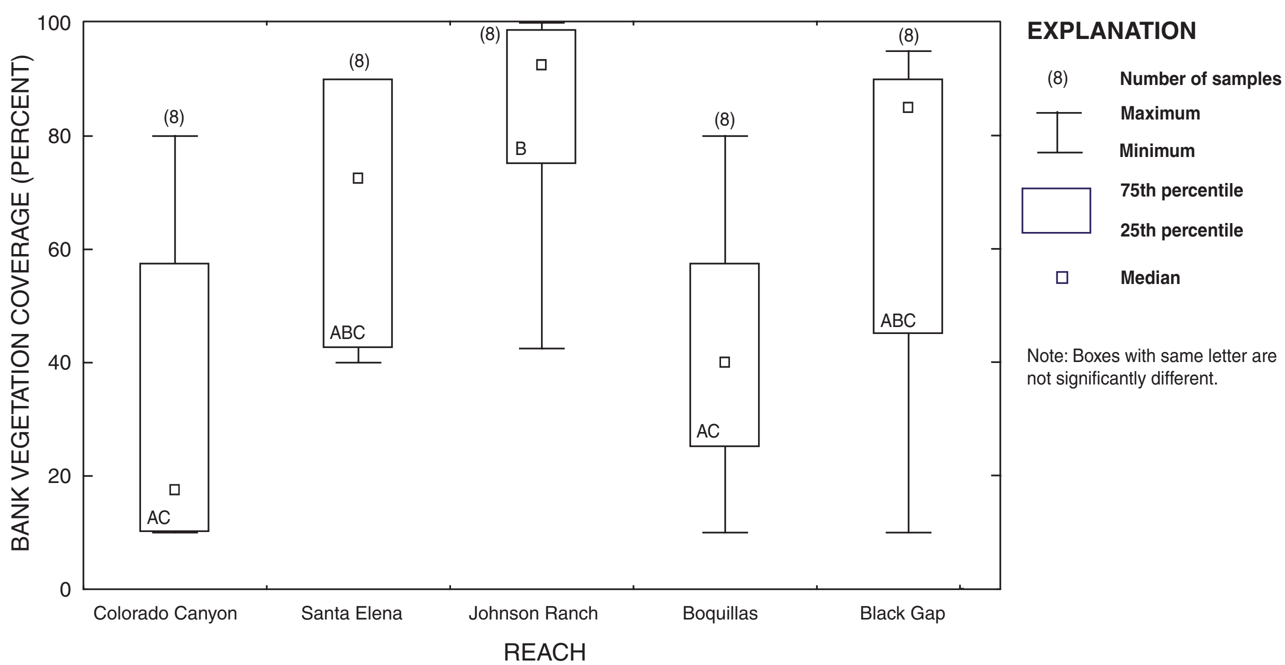

Figure 13. Bank vegetation coverage for five bioassessment reaches in and near Big Bend National Park, Texas.

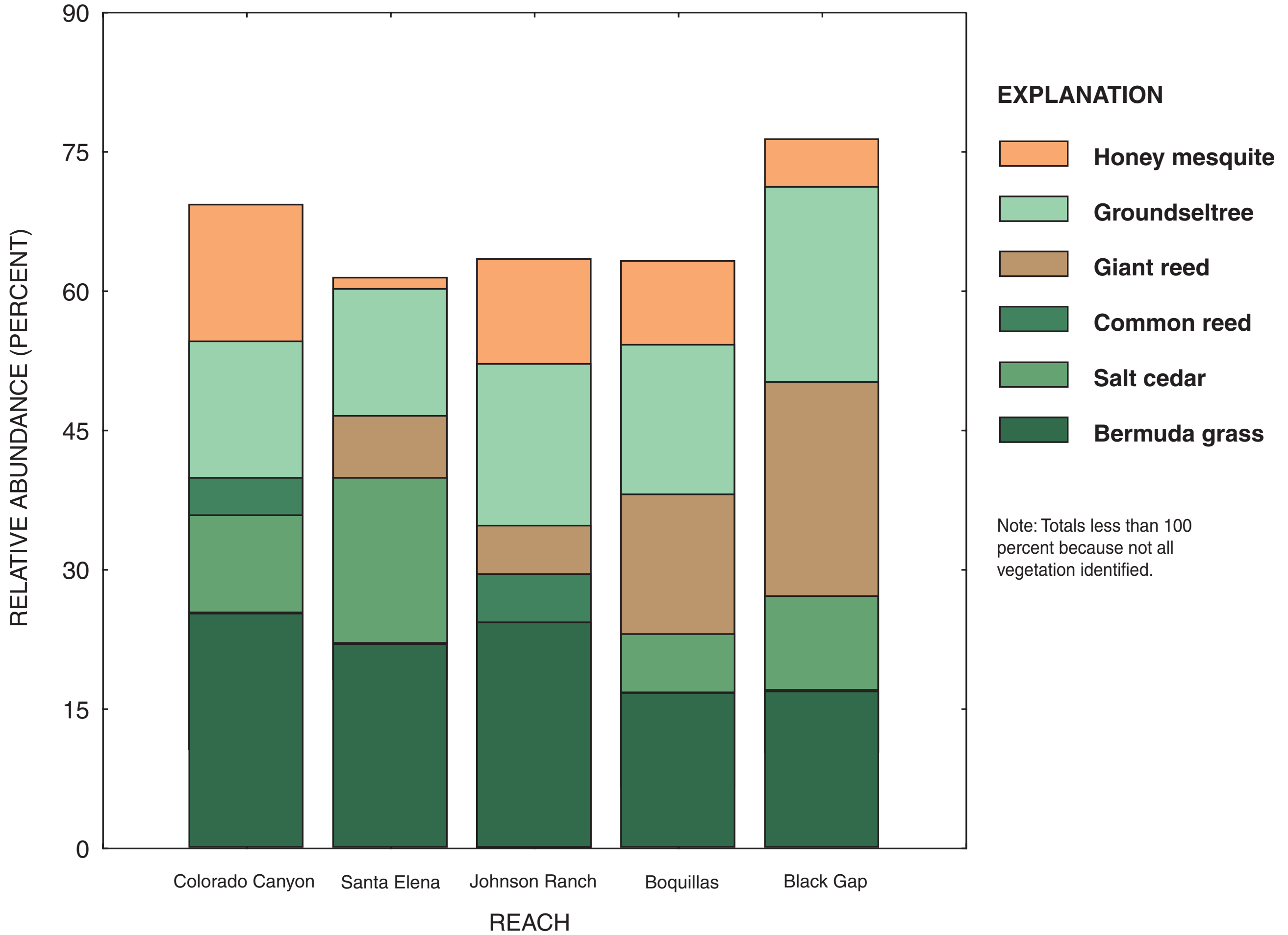

Figure 14. Relative abundance of selected species of bank vegetation for five bioassessment reaches in and near Big Bend National Park, Texas.

among the reaches, and of these, 348 were minnows. Among the minnows, the most commonly collected species was the red shiner (*Cyprinella lutrensis*). Red shiners were the most frequently collected species from a mid-1980s survey of the same region (Platania, 1990). The least frequently collected species were the western mosquitofish (*Gambusia affinis*) and the freshwater drum (*Aplodinotus grunniens*). The introduced species, common carp (*Cyprinus carpio*), was collected at all reaches except Santa Elena. At least one of two species of suckers, the blue sucker (*Cycleptus elongatus*) or the river carpsucker (*Carpiodes carpio*), was collected at all reaches. The blue sucker is listed by the State of Texas as a threatened species; this species was collected at all reaches except Johnson Ranch. The only sunfish collected was the longear sunfish (*Lepomis megalotis*). Other species of sunfish, including the green and redear sunfish, have been collected in BBNP in the past but not in the main stem of the Rio Grande (Hubbs, 1958; Platania, 1990).

The most fish species (15) were collected at Santa Elena and the fewest species (9) at Colorado Canyon and Johnson Ranch (fig. 15). Unlike the four other reaches, the Santa Elena reach was wadeable throughout, and this could account for the larger number of species collected at this reach. The other reaches had deep pools and runs and some rapids that made fish-community assessment more difficult than at the Santa Elena reach.

The number of species collected can be influenced by the number of individuals collected, and the number of individuals can introduce bias into any interpretation of biological diversity indices or other metrics (Ludwig and Reynolds, 1988). The relation of sample

Table 3. Fish taxa and individual counts of fish collected in the Rio Grande in and near Big Bend National Park, Texas

Group	Common name	Family	Scientific name	Study reaches on the Rio Grande by site name: Colorado Canyon	Santa Elena	Johnson Ranch	Boquillas	Black Gap	Total number of individuals
Gars		Lepisosteidae							
	Longnose gar		*Lepisosteus osseus*	0	1	0	0	3	4
Herrings		Clupeidae							
	Gizzard shad		*Dorosoma cepedianum*	2	0	0	4	0	6
Minnows		Cyprinidae							
	Red shiner		*Cyprinella lutrensis*	0	31	35	32	31	129
	Rio Grande shiner		*Notropis jemezanus*	0	31	4	0	0	35
	Tamaulipas shiner		*Notropis braytoni*	0	31	25	32	31	119
	Common carp		*Cyprinus carpio*	1	0	2	1	5	9
	Longnose dace		*Rhinichthys cataractae*	0	5	0	0	2	7
	Speckled chub		*Macrhybopsis aestivalis*	0	31	0	11	7	49
Suckers		Catostomidae							
	Blue sucker		*Cycleptus elongatus*	2	1	0	2	9	14
	River carpsucker		*Carpiodes carpio*	2	2	1	16	5	26
	Smallmouth buffalo		*Ictiobus bubalus*	0	1	0	0	0	1
Catfish		Ictaluridae							
	Blue catfish		*Ictalurus furcatus*	7	1	1	7	8	24
	Channel catfish		*Ictalurus punctatus*	2	1	2	8	2	15
	Flathead catfish		*Pylodictis olivaris*	8	4	2	6	3	23
Killifishes		Cyprinodontidae							
	Plains killifish		*Fundulus zebrinus*	0	4	2	0	0	6
Livebearers		Poeciliidae							
	Western mosquitofish		*Gambusia affinis*	0	1	0	0	0	1
Sunfishes		Centrarchidae							
	Longear sunfish		*Lepomis megalotis*	2	3	0	0	0	5
Drums		Sciaenidae							
	Freshwater drum		*Aplodinotus grunniens*	1	0	0	0	0	1
Number of fish				27	148	74	119	106	474
Number of fish species				9	15	9	10	11	18

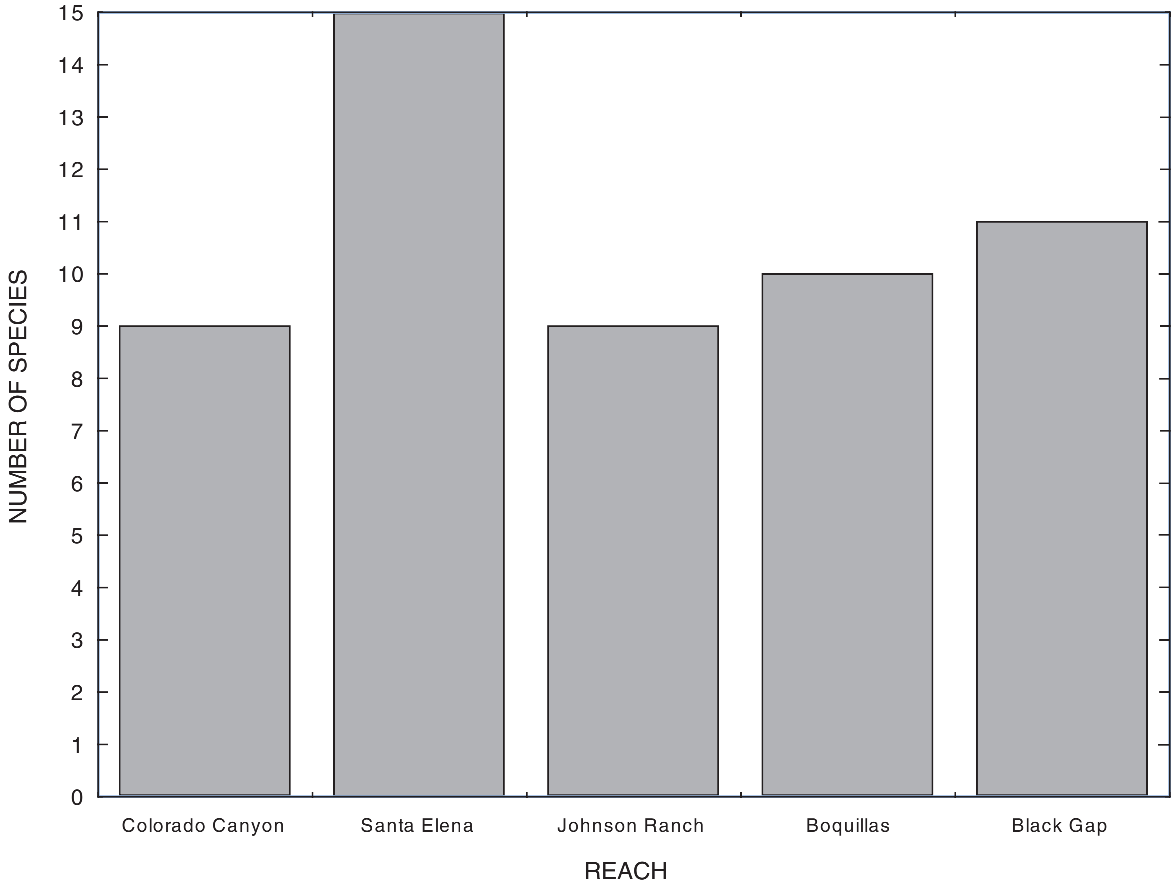

Figure 15. Number of fish species for five bioassessment reaches in and near Big Bend National Park, Texas.

size to the number of species is illustrated by the high linear correlation (Pearson's r = 0.793, p = 0.109) between these variables, even with the non-significant p-value, because of the small sample size of five (fig. 16).

Channel widths and stream order are similar among the reaches. The number of taxa often increase with increasing stream size (Vannote and others, 1980). The number of species can be standardized by computing species richness as the number of species related in some way to sample size or to the number of individuals collected. For example, Menhinick's species richness (R) (Menhinick, 1964) was largest at Colorado Canyon and smallest at Santa Elena (fig. 17)—the opposite of the result when only the number of species is considered. Menhinick's R takes into account the number of fish collected in addition to the number of species. It is computed as the number of species collected (S) divided by the square root of the total number of individuals collected (N). The lower R for Santa Elena is influenced by the fact that 63 percent of the fish collected were three species of minnows, whereas the higher R for Colorado Canyon is influenced by a more even distribution of the number of fish sampled among the nine species collected (table 3).

A cluster analysis was done using absolute abundance data to compare overall fish-community similarity among the five reaches, and euclidean (linkage) distance was used as the distance measure for each cluster node (fig. 18). Distance in this context refers to a quantification of the similarity or dissimilarity between samples. The more similar samples from different reaches are in species composition and quantity, the closer their linkage distance (Ludwig and Reynolds, 1988). Colorado Canyon was the least similar to the other reaches. Johnson Ranch, Boquillas, and Black Gap were more similar to one another than any one of these three reaches was to the Santa Elena reach in overall fish-community structure.

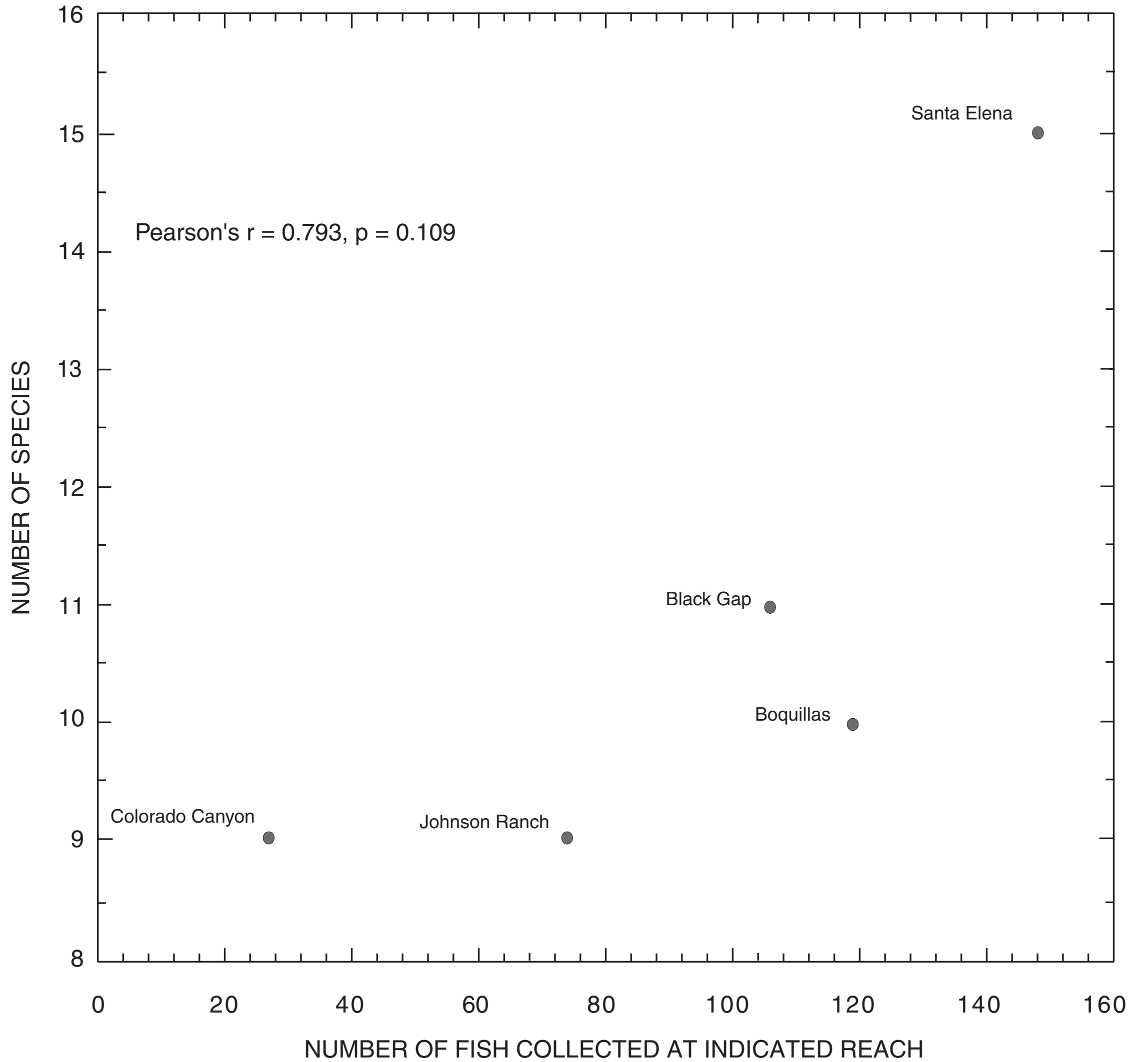

Figure 16. Number of fish versus number of species for five bioassessment reaches in and near Big Bend National Park, Texas.

Minnows dominated fish-community structure at all reaches except Colorado Canyon (fig. 19). Minnows accounted for 89 percent of the community at Johnson Ranch, 88 percent at Santa Elena, and a minimum of about 4 percent at Colorado Canyon. Minnow populations generally are much larger than other fish populations in streams, and the dominance of minnows is not surprising. Red shiners and Tamaulipas shiners (*Notropis braytoni*) dominated the minnow community at all of the sites except Colorado Canyon where one common carp was the only minnow species collected. Catfish, particularly flathead catfish (*Pylodictis olivaris*), dominated the fish community at Colorado Canyon. In general, fish-community structure was similar among Santa Elena, Johnson Ranch, Boquillas, and Black Gap, and most different at Colorado Canyon. Colorado Canyon was more problematic to sample because of swift riffles and rapids, large cobble and boulders, and one very deep pool in the reach.

As with community structure, fish trophic structure varied among the reaches (fig. 20). Trophic structure largely reflected community structure. Invertivores, predominantly minnows, made up at least 60 percent of the trophic structure at all reaches except Colorado Canyon. Piscivores, weighted by blue catfish, dominated the trophic structure at Colorado Canyon. At the four other reaches, piscivores were the smallest trophic group. This finding is consistent with the trophic structure of

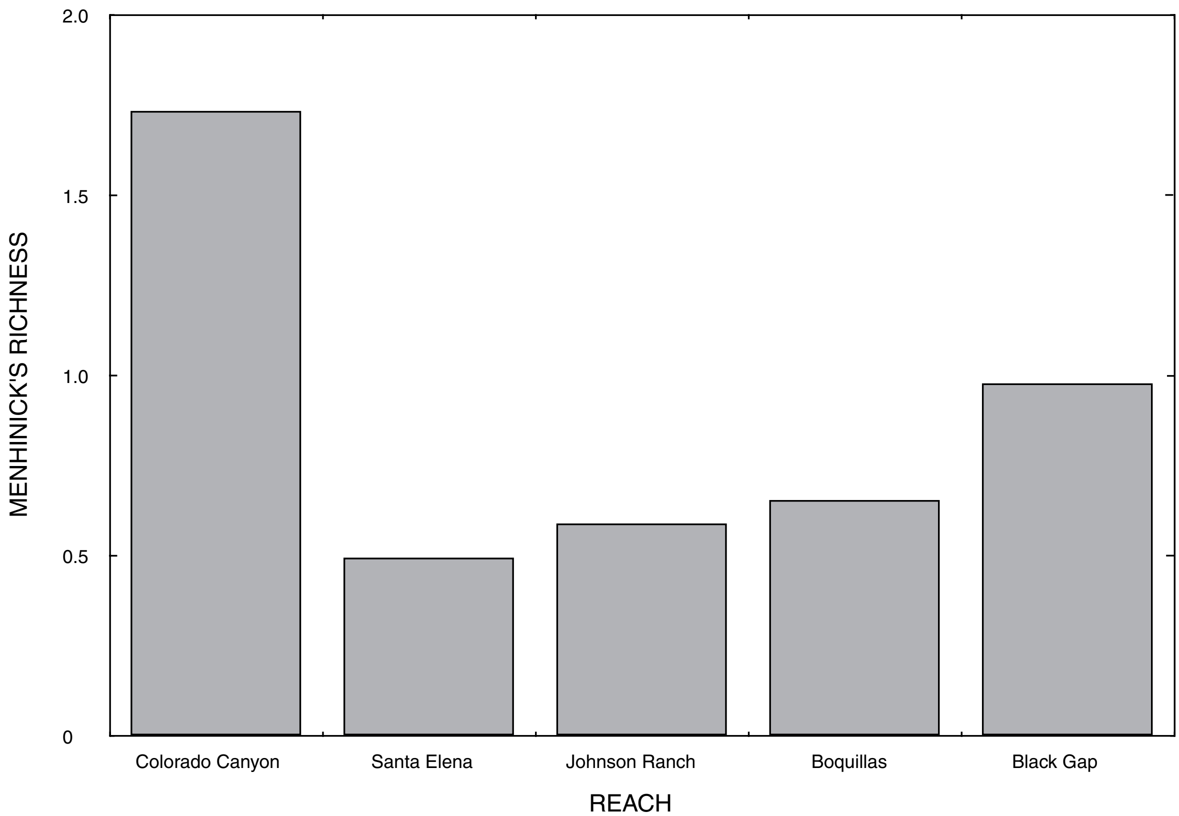

Figure 17. Menhinick's species richness for fish communities for five bioassessment reaches in and near Big Bend National Park, Texas.

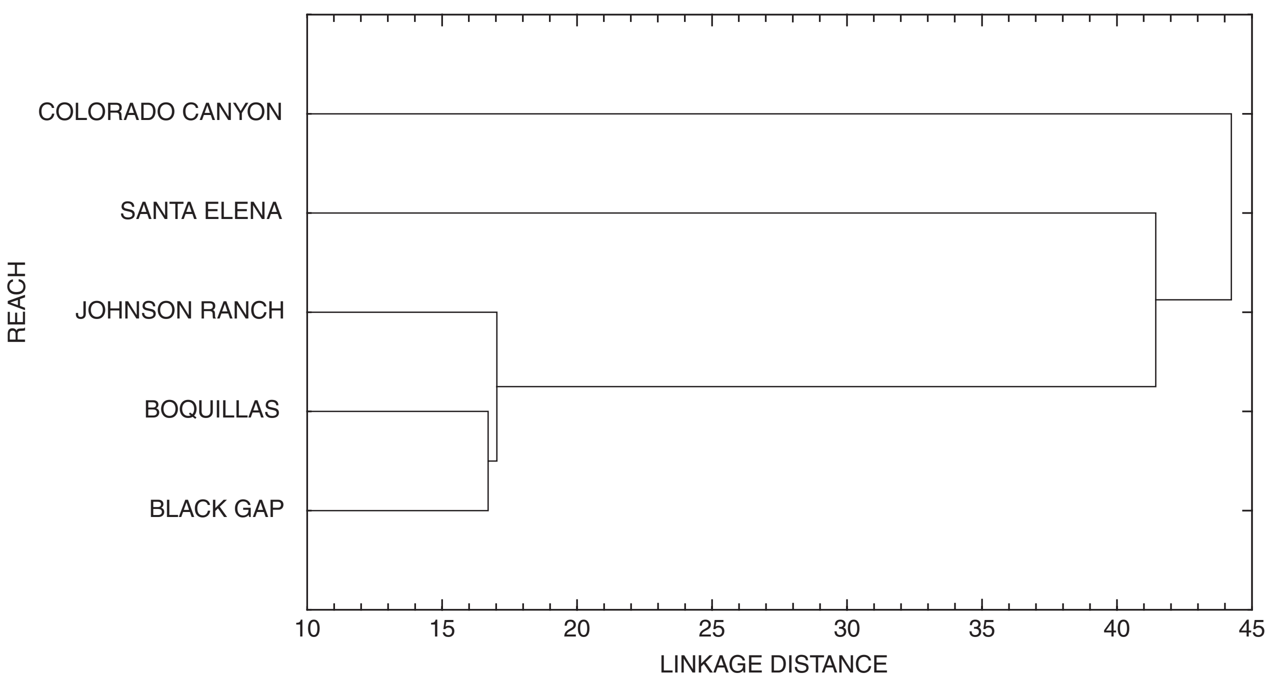

Figure 18. Results of cluster analysis to indicate similarity of fish communities for five bioassessment reaches in and near Big Bend National Park, Texas.

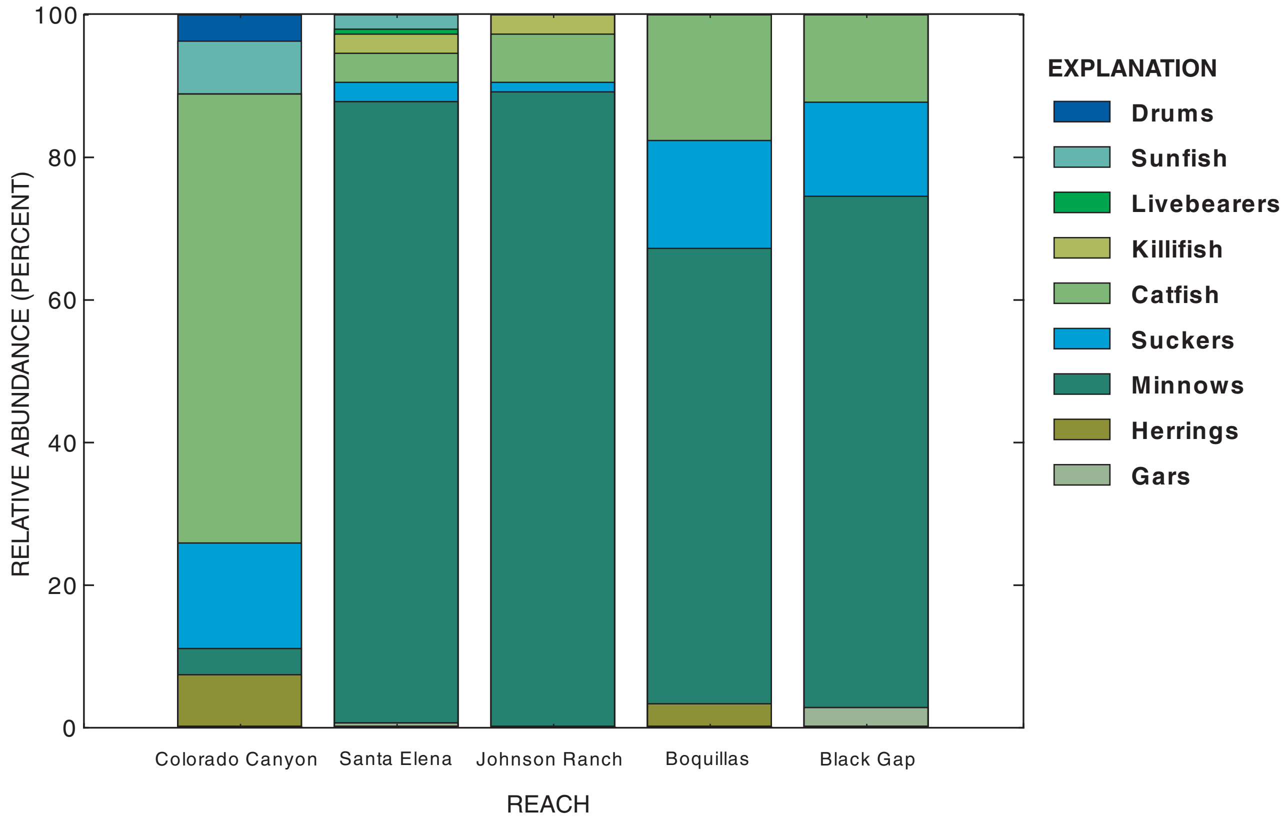

Figure 19. Relative abundance of major fish families for five bioassessment reaches in and near Big Bend National Park, Texas.

most aquatic communities. The principal carbon and energy source in large rivers such as the Rio Grande in the Big Bend region are the finer particulate organic materials, making the river a heterotrophically based system rather than autotrophically based (Vannote and others, 1980; Minshall and others, 1983). Fish communities in large heterotrophic rivers often are dominated by omnivorous species such as suckers, many species of catfish, smallmouth buffalo, and common carp. These omnivores feed extensively on detritus that constitutes a large percentage of the finer particulate organics in the river.

Benthic Macroinvertebrates

A cumulative total of 92 benthic macroinvertebrate taxa were collected among the five reaches sampled (table 4 at end of report). Seventy-four of these taxa were aquatic insects, and eighteen were non-insect taxa including freshwater worms (Oligochaeta), clams (Bivalvia), snails (Gastropoda), ostracods (Ostracoda), leeches (Hirudinea), mites (Acarina), and flat worms (Turbellaria). Sampling in the study was intentionally biased for the collection of aquatic insects. Therefore, results discussed below will compare aquatic-insect communities among the five reaches.

The most frequently collected aquatic insects were two blackfies—*Simulium* sp. and *Cnephia* sp. (table 4). Three species (*Polypedilum convictum, Polypedilum scalaenum,* and *Telopelopia okoboji*) were predominant among midges at the five sites. Midges, family Chironomidae, often are the dominant aquatic-insect taxon in number of species, number of individuals, and in biomass in large rivers such as the Rio Grande (Resh and Rosenberg, 1984). The net-spinning caddisfly, *Cheumatopsyche* sp., was common at all reaches except Santa Elena and was the third most frequently collected aquatic insect at the Boquillas reach. This taxon, a few additional caddisfly families, and members of the family Simulidae commonly are the most abundant filter feeders in the coarse substrate such as cobble or boulders in fast-flowing streams (Wallace and Merritt, 1980) that characterized the five reaches.

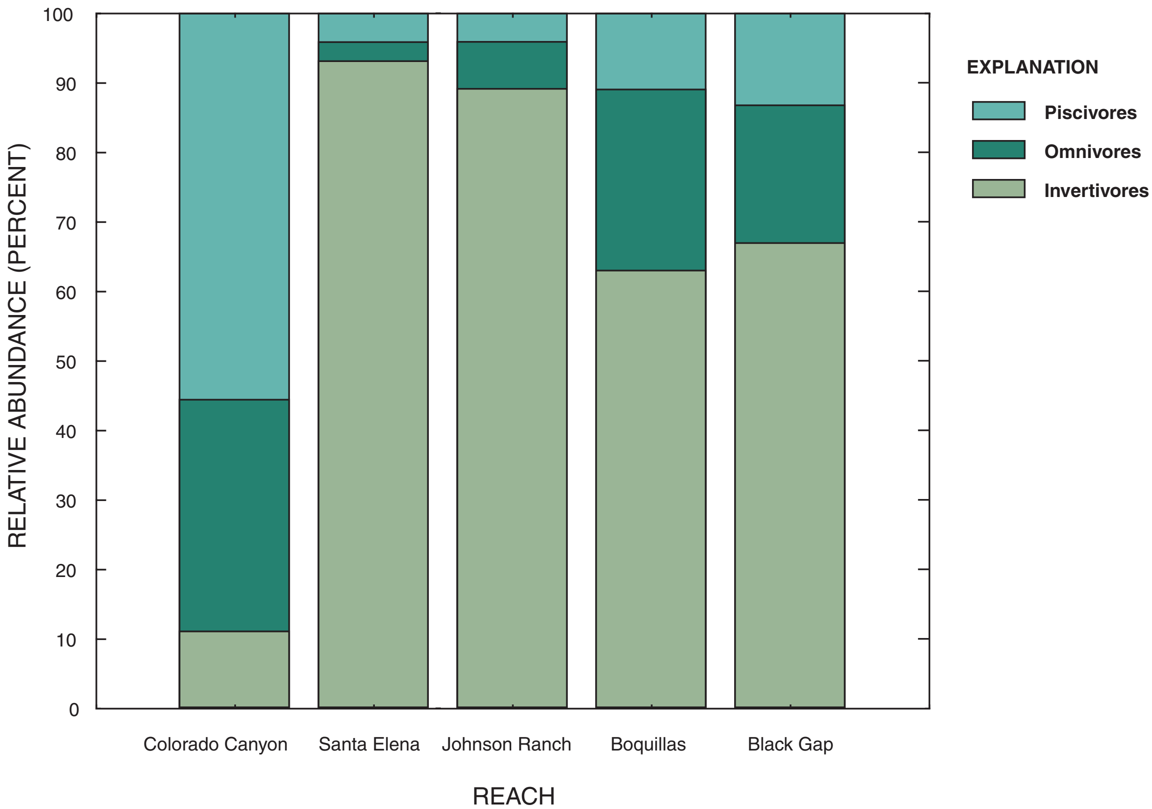

Figure 20. Relative abundance of major fish trophic groups for five bioassessment sites in and near Big Bend National Park, Texas.

A cluster analysis using absolute abundance data indicated that the benthic aquatic-insect communities were most alike between the Santa Elena and Black Gap reaches (fig. 21). Colorado Canyon, Santa Elena, Black Gap, and Johnson Ranch were more similar in aquatic-insect community structure than any one of these reaches was to Boquillas. Boquillas had fewer species of midges than the other reaches, which accounted for the dissimilarity with the other reaches, as indicated by the relatively large linkage distance in the cluster analysis (fig. 21).

A maximum of 51 aquatic-insect taxa were collected at Black Gap, and a minimum of 41 were collected at Santa Elena (fig. 22). These total numbers of aquatic-insect taxa are cumulative from all three methods of collection—the QMH, RTH, and traveling kick-seine. The RTH method is a more quantitative method of sampling than the QMH (Cuffney and others, 1993) or traveling kick-seine method. RTH sampling for benthic macroinvertebrates was done to provide a standardized method of collection that would allow reliable comparisons among the reaches. Therefore, all comparative discussions below are based on findings from the RTH method. The other methods, QMH and traveling kick seine, are less quantitative and were done in addition to the RTH method to obtain the most comprehensive information on taxa richness for each reach. Aquatic-insect data from the RTH method were used to compute aquatic-insect community metrics for the five reaches. Sample size, or the total number of individual insects collected at each reach, and the number of individuals per taxon can bias community metrics such as species diversity and richness (Ludwig and Reynolds, 1988). Generally the number of species or number of taxa will correlate positively to the number of individuals collected. This was the case in comparing the number of species of fish to the number of individuals collected per reach (fig. 16). However, the number of aquatic-insect taxa was inversely correlated (Pearson's $r = -0.73$, $p = 0.045$) to the number of individuals collected at each reach (fig. 23). The relatively large number of individuals in contrast to the smaller number of taxa for the Boquillas and Santa Elena reaches is attributed to the relatively large numbers of *Simulium* sp.

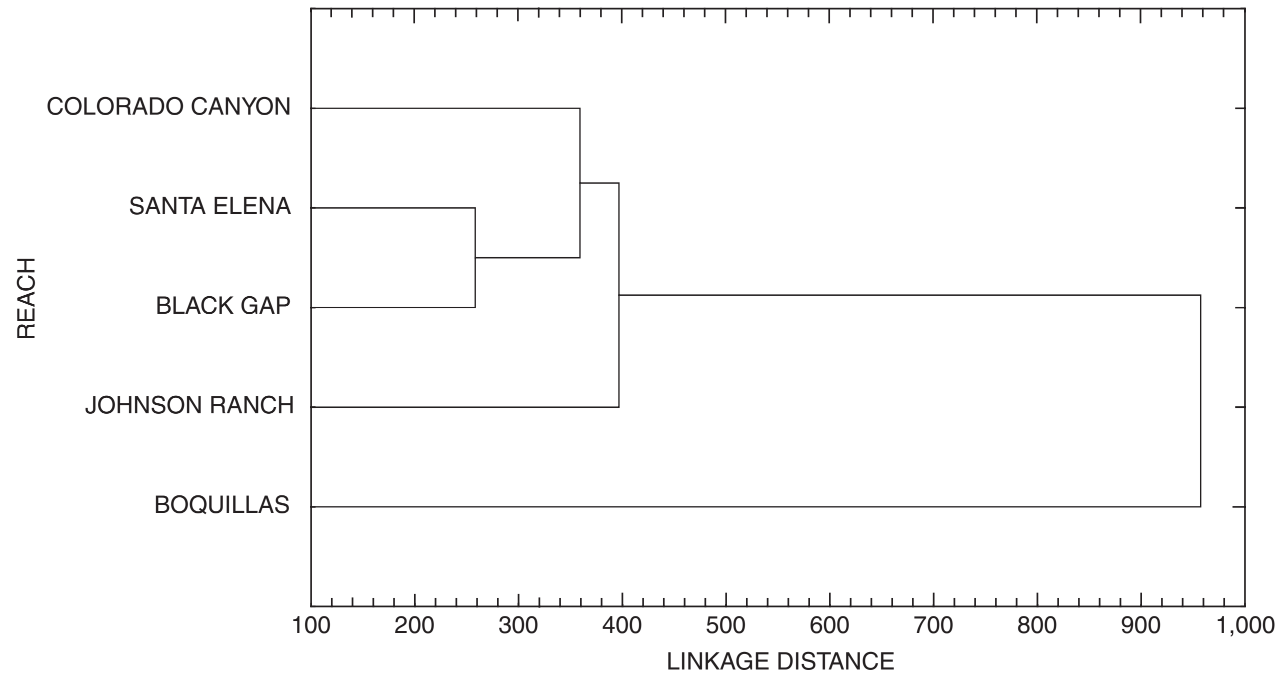

Figure 21. Results of cluster analysis to indicate similarity of benthic aquatic-insect communities for five bioassessment reaches in and near Big Bend National Park, Texas.

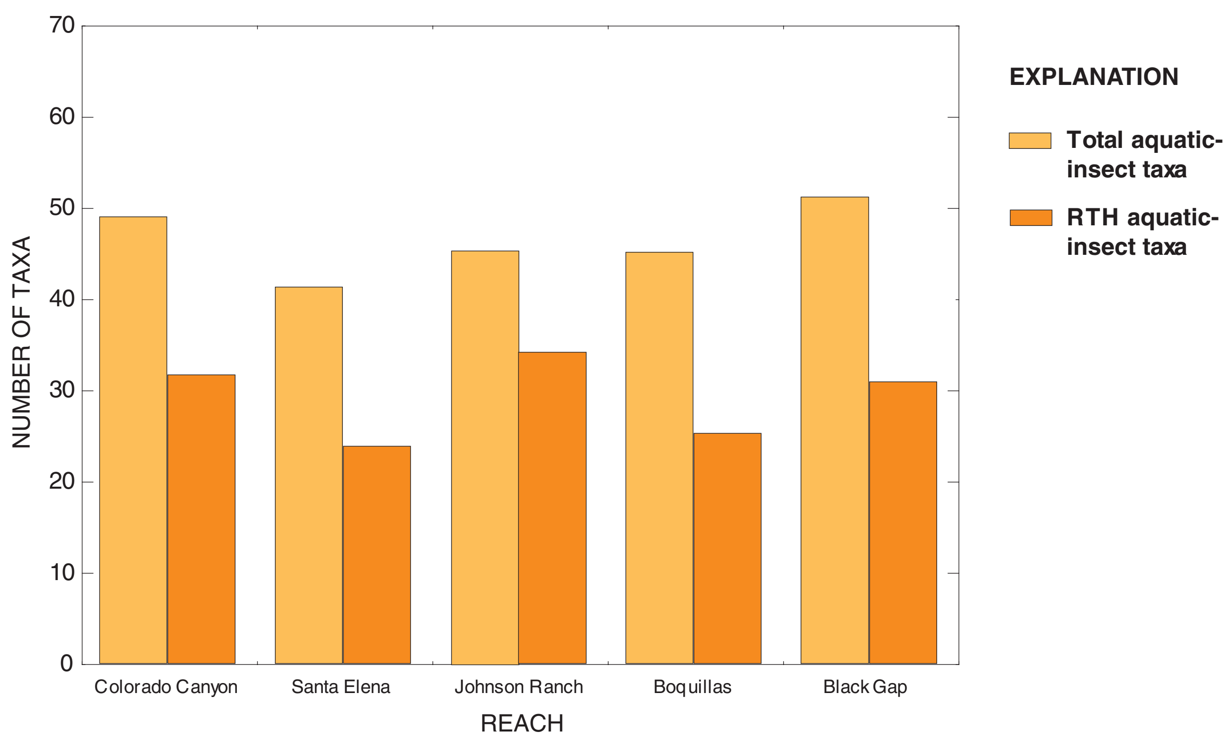

Figure 22. Comparison of total aquatic-insect taxa and richest targeted habitat (RTH) aquatic-insect taxa for five bioassessment reaches in and near Big Bend National Park, Texas.

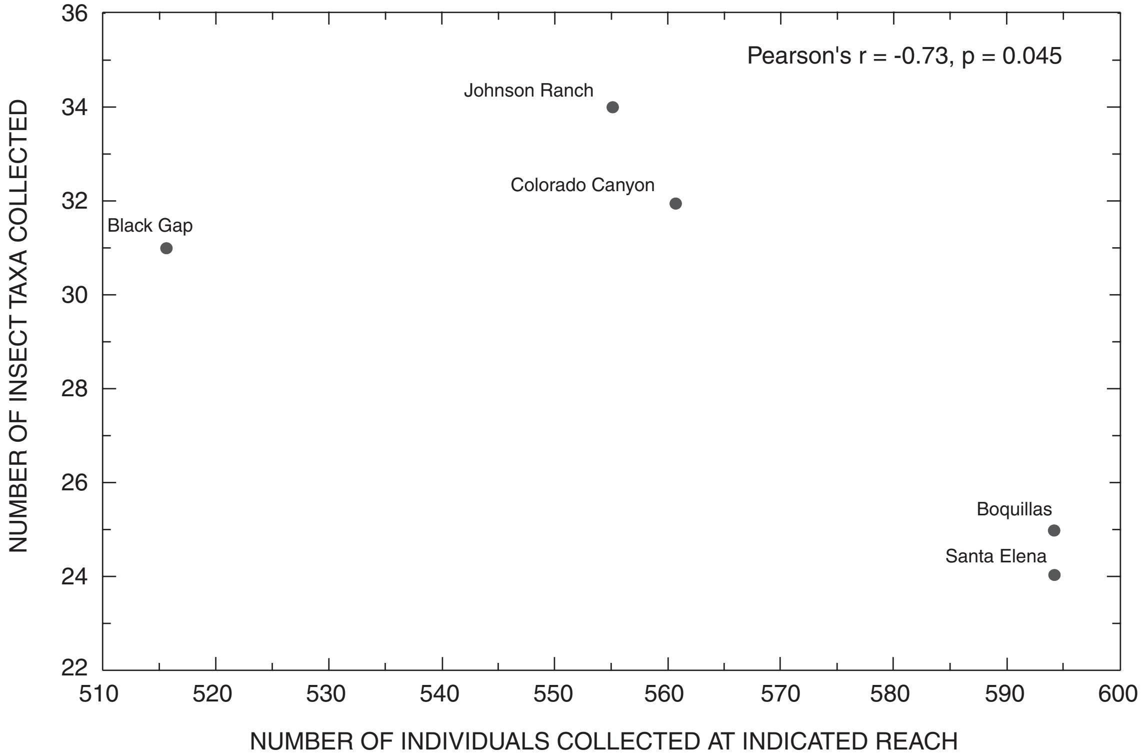

Figure 23. Number of aquatic-insect taxa versus number of aquatic-insect individuals (richest targeted habitat [RTH] samples only) for five bioassessment reaches in and near Big Bend National Park, Texas.

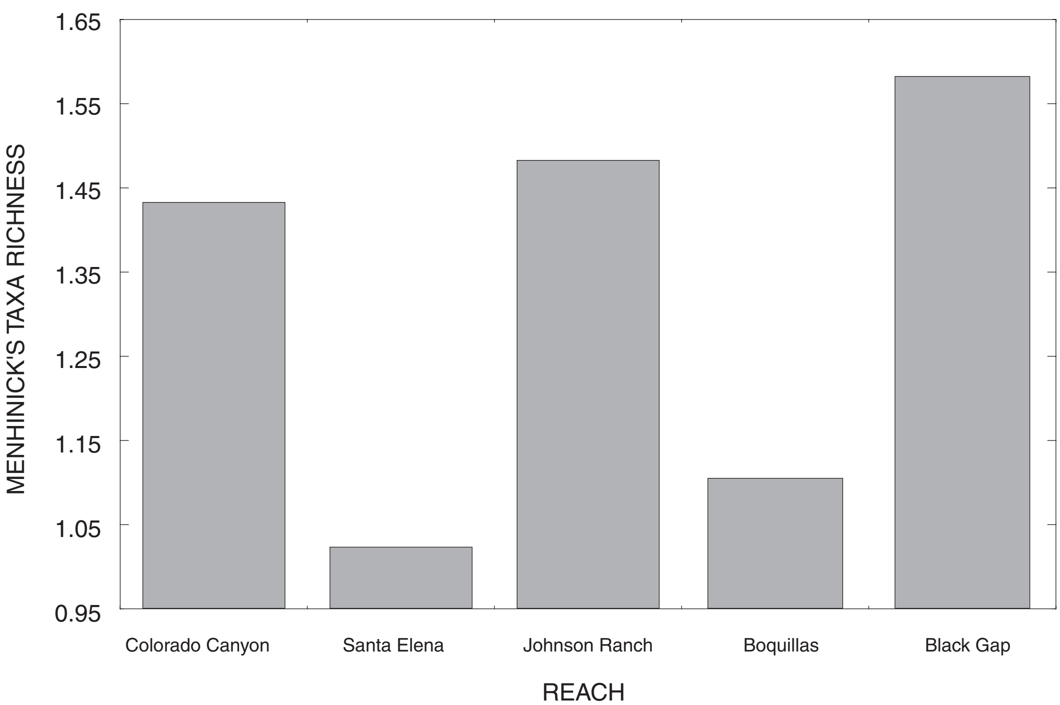

Figure 24. Menhinick's taxa richness for aquatic insects for five bioassessment reaches in and near Big Bend National Park, Texas.

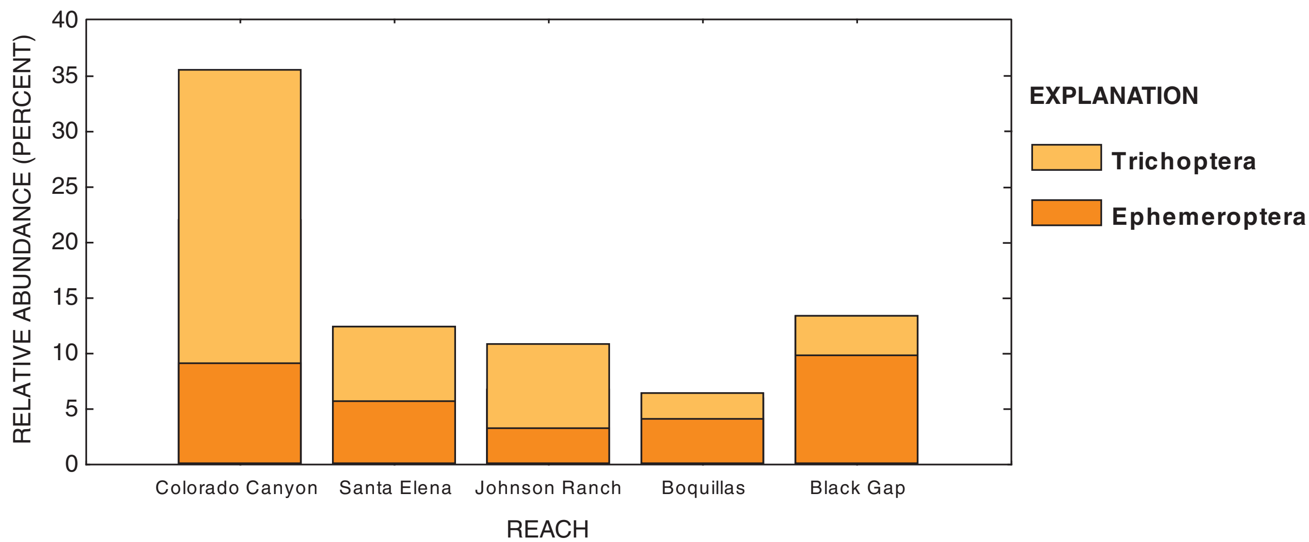

Figure 25. Relative abundance of ephemeroptera and trichoptera taxa (richest targeted habitat [RTH] samples only) for five bioassessment reaches in and near Big Bend National Park, Texas.

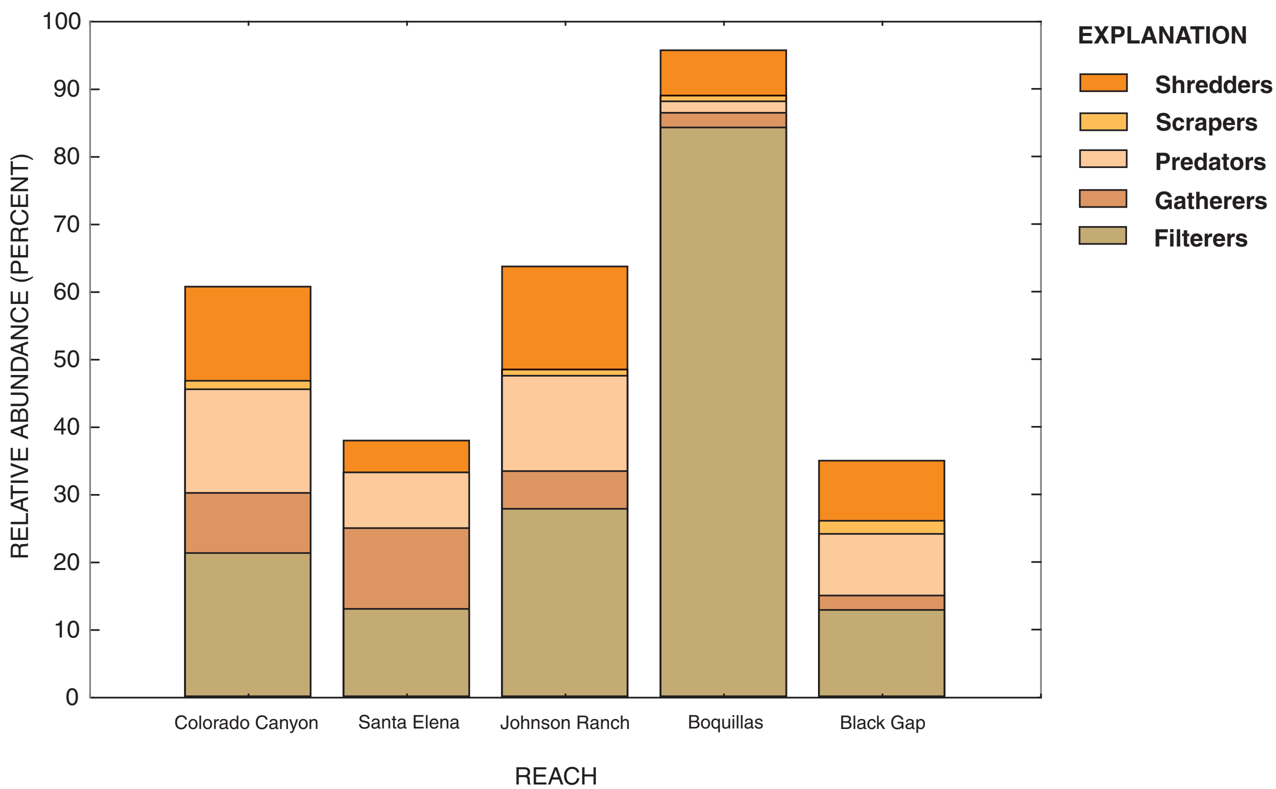

Figure 26. Relative abundance of major aquatic-insect trophic groups (richest targeted habitat [RTH] samples only) for five bioassessment reaches in and near Big Bend National Park, Texas.

collected at Boquillas (1,075) and *Cnephia* sp. collected at Santa Elena (745). Considering sample size as a factor, Menhinick's taxa richness, computed as the number of RTH taxa divided by the square root of the RTH sample size (Menhinick, 1964), was highest for Black Gap and lowest for Santa Elena (fig. 24).

The Ephemeroptera, Plecoptera, and Trichoptera (EPT) index often is used as an indicator of the ecological health of streams (Loeb and Spacie, 1994). The index is the sum of the relative abundance of each of these three taxa expressed as a percentage of all identified taxa. The index has been found to be sensitive to changes in water quality and often is less variable seasonally and perennially than other metrics such as taxa richness (Lenat and Barbour, 1994). No plecopterans were collected at any of the five reaches. Therefore, the EPT index for the five reaches is the sum of the percentages of ephemeropterans and trichopterans only. The EPT index was largest for Colorado Canyon and smallest for Boquillas (fig. 25). Trichopterans (caddisflies) were a larger percentage than ephemeropterans (mayflies) at Colorado Canyon, Santa Elena, and Johnson Ranch; and mayflies were more abundant at Boquillas and Black Gap. The net-spinning caddisflies and many of the mayflies often are more abundant on larger, more stable bed materials. The large cobble and boulders that are characteristic of Colorado Canyon should be more stable than the smaller cobble common at Johnson Ranch and Boquillas.

The trophic structure of the aquatic-insect community of a stream is controlled by many factors including channel size, depth, stream velocity, nutrient composition and availability, and composition of the bed materials (Hynes, 1970). Large rivers like the Rio Grande are dominated by filter feeders and gatherers (fig. 26) that feed on particulate organic material that is suspended in the water column or abundant in depositional areas such as pools. Filter feeders such as the net-spinning caddisfly (*Cheumatopsyche* sp.) were the most abundant trophic group at Colorado Canyon, Johnson Ranch, and Boquillas. The filter feeders were dominated by *Simulium* sp. at the Boquillas reach and were more abundant at Boquillas than at any of the four other reaches. The majority of the mayfly taxa are collector-gatherers; the mayflies were a major trophic component at the Colorado Canyon and Santa Elena reaches.

SUMMARY

The NPS manages a 386-km segment of the Rio Grande in the Big Bend region of West Texas. The Rio Grande in the region represents the Chihuahuan Desert's most extensive aquatic and associated riparian environments. Increases in population and industrial development in the region associated with the North American Free Trade Agreement, flows altered by upstream dams and diversions, and several water-quality issues could be affecting the status and health of aquatic biota in the river. This study was designed to collect and interpret the essential data needed to effectively manage aquatic-life resources of the Rio Grande in reaches in and near BBNP—and to establish benchmark sites to assess the status and trends in stream habitat, fish communities, and benthic macroinvertebrates over time.

Five study sites, and a sampling reach within each, were selected: one upstream of BBNP adjacent to Big Bend Ranch State Park, three in BBNP, and one downstream of the Park adjacent to Black Gap Wildlife Refuge. The three sites in BBNP are benchmark sites, marked with identifying monuments, for proposed long-term monitoring. Several reach-based and within-reach, transect-based stream-habitat measures were taken. The fish community at each reach was sampled once in early spring 1999 and once in late summer 1999. Benthic macroinvertebrate samples were collected once, in early March 1999.

Differences in stream-habitat conditions and riparian vegetation reflect differences in surface geology among the five reaches. The Colorado Canyon reach is dominated by igneous rock; streambed material is larger, and riparian vegetation is less diverse and not as dense as at the four other sampling reaches downstream. The Santa Elena, Johnson Ranch, Boquillas, and Black Gap reaches each have a limestone channel that is more weathered and thus characterized by smaller streambed material and more diverse and dense stands of riparian vegetation. The relative abundance of the dominant native and non-native species common to the banks of the Rio Grande varied among the five reaches. Of the native species, honey mesquite, giant reed, common reed, and groundseltree were the most common. The non-native species salt cedar and bermuda grass accounted for about 25 to 40 percent of the vegetation on the banks of the five reaches.

Eighteen species of fish and a total of 474 individuals were collected among the five reaches; 348 of the 474 were minnows. The most fish species (15) were

collected at Santa Elena and the fewest species (9) at Colorado Canyon and Johnson Ranch. The fish community at Colorado Canyon was least like the fish communities at the four other reaches. Minnows dominated fish-community structure at all reaches except Colorado Canyon. The common carp was collected at all reaches except Santa Elena; and the blue sucker, listed as threatened by the State of Texas, was collected at all reaches except Johnson Ranch.

Fish trophic structure reflected fish-community structure among the five reaches. Invertivores, predominantly minnows, made up at least 60 percent of the trophic structure at all reaches except Colorado Canyon. Piscivores, weighted by blue catfish, dominated the trophic structure at Colorado Canyon. At the four other reaches, piscivores were the smallest trophic group.

Eighty percent of the benthic macroinvertebrate taxa collected were aquatic insects. Two species of blackfly, *Simulium* sp. and *Cnephia* sp., were the most frequently collected invertebrate taxon. Net-spinning caddisflies such as *Cheumatopsyche* sp. were common at all reaches except Santa Elena. The aquatic-insect community at the Boquillas reach was least similar to the aquatic-insect community at the other reaches. The EPT index, an indicator of the ecological health of streams, was largest for the Colorado Canyon reach and smallest for the Johnson Ranch reach. The larger streamflow velocities and larger, more stable substrates at Colorado Canyon might facilitate a larger relative abundance of EPT taxa than at the other reaches.

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Table 4. Taxonomic classification of benthic macroinvertebrates and counts for individual taxa collected in the Rio Grande in and near Big Bend National Park, Texas

[Number of individuals per taxon shown for each site.]

Class	Order	Family	Subfamily	Tribe	Genus or scientific name	Study reach				
						Colorado Canyon	Santa Elena	Johnson Ranch	Boquillas	Black Gap
Turbellaria						0	0	1	0	0
Aphanoneura	Araeolaimida				*Aelosoma* sp.	2	0	0	0	0
Ostracoda						3	2	0	2	0
Bivalvia	Pelecypoda	Corbiculidae			*Corbicula fluminea*	0	0	0	0	8
		Sphaeriidae				1	0	0	0	0
					Sphaerium sp.	23	0	0	0	0
Gastropoda	Limnophila	Physidae				0	1	0	0	0
					Stenophysa sp.	3	0	4	43	13
Hirudinea	Pharyngobdellida	Erpobdellidae				0	0	0	0	1
Oligochaeta	Haplotaxida	Tubificidae			*Branchiura sowerbyi*	0	0	0	2	0
					Limnodrilus hoffmeisteri	1	47	35	3	2
		Lumbricidae			*Lumbricina*	1	0	0	0	1
		Enchytraeidae				0	0	0	1	1
		Naididae			*Nais pardalis*	23	0	0	0	0
					Paranais sp.	1	0	0	0	0
					Pristina breviseta	2	0	0	3	0
					Dero sp.	0	0	0	3	0
Arachnida	Acarina	Acari				0	0	1	0	0
Insecta	Ephemeroptera	Baetidae			*Callibaetis* sp.	0	0	1	0	0
					Camelobaaetidius sp.	0	0	0	0	1
					Fallceon quilleri	0	0	0	0	1
		Heptageniidae			*Neochoroterpes* sp.	32	51	11	35	33
		Leptophlebiidae				1	12	10	0	0
					Thraulodes sp.	15	5	6	7	19
					Thraulodes gonzalesi	18	16	0	15	41
					Traverella sp.	5	6	0	17	0
					Traverella presidiana	3	0	1	8	23
		Tricorythidae			*Tricorythodes* sp.	44	20	10	6	10
	Odonata	Coenagrionidae			*Argia* sp.	3	3	1	9	9

Table 4. Taxonomic classification of benthic macroinvertebrates and counts for individual taxa collected in the Rio Grande in and near Big Bend National Park, Texas—Continued

Class	Order	Family	Subfamily	Tribe	Genus or scientific name	Study reach: Colorado Canyon	Study reach: Santa Elena	Study reach: Johnson Ranch	Study reach: Boquillas	Study reach: Black Gap
Insecta—Cont.	Odonata—Cont.	Calopterygidae			*Hetaerina americana*	1	0	0	0	1
		Gomphidae				6	1	5	0	1
					Erpetogomphus sp.	0	1	0	2	5
					Stylurus sp.	0	0	0	0	1
		Macromiidae			*Macromia* sp.	0	0	0	0	1
	Hemiptera	Belostomatidae			*Abedus* sp.	0	1	0	0	0
		Corixidae				2	14	33	18	44
					Trichocorixa sp.	1	3	7	2	20
		Naucoridae			*Ambryus* sp.	1	1	1	0	4
					Cryphocricos sp.	4	1	6	0	0
		Veliidae				1	0	0	6	0
					Trochopus sp.	0	0	0	0	1
	Megaloptera	Corydalidae			*Corydalus* sp.	6	3	2	0	0
	Trichoptera					0	0	1	0	0
		Glossomatidae				0	0	0	1	0
					Protoptila sp.	0	0	2	0	6
		Hydropsychidae				1	0	3	0	0
					Cheumatopsyche sp.	64	1	52	42	15
					Smicridea sp.	25	10	14	1	7
		Hydroptilidae				0	0	0	0	1
					Hydroptila sp.	2	0	1	2	2
					Mayatrichia sp.	89	58	19	0	6
					Ochrotrichia sp.	20	0	0	2	4
	Lepidoptera	Pyralidae			*Petrophila* sp.	9	0	5	1	5
	Coleoptera	Dytiscidae			*Laccophilus* sp.	0	0	0	1	0
		Hydrophilidae				0	0	1	0	0
		Elmidae			*Heterlimnius* sp.	0	0	2	2	0
					Hexacylloepus sp.	0	0	0	0	1
					Microcylloepus sp.	0	0	0	2	1
					Microcylloepus pusillus	75	6	30	7	2
		Dryopidae			*Helichus* sp.	10	2	5	13	11
		Ceratopogonidae	Ceratopogoninae			1	0	0	1	0

Table 4. Taxonomic classification of benthic macroinvertebrates and counts for individual taxa collected in the Rio Grande in and near Big Bend National Park, Texas—Continued

Class	Order	Family	Subfamily	Tribe	Genus or scientific name	Study reach				
						Colorado Canyon	Santa Elena	Johnson Ranch	Boquillas	Black Gap
Insecta—Cont.	Coleoptera—Cont.				*Hemerodromia* sp.	2	0	1	2	0
		Ephydridae				0	3	0	0	0
		Simulidae				6	15	23	0	0
					Simulium sp.	0	48	256	1,075	159
					Cnephia sp.	423	745	336	0	682
		Tabanidae				1	1	0	0	0
		Chironomidae	Tanypodinae	Pentaneurini		0	0	0	0	1
					Ablabesmyia sp.	6	28	24		14
					Labrundinia sp.	13	2	3	2	1
					Thienemannimyia gr. sp.	1	0	0	12	58
					Thienemannimyia sp.	0	0	0	14	0
					Telopelopia okoboji	167	155	207	1	57
			Orthocladiinae	Orthocladiini	*Cricotopus bicinctus* gr.	15	12	216	2	11
					Cricotopus sp.	42	11	86	4	61
					Cricotopus trifascia	0	0	0	9	2
					Nanocladius sp.	42	0	0	0	0
					Nanocladius distinctus	48	89	33	0	2
					Orthocladius rivicola gr.	4	13	14	0	12
					Orthocladius complex	6	4	5	7	0
					Parakiefferiella sp.	193	133	52	2	14
					Thienemanniella sp.	6	3	15	5	6
			Chironominae	Chironomini		0	0	0	1	0
					Chironomus sp.	12	21	38	19	18
					Cryptochironomus sp.	2	5	10	3	1
					Dicrotendipes sp.	0	2	0	1	2
					Paralauterborniella nigrohalteris	15	0	0	9	3
					Polypedilum	6	0	3	4	47
					Polypedilum convictum	0	5	15	125	6
					Polypedilum scalaenum	44	48	114	3	26
					Polypedilum tritum	6	0	0	8	0
					Tanytarsus sp.	4	5	1	29	6

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