

Prepared in cooperation with the National Park Service and Amistad National Recreation Area

# **Water Quality and the Composition of Fish and Macroinvertebrate Communities in the Devils and Pecos Rivers In and Upstream from the Amistad National Recreation Area, Texas, 2005–7**



Scientific Investigations Report 2012–5038

**Cover Left.** Dolan Falls on the Devils River, Texas.

**Cover Right.** Photo was taken where the International Boundary and Water Commission (IBWC) gaging station near Langtry is located. The wier dam where the gage sensor is located is in the picture.

# **Water Quality and the Composition of Fish and Macroinvertebrate Communities in the Devils and Pecos Rivers In and Upstream from the Amistad National Recreation Area, Texas, 2005–7**

By J. Bruce Moring

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Scientific Investigations Report 2012–5038

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

**U.S. Department of the Interior**  
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U.S. Geological Survey, Reston, Virginia: 2012

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Suggested citation:

Moring, J.B., 2012, Water quality and the composition of fish and macroinvertebrate communities in the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area, Texas, 2005-7: U.S. Geological Survey Scientific Investigations Report 2012–5038, 70 p.

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## Conversion Factors, Acronyms, Abbreviations, and Datum

SI to Inch/Pound

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
centimeter per year (cm/yr)	0.3937	inch (in./yr)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
square kilometer (km <sup>2</sup> )	0.3861	square mile (mi <sup>2</sup> )
liter per second (L/s)	15.85	gallon per minute (gal/min)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

### Acronyms

ANRA	Amistad National Recreation Area
LRL	Laboratory reporting level
NASQAN	National Stream Quality Accounting Network
NMDS	Non-metric Multidimensional Scaling
NPS	National Park Service
TDS	Total dissolved solids
USGS	U.S. Geological Survey

### Abbreviations

mg/kg	milligram per kilogram
mg/L	milligram per liter
µg/L	microgram per liter



# Water Quality and the Composition of Fish and Macroinvertebrate Communities in the Devils and Pecos Rivers In and Upstream from the Amistad National Recreation Area, Texas, 2005–7

By J. Bruce Moring

## Abstract

To gain a better understanding of the water quality and status of fish and macroinvertebrate communities, the U.S. Geological Survey, in cooperation with the National Park Service and Amistad National Recreation Area, completed a reconnaissance-level survey of the water quality and fish and macroinvertebrate communities in the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area in southwest Texas during 2005–7. Water-quality conditions during the spring and summer months of 2005 in the Devils and Pecos Rivers were assessed at locations just upstream from the Amistad National Recreation Area, and the composition of fish and macroinvertebrate communities were assessed during 2006 and 2007 in and upstream from the Amistad National Recreation Area and Amistad Reservoir. Water-quality samples were collected at one site on both the Devils and Pecos Rivers. Fish and macroinvertebrates were collected at the water-quality sampling site on each river and at three additional sites on each river. The water-quality constituents of primary concern were total dissolved solids, chloride, sulfate, ammonia plus organic nitrogen, nitrate plus nitrite, orthophosphate, phosphorus, selenium, and selected pesticides. During the spring and summer of 2005, the concentrations of total dissolved solids ranged from 208 to 232 milligrams per liter (mg/L) in samples from the Devils River compared to 1,460 to 2,390 mg/L in samples from the Pecos River. Total dissolved solid concentrations measured in samples collected from the Devils River and Pecos River did not exceed the proposed State of Texas water-quality standard applicable for the segments of each river where samples were collected. During the spring and summer of 2005, chloride concentrations measured in samples collected in 2005 from the Devils River ranged from 11.6 to 12.9 mg/L, compared to chloride concentrations measured in samples collected from the Pecos River, which ranged from 519 to 879 mg/L. Chloride concentrations in samples collected from the Devils River in 2005 were less than the

lower quartile (25th percentile) value of 14.0 mg/L reported for chloride concentrations in water-quality samples collected at the same sampling location during 1978–95 by the U.S. Geological Survey as part of the Hydrologic Benchmark Network program. The chloride concentrations measured in samples collected from the Pecos River during the spring and summer of 2005 represented a range of values similar to the interquartile range of 548 to 942 mg/L reported for samples collected during 1974–2007 at the same sampling location by the U.S. Geological Survey as part of the National Stream Quality Accounting Network program. None of the chloride concentrations measured in samples collected from the Devils or Pecos Rivers in 2005 exceeded applicable proposed State of Texas water-quality standards for chloride. Sulfate concentrations ranged from 7.55 to 8.20 mg/L in samples from the Devils River compared to 298 to 503 mg/L in samples from the Pecos River. Concentrations of sulfate did not exceed applicable proposed State of Texas water-quality standards. Ammonia plus organic nitrogen concentrations were reported as nitrogen ranged from 0.12 to 0.14 mg/L of nitrogen in samples collected from the Devils River compared to 0.15 to 0.32 mg/L of nitrogen in samples collected from the Pecos River. Ammonia plus organic nitrogen concentrations measured in samples collected from the Devils River in 2005 were less than the lower quartile (25th percentile) value of 0.23 mg/L of nitrogen for concentrations in water-quality samples collected at the same sampling location during 1978–95 by the U.S. Geological Survey as part of the Hydrologic Benchmark Network program. Ammonia plus nitrogen concentrations measured in samples collected from the Pecos River were similar to the range of historical concentrations measured in samples collected from the same Pecos River sampling location by the U.S. Geological Survey National Stream Quality Accounting Network program. Nitrate plus nitrite concentrations in samples from the Devils River and Pecos Rivers were within the historical range of concentrations for samples collected at the same locations on each river. Total phosphorous and orthophosphate

concentrations were less than the laboratory reporting levels in the water samples from the Devils and Pecos Rivers. None of the selenium concentrations measured in samples collected during the spring and summer of 2005 from the Devils or Pecos Rivers exceeded the Texas Surface Water Quality Standards (chronic criterion of 5 µg/L or the acute criterion of 20 µg/L) established by the State for the protection of aquatic life. Concentrations of pesticides in the samples collected from the Devils and Pecos Rivers during March–August 2005 were very low and not present in detectable amounts (all reported concentrations were below laboratory reporting levels).

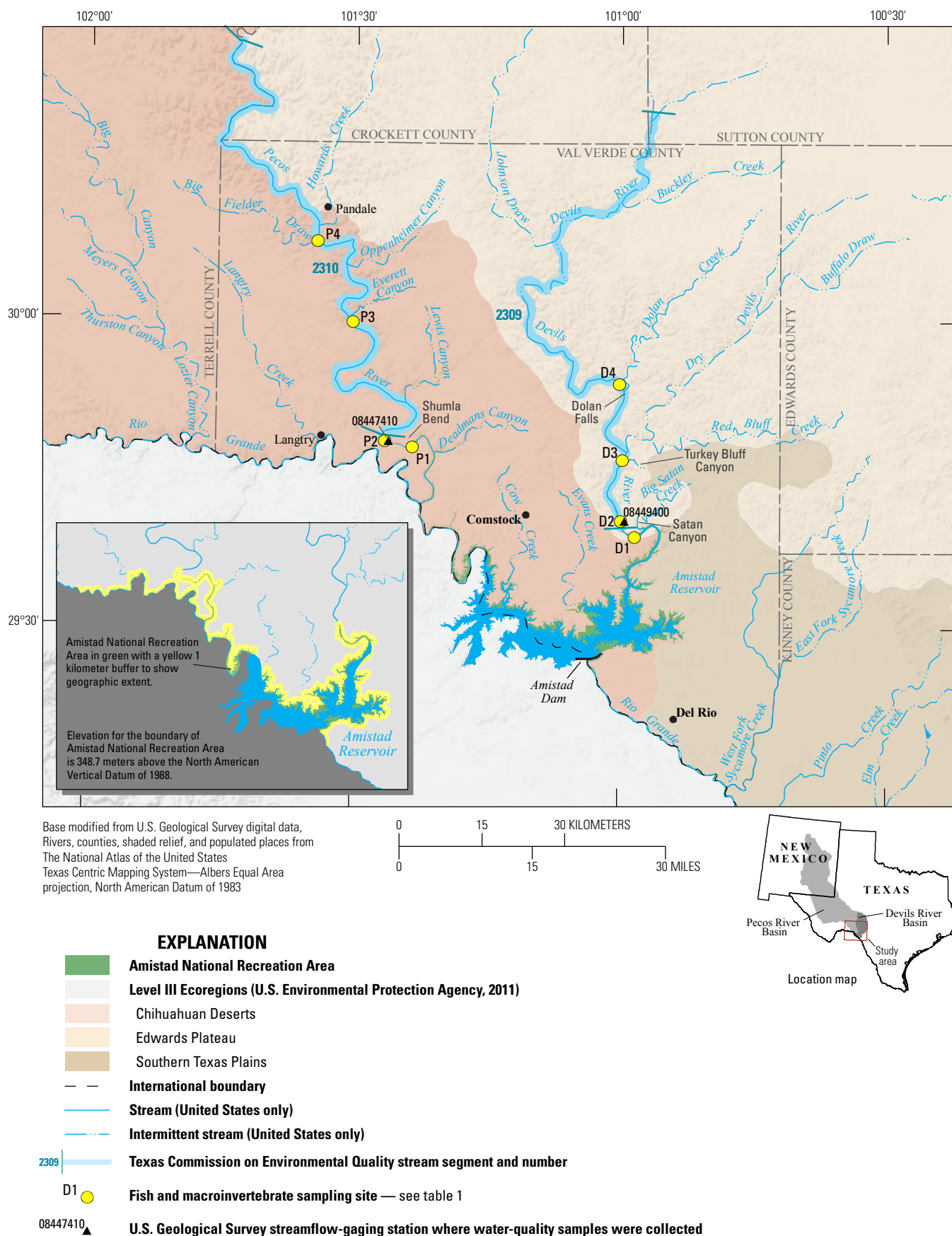
The total number of fish species collected was the same in the Devils River and Pecos River, but the species found in the two rivers varied slightly. The number of fish species generally increased from the site farthest upstream to the site farthest downstream in the Devils River, and decreased between the site farthest upstream and site farthest downstream in the Pecos River. The redbreast sunfish was the most abundant species collected in the Devils River, and the blacktail shiner was the most abundant species collected in the Pecos River. Comparing the species from each river, the percentage of omnivorous fish species was larger at the more downstream sites closer to Amistad Reservoir, and the percentage of species tolerant of environmental stressors was larger in the Pecos River. The fish community, assessed on the basis of the number of shared species among the sites sampled, was more similar to the fish community at the other sites on the same river than it was to the fish community from any other site in the other river. More macroinvertebrate taxa were collected in the Devils River than in the Pecos River. The largest number of macroinvertebrate taxa were from the site second farthest downstream on the Devils River, and the smallest numbers of macroinvertebrate taxa were from the farthest downstream site on the Pecos River. Mayflies were more common in the Devils River, and caddisflies were less common than mayflies at most sites. Net-spinning caddisflies were more common at the Devils River sites. The combined percent of mayfly, caddisfly, and stonefly taxa was generally larger at the Pecos River sites. Riffle beetles were the most commonly collected beetle taxon among all sites, and water-penny beetles were only collected at the Pecos River sites. A greater number of true midge taxa were collected more than any other taxa at the genus and species taxonomic level. Non-insect macroinvertebrate taxa were more common at the Devils River sites. *Corbicula* sp. (presumably the introduced Asian clam) was found at sites in both rivers, and amphipods were more abundant in the Devils River. The Margalef species richness index, based on aquatic insect taxa only, was larger at the Devils River sites than at the Pecos River sites. The Hilsenhoff's biotic index was largest at the site farthest downstream in the Devils River and smallest at the site second farthest downstream in the Pecos River. Overall similarity among sites based on the number of shared macroinvertebrate taxa indicated that each site is more similar to other sites on the same river than to sites on the other river.

## Introduction

A treaty between the United States and Mexico in 1944 authorized the construction of the Amistad Dam on the Rio Grande downstream from where the Devils and Pecos Rivers flowed into the Rio Grande in Texas (Purchase and others, 2001). The Amistad Dam was completed in 1969 and impounded the Rio Grande, Devils River, and Pecos Rivers; at the conservation pool elevation of 1,117 ft (about 340 m) above the North American Vertical Datum of 1988 (NAVD 88), the surface area of the reservoir is 65,000 acres (about 26,300 hectares) (International Boundary and Water Commission, 2011).

The Amistad National Recreation Area was established in and near the Amistad Reservoir in November 1990 to “provide for outdoor recreational use and to protect the scenic, natural, and cultural values of the lands and waters” (Purchase and others, 2001). Surface-water resources (impounded and flowing) in the Amistad National Recreation Area are primarily derived from the Rio Grande, Devils River, and Pecos River (fig. 1). The Devils and Pecos Rivers in the Amistad National Recreation Area, and the adjacent riparian habitat they provide (together referred to as the Devils and Pecos River corridors), are important to the National Park Service (NPS) in part because of the aquatic life they support. The development in 2000 of an international fisheries management plan for the Amistad Reservoir and surrounding areas (including the Amistad National Recreation Area) by the Secretariat of the Environment, Natural Resources, and Fisheries of Mexico; NPS; and Texas Parks and Wildlife Department underscored the importance of aquatic life (Purchase and others, 2001).

When the Amistad Reservoir reached its conservation pool elevation for the first time in 1970, many species of fish native to the Rio Grande and its major tributaries (the Devils and Pecos Rivers) disappeared from the impounded sections of these rivers (Brune, 1981). The Amistad gambusia (*Gambusia amistadensis*) was extirpated from its only known habitat when Goodenough Springs, historically the third largest spring in Texas with an annual mean discharge of 3,900 liters per second, was inundated when Amistad Reservoir reached conservation pool for the first time (Brune, 1981). Of the 65 native species of fish historically documented in what is now (2011) the Amistad National Recreation Area, 16 species might have been locally extirpated because of the environmental changes resulting from the impoundment of the Rio Grande and its major tributaries by the Amistad Reservoir (Lobello, 1976). Many of these native fish species are rheophilous or “flow-loving” species of the family Cyprinidae (minnows) and are dependent upon flowing sections of a river and might not survive in the impounded reservoir waters. For example, the Devils River minnow (*Dionda diaboli*), found in the Devils River in and near the Amistad National Recreation Area, is federally listed as a threatened species, and the blotched gambusia (*Gambusia senilis*) has not been confirmed in the Devils River section of the Amistad National Recreation





Area since the reservoir filled in 1970 (Hubbs and others, 1991). The Proserpine shiner (*Cyprinella proserpina*), listed as a species of concern (U.S. Fish and Wildlife Service, 1999), was confirmed as occurring upstream from the reservoir inundation zone on the Devils River (Lobello, 1976) after impoundment of the Amistad Reservoir in 1969, but has not been observed downstream from the reservoir.

In addition to the extirpation of some native fish species, the proliferation of non-native species is a cause for concern for several reasons. Non-native species can degrade the fish community by feeding on native fishes and competing with them for food and habitat. Non-native species can interbreed with closely related native species, and if the non-native species is at a selective advantage, the population will gradually be phenotypically and genotypically dominated by a “pure” non-native species (Moyle and Cech, 1982). Some non-native fish species common in the lower Devils River near Amistad Reservoir include blue tilapia, smallmouth bass, and common carp (Linam and Kleinsasser, 2002). Blue tilapia and common carp also inhabit the lower Pecos River (Linam and Kleinsasser, 1996).

Little is known about the status of fish and macroinvertebrate communities of the Devils and Pecos Rivers in the Amistad National Recreation Area, primarily because previous studies focused mostly on the status of fish and macroinvertebrates in the Rio Grande in this region (International Boundary and Water Commission, 1994). In this report the term macroinvertebrates refers to aquatic insects (macroinvertebrates that have six legs; the adults also have wings and antennae) along with other macroinvertebrates such as freshwater worms, snails, mites, and crayfish. Macroinvertebrates are large enough to be seen without the aid of a dissecting scope or hand lens (Pacific Northwest Region Water Quality Program, 2011). To gain a better understanding of the water quality and the status of fish and macroinvertebrate communities, the U.S. Geological Survey (USGS), in cooperation with the NPS and the Amistad National Recreation Area, completed a reconnaissance-level survey of selected water-quality constituents and aquatic biota (fish and macroinvertebrates) in the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area during 2005–7. The water quality and aquatic biota of the Devils River were of primary interest to the USGS and NPS because the species of greatest concern (Devils river minnow) is unique to this river, and because the Devils River has historically been less affected by human activities compared to the Pecos River.

## Purpose and Scope

This report presents the results of a reconnaissance-level survey to characterize the concentrations of selected

water-quality constituents and the composition of fish and macroinvertebrate communities at sites on the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area in southwestern Texas by using water-quality data collected in 2005, and fish and macroinvertebrate data collected during 2006–7.

Comparisons are made between water-quality data collected in 2005 and water-quality data collected at the same sites from 1974 through 2007 as part of either the USGS Hydrologic Benchmark Network (HBN) program or the National Stream Quality Accounting Network (NASQAN) program. Concentrations of selected water-quality constituents from the two sites sampled in 2005 are also compared to State of Texas water-quality criteria. Finally, fish and macroinvertebrate communities sampled along the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area during 2006–7 are compared by using various biological metrics and a nonparametric multivariate statistical analysis, Non-metric Multidimensional Scaling (NMDS).

## Description of Study Area

Upstream from the Amistad Reservoir in southwestern Texas, the Devils and Pecos Rivers are perennial streams with base flows that are sustained by groundwater discharges (Purchase and others, 2001). Segments of these rivers are in the Amistad National Recreation Area, which includes 15 kilometers (km) of the Devils River and 24 km of the Pecos River when the Amistad Reservoir is at conservation pool (fig. 1). The lengths of flowing sections of the Pecos River and Devils River change in the Amistad National Recreation Area depending on the surface-water elevation of Amistad Reservoir. When the water-surface elevations in the reservoir are relatively low, the Devils River in the Amistad National Recreation Area can be as much as 16 km long and the Pecos River as much as 32 km long (Purchase and others, 2001). The sampling sites on the Devils River were established in river segment 2309; those on the Pecos River were established in river segment 2310 (fig. 1). Segments 2309 and 2310 of the Devils and Pecos Rivers, respectively, have been assigned State water-quality standards (Texas Commission on Environmental Quality, 2010) by the Texas Commission on Environmental Quality for many of the water-quality constituents discussed in this report.

The Devils River basin is sparsely populated; land use is dominated by ranching, and relatively large nutrient concentrations in the Devils River are the primary water-quality concern (Mast and Turk, 1999). The relatively large nutrient concentrations noted in previous investigations of the Devils River are surprising because the watershed is sparsely populated and the ranches are not heavily grazed; no evidence of upward trends in atmospheric deposition or land-use

related sources was identified that might have explained the relatively large nutrient concentrations (Mast and Turk, 1999). Ecological concerns for aquatic biota in the Devils River include the extirpation (local extinction) of native aquatic species after completion of the Amistad Reservoir Dam, the effects of nutrient enrichment on aquatic biota, and the influence of changes in reservoir elevation on riparian habitat for native species (Purchase and others, 2001).

For the part of the Pecos River basin in Texas (fig. 1), rangeland is the predominant land use (Thompson, 2008). About 73,000 acres (about 30,000 hectares) (Jensen and others, 2006) of the Pecos River basin in Texas are irrigated croplands dominated by cotton, small grains, and sorghum; oil and natural gas production is the largest industry (Thompson, 2008). Water-quality and biological concerns in the Pecos River within the Amistad National Recreation Area have historically been related to increasing salinity concentrations, increasing loads of suspended sediment, discharge of waste waters from oil and gas production, and agricultural runoff and irrigation return flows in the contributing watershed (Linam and Kleinsasser, 1996; Purchase and others, 2001).

The climate of the study area is semi-arid, with an average rainfall of about 43 to 46 centimeters per year and maximum daily temperatures that range from 18 degrees Celsius (°C) in the winter to 36 °C in the summer (National Park Service, 2010). The Amistad National Recreation Area is in an ecological transition zone between the southern Texas Plains, Chihuahuan Desert, and Edwards Plateau ecoregions, which enhances biodiversity in the Amistad National Recreation Area, particularly for plant species (National Park Service, 2010). Riparian zones of the Devils River in the Amistad National Recreation Area include native plants such as pecan (*Carya* sp.), live oak (*Quercus* sp.), and sycamore (*Platanus* sp.). Sections of the riparian zone adjacent to the Pecos River in the Amistad National Recreation Area are dominated by tamarisk (*Tamarix* sp.), an exotic invasive plant referred to locally as salt cedar (National Park Service, 2010).

## Methods of Investigation

One water-quality sampling site and four fish and macroinvertebrate sampling sites were established on both the Devils and Pecos Rivers (table 1). Water-quality samples were collected in 2005 and fish and macroinvertebrates were collected during 2006–7. The water-quality data were collected at two streamflow-gaging stations in the Amistad National Recreation Area operated by the International Boundary and Water Commission (IBWC) and identified with USGS station numbers and names in the USGS National Water Information System (NWIS) (U.S. Geological Survey, 2011)—USGS stations 08449400 Devils River at Pafford

Crossing near Comstock, Tex. (hereinafter the Devils River at Pafford Crossing gage [site D2]), and 08447410 Pecos River near Langtry, Tex. (hereinafter the Pecos River near Langtry gage ] [site P2]) (fig. 1; table 1). Discharge data (mean-daily discharge) was obtained from USGS NWIS for the dates that water-quality samples were collected at each of the gaging stations. The water-quality sampling sites were in the Amistad National Recreation Area and near where each river flows directly into Amistad Reservoir. The location of each sampling site was documented by using a Global Positioning System (GPS) unit, digital photographs, and field notes to describe the site relative to surrounding landmarks, as well as by plotting the site on USGS quadrangle maps or smaller scale site maps when necessary.

Water-quality sampling was done in the spring and summer because selected constituents, such as nutrients and pesticides, might be applied more frequently in upstream contributing areas in Texas and New Mexico during the spring and summer compared to other times of the year resulting in relatively large concentrations of nutrients and pesticides in the streams compared to other seasons. Water-quality samples were collected at the Devils River near Pafford Crossing gage (site D2) in March, May, June and August of 2005, and in March, April, May, June, and August of 2005 at the Pecos River near Langtry gage (site P2); the March samples collected at site D2 and the March, April, and August samples collected at site P2 included quality-control samples. Spring and summer also are when fish and macroinvertebrates might have heightened sensitivity to changes in water quality because many species are reproducing and their offspring are developing. For example, the federally threatened Devils River minnow (*Dionda diaboli*) spawn from late winter through the summer, and lay non-adhesive eggs that can be suspended in the water column (Hubbs, 1951).

Historical and recent water-quality samples have been collected by the USGS at the two sites where water-quality data were collected in 2005. The data collected in 2005 were compared with historical water-quality data collected as part of the USGS HBN program during 1978–95 (U.S. Geological Survey, 2011; Mast and Turk, 1999) at the Devils River at Pafford Crossing gage (site D2), and with data collected as part of the USGS NASQAN program during 1974–2007 at the Pecos River near Langtry gage (site P2) (U.S. Geological Survey, 2010). Data from samples collected in 2005 were compared with data collected and processed similarly as part of the USGS HBN or NASQAN program (for example, results from filtered samples collected in 2005 were compared with results from filtered samples collected as part of the USGS HBN or NASQAN programs).

**Table 1.** Sample-collection sites on the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area, Texas, 2005–07.

[USGS, U.S. Geological Survey; Site latitude and longitude correspond to downstream boundary of biological assessment reach at each site; Yes, data-collection activity for site; No, no data collected]

Site identifier (fig. 1)	USGS station number	USGS station name	Site latitude (decimal degrees)	Site longitude (decimal degrees)	Bioassessment reach length (meters)	Water-quality sampling (2005)	Fish community assessment (2006)	Fish community assessment (2007)	Macro-invertebrate community assessment (2006)
D1	293894100582901	Devils River near Satan Canyon, Tex.	29.649	100.972	525	No	Yes	No	Yes
D2	08449400	Devils River at Pafford Crossing near Comstock, Tex.	29.675	101.001	403	Yes	Yes	Yes	Yes
D3	29774610099501	Devils River near Turkey Bluff Canyon, Tex.	29.775	100.995	407	No	Yes	No	Yes
D4	2988810099601	Devils River at Dolan Falls, Tex.	29.888	100.996	254	No	Yes	Yes	Yes
P1	294735101232401	Pecos River at Shumla Bend, Tex.	29.793	101.390	490	No	Yes	No	Yes
P2	08447410	Pecos River near Langtry, Tex.	29.802	101.442	431	Yes	Yes	Yes	Yes
P3	295945101301501	Pecos River near Everett Canyon, Tex.	29.996	101.504	520	No	Yes	No	Yes
P4	300737101342201	Pecos River at Pandale, Tex.	30.127	101.573	272	No	Yes	Yes	Yes

## Collection and Analysis of Water-Quality Samples

Depth- and width-integrated composite samples were collected and processed in 2005 for water-quality analyses in accordance with standard USGS protocols (U.S. Geological Survey, variously dated). Some samples were filtered in the field within 2 hours of collection. Analyses of filtered samples provided concentrations of total dissolved solids, major ions, nutrients, trace metals, and pesticides. Samples were filtered through 0.45- $\mu$ m pore-diameter filters with the exception of those analyzed for organic carbon and pesticides, which were filtered through 0.7- $\mu$ m pore-diameter filters. Reusable bottles and sampling equipment were cleaned with Liqui-Nox soap, hydrochloric acid, methanol, and deionized

water prior to use. When used, preservatives such as nitric acid were added to the samples in a preservation chamber. Ultrapure nitric acid was added to each bottle for cation or trace-element analysis, lowering the pH to 2 or less. Samples for temperature-sensitive constituents that could change as a result of biological activity were chilled with ice to maintain them at 4°C from the time they were collected in the field until they were analyzed (U.S. Geological Survey, variously dated). All of the samples were shipped for analysis within 24 hours of collection to the USGS National Water Quality Laboratory in Denver, Colorado. Analytical methods are described in Fishman (1993), Fishman and Friedman (1989), Furlong and others (2001), Lindley and others (1996), Madsen and others (2003), Patton and Truitt (2000), Sandstrom and others (2001), U.S. Environmental Protection Agency (1993), and Zaugg and others (1995).

The following water-quality constituents were analyzed:

- Total dissolved solids;
- Major ions—calcium, magnesium, potassium, sodium, chloride, fluoride, silica, and sulfate;
- Nutrients— ammonia plus organic nitrogen as nitrogen, ammonia as nitrogen, nitrate plus nitrite as nitrogen ( $\text{NO}_3 + \text{NO}_2$  as N), nitrate ( $\text{NO}_3$ ), nitrite ( $\text{NO}_2$ ), phosphorous (P), and orthophosphate ( $\text{PO}_4$ );
- Trace metals—aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, silver, strontium, vanadium, zinc, antimony, arsenic, boron, and selenium; and
- Organic carbon and pesticides.

Samples for quality-control purposes were collected following USGS protocols (U.S. Geological Survey, variously dated) at the Devils River at Pafford Crossing gage (site D2) and Pecos River near Langtry gage (site P2) at the same time the environmental samples were collected in March at site D2 and in March, April, and August at site P2. A more extensive analysis of samples for polar pesticides and their metabolites was done for samples collected at site D2 to provide a more complete screening of pesticides in what is considered a relatively pristine spring-fed river with no impoundments and few land uses in the runoff-contributing area that might affect water quality (Purchase and others, 2001).

The constituents of primary concern are total dissolved solids, chloride, sulfate, ammonia plus organic nitrogen, nitrate plus nitrite, orthophosphate, phosphorous, selenium, and selected pesticides. These constituents are among those of greatest concern to the Amistad National Recreation Area in previous studies of the Devils and Pecos Rivers (Purchase and others, 2001).

## Collection and Processing of Fish and Macroinvertebrate Samples

The composition of fish macroinvertebrate communities were evaluated by collecting fish and macroinvertebrate samples in 2006 at the Devils River at Pafford Crossing gage (site D2), and at the Pecos River near Langtry gage (site P2), and from three additional sites in or near the Amistad National Recreation Area on each river. The three additional sites where fish and macroinvertebrates were collected in 2006 from the Devils River were USGS stations 293894100582901 Devils River near Satan Canyon, Tex. (site D1); 29774610099501 Devils River near Turkey Bluff Canyon, Tex. (site D3); and 2988810099601 Devils River at Dolan Falls, Tex. (site D4). The three additional sites in or near the Amistad National Recreation Area on the Pecos River where fish and macroinvertebrates were collected in 2006 were USGS stations 294735101232401 Pecos River at Shumla Bend, Tex.

(site P1); 295945101301501 Pecos River near Everett Canyon, Tex. (site P3); and 300737101342201 Pecos River at Pandale, Tex. (site P4) (fig. 1; table 1). Fish community surveys were repeated in the spring of 2007 at two sites along the Devils River (sites D2 and D4) and two sites on the Pecos River (sites P2 and P4). The farthest downstream sites where fish and macroinvertebrates were collected (site D1 on the Devils River and site P1 on the Pecos River) were in sections of the Devils and Pecos Rivers that flow during lower water-surface elevations in Amistad Reservoir, but are in backwater during periods of higher water-surface elevations in the reservoir.

The fish and macroinvertebrate communities were sampled by using procedures developed for the USGS National Water Quality Assessment (NAWQA) Program (Moulton and others, 2002; Moring 2002). Reach length at each site where fish and macroinvertebrates were collected was not determined as a multiple of wetted channel width, which is commonly done (Moulton and others, 2002; Texas Commission on Environmental Quality, 2007), because this approach would have resulted in reach lengths of several thousand meters or more at some sites that would not have been practical for wading and the collection of fish and macroinvertebrates. Instead, each reach defining a sampling site was selected to include at least two of the most common of the basic geomorphic units associated with rivers—for example, riffles, runs, and or pools (Church, 1992)—so that each reach had a similar variety of habitat types for the sampling of fish and macroinvertebrates allowing for more standardized equal-effort sampling and between site comparisons. Reach lengths at each sampling site ranged from 272 to 525 m and are listed in table 1.

The total number of fish species and the number of individuals of each fish species were compared in and between sites on the Devils and Pecos Rivers. Selected fish community metrics including the Menhinick species richness (Ludwig and Reynolds, 1988), number of non-native individuals, number of tolerant and intolerant species, number of fish representing different feeding groups, and taxa were compared among sites (Linam and others, 2002). Taxon (singular) or taxa (plural) refers to a genetically related group or groups of one or more organisms with common characteristics that differentiate them as a unit (International Commission on Zoological Nomenclature, 2010).

The overall similarity among the fish communities at the eight sampling sites was evaluated by the number of shared species observed among each of the sites by using a Bray-Curtis similarity matrix (Clarke and Warwick, 2001). The Bray-Curtis similarity matrix was based on the number of unique fish taxa in common among sites and was used as input to a statistical procedure known as Non-metric Multidimensional Scaling (NMDS). Euclidean distances between objects were determined by using the Bray-Curtis similarity matrix values as inputs to the NMDS procedure (Field and others, 1982; Clark and Warwick, 2001). Statistica Version 7 (StatSoft, 2006) was used to calculate the Bray-Curtis similarity matrix and to run the NMDS procedure. The



overall similarity among the fish communities at the eight sampling sites was illustrated by graphically depicting the Euclidean distances between them in two dimensions (Clark and Warwick, 2001).

The total number of unique macroinvertebrate taxa, number of individuals per unique taxon, and several species diversity metrics and indexes (Margalef richness, Hilsenhoff biotic, Pielou's J, and Simpson's heterogeneity indexes) (Ludwig and Reynolds, 1988; Hilsenhoff, 1987), were determined for each site. Except for the Margalef richness, all of the indexes were determined by The EcoAnalysts, Inc., laboratory in Moscow, Idaho (Gary Lester, EcoAnalysts, Inc., written commun., 2006). Only the Margalef richness and Hilsenhoff biotic index are discussed. The Margalef richness index was calculated by using only aquatic insect taxa, whereas the other indexes were calculated by using all macroinvertebrate taxa. As was done to evaluate the fish communities, a Bray-Curtis similarity matrix was also used to evaluate the aquatic insect assemblages (number of unique aquatic insect taxa only). Aquatic insect assemblages are a subset of the macroinvertebrate community; because the vast majority of the macroinvertebrates collected were aquatic insects, it was deemed most appropriate to use aquatic insect assemblages in the Bray-Curtis similarity matrix and subsequent NMDS procedure. The number of unique aquatic insect taxa in common between sites was evaluated with the Bray-Curtis similarity matrix and used as input to the NMDS procedure to compare the overall similarity of aquatic insect assemblages among sites, and the results of the NMDS procedure were displayed graphically as Euclidean distances to illustrate the overall similarity among aquatic insect assemblages.

## **Fish Community Surveys and Processing of Samples**

Following methods described in Moring (2002), the fish community at each site was sampled by using a combination of electrofishing from boats and barges, wading with backpack electrofishing equipment, seining, and trap netting. Fish were collected in spring and summer (during March and June) when the rivers were relatively accessible for fish sampling; streamflow amounts are generally smaller in spring and summer in the Devils and Pecos Rivers compared to fall and winter, when runoff from storm events is more common (U.S. Geological Survey, 2010). By collecting fish in the spring and summer, the representativeness of the samples was also enhanced because fish are more dispersed during these seasons—the higher water temperatures in spring and summer enhance fish mobility compared to fall and winter when cooler temperatures tend to make fish less active (Lucas and others, 2008). Two electrofishing passes were made through the reach at each sample-collection site by using the most appropriate

equipment considering river depth and flow velocity. At least six seine hauls were equally distributed among the types of geomorphic units present at each site. Seines used were a 7.5- by 3.0-m, 0.64-cm mesh-size bag seine and a 3.0- by 3.0-m, 0.17-cm flat-panel seine. Collected fish were placed in aerated holding tanks; each species of fish was identified, standard and total lengths were measured to the nearest millimeter, and each fish was weighed to the nearest gram.

## **Macroinvertebrate Community Surveys and Processing of Samples**

The macroinvertebrate community at each site was surveyed in 2006 by the collection of a composite sample referred to as a qualitative multi-habitat sample (Moulton and others, 2002). Macroinvertebrate community data from each sample-collection site were determined by using a qualitative multi-habitat sample that is biased to maximize the number of taxa collected at each site and not to provide quantitative data on the number of taxa per unit area from one or more habitat types.

A 0.05-mm mesh size D-frame shaped net was used to collect the macroinvertebrate samples equally distributed among habitat types as described in Moulton and others (2002). Each macroinvertebrate sample was preserved on site in 10-percent phosphate-buffered formalin, and submitted to the EcoAnalysts, Inc., laboratory in Moscow, Idaho, for identification and enumeration of macroinvertebrate taxa, and calculation of the Pielou's J, Simpson's heterogeneity, and Hilsenhoff biotic indexes (Gary Lester, EcoAnalysts, Inc., written commun., 2006).

## **Quality Control**

A water-quality field-blank sample was collected March 22, 2005, at the Devils River near Pafford Crossing gage (site D2) and analyzed for selected major ions, nutrients, trace metals, and pesticides in 2005 to evaluate potential contamination from field processing and laboratory handling and analysis. Sequential-replicate samples were collected at the Pecos River near Langtry gage (P2) on March 8, 2005, along with a field-blank sample on April 5, 2005, and a field-spike sample on August 2, 2005. Quality-control water samples were collected as described in the National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, variously dated) and analyzed by the same laboratory following the same methods as the environmental samples.

Calcium exceeded the laboratory reporting level (LRL) of 0.02 milligrams per liter [mg/L] in the March 2005 field-blank sample but was two orders of magnitude less than the calcium concentrations of all the environmental samples collected

at the Devils River near Pafford Crossing gage. No other concentrations of major ions exceeded laboratory reporting levels (LRLs) in the field-blank sample (indicated by less-than values in table 2). Trace metal concentrations measured in this field-blank sample did not exceed applicable LRLs with the exception of nickel (0.12 micrograms per liter [mg/L]; LRL of 0.06 µg/L) and zinc (1.6 mg/L; LRL of 0.6 µg/L). An estimated vanadium concentration of 0.1 mg/L was less than the LRL of 0.14 µg/L (table 3). Nutrients and pesticides in this field-blank sample (tables 2 and 4, respectively) did not exceed the any of the applicable LRLs. An estimated concentration of 0.2 mg/L for organic carbon was detected (table 4), but this concentration was several times smaller than the concentrations of 1.1 to 1.2 mg/L organic carbon measured in the environmental samples from this site.

In addition to the field-blank sample collected at the Devils River at Pafford Crossing gage on March 22, 2005, sequential-replicate samples were collected at the Pecos River near Langtry gage on March 8, 2005, and analyzed to determine the precision of the results for major ions and trace metals. The relative percent difference (RPD) was determined for each pair of replicate analyses as a measure of variability. The relative percent difference (RPD) for each constituent was computed by using the equation

$$RPD = |C_1 - C_2| / ((C_1 + C_2) / 2) \times 100, \quad (1)$$

where

$C_1$  is the concentration from the first sample in the replicate pair; and

$C_2$  is the concentration from the second sample in the replicate pair.

The RPDs for total dissolved solids, major ions, nutrients, and trace metals were generally 5 percent or smaller, indicating good analytical precision; exceptions were arsenic and selenium, which had RPDs of 16.67 and 6.90 percent, respectively. The RPDs for arsenic and selenium also indicated good analytical precision because the concentrations measured in the replicate samples were small (1.1 and 1.3 mg/L for arsenic, and 2.8 and 3.0 mg/L for selenium).

A field-blank and a field-spike (matrix spike) sample were collected on April 5, 2005, and August 2, 2005, respectively, at the Pecos River near Langtry gage and analyzed for selected pesticides; no detectable amounts of pesticides were measured in the field-blank samples. The recovery rates for the field-spike sample were reviewed; most recovery rates were in the acceptable range and recovery rates overall were typical for the constituents analyzed (Cary Carman, U.S. Geological Survey, oral commun., 2011). To evaluate the accuracy of the laboratory analysis of pesticides, the insecticides diazinon and alpha-hexachlorocyclohexane (alpha-HCH) were added as surrogates to environmental samples. The average surrogate recoveries were 106.8 percent

for diazinon and 96.6 percent for alpha-HCH (appendix 1). These surrogate recoveries for diazinon and alpha-HCH are within the continuing laboratory calibration verification limits of 80- to 120-percent recovery for these insecticides (Duane Wydoski, U.S. Geological Survey, National Water Quality Laboratory, written commun., 2011).

For quality control, the fish species identified at each site were photographed onsite with a digital camera, and photo vouchers were prepared to record observations pertaining to each fish in an electronic log book. Photo vouchers are maintained by the USGS in Austin, Tex. Fish that could not be identified in the field were preserved onsite with 10-percent phosphate-buffered formalin and returned to the USGS office in Austin for sorting and preliminary identification. Verification of all species that were identified and permanent curation of all preserved specimens was done by the Curator of Fishes at the University of Texas Natural History Collection in Austin.

Macroinvertebrate samples were processed by using a 300-count procedure. If a macroinvertebrate sample contained 300 or fewer organisms, all the organisms in the samples were sorted, identified to the lowest possible taxon, and counted by laboratory personnel. If the sample contained more than 300 organisms, then a 300-count sub-sampling routine was used (Lester, 1999). The sub-sampling routine involved sorting the organisms in a tray with a grid overlay, and the organisms in randomly selected grids were counted up to 300 organisms. If the 300 count was met before the organisms in one grid were completely counted, all the organisms in that grid were counted. Sub-sampling sorting efficiency was checked by a separate laboratory technician who re-sorted the original sample and processed 20 percent of the total grids that were sampled by the original technician. Sorting efficiency was measured as a ratio of the number of organisms counted during the initial sorting divided by the number from the sorting of 20 percent of the grids. If sorting efficiency was 90 percent or greater, the sample passed this quality-control check. If less than 90 percent, the samples underwent the quality-control check again until the 90-percent or better efficiency was reached. All of the samples for this study passed the initial sorting efficiency check. A reference collection was provided by EcoAnalysts, Inc., consisting of at least one specimen of each unique taxon identified. The accuracy of taxonomic identification was checked by a different taxonomist with the contract laboratory by checking the accuracy of 10 percent of the taxa in the reference collection to a target similarity of identification of at least 90 percent. The reference collection from this study passed this quality-control check as well. The reference collection is maintained at the USGS office in Austin to also provide verifiable taxonomic identification if any of the taxa identified in this study are questioned or should need to be verified in the future.

**Table 2.** Concentrations of total dissolved solids, selected major ions, and nutrients in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental]

Site identifier (fig. 1)	Date	Sample type code	USGS station number	USGS station name	Daily mean discharge, cubic feet per second	Dissolved solids dried at 180°C				Calcium, water, filtered, milligrams per liter	Magnesium, water, filtered, milligrams per liter	Potassium, water, filtered, milligrams per liter
						degrees Celsius, water, filtered, milligrams per liter (Total Dissolved Solids)						
D2	3/22/2005	2	08449400	Devils River at Pafford Crossing near Comstock, Tex.	576	<10				0.03	<0.008	<0.16
D2	3/22/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	576	232				64.8	12.9	1.32
D2	5/17/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	417	208				57.9	12.7	1.36
D2	6/29/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	480	214				53.8	12.1	1.22
D2	8/3/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	396	227				58.7	13.8	1.3
P2	3/8/2005	9	08447410	Pecos River near Langtry, Tex.	322	2,250				171	79.8	8.24
P2	3/8/2005	7	08447410	Pecos River near Langtry, Tex.	322	2,240				169	79.9	8.01
P2	4/5/2005	9	08447410	Pecos River near Langtry, Tex.	271	2,390				181	91.2	8.67
P2	4/5/2005	2	08447410	Pecos River near Langtry, Tex.	271	--				--	--	--
P2	5/24/2005	9	08447410	Pecos River near Langtry, Tex.	204	1,780				112	65.3	6.92
P2	5/24/2005	9	08447410	Pecos River near Langtry, Tex.	204	--				--	--	--
P2	6/28/2005	9	08447410	Pecos River near Langtry, Tex.	186	2,110				131	75.7	7.44
P2	8/2/2005	9	08447410	Pecos River near Langtry, Tex.	180	1,460				100	51.9	6.54
P2	8/2/2005	1	08447410	Pecos River near Langtry, Tex.	180	--				--	--	--
Relative Percent Difference for sequential-replicate						.45				1.18	.13	2.83

Relative Percent Difference for sequential-replicate samples collected March 8, 2005 from the Pecos River near Langtry, Tex., station

.45 1.18 .13 2.83

**Table 2.** Concentrations of total dissolved solids, selected major ions, and nutrients in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued

[USGS, U.S. Geological Survey; --, no data; &lt;, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental]

Site identifier (fig. 1)	Date	Sample type code	USGS station number	Ammonia							Nitrite, water, filtered, milligrams per liter	Ortho phosphate, water, filtered, milligrams per liter	Phosphorus, water, filtered, milligrams per liter as phosphorus
				Chloride, water, filtered, milligrams per liter	Fluoride, water, filtered, milligrams per liter	Silica, water, filtered, milligrams per liter as SiO <sub>2</sub>	Sulfate, water, filtered, milligrams per liter	Ammonia, plus organic nitrogen, water, filtered, milligrams per liter as nitrogen	Nitrate, plus nitrite, water, filtered, milligrams per liter as nitrogen	Nitrate, water, filtered, milligrams per liter			
D2	3/22/2005	2	08449400	<0.20	<0.10	0.10	<0.18	<0.10	<0.04	<0.06	<0.266	<0.018	<0.004
D2	3/22/2005	9	08449400	11.8	.3	13.7	8.20	.12	<.04	1.24	E 5.46	<.018	<.004
D2	5/17/2005	9	08449400	11.6	.29	15.6	7.55	.13	<.04	1.15	E 5.05	<.018	E.003
D2	6/29/2005	9	08449400	12.9	.3	15.8	7.99	.14	E.02	.99	4.33	<.018	E.003
D2	8/3/2005	9	08449400	12.5	.26	16.6	7.86	.13	E.02	1.02	4.49	<.018	E.003
P2	3/8/2005	9	08447410	819	.86	15.9	472	.15	<.04	1.04	4.61	<.018	<.004
P2	3/8/2005	7	08447410	830	.83	16.3	473	.15	<.04	1.04	4.59	<.018	<.004
P2	4/5/2005	9	08447410	879	.89	13.9	503	.22	<.04	.83	E 3.63	<.018	E.004
P2	4/5/2005	2	08447410	--	--	--	--	--	--	--	--	--	--
P2	5/24/2005	9	08447410	623	.87	13.3	364	.32	E.03	.40	1.74	<.018	E.002
P2	5/24/2005	9	08447410	--	--	--	--	--	--	--	--	--	--
P2	6/28/2005	9	08447410	795	.87	13.4	443	.29	E.03	.22	E.969	<.018	E.003
P2	8/2/2005	9	08447410	519	.87	16	298	.29	.04	.29	E 1.24	<.018	<.004
P2	8/2/2005	1	08447410	--	--	--	--	--	--	--	--	--	--
Relative Percent Difference for sequential-replicate samples collected March 8, 2005 from the Pecos River near Langtry, Tex., station				1.33	3.55	2.48	.21	.00	.00	.00	.43	.00	.00

**Table 3.** Concentrations of trace metals in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental]

Site identifier (fig. 1)	Date	Sample type code	USGS station number	USGS station name	Daily mean discharge, cubic feet per second	Aluminum, water, filtered, micrograms per liter	Barium, water, filtered, micro-grams per liter	Beryllium, water, filtered, micrograms per liter	Cadmium, water, filtered, micro-grams per liter	Chromium, water, filtered, micro-grams per liter	Cobalt, water, filtered, micro-grams per liter	Copper, water, filtered, micro-grams per liter
D2	3/22/2005	2	08449400	Devils River at Pafford Crossing near Comstock, Tex.	576	<1.6	<0.2	<0.06	<0.04	<0.8	<0.014	<0.4
D2	3/22/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	576	E 1.0	117	<06	0.16	<8	.139	.4
D2	5/17/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	417	E 1.2	113	<06	<.04	<8	.182	.4
D2	6/29/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	480	2.7	106	<06	<.04	<8	.14	E.4
D2	8/3/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	396	<1.6	109	<06	<.04	<8	.098	E.2
P2	3/8/2005	9	08447410	Pecos River near Langtry, Tex.	322	--	--	--	--	--	--	--
P2	3/8/2005	7	08447410	Pecos River near Langtry, Tex.	322	--	--	--	--	--	--	--
P2	4/5/2005	9	08447410	Pecos River near Langtry, Tex.	271	--	--	--	--	--	--	--
P2	4/5/2005	2	08447410	Pecos River near Langtry, Tex.	271	--	--	--	--	--	--	--
P2	5/24/2005	9	08447410	Pecos River near Langtry, Tex.	204	--	--	--	--	--	--	--
P2	6/28/2005	9	08447410	Pecos River near Langtry, Tex.	186	--	--	--	--	--	--	--
P2	8/2/2005	9	08447410	Pecos River near Langtry, Tex.	180	--	--	--	--	--	--	--
P2	8/2/2005	1	08447410	Pecos River near Langtry, Tex.	180	--	--	--	--	--	--	--

Relative Percent Difference for sequential-replicate samples collected March 8, 2005 from the Pecos River near Langtry, Tex., station

**Table 3.** Concentrations of trace metals in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; &lt;, less than; E, estimated; 1, Field spike; 2, Field blank; 7, Sequential replicate; 9, environmental]

Site identifier (fig. 1)	Date	Sample type code	Iron, water, filtered, micro-grams per liter	Lead, water, filtered, micro-grams per liter	Lithium, water, filtered, micro-grams per liter	Manganese, water, filtered, micrograms per liter	Molybdenum, water, filtered, micrograms per liter	Nickel, water, filtered, micro-grams per liter	Silver, water, filtered, micro-grams per liter	Strontium, water, filtered, micro-grams per liter	Vanadium, water, filtered, micro-grams per liter	Zinc, water, filtered, micro-grams per liter	Antimony, water, filtered, micro-grams per liter	Arsenic, water, filtered, micro-grams per liter	Boron, water, filtered, micro-grams per liter	Selenium, water, filtered, micro-grams per liter
D2	3/22/2005	2	<6	<0.08	<0.6	<0.2	<0.4	0.12	<0.20	<0.40	E.1	1.6	<0.20	<0.2	<8	<0.4
D2	3/22/2005	9	<6	<0.8	4.9	.9	.7	1.07	<20	472	9.1	5.6	<20	1.1	72	.5
D2	5/17/2005	9	<6	<0.8	5	.6	.7	2.57	<20	432	8.1	2.3	<20	1	58	.6
D2	6/29/2005	9	<6	<0.8	5.5	.6	.7	1.8	<20	472	8.5	E.3	<20	1.1	57	E.4
D2	8/3/2005	9	<6	<0.8	4.4	.5	.7	2	<20	473	7.8	1.3	<20	1.1	46	E.3
P2	3/8/2005	9	<18	--	68.4	--	--	--	--	3,020	6.9	--	--	1.1	265	2.8
P2	3/8/2005	7	<18	--	69.8	--	--	--	--	3,050	7.1	--	--	1.3	271	3.0
P2	4/5/2005	9	E 10	--	77	--	--	--	--	3,090	6.9	--	--	1.3	304	3.1
P2	4/5/2005	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P2	5/24/2005	9	<18	--	59.8	--	--	--	--	2,200	8.5	--	--	1.4	222	1.2
P2	6/28/2005	9	<18	--	67.2	--	--	--	--	2,720	7.2	--	--	1.2	221	1.2
P2	8/2/2005	9	<18	--	55.5	--	--	--	--	1,930	8.3	--	--	1.6	210	1.0
P2	8/2/2005	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Relative Percent Difference for sequential-replicate samples collected March 8, 2005 from the Pecos River near Langtry, Tex., station			--	--	2.03	--	--	--	--	.99	2.86	--	--	16.67	2.24	6.90

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Station number	USGS Station name	Daily mean discharge, cubic feet per second	Organic carbon, water, filtered, milligrams per liter	2,4-D methyl ester, water, filtered, recoverable, micrograms per liter	2,4-D, water, filtered, recoverable, micrograms per liter	2,4-DB, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter
D2	3/22/2005	2	08449400	Devils River at Pafford Crossing near Comstock, Tex.	576	E.2	<0.016	<0.04	<0.02
D2	3/22/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	576	1.1	<.016	<.04	<.02
D2	5/17/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	417	1.2	<.016	<.04	<.05
D2	6/29/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	480	1.2	<.016	<.04	<.02
D2	8/3/2005	9	08449400	Devils River at Pafford Crossing near Comstock, Tex.	396	1.2	<.016	<.04	<.02
P2	3/8/2005	9	08447410	Pecos River near Langtry, Tex.	322	1.4	--	--	--
P2	3/8/2005	7	08447410	Pecos River near Langtry, Tex.	322	1.3	--	--	--
P2	4/5/2005	9	08447410	Pecos River near Langtry, Tex.	271	0.9	--	--	--
P2	4/5/2005	2	08447410	Pecos River near Langtry, Tex.	271	<.3	--	--	--
P2	5/24/2005	9	08447410	Pecos River near Langtry, Tex.	204	1.7	--	--	--
P2	5/24/2005	9	08447410	Pecos River near Langtry, Tex.	204	--	--	--	--
P2	6/28/2005	9	08447410	Pecos River near Langtry, Tex.	186	1.3	--	--	--
P2	8/2/2005	9	08447410	Pecos River near Langtry, Tex.	180	2.8	--	--	--
P2	8/2/2005	1	08447410	Pecos River near Langtry, Tex.	180	--	--	--	--



**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	2,6-Diethylaniiline, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	2-Chloro-4-isopropylamino-6-amino-s-triazine, water, filtered, recoverable, micrograms per liter	2-Chloro-6-ethylamino-4-amino-s-triazine, water, filtered, recoverable, micrograms per liter	2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine, water, filtered, recoverable, micrograms per liter	3-Hydroxy carbofuran, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	3-Ketocarbafuran, water, filtered, recoverable, micrograms per liter	Acetochlor, water, filtered, recoverable, micrograms per liter	Acifluorfen, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter
D2	3/22/2005	2	<0.006	<0.006	<0.08	<0.032	<0.008	<0.02	<0.006	<0.028
D2	3/22/2005	9	<0.006	<0.006	<0.08	<0.032	<0.008	<0.02	<0.006	<0.028
D2	5/17/2005	9	<0.006	<0.006	<0.08	<0.032	<0.008	<0.02	<0.006	<0.028
D2	6/29/2005	9	<0.006	<0.006	<0.08	<0.032	<0.008	--	<0.006	<0.028
D2	8/3/2005	9	<0.006	<0.006	<0.08	<0.032	<0.008	<0.02	<0.006	<0.028
P2	3/8/2005	9	<0.006	<0.006	--	--	--	--	<0.006	--
P2	3/8/2005	7	<0.006	<0.006	--	--	--	--	<0.006	--
P2	4/5/2005	9	<0.006	<0.006	--	--	--	--	<0.006	--
P2	4/5/2005	2	<0.006	<0.006	--	--	--	--	<0.006	--
P2	5/24/2005	9	<0.006	<0.006	--	--	--	--	<0.006	--
P2	5/24/2005	9	--	--	<0.08	--	--	<0.02	--	--
P2	6/28/2005	9	<0.006	<0.006	--	--	--	--	<0.006	--
P2	8/2/2005	9	<0.006	<0.006	<0.08	--	--	<0.02	<0.006	--
P2	8/2/2005	1	.089	E.033	--	--	--	--	.125	--

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Alachlor, water, filtered, recoverable, micrograms per liter	Aldicarb sulfone, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Aldicarb sulfide, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Aldicarb, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	alpha-HCH, water, filtered, recoverable, micrograms per liter	Atrazine, water, filtered, recoverable, micrograms per liter	Azinphos-methyl, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Bendiocarb, water, filtered, recoverable, micrograms per liter
D2	3/22/2005	2	<0.005	<0.02	<0.022	<0.04	<0.005	<0.007	<0.050	<0.02
D2	3/22/2005	9	<0.005	<0.02	<0.022	<0.04	<0.005	<0.007	<0.050	<0.02
D2	5/17/2005	9	<0.005	<0.02	<0.022	<0.04	<0.005	<0.007	<0.050	<0.02
D2	6/29/2005	9	<0.005	<0.02	<0.022	<0.04	<0.005	<0.007	<0.050	<0.02
D2	8/3/2005	9	<0.005	<0.02	<0.022	<0.04	<0.005	<0.007	<0.050	<0.02
P2	3/8/2005	9	<0.005	--	--	--	<0.005	<0.007	<0.050	--
P2	3/8/2005	7	<0.005	--	--	--	<0.005	<0.007	<0.050	--
P2	4/5/2005	9	<0.005	--	--	--	<0.005	<0.007	<0.050	--
P2	4/5/2005	2	<0.005	--	--	--	<0.005	<0.007	<0.050	--
P2	5/24/2005	9	<0.005	--	--	--	<0.005	<0.007	<0.050	--
P2	5/24/2005	9	--	--	--	<0.04	--	--	--	--
P2	6/28/2005	9	<0.005	--	--	--	<0.005	<0.007	<0.050	--
P2	8/2/2005	9	<0.005	--	--	<0.04	<0.005	<0.007	<0.050	--
P2	8/2/2005	1	.118	--	--	--	.129	.119	E.099	--

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Benfluralin, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Benomyl, water, filtered, recoverable, micrograms per liter	Bensulfuron-methyl, water, filtered, recoverable, micrograms per liter	Bentazon, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Bromacil, water, filtered, recoverable, micrograms per liter	Bromoxynil, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Butylate, water, filtered, recoverable, micrograms per liter
D2	3/22/2005	2	<0.010	<0.022	<0.02	<0.01	<0.02	<0.03	<0.004
D2	3/22/2005	9	<0.010	<0.022	<0.02	<0.01	<0.02	<0.03	<0.004
D2	5/17/2005	9	<0.010	<0.022	<0.02	<0.01	<0.02	<0.03	<0.004
D2	6/29/2005	9	<0.010	<0.022	<0.02	<0.01	<0.02	<0.03	<0.004
D2	8/3/2005	9	<0.010	<0.022	<0.02	<0.01	<0.02	<0.03	<0.004
P2	3/8/2005	9	<0.010	--	--	--	--	--	<0.004
P2	3/8/2005	7	<0.010	--	--	--	--	--	<0.004
P2	4/5/2005	9	<0.010	--	--	--	--	--	<0.004
P2	4/5/2005	2	<0.010	--	--	--	--	--	<0.004
P2	5/24/2005	9	<0.010	--	--	--	--	--	<0.004
P2	5/24/2005	9	--	--	--	--	--	--	--
P2	6/28/2005	9	<0.010	--	--	--	--	--	<0.004
P2	8/2/2005	9	<0.010	--	--	--	--	--	<0.004
P2	8/2/2005	1	.086	--	--	--	--	--	.11

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Carbaryl, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Carbaryl, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Carbofuran, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Chloramben methyl ester, water, filtered, recoverable, micrograms per liter	Chlorimuron-ethyl, water, filtered, recoverable, micrograms per liter	Chlorodiamino-s-triazine, water, filtered, recoverable, micrograms per liter	Chlorothalonil, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter
D2	3/22/2005	2	<0.02	<0.041	<0.016	<0.020	<0.02	<0.032	<0.04
D2	3/22/2005	9	<0.02	<0.041	<0.016	<0.020	<0.02	<0.032	<0.04
D2	5/17/2005	9	<0.02	<0.041	<0.016	<0.020	<0.02	<0.032	<0.04
D2	6/29/2005	9	<0.02	<0.041	<0.016	<0.020	<0.02	<0.032	<0.04
D2	8/3/2005	9	<0.02	<0.041	<0.016	<0.020	<0.02	<0.032	<0.04
P2	3/8/2005	9	--	<0.041	--	<0.020	--	--	--
P2	3/8/2005	7	--	<0.041	--	<0.020	--	--	--
P2	4/5/2005	9	--	<0.041	--	<0.020	--	--	--
P2	4/5/2005	2	--	<0.041	--	<0.020	--	--	--
P2	5/24/2005	9	--	<0.041	--	<0.020	--	--	--
P2	5/24/2005	9	--	--	--	--	--	--	<0.04
P2	6/28/2005	9	--	<0.041	--	<0.020	--	--	--
P2	8/2/2005	9	--	<0.041	--	<0.020	--	<0.04	<0.04
P2	8/2/2005	1	--	E.070	--	E.090	--	--	--

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB; 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Chlorpyrifos, water, filtered, recoverable, micrograms per liter	cis-Permethrin, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Clpyralid, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Cyanazine, water, filtered, recoverable, micrograms per liter	Cycloate, water, filtered, recoverable, micrograms per liter	Dacthal monoacid, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	DCPA, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter
D2	3/22/2005	2	<0.005	<0.006	<0.02	<0.018	<0.01	<0.03	<0.003
D2	3/22/2005	9	<0.005	<0.006	<0.02	<0.018	<0.01	<0.03	<0.003
D2	5/17/2005	9	<0.005	<0.006	<0.02	<0.018	<0.01	<0.03	<0.003
D2	6/29/2005	9	<0.005	<0.006	<0.02	<0.018	<0.01	<0.03	<0.003
D2	8/3/2005	9	<0.005	<0.006	<0.02	<0.018	<0.01	<0.03	<0.003
P2	3/8/2005	9	<0.005	<0.006	--	<0.018	--	--	<0.003
P2	3/8/2005	7	<0.005	<0.006	--	<0.018	--	--	<0.003
P2	4/5/2005	9	<0.005	<0.006	--	<0.018	--	--	<0.003
P2	4/5/2005	2	<0.005	<0.006	--	<0.018	--	--	<0.003
P2	5/24/2005	9	<0.005	<0.006	--	<0.018	--	--	<0.003
P2	5/24/2005	9	--	--	--	--	--	--	--
P2	6/28/2005	9	<0.005	<0.006	--	<0.018	--	--	<0.003
P2	8/2/2005	9	<0.005	<0.006	--	<0.018	--	--	<0.003
P2	8/2/2005	1	.117	.055	--	.092	--	--	.128

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Desulfinylfipronil amide, water, filtered, recoverable, micrograms per liter	Desulfinylfipronil, water, filtered, recoverable, micrograms per liter	Diazinon, water, filtered, recoverable, micrograms per liter	Dicamba, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Dichlorprop, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Dieldrin, water, filtered, recoverable, micrograms per liter	Dinoseb, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Diphenamid, water, filtered, recoverable, micrograms per liter
D2	3/22/2005	2	<0.029	<0.012	<0.005	<0.04	<0.03	<0.009	<0.04	<0.01
D2	3/22/2005	9	<0.029	<0.012	<0.005	<0.04	<0.03	<0.009	<0.04	<0.01
D2	5/17/2005	9	<0.029	<0.012	<0.005	<0.04	<0.03	<0.009	<0.04	<0.01
D2	6/29/2005	9	<0.029	<0.012	<0.005	<0.04	<0.03	<0.009	<0.04	<0.01
D2	8/3/2005	9	<0.029	<0.012	<0.005	<0.04	<0.03	<0.009	<0.04	<0.01
P2	3/8/2005	9	<0.029	<0.012	<0.005	--	--	<0.009	--	--
P2	3/8/2005	7	<0.029	<0.012	<0.005	--	--	<0.009	--	--
P2	4/5/2005	9	<0.029	<0.012	<0.005	--	--	<0.009	--	--
P2	4/5/2005	2	<0.029	<0.012	<0.005	--	--	<0.009	--	--
P2	5/24/2005	9	<0.029	<0.012	<0.005	--	--	<0.009	--	--
P2	5/24/2005	9	--	--	--	--	--	--	--	--
P2	6/28/2005	9	<0.029	<0.012	<0.005	--	--	<0.009	--	--
P2	8/2/2005	9	<0.029	<0.012	<0.005	--	--	<0.009	--	--
P2	8/2/2005	1	E.066	.115	.125	--	--	.14	--	--

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2, 4-D, 2, 4-Dichlorophenoxyacetic acid; 2, 4-DB; 2, 4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Disulfoton, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Diuron, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	EPTC, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Ethalfuralin, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Ethoprop, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Fenuron, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Fipronil sulfide, water, filtered, recoverable, micrograms per liter
D2	3/22/2005	2	<0.02	<0.01	<0.004	<0.009	<0.005	<0.02	<0.013
D2	3/22/2005	9	<0.02	<0.01	<0.004	<0.009	<0.005	<0.02	<0.013
D2	5/17/2005	9	<0.02	<0.01	<0.004	<0.009	<0.005	<0.02	<0.013
D2	6/29/2005	9	<0.02	<0.01	<0.004	<0.009	<0.005	<0.02	<0.013
D2	8/3/2005	9	<0.02	<0.01	<0.004	<0.009	<0.005	<0.02	<0.013
P2	3/8/2005	9	<0.02	--	<0.004	<0.009	<0.005	--	<0.013
P2	3/8/2005	7	<0.02	--	<0.004	<0.009	<0.005	--	<0.013
P2	4/5/2005	9	<0.02	--	<0.004	<0.009	<0.005	--	<0.013
P2	4/5/2005	2	<0.02	--	<0.004	<0.009	<0.005	--	<0.013
P2	5/24/2005	9	<0.02	--	<0.004	<0.009	<0.005	--	<0.013
P2	5/24/2005	9	--	<0.01	--	--	--	<0.02	--
P2	6/28/2005	9	<0.02	--	<0.004	<0.009	<0.005	--	<0.013
P2	8/2/2005	9	<0.02	<0.01	<0.004	<0.009	<0.005	<0.02	<0.013
P2	8/2/2005	1	E.02	--	.1	.084	.099	--	.109



**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Fipronil sulfone, water, filtered, recoverable, micrograms per liter	Fipronil, water, filtered, recoverable, micrograms per liter	Flumetsulam, water, filtered, recoverable, micrograms per liter	Fluometuron, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Fonofos, water, filtered, recoverable, micrograms per liter	Imazaquin, water, filtered, recoverable, micrograms per liter	Imazethapyr, water, filtered, recoverable, micrograms per liter	Imidacloprid, water, filtered, recoverable, micrograms per liter
D2	3/22/2005	2	<0.024	<0.016	<0.04	<0.02	<0.003	<0.004	<0.004	<0.020
D2	3/22/2005	9	<0.024	<0.016	<0.04	<0.02	<0.003	<0.004	<0.004	<0.020
D2	5/17/2005	9	<0.024	<0.016	<0.04	<0.02	<0.003	<0.004	<0.004	<0.020
D2	6/29/2005	9	<0.024	<0.016	<0.04	<0.02	<0.003	<0.004	<0.004	<0.020
D2	8/3/2005	9	<0.024	<0.016	<0.04	<0.02	<0.003	<0.004	<0.004	<0.020
P2	3/8/2005	9	<0.024	<0.016	--	--	<0.003	--	--	--
P2	3/8/2005	7	<0.024	<0.016	--	--	<0.003	--	--	--
P2	4/5/2005	9	<0.024	<0.016	--	--	<0.003	--	--	--
P2	4/5/2005	2	<0.024	<0.016	--	--	<0.003	--	--	--
P2	5/24/2005	9	<0.024	<0.016	--	--	<0.003	--	--	--
P2	5/24/2005	9	--	--	--	--	--	<0.04	--	--
P2	6/28/2005	9	<0.024	<0.016	--	--	<0.003	--	--	--
P2	8/2/2005	9	<0.024	<0.016	--	--	<0.003	--	--	--
P2	8/2/2005	1	.09	E.099	--	--	.126	--	--	--

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Lindane, water, filtered, recoverable, micrograms per liter	Linuron, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Linuron, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Malathion, water, filtered, recoverable, micrograms per liter	MCPA, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	MCPB, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Metalaxyl, water, filtered, recoverable, micrograms per liter	Methiocarb, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter
D2	3/22/2005	2	<0.004	<0.01	<0.035	<0.027	<0.03	<0.01	<0.01	<0.010
D2	3/22/2005	9	<.004	<.01	<.035	<.027	<.03	<.01	<.01	<.010
D2	5/17/2005	9	<.004	<.01	<.035	<.027	<.03	<.05	<.01	<.010
D2	6/29/2005	9	<.004	<.01	<.035	<.027	<.03	<.01	<.01	<.010
D2	8/3/2005	9	<.004	<.01	<.035	<.027	<.03	<.01	<.01	<.010
P2	3/8/2005	9	<.004	--	<.035	<.027	--	--	--	--
P2	3/8/2005	7	<.004	--	<.035	<.027	--	--	--	--
P2	4/5/2005	9	<.004	--	<.035	<.027	--	--	--	--
P2	4/5/2005	2	<.004	--	<.035	<.027	--	--	--	--
P2	5/24/2005	9	<.004	--	<.035	<.027	--	--	--	--
P2	5/24/2005	9	--	--	--	--	--	--	--	--
P2	6/28/2005	9	<.004	--	<.035	<.027	--	--	--	--
P2	8/2/2005	9	<.004	--	<.035	<.027	--	--	--	--
P2	8/2/2005	1	.123	--	E.162	.084	--	--	--	--

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB; 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Methomyl, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Methyl parathion, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Metolachlor, water, filtered, recoverable, micrograms per liter	Metribuzin, water, filtered, recoverable, micrograms per liter	Metsulfuron-methyl, water, filtered, recoverable, micrograms per liter	Molinate, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	N-(4-Chlorophenyl)-N'-methylurea, water, filtered, recoverable, micrograms per liter
D2	3/22/2005	2	<0.020	<0.015	<0.006	<.006	<0.03	<0.003	<0.04
D2	3/22/2005	9	<0.020	<0.015	<0.006	<.006	<0.03	<0.003	<.04
D2	5/17/2005	9	<0.020	<0.015	<0.006	<.006	<0.03	<0.003	<.04
D2	6/29/2005	9	<0.020	<0.015	<0.006	<.006	<0.03	<0.003	<.04
D2	8/3/2005	9	<0.020	<0.015	<0.006	<.006	<0.03	<0.003	<.04
P2	3/8/2005	9	--	<0.015	<0.006	<.006	--	<0.003	--
P2	3/8/2005	7	--	<0.015	<0.006	<.006	--	<0.003	--
P2	4/5/2005	9	--	<0.015	<0.006	<.006	--	<0.003	--
P2	4/5/2005	2	--	<0.015	<0.006	<.006	--	<0.003	--
P2	5/24/2005	9	--	<0.015	<0.006	<.006	--	<0.003	--
P2	5/24/2005	9	--	--	--	--	<0.03	--	--
P2	6/28/2005	9	--	<0.015	<0.006	<.006	--	<0.003	--
P2	8/2/2005	9	--	<0.015	<0.006	<.006	<0.03	<0.003	--
P2	8/2/2005	1	--	.111	.12	.074	--	.105	--

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2, 4-D, 2, 4-Dichlorophenoxyacetic acid; 2, 4-DB; 2, 4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Napropamide, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Neburon, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Nicosulfuron, water, filtered, recoverable, micrograms per liter	Norflurazon, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Oryzalin, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Oxamyl, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	p,p'-DDE, water, filtered, recoverable, micrograms per liter	Parathion, water, filtered, recoverable, micrograms per liter
D2	3/22/2005	2	<0.007	<0.01	<0.04	<0.02	<0.01	<0.03	<0.003	<0.010
D2	3/22/2005	9	<0.007	<0.01	<0.04	<0.02	<0.01	<0.03	<0.003	<0.010
D2	5/17/2005	9	<0.007	<0.01	<0.04	<0.02	<0.01	<0.03	<0.003	<0.010
D2	6/29/2005	9	<0.007	<0.01	<0.04	<0.02	<0.01	<0.03	<0.003	<0.010
D2	8/3/2005	9	<0.007	<0.01	<0.04	<0.02	<0.01	<0.03	<0.003	<0.010
P2	3/8/2005	9	<0.007	--	--	--	--	--	<0.003	<0.010
P2	3/8/2005	7	<0.007	--	--	--	--	--	<0.003	<0.010
P2	4/5/2005	9	<0.007	--	--	--	--	--	<0.003	<0.010
P2	4/5/2005	2	<0.007	--	--	--	--	--	<0.003	<0.010
P2	5/24/2005	9	<0.007	--	--	--	--	--	<0.003	<0.010
P2	5/24/2005	9	--	--	--	--	--	--	--	--
P2	6/28/2005	9	<0.007	--	--	--	--	--	<0.003	<0.010
P2	8/2/2005	9	<0.007	--	--	--	--	--	<0.003	<0.010
P2	8/2/2005	1	.133	--	--	--	--	--	.071	.112

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Pebulate, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Pendimethalin, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Phorate, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Picloram, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Prometon, water, filtered, recoverable, micrograms per liter	Propachlor, water, filtered, recoverable, micrograms per liter	Propanil, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter
D2	3/22/2005	2	<0.004	<0.022	<0.011	<0.03	<0.01	<0.025	<0.011
D2	3/22/2005	9	<0.004	<0.022	<0.011	--	<0.01	<0.025	<0.011
D2	5/17/2005	9	<0.004	<0.022	<0.011	<0.03	<0.01	<0.025	<0.011
D2	6/29/2005	9	<0.004	<0.022	<0.011	<0.03	<0.01	<0.025	<0.011
D2	8/3/2005	9	<0.004	<0.022	<0.011	<0.03	<0.01	<0.025	<0.011
P2	3/8/2005	9	<0.004	<0.022	<0.011	--	<0.01	<0.025	<0.011
P2	3/8/2005	7	<0.004	<0.022	<0.011	--	<0.01	<0.025	<0.011
P2	4/5/2005	9	<0.004	<0.022	<0.011	--	<0.01	<0.025	<0.011
P2	4/5/2005	2	<0.004	<0.022	<0.011	--	<0.01	<0.025	<0.011
P2	5/24/2005	9	<0.004	<0.022	<0.011	--	<0.01	<0.025	<0.011
P2	5/24/2005	9	--	--	--	--	--	--	--
P2	6/28/2005	9	<0.004	<0.022	<0.011	--	<0.01	<0.025	<0.011
P2	8/2/2005	9	<0.004	<0.022	<0.011	--	<0.01	<0.025	<0.011
P2	8/2/2005	1	.102	.084	.028	--	.11	.119	.113

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Propargite, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Propham, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Propiconazole, water, filtered, recoverable, micrograms per liter	Propoxur, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Propyzamide, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Siduron, water, filtered, recoverable, micrograms per liter	Simazine, water, filtered, recoverable, micrograms per liter	Sulfometuron-methyl, water, filtered, recoverable, micrograms per liter
D2	3/22/2005	2	<0.02	<0.030	<0.01	<0.008	<0.004	<0.02	<0.005	<0.038
D2	3/22/2005	9	<0.02	<0.030	<0.01	<0.008	<0.004	<0.02	<0.005	<0.038
D2	5/17/2005	9	<0.02	<0.030	<0.01	<0.008	<0.004	<0.02	<0.005	<0.038
D2	6/29/2005	9	<0.02	<0.030	<0.01	<0.008	<0.004	<0.02	<0.005	<0.038
D2	8/3/2005	9	<0.02	<0.030	<0.01	<0.008	<0.004	<0.02	<0.005	<0.038
P2	3/8/2005	9	<0.02	--	--	--	<0.004	--	<0.005	--
P2	3/8/2005	7	<0.02	--	--	--	<0.004	--	<0.005	--
P2	4/5/2005	9	<0.02	--	--	--	<0.004	--	<0.005	--
P2	4/5/2005	2	<0.02	--	--	--	<0.004	--	<0.005	--
P2	5/24/2005	9	<0.02	--	--	--	<0.004	--	<0.005	--
P2	5/24/2005	9	--	--	--	--	--	--	--	--
P2	6/28/2005	9	<0.02	--	--	--	<0.004	--	<0.005	--
P2	8/2/2005	9	<0.02	--	--	--	<0.004	--	<0.005	--
P2	8/2/2005	1	.09	--	--	--	.116	--	.104	--

**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Terbacil, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Terbacil, water, filtered, recoverable, micrograms per liter	Terbufos, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Thiobencarb, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Triallate, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Triclopyr, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter	Trifluralin, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter
D2	3/22/2005	2	<0.02	<0.034	<0.016	<0.02	<0.010	<0.006	<0.009
D2	3/22/2005	9	<0.02	<0.034	<0.016	<0.02	<0.010	<0.006	<0.009
D2	5/17/2005	9	<0.02	<0.034	<0.016	<0.02	<0.010	<0.006	<0.009
D2	6/29/2005	9	<0.02	<0.034	<0.016	<0.02	<0.010	<0.006	<0.009
D2	8/3/2005	9	<0.02	<0.034	<0.016	<0.02	<0.010	<0.006	<0.009
P2	3/8/2005	9	<0.02	<0.034	--	<0.02	<0.010	<0.006	<0.009
P2	3/8/2005	7	<0.02	<0.034	--	<0.02	<0.010	--	<0.009
P2	4/5/2005	9	<0.02	<0.034	--	<0.02	<0.010	--	<0.009
P2	4/5/2005	2	<0.02	<0.034	--	<0.02	<0.010	--	<0.009
P2	5/24/2005	9	<0.02	<0.034	--	<0.02	<0.010	--	<0.009
P2	5/24/2005	9	<0.026	--	--	--	--	--	--
P2	6/28/2005	9	<0.02	<0.034	--	<0.02	<0.010	--	<0.009
P2	8/2/2005	9	<0.02	<0.034	--	<0.02	<0.010	--	<0.009
P2	8/2/2005	1	.1	E.056	--	.05	.127	--	.082



**Table 4.** Concentrations of organic carbon and pesticides in water-quality samples collected at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, Tex., 2005—Continued.

[USGS, U.S. Geological Survey; --, no data; <, less than; E, estimated; 1, field spike; 2, field blank; 7, sequential replicate; 9, environmental; 2,4-D, 2,4-Dichlorophenoxyacetic acid; 2,4-DB, 2,4-dichlorophenoxybutyric acid; DCPA, Dimethyl tetrachloroterephthalate; EPTC, S-Ethyl-Dipropylthiocarbamate; MCPA, 2-methyl-4-chlorophenoxyacetic acid; MCPB, 4-(4-chloro-2-methylphenoxy)]

Site identifier (fig. 1)	Date	Sample type code	Caffeine, water, filtered, recoverable, micrograms per liter	Reference material or spike lot number
D2	3/22/2005	2	E0.012	--
D2	3/22/2005	9	.02	--
D2	5/17/2005	9	.025	--
D2	6/29/2005	9	<.050	--
D2	8/3/2005	9	<.018	--
P2	3/8/2005	9	--	--
P2	3/8/2005	7	--	--
P2	4/5/2005	9	--	--
P2	4/5/2005	2	--	44,048
P2	5/24/2005	9	--	--
P2	5/24/2005	9	--	--
P2	6/28/2005	9	--	--
P2	8/2/2005	9	--	--
P2	8/2/2005	1	--	90,508

## Water Quality in the Devils and Pecos Rivers

The water-quality constituents of primary concern were total dissolved solids, chloride, sulfate, ammonia plus organic nitrogen, nitrate plus nitrite, orthophosphate, phosphorus, selenium, and selected pesticides. Water-quality samples collected at the Devils River at Pafford Crossing gage and Pecos River at Langtry gage are referred to in this section by the site identifiers of these gages (sites D2 and P2, respectively) (fig. 1 and table 1), and results discussed are for the environmental samples collected at each site in the spring and summer of 2005.

### Total Dissolved Solids

The concentrations of total dissolved solids (TDS) were an order of magnitude smaller in the environmental samples collected from the Devils River at site D2 compared to the concentrations of total dissolved solids measured in environmental samples collected from the Pecos River at site P2, ranging from 208 to 232 mg/L at site D2 and from 1,460 to 2,390 mg/L at site P2 (table 2). The higher TDS concentrations measured in the samples collected in the Pecos River compared to the TDS concentrations measured in the samples collected from the Devils River likely reflect some contribution to streamflow in the Pecos River of groundwater of different salinity characteristics, including relatively less saline groundwater with total dissolved solid concentrations less than 3,000 mg/L, moderately saline groundwater (3,000 to 10,000 mg/L total dissolved solids), and highly saline groundwater (more than 10,000 mg/L total dissolved solids) (Ashworth and Hopkins, 1995) (Purchase and others, 2001). Reduced inflows of relatively less saline groundwater compared to historical inflow amounts, caused by increases in groundwater pumping over time and impoundments on the Pecos River in New Mexico (upstream from the study area), have also contributed to the relatively high concentrations of total dissolved solids observed in the Pecos River (Purchase and others, 2001). Dissolved-solids concentrations did not exceed the State water-quality standard of 300 mg/L for the Devils River segment that includes site D2, nor the proposed State water-quality standard of 4,000 mg/L for the Pecos River segment that includes site P2 (Texas Commission on Environmental Quality, 2010).

### Chloride

Chloride concentrations were an order of magnitude smaller in the environmental samples collected from the Devils River at site D2 compared to chloride concentrations measured in environmental samples collected from the Pecos

River at site P2, ranging from 11.6 to 12.9 mg/L at site D2, and from 519 to 879 mg/L at site P2 (table 2). Chloride concentrations measured in samples collected in 2005 at site D2 did not exceed the proposed State water-quality standard of 50 mg/L for the segment of the Devils River containing this sampling site (Texas Commission on Environmental Quality, 2010) and were between the minimum (6.9 mg/L) and lower quartile (25th percentile) of 14 mg/L reported for chloride samples collected at this sampling site as part of the USGS HBN program during 1978–95 (U.S. Geological Survey, 2011) (table 5). Chloride concentrations measured in samples collected in 2005 at site P2 did not exceed the proposed State water-quality standard of 1,700 mg/L for the Pecos River segment that includes site P2 (Texas Commission on Environmental Quality, 2010) and represented a range of values similar to the interquartile range of 548 to 942 mg/L reported for chloride concentrations by the USGS NASQAN program during 1974–2007 (U.S. Geological Survey, 2010; table 5). The interquartile range represents the central 50 percent of the data (Helsel and Hirsch, 2002).

### Sulfate

Sulfate concentrations were an order of magnitude smaller in the environmental samples collected during March–August 2005 from the Devils River compared to sulfate concentrations measured in the environmental samples collected during April–August 2005 from the Pecos River. Sulfate concentrations ranged from 7.55 to 8.20 mg/L at site D2 and from 298 to 503 mg/L at site P2 (table 2), concentrations that were somewhat smaller compared to those measured in environmental samples for chloride. Sulfate concentrations measured in 2005 did not exceed proposed State water-quality standards of 50 mg/L and 1,000 mg/L for the Devils and Pecos River segments, respectively (Texas Commission on Environmental Quality, 2010).

### Ammonia Plus Organic Nitrogen

Concentrations of ammonia plus organic nitrogen as nitrogen (N) measured in environmental samples collected during the spring and summer of 2005 at site D2 were less variable compared to those measured at site P2, and the concentrations of ammonia plus organic nitrogen as N were approximately twice as large at site P2 compared to those at site D2 (table 2). Ammonia plus organic nitrogen concentrations ranged from 0.12 to 0.14 mg/L of N at site D2, and from 0.15 to 0.32 mg/L of N at site P2 (table 2). The minimum ammonia plus organic nitrogen concentrations (0.12 mg/L of N at site D2 and 0.15 mg/L of N at site P2) were measured in environmental samples collected in late March 2005 at site D2 and in early March 2005 at site P2.

**Table 5.** Concentrations of selected major ions and nutrients measured in water-quality samples collected in 2005 at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, with summary statistics from samples collected at station 08449400 during 1978–1995 as part of the U.S. Geological Survey Hydrologic Benchmark Network (U.S. Geological Survey, 2011), and summary statistics from samples collected at station 08447410 during 1974–2007 as part of U.S. Geological Survey National Stream Quality Accounting Network (U.S. Geological Survey, 2010).

[USGS, U.S. Geological Survey, ft<sup>3</sup>/s, cubic feet per second; mg/L, milligrams per liter; --, no data; <, less than the value; \*, data estimated by using a log-probability regression to predict the values of data below the detection limit (U.S. Geological Survey, 2006, p. 102; Helsel and Hirsch, 2002)]

Site identifier (fig. 1)	USGS station no.	USGS station name	Sample collection date	Daily mean discharge, ft <sup>3</sup> /s	Chloride, water, filtered, milligrams per liter	Minimum, mg/L	25th percentile, mg/L	Median, mg/L	75th percentile, mg/L	Maximum, mg/L	Number of analyses used in the summary statistics
D2	08449400	Devils River at Pafford Crossing near Comstock, Tex.	3/22/2005	576	11.8						
			5/17/2005	417	11.6						
			6/29/2005	480	12.9	6.90	14.0	15.0	16.0	26.0	104
			8/3/2005	396	12.5						
			3/8/2005	322	819						
P2	08447410	Pecos River near Langtry, Tex.	4/5/2005	271	879						
			5/24/2005	204	623	100	548	720	942	1,500	290
			6/28/2005	186	795						
			8/2/2005	180	519						
			3/8/2005	322	819						
Site identifier (fig. 1)	USGS station no.	USGS station name	Sample collection date	Daily mean discharge, ft <sup>3</sup> /s	Ammonia plus organic nitrogen, water, filtered, milligrams per liter as nitrogen	Minimum, mg/L	25th percentile, mg/L	Median, mg/L	75th percentile, mg/L	Maximum, mg/L	Number of analyses used in the summary statistics
D2	08449400	Devils River at Pafford Crossing near Comstock, Tex.	3/22/2005	576	0.12						
			5/17/2005	417	.13						
			6/29/2005	480	.14	0.10	0.23	0.42	0.62	1.4	40
			8/3/2005	396	.13						
			3/8/2005	322	.15						
P2	08447410	Pecos River near Langtry, Tex.	4/5/2005	271	.22						
			5/24/2005	204	.32	--	*.18	*.26	*.40	*1.4	145
			6/28/2005	186	.29						
			8/2/2005	180	.29						
			3/8/2005	322	.15						

**Table 5.** Concentrations of selected major ions and nutrients measured in water-quality samples collected in 2005 at U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, with summary statistics from samples collected at station 08449400 during 1978–1995 as part of the U.S. Geological Survey Hydrologic Benchmark Network (U.S. Geological Survey, 2011), and summary statistics from samples collected at station 08447410 during 1974–2007 as part of U.S. Geological Survey National Stream Quality Accounting Network (U.S. Geological Survey, 2010).—Continued.

[USGS, U.S. Geological Survey, ft<sup>3</sup>/s, cubic feet per second; mg/L, milligrams per liter; --, no data; <, less than the value; \*, data estimated by using a log-probability regression to predict the values of data below the detection limit (U.S. Geological Survey, 2006, p. 102; Helsel and Hirsch, 2002)]

Site identifier (fig. 1)	USGS station no.	USGS station name	Sample collection date	Daily mean discharge, ft <sup>3</sup> /s	Nitrate plus nitrite, water, filtered, mg/L as nitrogen	Minimum, mg/L	25th percentile, mg/L	Median, mg/L	75th percentile, mg/L	Maximum, mg/L	Number of analyses used in the summary statistics
D2	08449400	Devils River at Pafford Crossing near Comstock, Tex.	3/22/2005	576	1.24						
			5/17/2005	417	1.15						
			6/29/2005	480	0.99	0.10	1.2	1.4	1.6	3.9	48
			8/3/2005	396	1.02						
P2	08447410	Pecos River near Langtry, Tex.	3/8/2005	322	1.04						
			4/5/2005	271	.83						
			5/24/2005	204	.4	--	*0.19	*0.61	*0.95	*3.2	149
			6/28/2005	186	.22						
			8/2/2005	180	.29						

Ammonia plus organic nitrogen concentrations as N measured in the samples collected from the Devils River in 2005 at site D2 were less than the lower quartile (25th percentile) value of 0.23 mg/L reported for samples collected by the USGS HBN program at this site during 1978–95 (U.S. Geological Survey, 2011) (table 5). The concentrations of ammonia plus organic nitrogen as N measured in samples collected at site P2 in 2005 generally were within the interquartile range of ammonia plus organic nitrogen concentrations as N reported by the USGS NASQAN program for samples collected at this site during 1974–2007. The largest ammonia plus organic nitrogen concentration measured in 2005 (0.32 mg/L of N measured in a sample collected at site P2) was smaller than the 75th percentile (0.40 mg/L of N) measured in the samples collected by the USGS NASQAN program at site P2 during 1974–2007 (table 5).

## Nitrate Plus Nitrite Nitrogen

Nitrate plus nitrite concentrations measured in 2005 ranged from 0.99 to 1.24 mg/L of N in the environmental samples collected at site D2 and from 0.22 to 1.04 mg/L of N in the environmental samples collected at site P2 (table 2). The highest nitrate plus nitrite concentrations were measured in samples collected in the early spring (March 2005 at sites D2 and P2). Although nitrate plus nitrite concentrations measured in 2005 in samples collected at site D2 were within the historical range of concentrations for samples collected by the USGS HBN program during 1978–95, the 2005 concentrations were lower compared to the historical median concentration of nitrate plus nitrite (1.4 mg/L of N). The nitrate plus nitrite concentrations measured in 2005 in samples collected at site P2 generally were within the historical interquartile range of nitrate plus nitrite concentrations (0.19 to 0.95 mg/L) measured in samples collected as part of the USGS NASQAN program (table 5).

## Orthophosphate and Total Phosphorus

Orthophosphate and total phosphorous concentrations in water were not detected in samples collected in 2005 from sites D2 and P2 at concentrations equal to or larger than the laboratory reporting levels (LRLs) for these constituents (the LRLs were 0.018 mg/L for orthophosphate and 0.004 mg/L for total phosphorous) (table 2). During previous studies by the National Park Service, total phosphorous and orthophosphate concentrations generally were between 0.01 and 0.03 mg/L at site D2 (Purchase and others, 2001).

## Selenium

Selenium concentrations at site D2 ranged from 0.3 µg/L (estimated value) to 0.6 µg/L; two values equal to or more than the laboratory reporting level of 0.5 µg/L were obtained—values of 0.5 and 0.6 µg/L were measured in

samples collected in March and May 2005 at site D2. At site P2, selenium concentrations ranged from 1.0 µg/L to 3.1 µg/L (table 3). None of the selenium concentrations measured in samples collected during the spring and summer of 2005 from the Devils or Pecos Rivers exceeded the Surface Water Quality Standards established by the State for the protection of aquatic life (chronic criterion of 5 µg/L or the acute criterion of 20 µg/L) (Texas Commission on Environmental Quality, 2010). In previous sediment studies, selenium values did exceed screening guidelines of 2 mg/kg in a different sample medium (river-bed sediment samples from the Pecos River) (Purchase and others, 2001) and in lake-bed sediment samples collected from the Amistad Reservoir (Lee and Wilson, 1997).

## Pesticides

Water-quality samples collected at site D2 during March–August 2005 were analyzed for 162 pesticides (including both polar and non-polar compounds), and samples collected at site P2 during April–August 2005 were analyzed for 54 polar and non-polar pesticides (table 4). No pesticide concentrations were reported at concentrations equal to or larger than the laboratory reporting level (LRL) in the environmental samples collected at sites D2 or P2. In a previous study, no pesticides were reported at concentrations equal to or larger than the LRLs in samples collected from the Pecos River downstream from site P2 (International Boundary and Water Commission, 1994), and none were reported at concentrations equal to or larger than the LRLs at site P2 between 1996 and 2000 as part of the NASQAN program (U.S. Geological Survey, 2010). Sites D2 and P2 are downstream from where these rivers gain streamflow from springs; the inflows from these springs are unlikely to contain appreciable amounts of pesticides. As noted in the “Description of Study Area” section, land use in the Devils River watershed is dominated by ranches and small rural home developments, and these land uses are not likely to be a major source of pesticides to the river (Purchase and others, 2001).

## Composition of Fish and Macroinvertebrate Communities in the Devils and Pecos Rivers

As explained in the section “Collection and Processing of Fish and Macroinvertebrate Samples,” the composition of fish and macroinvertebrate communities in the Devils and Pecos Rivers were evaluated by collecting fish and macroinvertebrate samples in stream reaches at the Devils River at Pafford Crossing gage and Pecos River at Langtry gage (sites D2, and P2, respectively) and in stream reaches at six additional sites, three on each river (fig. 1; table 1). Fish and macroinvertebrate community assessments are referred to in this section by the site numbers where the fish and macroinvertebrate samples were collected (sites D1–D4 on the Devils River and sites P1–P4 on the Pecos River) (fig. 1 and table 1).



## Fish Communities

A total of 29 species of fish each was collected during 2006–7 from both the Devils and Pecos Rivers, and 25 species were common to both rivers (tables 6–8). Among the species of fish at the Devils River sites, 7 species are non-native (introduced), and 22 species are native to the Devils River (table 6). At the Pecos River sites, 6 species of fish are non-native, and 23 species are native to the river (table 6).

### Devils River

The species of fish collected in the Devils River varied among sites, from a minimum of 17 species (2006 sampling only) at site D3 to a maximum of 23 species (2006 and 2007 samplings combined) at site D2 (table 7). Five species collected at site D2 in 2006 were not collected from this site in 2007, and four species collected at site D2 in 2007 were not collected from this site in 2006. Previous fish community surveys that found 15 species of fish at the site farthest downstream (site D2) (International Boundary and Water Commission, 1994) and 18 species at the site farthest upstream (site D4) (Linam and Kleinsasser, 2002) differed slightly from the number of species collected at sites D2 and D4 in this study. The difference in the number of species collected in this study compared to the previous studies could be because of differences in the types of sampling equipment used, fish mobility, or both. Additionally, two surveys were done in this study in 2006 and 2007 at sites D2 and D4, and only one survey was done in each of the previous studies (International Boundary and Water Commission, 1994; Linam and Kleinsasser, 2002).

More redbreast sunfish were collected than any other species of fish in the Devils River followed by a number of species of shiners (family Cyprinidae) including the blacktail shiner and prosperine shiner (table 7). The Rio Grande cichlid, the only native member of the family Cichlidae in Texas, was also abundant at the Devils River sites, particularly the two most upstream sites (D3 and D4). Fish species collected in the Devils River that were not found at the Pecos River study sites included the Devils River minnow, sailfin molly, smallmouth bass, spotted bass, and warmouth (tables 6–8). The redbreast sunfish, sailfin molly, and smallmouth bass are all introduced species that are not native to the Devils River (Hubbs and others, 1991).

### Pecos River

Of the 29 species of fish collected from the Pecos River, 6 species are non-native (introduced) and include the bullhead minnow, common carp, sheepshead minnow, inland silverside, redbreast sunfish, and redear sunfish (table 8). Considering only the 2006 sampling results, the number of fish species decreased about 42 percent (from 19 to 11) between the most

upstream and the sites farthest downstream on the Pecos River. When both the 2006 and 2007 sampling results are considered, the largest number of species (26) was collected from site P4. Previous studies found similar upstream to downstream decreases in species richness in the lower Pecos River, with 13 species documented at site P4 compared to 6 species at site P1 (International Boundary and Water Commission, 1994; Linam and Kleinsasser, 1996).

The most abundant species among the Pecos River sites were the blacktail shiner followed by the red shiner and central stoneroller; however, central stonerollers were collected only at site P4 (table 8). These and other members of the family Cyprinidae were the most abundant fishes overall among the Pecos River sites followed by species of sunfish and bass—all of the family Centrarchidae. The redbreast sunfish was the most common species of sunfish in both rivers, although less abundant in the Devils River. Fish species collected in the Pecos River but not in the Devils River include the bullhead minnow, red shiner, smallmouth buffalo, rainwater killifish, and freshwater drum.

## Comparison between the Devils and Pecos Rivers

Butler and von Guerard (1996) note “salinity, or the dissolved-solids concentration, is the measure of salts such as sodium chloride, calcium bicarbonate, and calcium sulfate that are dissolved in water.” Most freshwater fishes adjust to changes in salinity through a physiological process known as osmoregulation, and some species are more tolerant than others of higher salinity because of their ability to osmoregulate in more saline freshwater environments (Moyle and Cech, 1982). The percentage of tolerant fish species was larger at the two sites farthest upstream on the Pecos River compared to the two most upstream sites on the Devils River (table 9). This is likely because salinity in the Pecos River has historically been higher compared to salinity in the Devils River (Linam and Kleinsasser, 1996). The percentage of fish collected at the site farthest downstream on each river that were omnivores (fish that feed on a mixed diet of plant and animals) was considerably larger compared to the percentage of omnivores at the more upstream sites. Compared to upstream sites, the relatively larger percentage of omnivorous fish species at the most downstream sites on the Devils and Pecos Rivers might be because of their proximity to the impounded waters of Amistad Reservoir where omnivorous species of fish are likely more common; fish assemblages in temperate southern reservoirs such as Amistad Reservoir typically are dominated by large-bodied benthic omnivores (Gido, 2001). The percentage of introduced individuals was two to three times larger at Devils River sites D2 and D3 compared to Pecos River sites P2 and P3 and was influenced by the relatively large abundance of the non-native redbreast sunfish and smallmouth bass at the Devils River study sites.



**Table 6.** Presence or absence of fish taxa and total number of fish species collected from sites on the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area, Texas, 2006–7.

[Shading indicates individual organisms representing the species of fish that were collected. Taxon (singular) or taxa (plural) refers to a genetically related group or groups of one or more organisms with common characteristics that differentiated them as a unit. From International Commission on Zoological Nomenclature (2010)]

Family	Species	Common name	Status	Devils River	Pecos River
Lepisosteidae	<i>Lepisosteus osseus</i>	Longnose gar	Native		
Clupeidae	<i>Dorosoma cepedianum</i>	Gizzard shad	Native		
Cyprinidae	<i>Cyprinella venustus</i>	Blacktail shiner	Native		
	<i>Pimphales vigilax</i>	Bullhead minnow	Introduced		
	<i>Campostoma anomalum</i>	Central stoneroller	Native		
	<i>Cyprinus carpio</i>	Common carp	Introduced		
	<i>Dionda diobala</i>	Devils River minnow	Native		
	<i>Cyprinella prosperpina</i>	Prosperine shiner	Native		
	<i>Cyprinella lutrensis</i>	Red shiner	Native		
	<i>Dionda episcopa</i>	Roundnose minnow	Native		
	<i>Notropis amabilis</i>	Texas shiner	Native		
	<i>Scartomyzon cangestum</i>	Gray redbhorse	Native		
	<i>Ictiobus bubalus</i>	Smallmouth buffalo	Native		
	<i>Carpionodes carpio</i>	River carpsucker	Native		
Characidae	<i>Astyanax mexicanus</i>	Mexican tetra	Native		
Ictaluridae	<i>Ictalurus punctatus</i>	Channel catfish	Native		
Ictaluridae	<i>Pylodictis olivaris</i>	Flathead catfish	Native		
	<i>Lucania parva</i>	Rainwater killifish	Native		
Cyprinodontidae	<i>Cyprinodon variegatus</i>	Sheepshead minnow	Introduced		
Poeciliidae	<i>Poecilia latipinna</i>	Sailfin molly	Introduced		
	<i>Gambusia affinis</i>	Western mosquitofish	Native		
Atherinopsidae	<i>Menidia beryllina</i>	Inland silverside	Introduced		
Percidae	<i>Etheostoma grahami</i>	Rio Grande darter	Native		
Cichlidae	<i>Cichlasoma cyanoguttatum</i>	Rio Grande cichlid	Native		
Centrarchidae	<i>Lepomis macrochirus</i>	Bluegill	Native		
	<i>Lepomis cyanellus</i>	Green sunfish	Native		
	<i>Micropterus salmoides</i>	Largemouth bass	Native		
	<i>Lepomis megalotis</i>	Longear sunfish	Native		
	<i>Lepomis auritus</i>	Redbreast sunfish	Introduced		
	<i>Lepomis microlophus</i>	Redear sunfish	Introduced		
	<i>Micropterus dolomieu</i>	Smallmouth bass	Introduced		
	<i>Micropterus punctulatus</i>	Spotted bass	Native		
	<i>Lepomis gulosus</i>	Warmouth	Native		
Scianidae	<i>Aplodinotus grunniens</i>	Freshwater drum	Native		
Number of species				29	29

**Table 7.** Fish species, number of individuals, native status, trophic group, tolerance classification, and total number of species collected from the study sites along the Devils River in and upstream from the Amistad National Recreation Area, Texas, 2006–7.

[DN-N, replicate sampling of fish at selected sites in 2007; NA, tolerance classification not available for this species of fish; \*, confirmed presence of species but accurate total not available]

Family	Species	Common name	Status	Trophic Group	Tolerance	Site identifier and USGS station name						No. of individuals from all sites on Devils River
						D1	D2	D2	D3	D4	D4	
						Devils River near Satan Canyon, Tex.	Devils River at Pafford Crossing near Comstock, Tex. (sample 1)	Devils River at Pafford Crossing near Comstock, Tex. (sample 2)	Devils River near Turkey Bluff Canyon, Tex.	Devils River at Dolan Falls, Tex. (sample 1)	Devils River at Dolan Falls, Tex. (sample 2)	
						06/05/2006	06/06/2006	03/06/2007	06/07/2006	06/08/2006	03/07/2006	
Lepisosteidae	<i>Lepisosteus osseus</i>	Longnose gar	Native	Piscivore	Tolerant		1	3	4	1		9
Clupeidae	<i>Dorosoma cepedianum</i>	Gizzard shad	Native	Omnivore	Tolerant	6						6
Cyprinidae	<i>Cyprinella venustus</i>	Blacktail shiner	Native	Invertivore	NA	24	14	7	101	37	53	236
	<i>Pimphales vigilax</i>	Bullhead minnow	Introduced	Invertivore	NA							0
	<i>Campostoma anomalum</i>	Central stoneroller	Native	Herbivore	NA		4		2	66	37	109
	<i>Cyprinus carpio</i>	Common carp	Introduced	Omnivore	Tolerant	1	5	5				11
	<i>Dionda diobala</i>	Devils River minnow	Native	Invertivore	Intolerant			*1	3		1	5
	<i>Cyprinella prosperpina</i>	Prosperine shiner	Native	Invertivore	NA		18	18	43	16	86	181
	<i>Cyprinella lutrensis</i>	Red shiner	Native	Invertivore	Tolerant							0
	<i>Dionda episcopa</i>	Roundnose minnow	Native	Invertivore	Intolerant			4		9		13
	<i>Notropis amabilis</i>	Texas shiner	Native	Invertivore	NA			3	50	10	5	68
Catastomidae	<i>Scartomyzon cangestum</i>	Gray redborse	Native	Invertivore	NA	1	9	11	39	10	28	98
	<i>Ictiobus bubalus</i>	Smallmouth buffalo	Native	Omnivore	NA							0

**Table 7.** Fish species, number of individual specimens, native status, trophic group, tolerance classification, and total number of species collected from the study sites along the Devils River in and upstream from the Amistad National Recreation Area, Texas, 2006–7. —Continued.

[DN-N, replicate sampling of fish at selected sites in 2007; NA, tolerance classification not available for this species of fish; \*, confirmed presence of species but accurate total not available]

Family	Species	Common name	Status	Trophic Group	Tolerance	Site identifier and USGS station name						No. of individuals from all sites on Devils River
						D1	D2	D2	D3	D4	D4	
						Devils River near Satan Canyon, Tex.	Devils River at Pafford Crossing near Comstock, Tex. (sample 1)	Devils River at Pafford Crossing near Comstock, Tex. (sample 2)	Devils River near Turkey Bluff Canyon, Tex.	Devils River at Dolan Falls, Tex. (sample 1)	Devils River at Dolan Falls, Tex. (sample 2)	
						06/05/2006	06/06/2006	03/06/2007	06/07/2006	06/08/2006	03/07/2006	
	<i>Carpoides carpio</i>	River carpsucker	Native	Omnivore	Tolerant	6	7	13	2			28
Characidae	<i>Astyanax mexicanus</i>	Mexican tetra	Native	Invertivore	NA	3				21	54	78
Ictaluridae	<i>Ictalurus punctatus</i>	Channel catfish	Native	Omnivore	Tolerant	22	11	1	6	19	15	74
	<i>Pylodictis olivaris</i>	Flathead catfish	Native	Piscivore	NA	1	2		7	4		14
Cyprinodontidae	<i>Lucania parva</i>	Rainwater killifish	Native	Invertivore	NA							0
	<i>Cyprinodon variegatus</i>	Sheepshead minnow	Introduced	Omnivore	Tolerant		4	1				5
Poeciliidae	<i>Poecilia latipinna</i>	Sailfin molly	Introduced	Omnivore	Tolerant		1					1
	<i>Gambusia affinis</i>	Western mosquitofish	Native	Invertivore	Tolerant		7	12	9	19	53	100
Atherinidae	<i>Menidia beryllina</i>	Inland silverside	Introduced	Invertivore	NA	1			1			2
Percidae	<i>Etheostoma grahami</i>	Rio Grande darter	Native	Invertivore	NA	6			4	1		11
Cichlidae	<i>Cichlasoma cyanoguttatum</i>	Rio Grande cichlid	Native	Invertivore	NA	2	5	1	25	84	34	151
Centrarchidae	<i>Lepomis macrochirus</i>	Bluegill	Native	Invertivore	Tolerant	59	21					80
	<i>Lepomis cyanellus</i>	Green sunfish	Native	Piscivore	Tolerant	1	2	1	1			5

**Table 7.** Fish species, number of individual specimens, native status, trophic group, tolerance classification, and total number of species collected from the study sites along the Devils River in and upstream from the Amistad National Recreation Area, Texas, 2006–7.—Continued.

[DN-N, replicate sampling of fish at selected sites in 2007; NA, tolerance classification not available for this species of fish; \*, confirmed presence of species but accurate total not available]

Family	Species	Common name	Status	Trophic Group	Tolerance	Site identifier and USGS station name						No. of individuals from all sites on Devils River
						D1	D2	D2	D3	D4	D4	
						Devils River near Satan Canyon, Tex.	Devils River at Pafford Crossing near Comstock, Tex. (sample 1)	Devils River at Pafford Crossing near Comstock, Tex. (sample 2)	Devils River near Turkey Bluff Canyon, Tex.	Devils River at Dolan Falls, Tex. (sample 1)	Devils River at Dolan Falls, Tex. (sample 2)	
						06/05/2006	06/06/2006	03/06/2007	06/07/2006	06/08/2006	03/07/2006	
	<i>Micropterus salmoides</i>	Largemouth bass	Native	Piscivore	NA	27	7			1	1	36
	<i>Lepomis megalotis</i>	Longear sunfish	Native	Invertivore	NA	17	31	9	12	13	5	87
	<i>Lepomis aurtus</i>	Redbreast sunfish	Introduced	Invertivore	NA	79	35	19	109	19	2	263
	<i>Lepomis microlophus</i>	Redear sunfish	Introduced	Invertivore	NA	36		1				37
	<i>Micropterus dolomieu</i>	Smallmouth bass	Introduced	Piscivore	Intolerant		5	1	26	21	2	55
	<i>Micropterus punctulatus</i>	Spotted bass	Native	Piscivore	NA	2				1		3
	<i>Lepomis gulosus</i>	Warmouth	Native	Piscivore	Tolerant	7						7
Scianidae	<i>Aplodinotus grunniens</i>	Freshwater drum	Native	Invertivore	Tolerant							0
		Number of individuals				301	189	111	437	355	380	1,773
		Number of species				19	19	17	17	18	15	29

**Table 8.** Fish species, number of individual specimens, native status, trophic group, tolerance classification, and total number of species collected from the study sites along the Pecos River in and upstream from the Amistad National Recreation Area, Texas, 2006–7.

[DN-N, replicate sampling of fish at selected sites in 2007; NA, tolerance classification not available for this species of fish]

Family	Species	Common name	Status	Trophic Group	Tolerance	Site Identifier and USGS station name							No. of individuals from all sites on Pecos River
						P1	P2	P2	P2	P3	P4	P4	
						Pecos River at Shumla Bend, Tex.	Pecos River near Langtry, Tex. (sample 1)	Pecos River near Langtry, Tex. (sample 2)	Pecos River near Everett Canyon, Tex.	Pecos River at Pandale, Tex. (sample 1)	Pecos River at Pandale, Tex. (sample 2)		
			06/27/2006	06/28/2006	03/08/2007	06/29/2006	06/22/2006	03/09/2007					
Lepisosteidae	<i>Lepisosteus osseus</i>	Longnose gar	Native	Piscivore	Tolerant		3		2	7	1	13	
Clupeidae	<i>Dorosoma cepedianum</i>	Gizzard shad	Native	Omnivore	Tolerant	20					1	21	
Cyprinidae	<i>Cyprinella venustus</i>	Blacktail shiner	Native	Invertivore	NA	14	5	368	12	14	8	421	
	<i>Pimphales vigilax</i>	Bullhead minnow	Introduced	Invertivore	NA				10	5		15	
	<i>Campostoma anomalum</i>	Central stoneroller	Native	Herbivore	NA						235	235	
	<i>Cyprinus carpio</i>	Common carp	Introduced	Omnivore	Tolerant	5		1	3	1	2	12	
	<i>Dionda diobala</i>	Devils River minnow	Native	Invertivore	Intolerant							0	
	<i>Cyprinella proserpina</i>	Prosperine shiner	Native	Invertivore	NA			32	71		44	147	
	<i>Cyprinella lutrensis</i>	Red shiner	Native	Invertivore	Tolerant		4		57	204		265	
	<i>Dionda episcopa</i>	Roundnose minnow	Native	Invertivore	Intolerant			18	16		4	38	
	<i>Notropis amabilis</i>	Texas shiner	Native	Invertivore	NA		2	8	9	2		21	
Catastomidae	<i>Scartomyzon cangestum</i>	Gray red-horse	Native	Invertivore	NA	1		4	11	2	1	19	
	<i>Ictiobus bubalus</i>	Smallmouth buffalo	Native	Omnivore	NA	4						4	
	<i>Carpoides carpio</i>	River carp-sucker	Native	Omnivore	Tolerant	4			1	1		6	

**Table 8.** Fish species, number of individual specimens, native status, trophic group, tolerance classification, and total number of species collected from the study sites along the Pecos River in and upstream from the Amistad National Recreation Area, Texas, 2006–7.—Continued.

[DN–N, replicate sampling of fish at selected sites in 2007; NA, tolerance classification not available for this species of fish]

Family	Species	Common name	Status	Trophic Group	Tolerance	Site Identifier and USGS station name							No. of individuals from all sites on Pecos River
						P1	P2	P2	P2	P3	P4	P4	
						Pecos River at Shumla Bend, Tex.	Pecos River near Langtry, Tex. (sample 1)	Pecos River near Langtry, Tex. (sample 2)	Pecos River near Everett Canyon, Tex. (sample 1)	Pecos River near Pandale, Tex. (sample 2)	Pecos River at Pandale, Tex. (sample 1)	Pecos River at Pandale, Tex. (sample 2)	
Characidae	<i>Astyanax mexicanus</i>	Mexican tetra	Native	Invertivore	NA	06/27/2006	06/28/2006	03/08/2007	06/29/2006	06/22/2006	03/09/2007		10
Ictaluridae	<i>Ictalurus punctatus</i>	Channel catfish	Native	Omnivore	Tolerant	16	4	2	3	7	6		38
	<i>Pylodictis olivaris</i>	Flathead catfish	Native	Piscivore	NA		2	1	2	6	5		16
Cyprinodontidae	<i>Lucania parva</i>	Rainwater killifish	Native	Invertivore	NA			1		2	1		4
	<i>Cyprinodon variegatus</i>	Sheepshead minnow	Introduced	Omnivore	Tolerant		1		8	10	31		50
Poeciliidae	<i>Poecilia latipinna</i>	Sailfin molly	Introduced	Omnivore	Tolerant								0
	<i>Gambusia affinis</i>	Western mosquitofish	Native	Invertivore	Tolerant		11		15	14	6		46
Atherinidae	<i>Menidia beryllina</i>	Inland silverside	Introduced	Invertivore	NA	57				4			61
Percidae	<i>Etheostoma grahami</i>	Rio Grande darter	Native	Invertivore	NA		2	1	6	1	10		20
Cichlidae	<i>Cichlasoma cyanoguttatum</i>	Rio Grande cichlid	Native	Invertivore	NA	1	2		3	14	3		23
Centrarchidae	<i>Lepomis macrochirus</i>	Bluegill	Native	Invertivore	Tolerant		6	1	2	1			10
	<i>Lepomis cyanellus</i>	Green sunfish	Native	Piscivore	Tolerant				2		1		3
	<i>Micropterus salmoides</i>	Largemouth bass	Native	Piscivore	NA	12	3		3	2	1		21



**Table 8.** Fish species, number of individual specimens, native status, trophic group, tolerance classification, and total number of species collected from the study sites along the Pecos River in and upstream from the Amistad National Recreation Area, Texas, 2006–7.—Continued.

[DN-N, replicate sampling of fish at selected sites in 2007; NA, tolerance classification not available for this species of fish]

Family	Species	Common name	Status	Trophic Group	Tolerance	Site Identifier and USGS station name							No. of individuals from all sites on Pecos River
						P1	P2	P2	P3	P4	P4		
						Pecos River at Shumla Bend, Tex.	Pecos River near Langtry, Tex. (sample 1)	Pecos River near Langtry, Tex. (sample 2)	Pecos River near Everett Canyon, Tex.	Pecos River at Pandale, Tex. (sample 1)	Pecos River at Pandale, Tex. (sample 2)		
						06/27/2006	06/28/2006	03/08/2007	06/29/2006	06/22/2006	03/09/2007		
	<i>Lepomis megalotis</i>	Longear sunfish	Native	Invertivore	NA		3		2	14	22	41	
	<i>Lepomis auritus</i>	Redbreast sunfish	Introduced	Invertivore	NA		20	7	2	20	69	118	
	<i>Lepomis microlophus</i>	Redear sunfish	Introduced	Invertivore	NA	1						1	
	<i>Micropterus dolomieu</i>	Smallmouth bass	Introduced	Piscivore	Intolerant							0	
	<i>Micropterus punctulatus</i>	Spotted bass	Native	Piscivore	NA							0	
	<i>Lepomis gulosus</i>	Warmouth	Native	Piscivore	Tolerant							0	
Sciaenidae	<i>Aplodinotus grunniens</i>	Freshwater drum	Native	Invertivore	Tolerant		4					4	
		Number of individuals				135	72	446	246	333	451	1,683	
		Number of species				11	15	13	22	21	19	29	

**Table 9.** Number of fish species, selected fish community metrics, and the total number of fish collected from the study sites along the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area, Texas, 2006–7.

[USGS, U.S. Geological Survey; Asterisk indicates fish data were combined for fish surveys done in 2006 and 2007; Sums of species groups will not equal total number of species because not all categories of species are represented and categories are not mutually exclusive; Percentages will not equal 100 because only selected groups of species and individuals are represented in the table]

Metric	Site identifier and USGS station name							
	D1	D2*	D3	D4*	P1	P2*	P3	P4*
	Devils River near Satan Canyon, Tex.	Devils River at Pafford Crossing near Comstock, Tex.	Devils River near Turkey Bluff Canyon, Tex.	Devils River at Dolan Falls, Tex.	Pecos River at Shumla Bend, Tex.	Pecos River near Langtry, Tex.	Pecos River near Everett Canyon, Tex.	Pecos River at Pandale, Tex.
Number of species <sup>1</sup>	19	23	17	19	11	21	22	26
Number of native cyprinid species	1	6	5	6	1	5	5	6
Number of invertivore species	10	12	11	12	5	14	14	16
Number of sunfish species (all species of the genus <i>Lepomis</i> sp.)	6	5	3	2	1	3	4	4
Number of intolerant species	0	3	2	3	0	1	1	1
Percent of tolerant species <sup>2</sup>	36.84	39.13	29.41	15.79	36.36	38.10	40.91	38.46
Percent of omnivorous individuals <sup>2</sup>	11.63	16.00	1.83	4.63	36.30	1.54	6.10	7.53
Percent of invertivorous individuals <sup>2</sup>	75.75	75.33	90.62	76.19	54.81	96.72	90.24	59.57
Percent of introduced individuals <sup>2</sup>	38.87	25.67	7.00	5.99	46.67	5.60	9.35	18.11
Total number of individuals collected	301	300	437	735	135	518	246	784
Menhinick species richness <sup>3</sup>	1.10	1.33	0.81	0.70	0.95	0.92	1.40	0.93

<sup>1</sup> The total number of species for each site is greater than the sum of the number of species in the metrics included in this table because not all species collected are included in the metrics selected. Refer to tables 7 and 8 for data used to calculate the count metrics.

<sup>2</sup> The percentages calculated in this table are based on the tolerance or intolerance of a species to degraded water-quality conditions or trophic group (for example, omnivore or invertivore) as shown in tables 7 and 8.

<sup>3</sup> Menhinick species richness is calculated as the cumulative number of species from a site divided by the square root of the total number of individuals collected at the site.

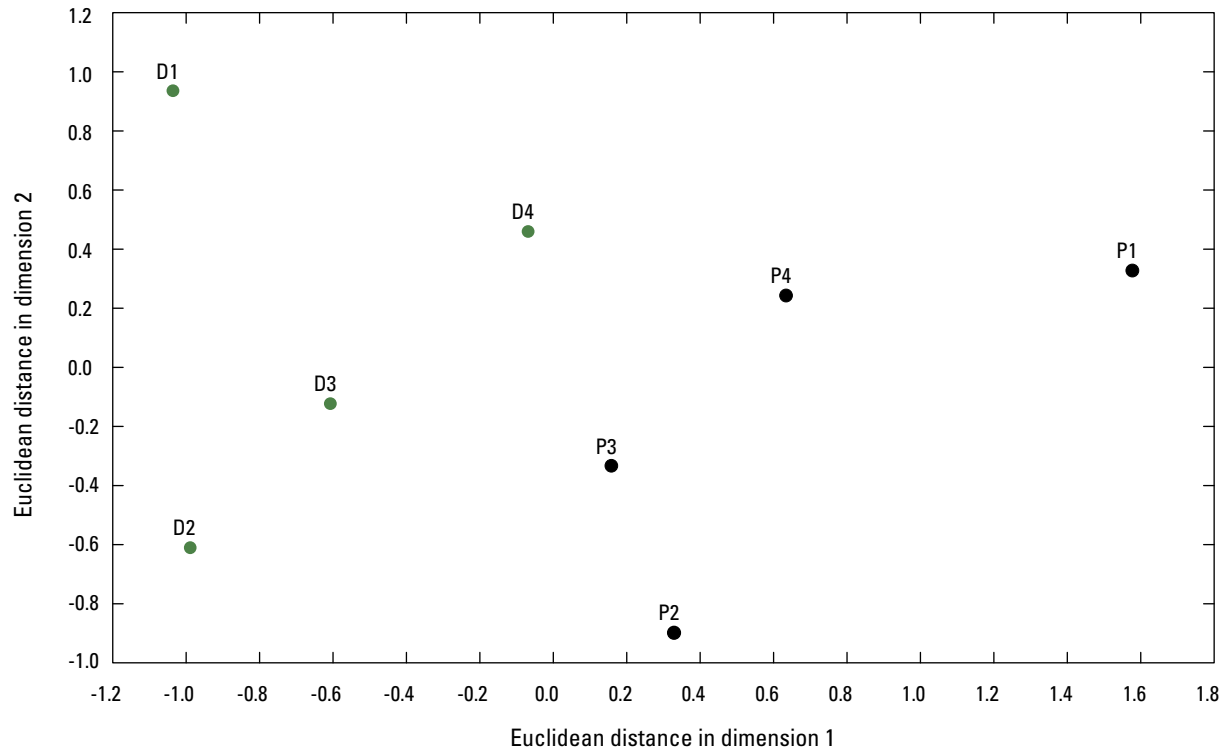
On the basis of the first Non-metric Multidimensional Scaling (NMDS) dimension (dimension 1 on the x-axis in fig. 2), the fish communities from all sites on a given river (determined from the species present at the time of collection from either the Devils or Pecos River) were more similar to one another than to the fish communities from sites on the other river. The second dimension of the NMDS (dimension 2 on the y-axis in fig. 2) indicates that between the two rivers, the fish community from any given site is most similar to the fish community at the site on the other river of the same downstream order.

The difference in fish communities between the study sites on the Devils and Pecos Rivers could be influenced by differences in water chemistry, particularly salinity (Linam and Kleinsasser, 1996); differences in zoogeographic history between the two river basins; and the fact that impounded waters of the Amistad Reservoir have removed the natural

free-flowing fluvial (riverine) connection between the Devils and Pecos Rivers to the Rio Grande. The Pecos River is in backwater conditions at its confluence with the Rio Grande most of the time. Sites on the Pecos River also are farther from the main body of Amistad Reservoir compared to those on the Devils River, and the distance of the study sites from the reservoir also might influence fish community structure.

## Macroinvertebrate Communities

Totals of 100 and 80 unique macroinvertebrate taxa were collected from the Devils and Pecos Rivers, respectively (table 10). A unique taxon was represented by the presence of one or more individual macroinvertebrate organisms at the family or lower taxonomic level (International Commission on Zoological Nomenclature, 2010).



### EXPLANATION

- D2 ● Sampling site on the Devils River (fig.1)—See table 1  
 P2 ● Sampling site on the Pecos River (fig.1)—See table 1

The overall similarity among the fish communities at the eight sampling sites is graphically depicted using Euclidean distances determined from a similarity matrix of common fish taxa between sites, and the distances are displayed in two dimensions that maximizes the separation among sites (Clark and Warwick, 2001).

In N dimensions, the Euclidean distance between two points p and q is

$$\sqrt{\sum_{i=1}^N (p_i - q_i)^2}$$

where

$p_i$  (or  $q_i$ ) is the coordinate of p (or q) in dimension i.

(Black, 2004)

**Figure 2.** Assessment of similarities among fish communities determined by using Non-metric Multi-Dimensional Scaling (first and second dimensions) for fish collected in 2006-7 at the Devils and Pecos Rivers sites in and upstream from the Amistad National Recreation Area, Texas.

For example, one macroinvertebrate identified to the family level only would be considered a unique taxon separate from any other macroinvertebrates identified to genus or species (also considered unique taxa) in the same family at the same sampling location. The number of unique macroinvertebrate taxa in the Devils River ranged from 34 at site D1 to 57 at site D2 (table 11). For all of sample-collection sites, the largest number of unique macroinvertebrate taxa (57) was from site D2 (table 11), and the smallest number of unique invertebrate taxa (26) was from site P1 (table 12). Unlike with fish, no pattern in the number of unique taxa in relation to distance from the Amistad Reservoir was observed for macroinvertebrates.

The number of unique mayfly taxa was similar among the Devils and Pecos River sites (tables 11 and 12). But mayfly taxa of the family Baetidae were more common in the Devils River, and mayfly taxa of the families Emphegeridae, Isonychidae, and Leptohyphidae were more common in the Devils River. The Baetidae mayfly, *Fallceon quilleri*, was the most abundant mayfly collected overall and occurred at all sites; the Baetidae mayfly, *Baetodes bibranchius*, was collected only at site D2. The Letophlebiidae mayfly, *Tricorythodes* sp., was collected at all sites, and was most common in the most upstream sampling location, site P4 (table 12). The Caenidae mayfly, *Caenis latipennis*, was only collected at site P1.

Caddisfly (Trichoptera) taxa were less abundant than mayfly (Ephemeroptera) taxa at all study sites. Caddisfly taxa, including net-spinning caddisfly taxa of the families Philopotamidae and Hydropsychidae, finger-net caddisflies (Philopotomidae), and snail-case caddisflies (Helicopsychidae), were more commonly collected at the Devils River sites (table 11). The combined percentage of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa was generally about twice as large at the Pecos River sites than at the Devils River sites, with the exception of site D2 (table 13). No stonefly (Plecoptera) taxa were collected in the Devils or Pecos River, and the study area is beyond the range of distribution for this taxon (Merritt and Cummins, 1996). Large EPT values can be an indication of less disturbed water-quality conditions, so the percent EPT taxa is a commonly used metric because it is less variable seasonally

and perennially than many other metrics such as species richness (Lenat and Barbour, 1994).

Damselfly and dragonfly taxa (Odonata) were not commonly collected at the Devils and Pecos River study sites (tables 10–12). This is probably the result of the chosen sampling that is biased toward the collection of more bottom-dwelling macroinvertebrates. This bias might explain why Odonata nymphs and other taxa that inhabit aquatic vegetation (and other taxa that move throughout the streambed rather than living exclusively on the river bed) were seldom found in the samples (Merritt and Cummins, 1996). The most commonly collected odonate was the narrow-winged damselfly, *Argia* sp., which was collected at all sites with the exception of site D1.

Riffle beetles (Elmidae) were the most commonly collected beetle taxon and were the most abundant beetle taxon in numbers of individuals collected at all sites (table 10). Travertine beetles (*Lutrochus* sp.) were collected at several Devils and Pecos River sites. Water-penny beetles (Psephenidae) were collected at one Pecos River site (site P4, Pecos River at Pandale), where coarser river-bed substrates, including large gravel and cobble, were more abundant than at the Devils River sites. The flattened shape of water-penny larvae (Borror and others, 1989), and the ability of this taxon to attach to riverbed substrates, may account for the very small number of members of this taxon that were collected by using a D-frame net.

True midge taxa of the family Chironomidae were the most taxa-rich macroinvertebrate taxon overall. Twenty-six unique true midge taxa (genera or species) were collected at the Devils River and Pecos River sites combined (tables 11 and 12). True midges of the family Chironomidae are often the most abundant aquatic insect taxon in aquatic ecosystems, frequently accounting for 50 percent or more of total macroinvertebrate diversity (Merritt and Cummins, 1996). True midge taxa are burrowing organisms requiring fine-material substrates such as sands, silts, and clays to survive (Minshall, 1984). The relatively small number of individuals collected for each true midge taxon is probably a result of the lack of fine-material substrates at the sampling sites on the Devils and Pecos Rivers observed during the collection of macroinvertebrate samples.

**Table 10.** Presence or absence of macroinvertebrate taxa and total number of taxa collected from the study sites along the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area, Texas, 2006.

[Shading indicates individual organisms representing the macroinvertebrate taxon were detected. Taxon (singular) or taxa (plural) refers to a genetically related group or groups of one or more organisms with common characteristics that differentiate them as a unit. From International Commission on Zoological Nomenclature (2010)]

Class	Order	Family	Genus or species	Common name	Devils River	Pecos River
Insecta	Ephemeroptera	Baetidae	<i>Baetodes bibranchius</i>	Mayflies		
			<i>Callibaetis</i> sp.			
			<i>Camelobaetidium variabilis</i>			
			<i>Fallceon quilleri</i>			
			<i>Proclueon</i> sp.			
		Caenidae	<i>Caenis latipennis</i>			
			<i>Caenis</i> sp.			
		Ephemeridae	<i>Hexagenia</i> sp.			
		Isonychiidae	<i>Isonychia</i> sp.			
		Leptohyphidae				
		Leptophlebiidae				
			<i>Neochoroterpes oklahoma</i>			
			<i>Thraulodes gonzalesi</i>			
			<i>Thraulodes</i> sp.			
			<i>Tricorythodes</i> sp.			
			<i>Vacupernius packeri</i>			
	Odonata	Coenagrionidae		Narrow-winged damselflies		
			<i>Argia</i> sp.			
			<i>Enallagma</i> sp.			
		Libellulidae				
			<i>Brechmorhoga mendax</i>	Common skimmers		
		Gomphidae				
			<i>Erpetogomphus designatus</i>			
			<i>Erpetogomphus</i> sp.			
		Calopterygidae	<i>Hetaerina americana</i>	Broad-winged damselflies		
			<i>Hetaerina</i> sp.			
	Hemiptera	Corduliidae	<i>Macromia illinoiensis</i>	Green-eyed skimmers		
		Naucoridae	<i>Ambrysus</i> sp.	Creeping water bugs		
			<i>Cryphocricos hungerfordi</i>			
			<i>Limnocoris</i> sp.			
	Coleoptera	Elmidae	<i>Dubiraphia</i> sp.	Rifle beetles		
			<i>Hexacylloepus</i> sp.			
			<i>Macrelmis</i> sp.			
			<i>Macrelmis texanus</i>			
			<i>Microcylloepus</i> sp.			
			<i>Neoelmis caesa</i>			
			<i>Phanocerus</i> sp.			
		Lutrochidae	<i>Lutrochus</i> sp.	Travertine beetles		

**Table 10.** Presence or absence of macroinvertebrate taxa and total number of taxa collected from the study sites along the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area, Texas, 2006.—Continued

[Shading indicates individual organisms representing the macroinvertebrate taxon were detected. Taxon (singular) or taxa (plural) refers to a genetically related group or groups of one or more organisms with common characteristics that differentiate them as a unit. From International Commission on Zoological Nomenclature (2010)]

Class	Order	Family	Genus or species	Common name	Devils River	Pecos River
		Psephenidae	<i>Psephenus</i> sp.	Water-penny beetles		
			<i>Stenelmis</i> sp.			
		Hydrophilidae	<i>Tropisternus</i> sp.	Water scavenger beetles		
	Megaloptera	Corydalidae	<i>Corydalus</i> sp.	Dobsonflies		
	Diptera	Chironomidae	<i>Ablabesmyia annulata</i>	Midges		
			<i>Ablabesmyia mallochi</i>			
			<i>Ablabesmyia</i> sp.			
			<i>Apedilum</i> sp.			
			<i>Beardius</i> sp.			
			<i>Cladotanytarsus</i> sp.			
			<i>Cryptochironomus</i> sp.			
			<i>Cryptotendipes</i> sp.			
			<i>Dicrotendipes</i> sp.			
			<i>Labrundinia</i> sp.			
			<i>Larsia</i> sp.			
			<i>Nanocladius</i> sp.			
			<i>Parachironomus</i> sp.			
			<i>Pentaneura</i> sp.			
			Pentaneurini			
			<i>Polypedilum flavum</i>			
			<i>Polypedilum halterale</i> gr.			
			<i>Procladius</i> sp.			
			<i>Pseudochironomus</i> sp.			
			<i>Rheocricotopus</i> sp.			
			<i>Rheotanytarsus exiguus</i> gr.			
			<i>Tanytarsus</i> sp.			
			<i>Thienemanniella</i> sp.			
			<i>Thienemannimyia</i> gr. sp.			
			<i>Tvetenia discoloripes</i> gr.			
			<i>Xenochironomus xenolabis</i>			
	Diptera	Ceratopogonidae	<i>Atrichopogon</i> sp.	Biting midges		
			<i>Bezzia/Palpomyia</i> sp.			
			<i>Dasyhelea</i> sp.			
		Tabanidae	<i>Atylotus/Tabanus</i> sp.	Deer flies, horse flies		
		Empididae		Balloon flies		
			<i>Hemerodromia</i> sp.			
		Simuliidae	<i>Simulium</i> sp.	Black flies		
		Stratiomyidae		Soldier flies		



**Table 10.** Presence or absence of macroinvertebrate taxa and total number of taxa collected from the study sites along the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area, Texas, 2006.—Continued

[Shading indicates individual organisms representing the macroinvertebrate taxon were detected. Taxon (singular) or taxa (plural) refers to a genetically related group or groups of one or more organisms with common characteristics that differentiate them as a unit. From International Commission on Zoological Nomenclature (2010)]

Class	Order	Family	Genus or species	Common name	Devils River	Pecos River
Gastropoda	Trichoptera	Polycentropodidae	<i>Cernotina</i> sp.	Tube-making caddisflies		
			<i>Neureclipsis</i> sp.			
			<i>Polypsectropus</i> sp.			
			<i>Cheumatopsyche</i> sp.			
		Hydropsychidae	<i>Hydropsyche</i> sp.	Net-spinning caddisflies		
			Smicridea (Smicridea) sp.			
			<i>Chimarra</i> sp.			
		Philoptamidae	<i>Helicopsyche</i> sp.	Finger-net caddisflies		
		Helicopsychidae	<i>Hydroptila</i> sp.	Snail-case caddisflies		
		Hydroptilidae	<i>Mayatrichia</i> sp.	Micro-caddisflies		
			<i>Neotrichia</i> sp.			
			<i>Ochrotrichia</i> sp.			
			<i>Oxyethira</i> sp.			
		Leptoceridae	<i>Nectopsyche</i> sp.	Long-horn caddisflies		
			<i>Oecetis avara</i>			
			<i>Petrophila</i> sp.			
	Lepidoptera	Crambidae	<i>Ferrissia</i> sp.	Semi-aquatic moths		
	Basommatophora	Ancylidae	<i>Melanoides tuberculata</i>	Aquatic snails		
		Lymnaeidae	<i>Physa</i> sp.			
		Planorbidae	<i>Valvata</i> sp.			
Clitellata	Bivalvia		<i>Corbicula</i> sp.	Basket clams		
		Sphaeriidae		Fingernail clams		
		Naididae		Aquatic worms		
			<i>Pristina</i> sp.			
	Trombidiformes			Mites		
		Arrenuridae	<i>Arrenurus</i> sp.			
		Hygrobatidae	<i>Atractides</i> sp.			
			<i>Hygrobatas</i> sp.			
		Hydromatidae	<i>Hydrodroma</i> sp.			
		Unionicolidae	<i>Koenikea</i> sp.			
			<i>Neumania</i> sp.			
		Libertiidae	<i>Lebertia</i> sp.			
		Limnesiidae	<i>Limnesia</i> sp.			
		Limnocharidae	<i>Limnocharas</i> sp.			
			<i>Rhyncholimnocharas</i> sp.			

**Table 10.** Presence or absence of macroinvertebrate taxa and total number of taxa collected from the study sites along the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area, Texas, 2006.—Continued

[Shading indicates individual organisms representing the macroinvertebrate taxon were detected. Taxon (singular) or taxa (plural) refers to a genetically related group or groups of one or more organisms with common characteristics that differentiate them as a unit. From International Commission on Zoological Nomenclature (2010)]

Class	Order	Family	Genus or species	Common name	Devils River	Pecos River
Malocos-traca	Amphipoda	Mideopsidae	<i>Mideopsis</i> sp.	Amphipods		
		Oribatidae	Oribatei			
		Oxidae	<i>Oxus</i> sp.			
		Sperchonidae	<i>Sperchon</i> sp.			
		Torrenticolidae	<i>Torrenticola</i> sp.			
		Hyaellidae	<i>Hyaella</i> sp.			
	Ostracoda			Ostracods		
Enopla	Decapoda	Cambaridae	<i>Procambarus</i> sp.	Crayfishes		
				Nematodes		
	Hoplonemertea	Tetrastemmatidae	<i>Prostoma</i> sp.	Proboscis worms		
Number of unique taxa					100	80

**Table 11.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Devils River study sites in and upstream from the Amistad National Recreation Area, Texas, 2006.

[USGS, U.S. Geological Survey; sp., species; Total: Total individuals by taxon for all sites on Devils River]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name					Total
						D1	D2	D3	D4		
						Devils River near Satan Canyon, Tex.	Devils River at Pafford Crossing near Comstock, Tex.	Devils River near Turkey Bluff Canyon, Tex.	Devils River at Dolan Falls, Tex.		
						06/05/2006	06/06/2006	06/06/2006	06/08/2006		
Insecta	Ephemeroptera	Baetidae		<i>Baetodes bibranchius</i>	Mayflies	0	3	0	0	3	
Insecta	Ephemeroptera	Baetidae		<i>Callibaetis</i> sp.		5	0	0	2	7	
Insecta	Ephemeroptera	Baetidae		<i>Camelobaetidius variabilis</i>		0	1	0	0	1	
Insecta	Ephemeroptera	Baetidae		<i>Fallceon quilleri</i>		1	107	34	53	195	
Insecta	Ephemeroptera	Baetidae		<i>Procloeon</i> sp.		45	9	6	1	61	
Insecta	Ephemeroptera	Caenidae		<i>Caenis latipennis</i>		0	0	0	0	0	
Insecta	Ephemeroptera	Caenidae		<i>Caenis</i> sp.		2	0	0	0	2	
Insecta	Ephemeroptera	Ephemeridae		<i>Hexagenia</i> sp.		3	1	0	0	4	
Insecta	Ephemeroptera	Isonychidae		<i>Isonychia</i> sp.		0	2	1	0	3	
Insecta	Ephemeroptera	Leptolynphidae				0	4	0	4	8	
Insecta	Ephemeroptera	Leptophlebiidae				1	0	0	0	1	
Insecta	Ephemeroptera	Leptophlebiidae		<i>Neochoroterpes oklahoma</i>		0	0	0	0	0	
Insecta	Ephemeroptera	Leptophlebiidae		<i>Thraulodes gonzalesi</i>		0	0	0	0	0	
Insecta	Ephemeroptera	Leptophlebiidae		<i>Thraulodes</i> sp.		0	0	0	0	0	
Insecta	Ephemeroptera	Leptophlebiidae		<i>Tricorythodes</i> sp.		22	4	2	13	41	
Insecta	Ephemeroptera	Leptophlebiidae		<i>Vacupernius packeri</i>		0	0	0	2	2	
Insecta	Odonata	Coenagrionidae			Narrow-winged damselflies	0	0	1	2	3	
Insecta	Odonata	Coenagrionidae		<i>Argia</i> sp.		0	5	16	1	22	
Insecta	Odonata	Coenagrionidae		<i>Enallagma</i> sp.		5	0	0	0	5	
Insecta	Odonata	Libellulidae				1	0	0	0	1	
Insecta	Odonata	Libellulidae		<i>Brechmorhoga mendax</i>	Common skimmers	0	0	0	0	0	
Insecta	Odonata	Gomphidae			Club-tail dragonflies	0	0	0	0	0	
Insecta	Odonata	Gomphidae		<i>Erpetogomphus designatus</i>		0	1	2	0	3	

**Table 11.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Devils River study sites in and upstream from the Amistad National Recreation Area, Texas, 2006.—Continued

[USGS, U.S. Geological Survey; sp., species; Total: Total individuals by taxon for all sites on Devils River.]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name				Total
						D1	D2	D3	D4	
Insecta	Odonata	Gomphidae		<i>Erpetogomphus</i> sp.		0	0	0	0	0
Insecta	Odonata	Calopterygidae		<i>Hetaerina americana</i>	Broad-winged damselflies	0	0	0	0	0
Insecta	Odonata	Calopterygidae		<i>Hetaerina</i> sp.		0	0	3	1	4
Insecta	Odonata	Corduliidae		<i>Macromia illinoensis</i>	Green-eyed skimmers	0	1	0	1	2
Insecta	Hemiptera	Naucoridae		<i>Ambrysus</i> sp.	Creeping water bugs	0	4	4	4	12
Insecta	Hemiptera	Naucoridae		<i>Cryphocricos hungerfordi</i>		0	0	0	0	0
Insecta	Hemiptera	Naucoridae		<i>Limnecoris</i> sp.		0	1	0	0	1
Insecta	Coleoptera	Elmidae		<i>Dubiraphia</i> sp.	Rifle beetles	1	0	0	0	1
Insecta	Coleoptera	Elmidae		<i>Hexacyloepus</i> sp.		0	29	36	9	74
Insecta	Coleoptera	Elmidae		<i>Macrelmis</i> sp.		0	0	0	1	1
Insecta	Coleoptera	Elmidae		<i>Macrelmis texanus</i>		0	0	0	0	0
Insecta	Coleoptera	Elmidae		<i>Microcyloepus</i> sp.		0	35	22	5	62
Insecta	Coleoptera	Elmidae		<i>Neolmis caesa</i>		0	0	0	0	0
Insecta	Coleoptera	Elmidae		<i>Phanocerus</i> sp.		0	0	0	1	1
Insecta	Coleoptera	Lutrochidae		<i>Lutrochus</i> sp.	Travertine beetles	0	6	7	0	13
Insecta	Coleoptera	Psephenidae		<i>Psephenus</i> sp.	Water-penny beetles	0	0	0	0	0
Insecta	Coleoptera	Psephenidae		<i>Stenelmis</i> sp.		0	0	0	0	0
Insecta	Coleoptera	Hydrophilidae		<i>Tropisternus</i> sp.	Water scavenger beetles	0	0	1	0	1
Insecta	Megaloptera	Corydalidae		<i>Corydalus</i> sp.	Dobsonflies	0	0	0	1	1
Insecta	Diptera	Chironomidae		<i>Ablabesmyia annulata</i>	Midges	1	0	0	0	1
Insecta	Diptera	Chironomidae		<i>Ablabesmyia mallochi</i>		1	0	0	0	1
Insecta	Diptera	Chironomidae		<i>Ablabesmyia</i> sp.		0	0	0	0	0
Insecta	Diptera	Chironomidae		<i>Apeditum</i> sp.		0	0	1	0	1

**Table 11.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Devils River study sites in and upstream from the Amistad National Recreation Area, Texas, 2006.—Continued

[USGS, U.S. Geological Survey; sp., species; Total: Total individuals by taxon for all sites on Devils River.]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name				Total
						D1	D2	D3	D4	
						Devils River near Satan Canyon, Tex.	Devils River at Pafford Crossing near Comstock, Tex.	Devils River near Turkey Bluff Canyon, Tex.	Devils River at Dolan Falls, Tex.	
Insecta	Diptera	Chironomidae		<i>Beardius</i> sp.		0	0	0	5	5
Insecta	Diptera	Chironomidae		<i>Cladotanytarsus</i> sp.		2	5	0	0	7
Insecta	Diptera	Chironomidae		<i>Cryptochironomus</i> sp.		0	1	0	0	1
Insecta	Diptera	Chironomidae		<i>Cryptotendipes</i> sp.		0	1	0	0	1
Insecta	Diptera	Chironomidae		<i>Dicrotendipes</i> sp.		0	1	0	0	1
Insecta	Diptera	Chironomidae		<i>Labrundinia</i> sp.		2	5	0	3	10
Insecta	Diptera	Chironomidae		<i>Larsia</i> sp.		1	3	7	1	12
Insecta	Diptera	Chironomidae		<i>Nanocladius</i> sp.		0	0	0	0	0
Insecta	Diptera	Chironomidae		<i>Parachironomus</i> sp.		0	0	0	0	0
Insecta	Diptera	Chironomidae		<i>Pentaneura</i> sp.		2	4	5	5	16
Insecta	Diptera	Chironomidae	Pentaneurini			0	1	0	0	1
Insecta	Diptera	Chironomidae		<i>Polypedilum flavum</i>		0	0	0	3	3
Insecta	Diptera	Chironomidae		<i>Polypedilum halterale</i> gr.		0	2	2	1	5
Insecta	Diptera	Chironomidae		<i>Procladius</i> sp.		2	3	4	3	12
Insecta	Diptera	Chironomidae		<i>Pseudochironomus</i> sp.		1	3	1	0	5
Insecta	Diptera	Chironomidae		<i>Rheocricotopus</i> sp.		0	0	0	1	1
Insecta	Diptera	Chironomidae		<i>Rheotanytarsus exiguus</i> gr.		0	0	0	0	0
Insecta	Diptera	Chironomidae		<i>Tanytarsus</i> sp.		0	11	3	0	14
Insecta	Diptera	Chironomidae		<i>Thienemanniella</i> sp.		0	0	0	0	0
Insecta	Diptera	Chironomidae		<i>Thienemannimyia</i> gr. sp.		0	8	6	0	14
Insecta	Diptera	Chironomidae		<i>Tvetenia discoloripes</i> gr.		0	0	0	0	0
Insecta	Diptera	Chironomidae		<i>Xenochironomus xenolabis</i>		0	0	0	0	0
Insecta	Diptera	Ceratopogoniidae		<i>Atrichopogon</i> sp.	Biting midges	0	0	0	0	0
Insecta	Diptera	Ceratopogoniidae		<i>Bezzia/Palpomyia</i> sp.		0	4	37	2	43
Insecta	Diptera	Ceratopogoniidae		<i>Dasyhelea</i> sp.		17	43	81	15	156

**Table 11.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Devils River study sites in and upstream from the Amistad National Recreation Area, Texas, 2006.—Continued

[USGS, U.S. Geological Survey; sp., species; Total: Total individuals by taxon for all sites on Devils River.]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name				Total
						D1	D2	D3	D4	
						Devils River near Satan Canyon, Tex.	Devils River at Pafford Crossing near Comstock, Tex.	Devils River near Turkey Bluff Canyon, Tex.	Devils River at Dolan Falls, Tex.	
Insecta	Diptera	Tabanidae		<i>Aylotus/Tabanus</i> sp.	Deer flies, horse flies	0	0	0	1	1
Insecta	Diptera	Empididae			Balloon flies	0	0	0	0	0
Insecta	Diptera	Empididae		<i>Hemerodromia</i> sp.		0	0	1	0	1
Insecta	Diptera	Simuliidae		<i>Simulium</i> sp.	Black flies	0	1	0	1	2
Insecta	Diptera	Stratiomyidae			Soldier flies	0	0	1	0	1
Insecta	Trichoptera	Polycentropodidae			Tube-net makers	0	0	0	0	0
Insecta	Trichoptera	Polycentropodidae		<i>Cernotina</i> sp.		2	0	0	0	2
Insecta	Trichoptera	Polycentropodidae		<i>Neureclipsis</i> sp.		0	0	1	0	1
Insecta	Trichoptera	Polycentropodidae		<i>Polypterus</i> sp.		0	1	0	1	2
Insecta	Trichoptera	Hydropsychidae		<i>Cheumatopsyche</i> sp.	Net-spinning caddisflies	0	24	0	0	24
Insecta	Trichoptera	Hydropsychidae		<i>Hydropsyche</i> sp.		0	6	6	2	14
Insecta	Trichoptera	Hydropsychidae		<i>Smicridea</i> sp.		0	0	0	0	0
Insecta	Trichoptera	Philopotamidae		<i>Chimarra</i> sp.	Finger-net caddisflies	0	3	1	1	5
Insecta	Trichoptera	Helicopsychidae		<i>Helicopsyche</i> sp.	Snail-case caddisflies	0	0	0	6	6
Insecta	Trichoptera	Hydroptilidae		<i>Hydroptila</i> sp.	Micro-caddisflies	0	0	8	1	9
Insecta	Trichoptera	Hydroptilidae		<i>Mayatrichia</i> sp.		0	1	6	0	7
Insecta	Trichoptera	Hydroptilidae		<i>Neotrichia</i> sp.		0	1	3	0	4
Insecta	Trichoptera	Hydroptilidae		<i>Ochrotrichia</i> sp.		0	1	0	6	7
Insecta	Trichoptera	Hydroptilidae		<i>Oxyethira</i> sp.		9	0	3	6	18
Insecta	Trichoptera	Leptoceridae			Long-horn caddisflies	0	0	0	0	0
Insecta	Trichoptera	Leptoceridae		<i>Nectopsyche</i> sp.		0	1	0	3	4
Insecta	Trichoptera	Leptoceridae		<i>Oecetis avara</i>		0	0	0	2	2



**Table 11.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Devils River study sites in and upstream from the Amistad National Recreation Area, Texas, 2006.—Continued

[USGS, U.S. Geological Survey; sp., species; Total: Total individuals by taxon for all sites on Devils River.]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name				Total
						D1	D2	D3	D4	
Insecta	Lepidoptera	Crambidae		<i>Petrophila</i> sp.	Semi-aquatic moths	0	1	4	1	6
Gastropoda	Basommatophora	Ancylidae		<i>Ferrissia</i> sp.	Aquatic snails	0	0	0	1	1
Gastropoda	Basommatophora	Lymnaeidae				0	1	0	0	1
Gastropoda	Basommatophora	Lymnaeidae		<i>Melanoides tuberculata</i>		0	0	0	1	1
Gastropoda	Basommatophora	Lymnaeidae		<i>Physa</i> sp.		1	6	0	4	11
Gastropoda	Basommatophora	Planorbidae				1	0	0	0	1
Gastropoda	Basommatophora	Planorbidae		<i>Valvata</i> sp.		0	0	1	27	28
Gastropoda	Bivalvia	Corbiculidae		<i>Corbicula</i> sp.	Basket clams	0	1	0	1	2
Gastropoda	Bivalvia	Sphaeriidae			Fingernail clams	1	3	5	3	12
Clitellata	Clitellata	Naididae			Aquatic worms	0	1	1	0	2
Clitellata	Clitellata	Naididae		<i>Pristina</i> sp.		0	0	0	0	0
Clitellata	Trombidiformes				Mites	1	0	0	1	2
Clitellata	Trombidiformes	Arrenuridae		<i>Arrenurus</i> sp.		12	2	7	8	29
Clitellata	Trombidiformes	Hygrobatidae		<i>Atractides</i> sp.		2	0	2	2	6
Clitellata	Trombidiformes	Hygrobatidae		<i>Hygrobates</i> sp.		0	0	12	8	20
Clitellata	Trombidiformes	Hydromatidae		<i>Hydrodroma</i> sp.		0	0	1	0	1
Clitellata	Trombidiformes	Unionicolidae		<i>Koenikea</i> sp.		0	0	0	2	2
Clitellata	Trombidiformes	Unionicolidae		<i>Neumania</i> sp.		0	2	1	1	4
Clitellata	Trombidiformes	Libertiidae		<i>Lebertia</i> sp.		1	0	0	0	1
Clitellata	Trombidiformes	Limnesiidae		<i>Limnesia</i> sp.		0	0	0	3	3
Clitellata	Trombidiformes	Limnocharidae		<i>Limnochares</i> sp.		1	0	0	0	1
Clitellata	Trombidiformes	Limnocharidae		<i>Rhyncholimnnochares</i> sp.		0	1	2	0	3
Clitellata	Trombidiformes	Mideopsidae		<i>Mideopsis</i> sp.		15	1	12	0	28
Clitellata	Trombidiformes	Oribatidae	Oribatei			0	1	0	0	1
Clitellata	Trombidiformes	Oxididae		<i>Oxus</i> sp.		2	0	0	0	2

**Table 11.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Devils River study sites in and upstream from the Amistad National Recreation Area, Texas, 2006.—Continued

[USGS, U.S. Geological Survey; sp., species; Total: Total individuals by taxon for all sites on Devils River.]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name				Total
						D1	D2	D3	D4	
						Devils River near Satan Canyon, Tex.	Devils River at Pafford Crossing near Comstock, Tex.	Devils River near Turkey Bluff Canyon, Tex.	Devils River at Dolan Falls, Tex.	
Clitellata	Trombidiformes	Sperchonidae		<i>Sperchon</i> sp.		0	0	0	1	1
Clitellata	Trombidiformes	Torrenticolidae		<i>Torrenticola</i> sp.		4	2	10	3	19
Malocos-traca	Amphipoda	Hyalellidae		<i>Hyalella</i> sp.	Amphipods	173	12	2	121	308
Malocos-traca	Ostracoda				Ostracods	4	3	7	6	20
Malocos-traca	Decapoda	Cambaridae		<i>Procambarus</i> sp.	Crayfishes	0	2	0	0	2
Malocos-traca	Decapoda				Nematodes	0	0	2	0	2
Enopla	Hoplonemertea	Tetrastemmatidae		<i>Prostoma</i> sp.	Proboscis worms	0	2	0	0	2
Turbellaria					Flatworms	0	3	9	10	22
Total number of organisms						344	391	390	374	1,499
Total number of unique taxa						34	57	48	56	100

**Table 12.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Pecos River study sites in and upstream of the Amistad National Recreation Area, Texas, 2006.

[USGS, U.S. Geological Survey, Total: Total individuals by taxon for all sites on Pecos River. Sites P1 to P4 are used to define sites on the Pecos River as shown in figure 1]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name					Total
						P1	P2	P3	P4		
						Pecos River at Shumla Bend, Tex.	Pecos River near Langtry, Tex.	Pecos River near Everett Canyon, Tex.	Pecos River at Pandale, Tex.		
						6/27/2006	6/28/2006	6/29/2006	6/22/2006		
Insecta	Ephemeroptera	Baetidae		<i>Baetodes bibranchius</i>	Mayflies	0	0	0	0	0	
Insecta	Ephemeroptera	Baetidae		<i>Callibaetis</i> sp.		1	0	0	0	1	
Insecta	Ephemeroptera	Baetidae		<i>Camelobaetidis variabilis</i>		0	1	1	5	7	
Insecta	Ephemeroptera	Baetidae		<i>Fallceon quilleri</i>		1	15	58	59	133	
Insecta	Ephemeroptera	Baetidae		<i>Proclleon</i> sp.		0	0	0	0	0	
Insecta	Ephemeroptera	Caenidae		<i>Caenis latipennis</i>		122	0	0	0	122	
Insecta	Ephemeroptera	Caenidae		<i>Caenis</i> sp.		0	1	0	0	1	
Insecta	Ephemeroptera	Ephemeridae		<i>Hexagenia</i> sp.		0	0	0	0	0	
Insecta	Ephemeroptera	Isonychiidae		<i>Isonychia</i> sp.		0	0	0	0	0	
Insecta	Ephemeroptera	Leptohyphidae				0	0	0	0	0	
Insecta	Ephemeroptera	Leptophlebiidae				0	0	0	0	0	
Insecta	Ephemeroptera	Leptophlebiidae		<i>Neochoroterpes oklahoma</i>		0	4	0	1	5	
Insecta	Ephemeroptera	Leptophlebiidae		<i>Thraulodes gonzalesi</i>		0	40	5	0	45	
Insecta	Ephemeroptera	Leptophlebiidae		<i>Thraulodes</i> sp.		0	0	0	12	12	
Insecta	Ephemeroptera	Leptophlebiidae		<i>Tricorythodes</i> sp.		9	28	37	107	181	
Insecta	Ephemeroptera	Leptophlebiidae		<i>Vacupernius packeri</i>		0	1	0	0	1	
Insecta	Odonata	Coenagrionidae			Narrow-winged damselflies	0	0	0	0	0	
Insecta	Odonata	Coenagrionidae		<i>Argia</i> sp.		4	3	1	1	9	
Insecta	Odonata	Coenagrionidae		<i>Enallagma</i> sp.		0	0	0	3	3	
Insecta	Odonata	Libellulidae				0	0	0	0	0	
Insecta	Odonata	Libellulidae		<i>Brechmorhoga mendax</i>	Common skimmers	0	1	0	0	1	
Insecta	Odonata	Gomphidae			Club-tail dragonflies	0	2	4	1	7	
Insecta	Odonata	Gomphidae		<i>Erpetogomphus designatus</i>		0	0	0	0	0	

**Table 12.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Pecos River study sites in and upstream of the Amistad National Recreation Area, Texas, 2006.—Continued  
 [USGS, U.S. Geological Survey; Total: Total individuals by taxon for all sites on Pecos River. Sites P1 to P4 are used to define sites on the Pecos River as shown in figure 1]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name					Total
						P1	P2	P3	P4		
						Pecos River at Shumla Bend, Tex. 6/27/2006	Pecos River near Langtry, Tex. 6/28/2006	Pecos River near Everett Canyon, Tex. 6/29/2006	Pecos River at Pandale, Tex. 6/22/2006		
Insecta	Odonata	Gomphidae		<i>Erpetogomphus</i> sp.		0	1	0	0	1	
Insecta	Odonata	Calopterygidae		<i>Hetaerina americana</i>	Broad-winged damselflies	0	0	0	1	1	
Insecta	Odonata	Calopterygidae		<i>Hetaerina</i> sp.		0	0	0	0	0	
Insecta	Odonata	Corduliidae		<i>Macromia illinoiensis</i>	Green-eyed skimmers	0	0	0	1	1	
Insecta	Hemiptera	Naucoridae		<i>Ambrysus</i> sp.	Creeping water bugs	0	5	1	1	7	
Insecta	Hemiptera	Naucoridae		<i>Cryphocricos hungerfordi</i>		0	1	6	2	9	
Insecta	Hemiptera	Naucoridae		<i>Linnocoris</i> sp.		0	0	0	5	5	
Insecta	Coleoptera	Elmidae		<i>Dubiraphia</i> sp.	Rifle beetles	0	0	0	0	0	
Insecta	Coleoptera	Elmidae		<i>Hexacylloepus</i> sp.		0	4	19	13	36	
Insecta	Coleoptera	Elmidae		<i>Macrelmis</i> sp.		0	0	27	1	28	
Insecta	Coleoptera	Elmidae		<i>Macrelmis texanus</i>		0	42	0	0	42	
Insecta	Coleoptera	Elmidae		<i>Microcyllloepus</i> sp.		5	72	17	14	108	
Insecta	Coleoptera	Elmidae		<i>Neelmis caesa</i>		0	3	8	0	11	
Insecta	Coleoptera	Elmidae		<i>Phanocerus</i> sp.		0	0	0	0	0	
Insecta	Coleoptera	Lutrochidae		<i>Lutrochus</i> sp.	Travertine beetles	0	1	2	0	3	
Insecta	Coleoptera	Psephenidae		<i>Psephenus</i> sp.	Water-penny beetles	0	0	0	1	1	
Insecta	Coleoptera	Psephenidae		<i>Stenelmis</i> sp.		0	5	0	3	8	
Insecta	Coleoptera	Hydrophilidae		<i>Tropisternus</i> sp.	Water scavenger beetles	0	0	0	0	0	
Insecta	Megaloptera	Corydalidae		<i>Corydatus</i> sp.	Dobsonflies	0	3	0	1	4	
Insecta	Diptera	Chironomidae		<i>Ablabesmyia annulata</i>	Midges	0	0	0	0	0	
Insecta	Diptera	Chironomidae		<i>Ablabesmyia mallochi</i>		5	0	0	0	5	
Insecta	Diptera	Chironomidae		<i>Ablabesmyia</i> sp.		0	0	0	1	1	
Insecta	Diptera	Chironomidae		<i>Apedilum</i> sp.		24	3	0	0	27	

**Table 12.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Pecos River study sites in and upstream of the Amistad National Recreation Area, Texas, 2006.—Continued

[USGS, U.S. Geological Survey, Total: Total individuals by taxon for all sites on Pecos River. Sites P1 to P4 are used to define sites on the Pecos River as shown in figure 1]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name					Total
						P1	P2	P3	P4		
						Pecos River at Shumla Bend, Tex.	Pecos River near Langtry, Tex.	Pecos River near Everett Canyon, Tex.	Pecos River at Pandale, Tex.		
						6/27/2006	6/28/2006	6/29/2006	6/22/2006		
Insecta	Diptera	Chironomidae		<i>Beardius</i> sp.		0	0	0	0	0	
Insecta	Diptera	Chironomidae		<i>Cladotanytarsus</i> sp.		0	0	0	1	1	
Insecta	Diptera	Chironomidae		<i>Cryptochironomus</i> sp.		0	0	0	0	0	
Insecta	Diptera	Chironomidae		<i>Cryptotendipes</i> sp.		0	0	0	0	0	
Insecta	Diptera	Chironomidae		<i>Dicrotendipes</i> sp.		1	0	0	0	1	
Insecta	Diptera	Chironomidae		<i>Labrundinia</i> sp.		4	0	0	0	4	
Insecta	Diptera	Chironomidae		<i>Larsia</i> sp.		0	2	1	0	3	
Insecta	Diptera	Chironomidae		<i>Nanocladius</i> sp.		0	1	0	0	1	
Insecta	Diptera	Chironomidae		<i>Parachironomus</i> sp.		1	0	0	0	1	
Insecta	Diptera	Chironomidae		<i>Pentaneura</i> sp.		0	0	4	0	4	
Insecta	Diptera	Chironomidae	Pentaneurini			0	0	0	0	0	
Insecta	Diptera	Chironomidae		<i>Polypedilum flavum</i>		0	0	0	0	0	
Insecta	Diptera	Chironomidae		<i>Polypedilum halterale</i> gr.		13	0	7	20	40	
Insecta	Diptera	Chironomidae		<i>Procladius</i> sp.		7	0	0	0	7	
Insecta	Diptera	Chironomidae		<i>Pseudochironomus</i> sp.		6	0	1	0	7	
Insecta	Diptera	Chironomidae		<i>Rheocricotopus</i> sp.		0	0	0	0	0	
Insecta	Diptera	Chironomidae		<i>Rheotanytarsus exiguus</i> gr.		0	0	0	27	27	
Insecta	Diptera	Chironomidae		<i>Tanytarsus</i> sp.		48	3	4	7	62	
Insecta	Diptera	Chironomidae		<i>Thienemanniella</i> sp.		0	0	0	3	3	
Insecta	Diptera	Chironomidae		<i>Thienemannimyia</i> gr. sp.		0	0	6	12	18	
Insecta	Diptera	Chironomidae		<i>Tvetenia discoloripes</i> gr.		0	0	0	1	1	
Insecta	Diptera	Chironomidae		<i>Xenochironomus xenolabis</i>		1	0	0	0	1	
Insecta	Diptera	Ceratopogoniidae		<i>Atrichopogon</i> sp.	Biting midges	1	0	0	0	1	
Insecta	Diptera	Ceratopogoniidae		<i>Bezzia/Palpomyia</i> sp.		3	6	7	2	18	

**Table 12.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Pecos River study sites in and upstream of the Amistad National Recreation Area, Texas, 2006.—Continued  
 [USGS, U.S. Geological Survey, Total: Total individuals by taxon for all sites on Pecos River. Sites P1 to P4 are used to define sites on the Pecos River as shown in figure 1]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name					Total
						P1	P2	P3	P4		
						Pecos River at Shumla Bend, Tex. 6/27/2006	Pecos River near Langtry, Tex. 6/28/2006	Pecos River near Everett Canyon, Tex. 6/29/2006	Pecos River at Pandale, Tex. 6/22/2006		
Insecta	Diptera	Ceratopogoniidae		<i>Dasyhelea</i> sp.		70	5	0	0	75	
Insecta	Diptera	Tabanidae		<i>Anylotus/Tabanus</i> sp.	Deer flies, horse flies	0	2	1	0	3	
Insecta	Diptera	Empididae			Balloon flies	0	1	0	0	1	
Insecta	Diptera	Empididae		<i>Hemerodromia</i> sp.		0	0	0	0	0	
Insecta	Diptera	Simuliidae		<i>Simulium</i> sp.	Black flies	0	0	0	2	2	
Insecta	Diptera	Stratiomyidae			Soldier flies	0	0	0	0	0	
Insecta	Trichoptera	Polycentropodidae			Tube-net makers	0	1	0	0	1	
Insecta	Trichoptera	Polycentropodidae		<i>Cernotina</i> sp.		6	0	0	0	6	
Insecta	Trichoptera	Polycentropodidae		<i>Neureclipsis</i> sp.		0	0	0	0	0	
Insecta	Trichoptera	Polycentropodidae		<i>Polyplectropus</i> sp.		0	0	0	0	0	
Insecta	Trichoptera	Hydropsychidae		<i>Cheumatopsyche</i> sp.	Net-spinning caddisflies	0	67	4	5	76	
Insecta	Trichoptera	Hydropsychidae		<i>Hydropsyche</i> sp.		0	0	0	0	0	
Insecta	Trichoptera	Hydropsychidae		<i>Smicridea</i> sp.		0	1	0	0	1	
Insecta	Trichoptera	Philopotamidae		<i>Chimarra</i> sp.	Finger-net caddisflies	0	1	18	1	20	
Insecta	Trichoptera	Helicopsychidae		<i>Helicopsyche</i> sp.	Snail-case caddisflies	0	0	0	0	0	
Insecta	Trichoptera	Hydroptilidae		<i>Hydroptila</i> sp.	Micro-caddisflies	0	2	2	9	13	
Insecta	Trichoptera	Hydroptilidae		<i>Mayatrichia</i> sp.		0	0	0	0	0	
Insecta	Trichoptera	Hydroptilidae		<i>Neotrichia</i> sp.		0	1	0	0	1	
Insecta	Trichoptera	Hydroptilidae		<i>Ochrotrichia</i> sp.		0	0	0	0	0	
Insecta	Trichoptera	Hydroptilidae		<i>Oxyethira</i> sp.		21	0	4	0	25	
Insecta	Trichoptera	Leptoceridae			Long-horn caddisflies	0	2	0	0	2	
Insecta	Trichoptera	Leptoceridae		<i>Nectopsyche</i> sp.		0	0	0	7	7	
Insecta	Trichoptera	Leptoceridae		<i>Oecetis avara</i>		0	0	1	6	7	



**Table 12.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Pecos River study sites in and upstream of the Amistad National Recreation Area, Texas, 2006.—Continued  
 [USGS, U.S. Geological Survey, Total: Total individuals by taxon for all sites on Pecos River. Sites P1 to P4 are used to define sites on the Pecos River as shown in figure 1]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name					Total
						P1	P2	P3	P4		
						Pecos River at Shumla Bend, Tex. 6/27/2006	Pecos River near Langtry, Tex. 6/28/2006	Pecos River near Everett Canyon, Tex. 6/29/2006	Pecos River at Pandale, Tex. 6/22/2006		
Insecta	Lepidoptera	Crambidae		<i>Petrophila</i> sp.	Semi-aquatic moths	0	1	0	0	1	
Gastropoda	Basommatophora	Ancylidae		<i>Ferrissia</i> sp.	Aquatic snails	0	0	0	0	0	
Gastropoda	Basommatophora	Lymnaeidae				0	0	0	0	0	
Gastropoda	Basommatophora	Lymnaeidae		<i>Melanoides tuberculata</i>		0	0	0	0	0	
Gastropoda	Basommatophora	Lymnaeidae		<i>Physa</i> sp.		4	6	24	1	35	
Gastropoda	Basommatophora	Planorbidae				0	0	0	0	0	
Gastropoda	Basommatophora	Planorbidae		<i>Valvata</i> sp.		0	0	0	0	0	
Gastropoda	Bivalvia	Corbiculidae		<i>Corbicula</i> sp.	Basket clams	0	2	8	13	23	
Gastropoda	Bivalvia	Sphaeriidae			Fingernail clams	0	0	0	0	0	
Clitellata		Naididae			Aquatic worms	0	0	2	1	3	
Clitellata		Naididae		<i>Pristina</i> sp.		0	0	1	0	1	
Arachnida	Trombidiformes				Mites	0	0	0	0	0	
Arachnida	Trombidiformes	Arrenuridae		<i>Arrenurus</i> sp.		0	0	0	0	0	
Arachnida	Trombidiformes	Hygrobatidae		<i>Atractides</i> sp.		0	0	2	0	2	
Arachnida	Trombidiformes			<i>Hygrobates</i> sp.		0	0	1	0	1	
Arachnida	Trombidiformes	Hydromatidae		<i>Hydrodroma</i> sp.		2	3	10	0	15	
Arachnida	Trombidiformes	Unionicolidae		<i>Koenikea</i> sp.		0	0	0	0	0	
Arachnida	Trombidiformes			<i>Neumania</i> sp.		0	0	0	0	0	
Arachnida	Trombidiformes	Libertiidae		<i>Lebertia</i> sp.		0	0	0	0	0	
Arachnida	Trombidiformes	Limnesiidae		<i>Limnesia</i> sp.		0	0	0	0	0	
Arachnida	Trombidiformes	Limnocharidae		<i>Limnochares</i> sp.		0	0	0	0	0	
Arachnida	Trombidiformes			<i>Rhyncholimnochares</i> sp.		0	0	0	0	0	
Arachnida	Trombidiformes	Mideopsidae		<i>Mideopsis</i> sp.		1	0	0	0	1	
Arachnida	Trombidiformes	Oribatidae	Oribatei			1	0	0	0	1	
Arachnida	Trombidiformes	Oxidae		<i>Oxus</i> sp.		0	0	0	0	0	
Arachnida	Trombidiformes	Sperchonidae		<i>Sperchon</i> sp.		0	0	2	0	2	

**Table 12.** Summary of taxonomic classification and counts of individuals by macroinvertebrate taxon collected from the Pecos River study sites in and upstream of the Amistad National Recreation Area, Texas, 2006.—Continued  
 [USGS, U.S. Geological Survey; Total: Total individuals by taxon for all sites on Pecos River. Sites P1 to P4 are used to define sites on the Pecos River as shown in figure 1]

Class	Order	Family	Tribe	Genus or species	Common name	USGS site identifier and station name				Total
						P1	P2	P3	P4	
						Pecos River at Shumla Bend, Tex.	Pecos River near Langtry, Tex.	Pecos River near Everett Canyon, Tex.	Pecos River at Pandale, Tex.	
						6/27/2006	6/28/2006	6/29/2006	6/22/2006	
Arachnida	Trombidiformes	Torrenticolidae		<i>Torrenticola</i> sp.		0	0	0	0	0
Malacostraca	Amphipoda	Hyalellidae		<i>Hyalella</i> sp.	Amphipods	4	1	10	9	24
Malacostraca	Ostracoda				Ostracods	0	0	11	13	24
Malacostraca	Decapoda	Cambaridae		<i>Procambarus</i> sp.	Crayfishes	0	0	0	0	0
Malacostraca	Decapoda				Nematodes	0	0	1	1	2
Enopla	Hoplonemertea	Tetrastemmatidae		<i>Prostoma</i> sp.	Proboscis worms	0	0	0	0	0
Turbellaria					Flatworms	0	0	7	0	7
Total number of organisms						356	344	325	374	1,408
Total number of unique taxa						26	40	38	40	80

**Table 13.** Selected macroinvertebrate community metrics and indexes from the collection of qualitative multihabitat samples at the study sites along the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area, Texas, 2006.

[USGS, U.S. Geological Survey. sp., species; gr., group; EPT, Combined Ephemeroptera, Plecoptera, and Trichoptera taxa]

Metric	USGS station name (and site identifier) and sample collection date							
	Devils River near Satan Canyon, Tex. (D1) 06/05/2006	Devils River at Pafford Crossing near Comstock, Tex. (D2) 06/06/2006	Devils River near Turkey Bluff Canyon, Tex. (D3) 06/07/2006	Devils River at Dolan Falls, Tex. (D4) 06/08/2006	Pecos River at Shumla Bend, Tex. (P1) 06/27/2006	Pecos River near Langtry, Tex. (P2) 06/28/2006	Pecos River near Everett Canyon, Tex. (P3) 06/29/2006	Pecos River at Pandale, Tex. (P4) 06/22/2006
Dominant taxon	<i>Hyalrella</i> sp.	<i>Fallceon quillieri</i>	<i>Dasyhelea</i> sp.	<i>Hyaella</i> sp.	<i>Caenis latipennis</i>	<i>Microcylloepus</i> sp.	<i>Fallceon quillieri</i>	<i>Tricorythodes</i> sp.
2nd dominant taxon	<i>Procloeon</i> sp.	<i>Dasyhelea</i> sp.	<i>Bezzia/ Palpomyia</i> sp.	<i>Fallceon quillieri</i>	<i>Dasyhelea</i> sp.	<i>Cheumatopsyche</i> sp.	<i>Tricorythodes</i> sp.	<i>Fallceon quillieri</i>
3rd dominant taxon	<i>Tricorythodes</i> sp.	<i>Microcylloepus</i> sp.	<i>Hexacylloepus</i> sp.	<i>Valvata</i> sp.	<i>Tanytarsus</i> sp.	<i>Macrelmis texanus</i>	<i>Macrelmis</i> sp.	<i>Rheotanytarsus exiguus</i> gr.
Metrics								
Number of total unique taxa <sup>1</sup>	34	57	48	56	26	40	38	40
Percent of indivs. as Ephemeoptera <sup>2</sup>	22.97	33.50	11.03	20.05	36.44	26.16	31.08	49.20
Percent of indivs. as Plecoptera <sup>2</sup>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Percent of indivs. as Trichoptera <sup>2</sup>	3.20	9.72	7.18	7.49	7.40	21.80	8.92	7.49
Percent of unique taxa as EPT taxa <sup>2</sup>	26.16	43.22	18.21	27.54	43.84	47.97	40.00	56.68
Percent of indivs. as Coleoptera <sup>2</sup>	.29	17.90	16.92	4.28	1.37	36.92	22.46	8.56
Percent of indivs. as Clitellata <sup>2</sup>	.00	.26	.26	.00	.00	.00	.92	.27
Percent of indivs. as Baetide <sup>2</sup>	14.83	30.69	10.26	14.97	.55	4.65	18.15	17.11
Percent of indivs. as Chironomidae <sup>2</sup>	3.49	12.28	7.44	5.88	30.14	2.62	7.08	19.25
Percent of indivs. as Hydropsychidae <sup>2</sup>	.00	7.67	1.54	.53	.00	19.77	1.23	1.34
Percent of indivs. as Odonata <sup>2</sup>	1.74	1.79	5.64	1.34	1.10	2.04	1.54	1.87
Percent of indivs. as Simuliidae <sup>2</sup>	.00	.26	.00	.27	.00	.00	.00	.54
Number of unique taxa as Coleoptera taxa <sup>1</sup>	1	3	4	4	1	6	5	5

**Table 13.** Selected macroinvertebrate community metrics and indexes from the collection of qualitative multihabitat samples at the study sites along the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area, Texas, 2006.—Continued.

Index	USGS station name (and site identifier) and sample collection date							
	Devils River near Satan Canyon, Tex. (D1) 06/05/2006	Devils River at Pafford Crossing near Comstock, Tex. (D2) 06/06/2006	Devils River near Turkey Bluff Canyon, Tex. (D3) 06/07/2006	Devils River at Dolan Falls, Tex. (D4) 06/08/2006	Pecos River at Shumla Bend, Tex. (P1) 06/27/2006	Pecos River near Langtry, Tex. (P2) (06/28/2006)	Pecos River near Everett Canyon, Tex. (P3) 06/29/2006	Pecos River at Pandale, Tex. (P4) 06/22/2006
Indexes								
Margalef richness (metric) <sup>3</sup>	4.14	6.84	5.56	7.20	3.41	6.03	4.54	5.67
Hilsenhoff biotic index (index)	7.31	5.67	5.69	6.88	5.77	4.92	5.45	5.03
Pielou's J' (index)	0.58	0.73	0.80	0.71	0.68	0.70	0.83	0.74
Simpson's heterogeneity (index)	.72	.89	.92	.86	.82	.88	.93	.87

<sup>1</sup> Number of unique taxa for these metrics determined by summing counts of taxa from each site listed in tables 11 and 12.

<sup>2</sup> Percentages determined by summing number of individuals collected in these taxa or taxa groups as in tables 11 and 12 and dividing by the total number of individuals collected from each site.

<sup>3</sup> Margalef richness was calculated by using aquatic insect taxa only.

Non-insect macroinvertebrate taxa—including freshwater worms, snails, mites, and crayfish—were more common and abundant at the Devils River study sites. Water mites (Trombidiformes) were abundant at the Devils River sites. The larger number of unique macroinvertebrate taxa at the Devils River sites probably relates to the more saline waters of the Pecos River because fewer macroinvertebrate taxa are likely tolerant of the higher salinity levels in the Pecos River compared to those in the Devils River. A more saline environment could be considered a physiological desert for many aquatic macroinvertebrates because of the tendency for water to move from the invertebrate to the environment in response to different osmotic pressures between the two (Ward, 1992). Basket clams (*Bivalvia*) of the genus *Corbicula* sp. were collected at two Devils River sites and three Pecos River sites (tables 11 and 12), and the largest number of this taxon was collected at site P4, the Pecos River at Pandale site (table 12). Collected individuals of this genus were not identified to species, but most likely were the introduced Asian clam, *Corbicula fluminea*. The Asian clam has been collected in the Rio Grande downstream from Amistad Reservoir (International Boundary and Water Commission, 1994) and in the Rio Grande in Big Bend National Park upstream from Amistad Reservoir (Moring, 2002).

The Margalef richness index, which was derived by using the total number of aquatic insect taxa (Ludwig and Reynolds, 1988), was larger at the Devils River sites than at the Pecos River sites (table 13). The Margalef richness index normalizes the number of species present to the number of individuals collected but does not differentiate between those communities that have the same or similar number of species and total individuals (Ludwig and Reynolds, 1988). The Hilsenhoff biotic index was largest at site D1 (Devils River near Satan Canyon site), the site farthest downstream on the Devils River, and smallest at site P2 (Pecos River near Langtry, Tex.), the site second farthest downstream on the Pecos River. The Hilsenhoff biotic index is a community metric that combines species diversity and tolerance characteristics of macroinvertebrate taxa (Hilsenhoff, 1987), and the larger the Hilsenhoff index value, generally the more impaired the macroinvertebrate community. The large Hilsenhoff index values for sites D1 and D4 (the Devils River at Dolan Falls site) were weighted by the comparatively large number of amphipods of the genus *Hyalomma* sp. (table 11) that were collected in these sampling locations. Members of this genus generally score as very tolerant to organic pollution (Plafkin and others, 1989; Texas Commission on Environmental Quality, 2007).

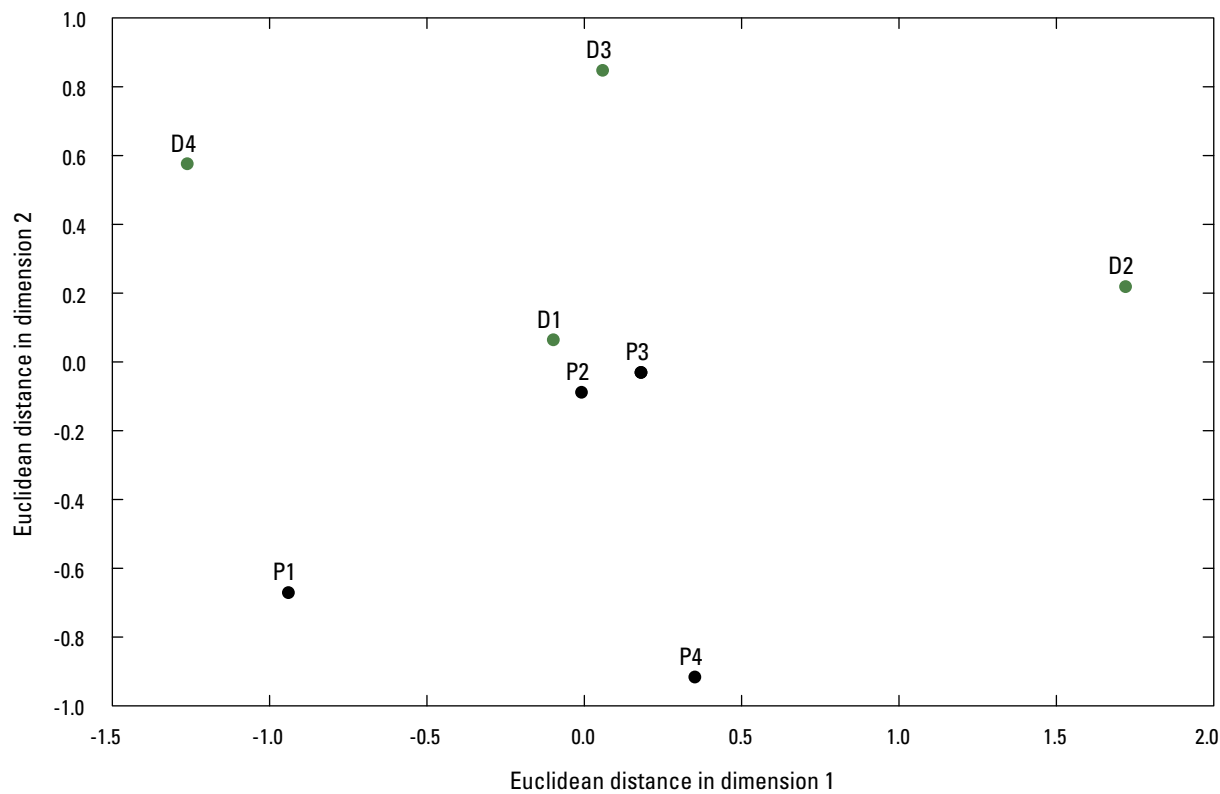
The first dimension in ordination of the NMDS analysis of aquatic insects (the only group of macroinvertebrate organisms used in the NMDS analysis because the sampling method was most favorable for collecting aquatic insects) did not separate the sites in a way that could be explained by the upstream to downstream stream order (fig. 3). The second

dimension in ordination of the aquatic insect community by using NMDS analysis indicates that each site is more similar to the other sites in the same river segment than to any of the sites in the other river segment. Unlike the grouping of fish (which can be readily identified to the species level), the grouping of aquatic insects data and NMDS analysis might be influenced by the lack of resolution of all aquatic insect taxa to the species level because many of the insects collected were in immature larvae or nymph developmental stages that are difficult or impossible to identify to species or even genus by using external morphological characteristics only. Sites may be more or less similar as a result of NMDS analysis if more of the aquatic insects collected could have been identified to a lower taxonomic level such as genus or species.

## Summary

When Amistad Reservoir reached its conservation pool elevation for the first time in 1970, many species of fish native to the Rio Grande and its major tributaries (the Devils and Pecos Rivers) disappeared from the newly impounded sections of these rivers. Of the 65 native species of fish historically documented in what is now the Amistad National Recreation Area, 16 species might have become locally extinct because of the environmental changes caused by the reservoir. In addition to the extirpation of some native fish species, the proliferation of non-native species is a cause for concern. To gain a better understanding of the water quality and status of fish and macroinvertebrate communities, the U.S. Geological Survey (USGS), in cooperation with the National Park Service (NPS) and Amistad National Recreation Area, did a reconnaissance-level survey of selected water-quality constituents and aquatic biota (fish and macroinvertebrates) in the Devils and Pecos Rivers in and upstream from Amistad National Recreation Area during 2005–7.

The reconnaissance-level survey of selected water-quality constituents was done during the spring (March, April, and May) and summer (June and August) of 2005 at sampling sites on the Devils and Pecos Rivers—USGS stations 08449400 Devils River at Pafford Crossing near Comstock, Tex., and 08447410 Pecos River near Langtry, Tex. (sites D2 and site P2, respectively). Water-quality data collected during 2005 were also compared with water-quality data collected as part of the USGS Hydrologic Benchmark Network program during 1978–95 at site D2 and with water-quality data collected as part of the USGS National Stream Quality Accounting Network program during 1974–2007 at site P2. Fish and macroinvertebrate samples were collected during 2006 from the Devils and Pecos Rivers, and fish samples were collected again in 2007 at selected sites on both rivers. Fish and macroinvertebrate samples were collected at sites D2 and P2 and at three additional sites on each river.



EXPLANATION

- D2 ● Sampling site on the Devils River (fig.1)—See table 1
- P2 ● Sampling site on the Pecos River (fig.1)—See table 1

The overall similarity among the fish communities at the eight sampling sites is graphically depicted using Euclidean distances determined from a similarity matrix of common fish taxa between sites, and the distances are displayed in two dimensions that maximizes the separation among sites (Clark and Warwick, 2001).

In N dimensions, the Euclidean distance between two points p and q is

$$\sqrt{\sum_{i=1}^N (p_i - q_i)^2}$$

where

$p_i$  (or  $q_i$ ) is the coordinate of p (or q) in dimension i.

(Black, 2004)

**Figure 3.** Assessment of similarities among macroinvertebrate communities determined by using Non-metric Multi-Dimensional Scaling (first and second dimensions) for aquatic insects collected in 2006 from sampling sites on the Devils and Pecos Rivers in and upstream from the Amistad National Recreation Area, Texas.



The three additional sites on the Devils River where fish and macroinvertebrate samples were collected were USGS stations 293894100582901 Devils River near Satan Canyon, Tex. (site D1); 29774610099501 Devils River near Turkey Bluff Canyon, Tex. (site D3); and 2988810099601 Devils River at Dolan Falls, Tex. (site D4). In addition to site P2, fish and macroinvertebrate samples were collected from the Pecos River at USGS stations 294735101232401 Pecos River at Shumla Bend, Tex. (site P1); 295945101301501 Pecos River near Everett Canyon, Tex. (site P3); and 300737101342201 Pecos River at Pandale, Tex. (site P4). Fish community surveys were repeated in spring 2007 near two sites along the Devils River (sites D2 and D4) and two sites on the Pecos River (sites P2 and P4).

Total dissolved solids (TDS) concentrations were an order of magnitude smaller in samples collected during March–August 2005 at site D2 in 2005 compared to TDS concentrations measured in samples collected during April–August 2005 at site P2. Total dissolved solid concentrations measured at the Devils River site did not exceed the State water-quality standard of 300 mg/L for the Devils River segment, and TDS concentrations measured in the Pecos River at site P2 did not exceed the proposed State water-quality standard for TDS of 4,000 mg/L for the segment of the Pecos River that includes site P2.

Chloride concentrations were an order of magnitude smaller in samples collected at the Devils River site D2 during March–August 2005 compared to those collected at the Pecos River site P2 during the same period, ranging from 11.6 to 12.9 mg/L at site D2, and from 519 to 879 mg/L at site P2. Chloride concentrations in the samples collected from the Pecos River at site P2 during March–August 2005 represent a range of values similar to the interquartile range of 548 to 942 mg/L for chloride concentrations measured in samples collected by the USGS National Stream Quality Accounting Network Program during 1974–2007. Chloride concentrations did not exceed the proposed State water-quality standard of 50 mg/L for the Devils River segment that includes site D2 or the proposed standard of 1,700 mg/L for the Pecos River segment that includes site P2. Sulfate concentrations in water-quality samples ranged from 7.55 to 8.20 mg/L at site D2 and from 298 to 503 mg/L at site P2 in 2005. Sulfate concentrations did not exceed proposed State water-quality standards of 50 mg/L and 1,000 mg/L for the Devils and Pecos River segments, respectively.

In 2005, ammonia plus organic nitrogen concentrations ranged from 0.12 to 0.14 mg/L of nitrogen at site D2 and from 0.15 to 0.32 mg/L of nitrogen at site P2. Ammonia plus organic nitrogen concentrations were within the historical range of concentrations measured in samples by the HBN program during 1978–95 at site D2. The ammonia plus

organic nitrogen concentrations at site P2 in 2005 were generally within the historical range of concentrations reported by the NASQAN program during 1974–2007. Nitrate plus nitrite concentrations ranged from 0.99 to 1.24 mg/L at site D2 and from 0.22 to 1.04 mg/L at site P2 in 2005. Although nitrate plus nitrite concentrations measured in 2005 in samples collected at site D2 were within the historical range of concentrations measured in samples collected by the USGS HBN program during 1978–95, the 2005 concentrations were smaller compared to the historical median concentration (1.4 mg/L). The nitrate plus nitrite concentrations measured in 2005 in samples collected at site P2 generally were within the historical interquartile range of concentrations (0.19 to 0.95 mg/L) measured in samples collected by the USGS NASQAN program. Orthophosphate and total phosphorous concentrations in water were not detected in samples collected in 2005 from sites D2 and P2 at concentrations equal to or larger than the laboratory reporting levels for these constituents.

Selenium concentrations measured in samples collected at site D2 in 2005 ranged from an estimated value of 0.3 micrograms per liter ( $\mu\text{g/L}$ ) to 0.6  $\mu\text{g/L}$ . At site P2, selenium concentrations ranged from 1.0  $\mu\text{g/L}$  to 3.1  $\mu\text{g/L}$  in the 2005 samples. None of the selenium concentrations measured in samples collected during the spring and summer of 2005 from the Devils or Pecos Rivers exceeded Texas Surface Water Quality Standards (chronic criterion of 5  $\mu\text{g/L}$  or the acute criterion of 20  $\mu\text{g/L}$ ) established for the protection of aquatic life.

Water-quality samples collected during March–August 2005 at sites D2 were analyzed for 162 pesticides, and water-quality samples collected during April–August 2005 at site P2 were analyzed for 54 pesticides. No pesticides were reported at concentrations equal to or larger than the laboratory reporting levels at sites D2 or P2.

Among all Devils River sites, 29 species of fish were collected. Of these 29 species, 7 are non-native (introduced), and 22 are native to the Devils River. The number of species collected varied from a minimum of 17 species (2006 sampling only) at the Devils River near Turkey Bluff site to a maximum of 23 species (2006 and 2007 samplings combined) as the Devils River at Pafford Crossing site. More redbreast sunfish were collected than any other species of fish in the Devils River followed by a number of species of minnows (Cyprinidae) including the blacktail shiner and prosperine shiner. Fish species collected in the Devils River that were not found at the Pecos River study sites included the Devils River minnow, sailfin molly, smallmouth bass, spotted bass, and warmouth. The redbreast sunfish, sailfin molly, and smallmouth bass are all introduced species that are not native to the Devils River.

A total of 29 species of fish was collected from the four sites on the Pecos River in and upstream from Amistad National Recreation Area. Six of the 29 species collected are introduced to the Pecos River, and these include the bullhead minnow, common carp, sheepshead minnow, inland silverside, redbreast sunfish, and redear sunfish. The number of fish species decreased about 42 percent between the site farthest upstream and the site farthest downstream on the Pecos River based on a comparison of 2006 sampling results. The most abundant species among the Pecos River sites was the blacktail shiner followed by the red shiner and central stoneroller. The redbreast sunfish, as in the Devils River, was the most common species of sunfish. Fish species collected in the Pecos River that were not collected at study sites on the Devils River included the bullhead minnow, red shiner, smallmouth buffalo, rainwater killifish, and freshwater drum. The percentage of tolerant fish species was larger at the two sites farthest upstream on the Pecos River compared to the two sites farthest upstream on the Devils River. The percentage of non-native or introduced individuals was from two to three times larger at two of the Devils River sites compared to two of the Pecos River sites and was influenced by the relatively large abundance of the non-native redbreast sunfish and smallmouth bass at the Devils River study sites.

The similarity of fish communities was assessed by the number shared species among each of the sites sampled. In this study, Non-metric Multidimensional Scaling (NMDS) was used to determine Euclidean distances between objects by using an input fish species similarity matrix (Bray-Curtis similarity matrix), and these distances were displayed graphically by using two NMDS dimensions. On the basis of the first NMDS dimension, the fish communities from a given site on either the Devils or Pecos Rivers (determined from the species present at the time of collection) were more similar to the fish communities at other sites on the same river than they were to fish communities at any of the sites on the other river. The second dimension of the NMDS (dimension 2 on the y-axis), indicates that between the two rivers, the fish community of any site is most similar to the fish community at the site on the other river that is in the same downstream order.

The difference in fish communities between the study sites on the Devils and Pecos Rivers could be influenced by differences in water chemistry, particularly salinity; differences in zoogeographic history between the two river basins; and the fact that impounded waters of Amistad Reservoir have removed the natural free-flowing fluvial (riverine) connection between the Devils and Pecos Rivers to the Rio Grande. The Pecos River is in backwater conditions at its confluence with the Rio Grande most of the time. Sites

on the Pecos River also are farther from the main body of Amistad Reservoir compared to those on the Devils River, and the distance of the study sites from the reservoir also might influence fish community structure.

Totals of 100 and 80 unique macroinvertebrate taxa were collected in the Devils and Pecos River, respectively. The number of unique macroinvertebrate taxa ranged in the Devils River from 34 at the Devils River near Satan Canyon site to 57 at Devils River at Pafford Crossing site. Considering the sites on both rivers, the largest number of unique macroinvertebrate taxa (57) was from the Devils River at Pafford Crossing site, and the smallest number of unique macroinvertebrate taxa (26) was from the Pecos River at Shumla Bend site. No pattern in the number of unique macroinvertebrate taxa in relation to distance from Amistad Reservoir was observed. Caddisfly (Trichoptera) taxa were less abundant than mayfly (Ephemeroptera) taxa in all study sites. The combined percentage of Ephemeroptera, Plecoptera, and Trichoptera taxa was generally about twice as large in the Pecos River than the Devils River with the exception of the Devils River at Pafford Crossing site. Damselfly and dragonfly taxa (Odonata) were not commonly collected in the Devils and Pecos study sites. Riffle beetles (Elmidae) were the most commonly collected beetle taxon and were the most abundant beetle taxon in numbers of individuals collected at all sites. True midge taxa of the family Chironomidae were the most taxa rich macroinvertebrate taxon overall. Twenty-six unique true midge taxa (genera or species) were collected at the Devil River and Pecos Rivers sites combined. A clam, most likely the introduced Asian clam, was collected at two sites on the Devils River and three sites on the Pecos River. The Margalef richness index, which was derived by using the relative abundance of aquatic insect taxa, was larger at the Devils River sites than at the Pecos River sites. The Hilsenhoff biotic index was largest at site D1 (Devils River near Satan Canyon site), the site farthest downstream on the Devils River, and smallest at site P2 (Pecos River near Langtry, Tex.), the site second farthest downstream on the Pecos River. Non-insect macroinvertebrate taxa—including freshwater worms, snails, mites, and crayfish—were more common and abundant at the Devils River study sites, and amphipods were more abundant at the Devils River sites.

The first dimension in ordination of the NMDS analysis of aquatic insect taxa did not separate the sites in a way that could be explained by the upstream to downstream stream order. The second dimension in ordination of the aquatic insect community by using NMDS analysis indicates that each site is more similar to the other sites on the same river segment than to any of the sites on the other river segment.

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**Appendix 1.    Laboratory recovery of surrogate compounds from four sets analyzed concurrently with water-quality samples from U.S. Geological Survey stations 08449400 Devils River at Pafford Crossing near Comstock, Texas, and 08447410 Pecos River near Langtry, Tex., in the Amistad National Recreation Area, 2005.**

[Values shown in percent. Alpha-HCH, alpha-hexachlorocyclohexanet]

<b>Surrogate compound</b>	<b>Set 1</b>	<b>Set 2</b>	<b>Set 3</b>	<b>Set 4</b>	<b>Average recovery</b>
Diazinon	114.0	93.9	116.0	104.0	106.8
alpha-HCH	88.7	96.9	107.0	93.6	96.6



