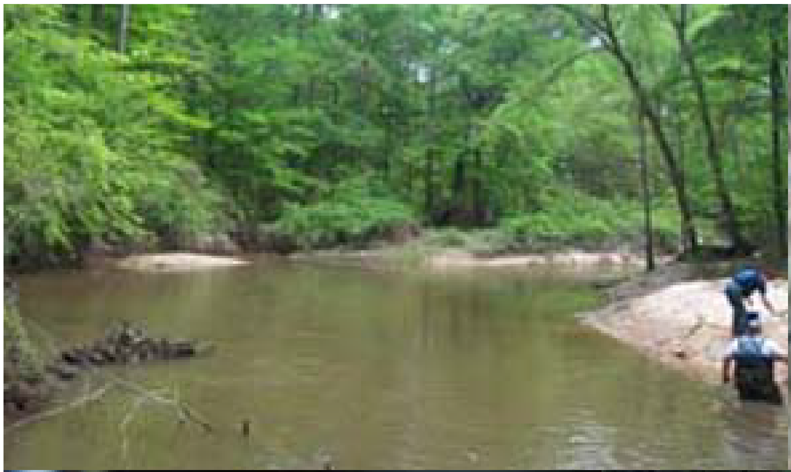
In cooperation with the National Park Service

Baseline Assessment of Fish Communities, Benthic Macroinvertebrate Communities, and Stream Habitat and Land Use, Big Thicket National Preserve, Texas, 1999–2001

Water-Resources Investigations Report 03–4270



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Cover:

Top left: Big Sandy Creek in the Big Thicket National Preserve near Livingston, Texas, 2002.

Top right: Longear sunfish from biological assessment surveys in Big Thicket National Preserve, 2002.

Bottom left: Adult dobsonfly from biological assessment surveys in Big Thicket National Preserve, 2002.

Bottom right: USGS personnel seining fish in Big Sandy Creek as part of fish community surveys during 2002 in Big Thicket National Preserve.

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By J. Bruce Moring

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U.S. DEPARTMENT OF THE INTERIOR

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By J. Bruce Moring

Abstract

The Big Thicket National Preserve comprises 39,300 hectares in the form of nine preserve units connected by four stream corridor units (with two more corridor units proposed) distributed over the lower Neches and Trinity River Basins of southeastern Texas.

Fish and benthic macroinvertebrate data were collected at 15 stream sites (reaches) in the preserve during 1999–2001 for a baseline assessment and a comparison of communities among stream reaches.

The fish communities in the preserve were dominated by minnows (family Cyprinidae) and sunfishes (family Centrarchidae). Reaches with smaller channel sizes generally had higher fish species richness than the larger reaches in the Neches River and Pine Island Bayou units of the preserve. Fish communities in geographically adjacent reaches were most similar in overall community structure. The blue sucker, listed by the State as a threatened species, was collected in only one reach—a Neches River reach a few miles downstream from the Steinhagen Lake Dam.

Riffle beetles (family Elmidae) and midges (family Chironomidae) dominated the aquatic insect communities at the 14 reaches sampled for aquatic insects in the preserve. The Ephemeroptera, Plecoptera and Trichoptera (EPT) Index, an index sensitive to water-quality degradation, was smallest at the Little Pine Island Bayou near Beaumont reach that is in a State 303(d)-listed stream segment on Little Pine Island Bayou. Trophic structure of the aquatic insect communities is consistent with the river continuum concept with shredder and scraper insect taxa more abundant in reaches with smaller stream channels and filter feeders more abundant in reaches with larger channels. Aquatic insect community metrics were not significantly correlated to any of the stream-habitat or land-use explanatory variables. The percentage of 1990s urban land use in the drainage areas upstream from 12 bioassessment reaches were negatively correlated to the reach structure index, which indicates less stable habitat for aquatic biota.

INTRODUCTION

Often described as the "biological crossroads" of North America, the Big Thicket National Preserve is an important holding of the National Park Service (NPS) because of its biological diversity and unique geographic distribution. The preserve's 39,300 hectares (97,000 acres) are a highly fragmented land base of nine preserve units connected by four established and two proposed stream corridor units (fig. 1). The riparian corridor units consist of black-water streams that provide critical ecological linkages to the otherwise isolated units of the preserve. These waters represent the western distributional limit for several aquatic invertebrates (Abbot and others, 1997) and contain a diverse assemblage of rare aquatic fauna. The preserve contains many Federal listed "Species of Concern," including the paddlefish (a large planktonic-feeding fish), Texas heelsplitter (a freshwater mussel), and two species of aquatic insects, *Somatochlora margarita* (a dragonfly), and *Phylocentropus harrisi* (a caddisfly). The State of Texas lists several more species as "threatened" or

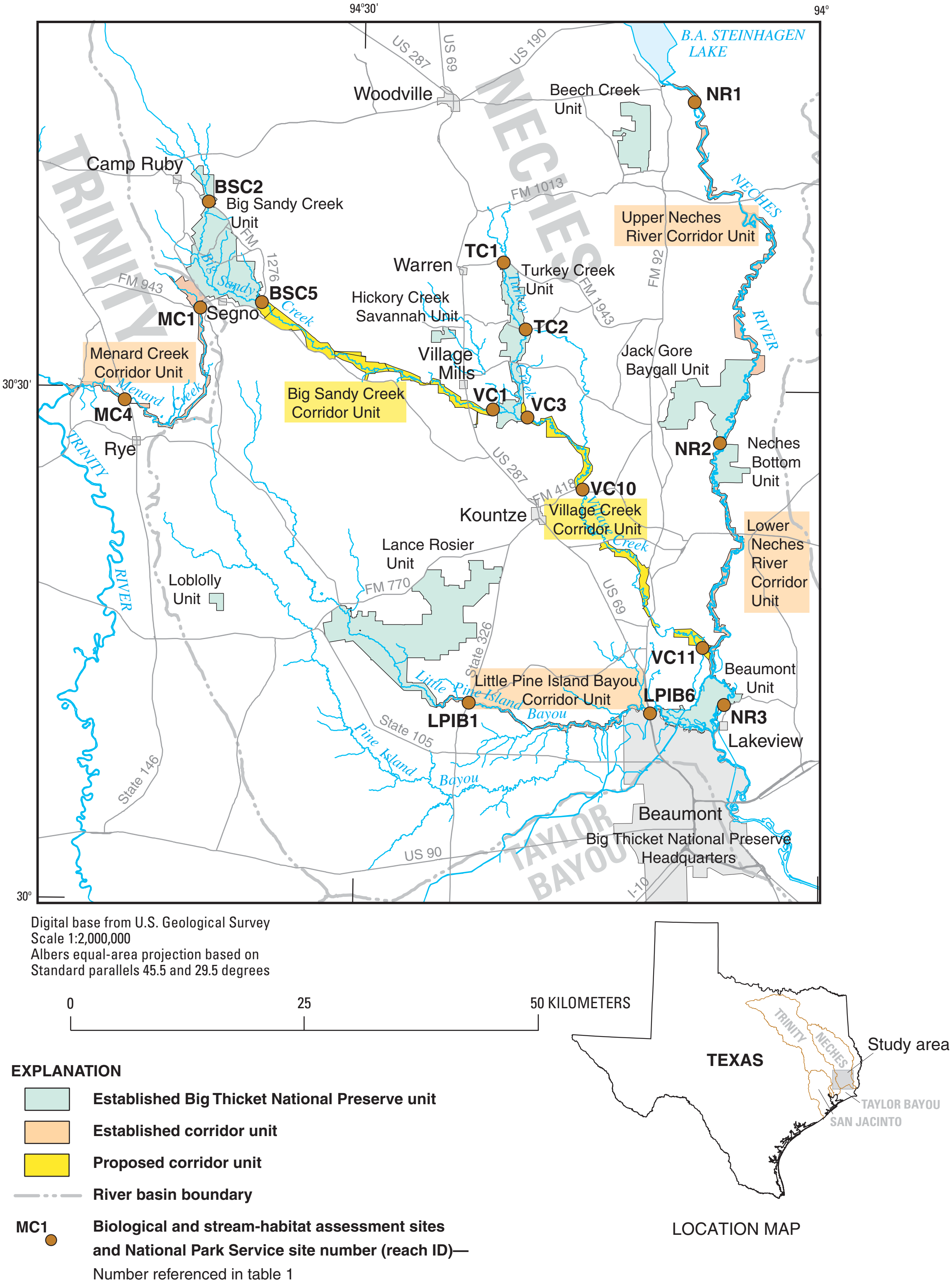


Figure 1. Locations of biological assessment sites (reaches) and study area, Big Thicket National Preserve, Texas, 1999–2001.

“endangered” (Texas Parks and Wildlife Department, 2003). These include two fish, the blue sucker and creek chubsucker, and the world’s largest freshwater turtle, the alligator snapping turtle.

The preserve land base includes 1,030 kilometers of boundary, more than Yellowstone National Park. The water resources of the preserve are sensitive to land uses in those areas outside of the preserve that drain into the streams and wetlands of the preserve. Most of the land surrounding the preserve is owned by private timber companies, and timber-harvesting practices on these lands have the potential to influence water quality through sedimentation, increased stream temperature, and the runoff of fertilizers and herbicides (Harcombe, 1996).

Although timber production is the dominant land use adjacent to the preserve, a trend of increased urbanization and industrialization is emerging. Regional decline in dissolved oxygen concentrations has been documented (Hall and Bruce, 1996). Two stream segments in the preserve, Little Pine Island Bayou (Segment 0607B) and Pine Island Bayou (Segment 0607) have been listed on the State 303(d)[1] list for not meeting aquatic-life use criteria because of low dissolved oxygen concentrations (Texas Commission on Environmental Quality, 2002).

Industrial point-source contaminants also influence water quality in the preserve. In 1986 and 1987, the U.S. Environmental Protection Agency documented toxic levels of dioxin in fish-tissue samples from the Lower Neches River Corridor Unit in the Big Thicket National Preserve (fig. 1). The dioxin source was traced to a pulp mill that discharges into the Neches River. The Texas Department of Health (TDH) issued a fish consumption advisory, which remained in effect until 1996. TDH continues to monitor this section of the Neches River, but sampling is infrequent (Harcombe, 1996).

Another source of contaminants is from active and abandoned oil and gas operations in and adjacent to the preserve. Oil and gas operations produce a variety of potential contaminants including excess sediments, biocides, oil, and brine. Historically, oil and gas operations have been the most important nonpoint-source influence on water quality in the preserve. In 1981, an oil spill adjacent to the Turkey Creek Unit flowed into a nearby tributary and eventually into the preserve. Although the spill was quickly contained, it almost extirpated the benthic macroinvertebrate community along a large section of stream (Harrel, 1985). More recently, innovations in three-dimensional seismic surveying technology and the economic incentives of increased gas prices have spawned an expansion of oil and gas exploration throughout the preserve. When the Big Thicket National Preserve was established, the U.S. Congress mandated that oil and gas operations would continue. Today (2001) there are 27 active oil and gas operations and 43 trans-park pipelines in the preserve (Roy Zipp, National Park Service, written commun., 2000).

To help guide management of running waters in the preserve, a variety of efforts related to collecting baseline water-quality information have been done since the inception of the preserve. The National Park Service sponsored several studies by outside researchers to collect baseline water-quality data at fixed monitoring stations (Harrel, 1976; Harrel and Darville, 1977, 1978; Harrel and Bass, 1979; Harrel and Commander, 1980, 1981). In 1984, preserve staff began monitoring water quality at fixed locations throughout the preserve (Flora, 1984). Baseline water-quality monitoring continues today (2001). However, missing in this water-quality-monitoring approach is an assessment of the status of aquatic biota that includes fish and benthic macroinvertebrates. The management of water resources can be improved if biological indexes that incorporate easily quantified and understood results of biological monitoring are used as a direct measure of water quality (Karr and others, 1986).

In recognition of the value and importance of baseline data on aquatic biota in the preserve to supplement traditional water-quality monitoring, the U.S. Geological Survey (USGS) and the NPS formed a water-quality-monitoring partnership in 1999. As a result, the USGS, in cooperation with the NPS, conducted a study to establish benchmark biological monitoring stations at 15 sites throughout the preserve from which to assess baseline biological conditions in streams and to supplement historical and ongoing water-quality monitoring at these sites. Fish community data were collected once in 1999 at 15 sites and again

[1] The State of Texas Clean Water Act 303(d) list comprises surface-water bodies in Texas identified by the Texas Commission on Environmental Quality as impaired (do not meet applicable water-quality standards) or threatened (are not expected to meet applicable water-quality standards in the near future). Section 303(d) of the Federal Clean Water Act (together with related regulations) requires each State to assess the quality of its surface waters and to develop water-quality improvement strategies for impaired and threatened waters.

in 2001 at eight sites. Benthic macroinvertebrate data also were collected in 1999 at 14 sites and again in 2001 at seven of the same eight sites. Stream-habitat conditions at each site and 1970s and 1990s land-use characterizations in the drainage area upstream from each site were assessed with regard to their effect on biological variables.

The USGS and the NPS expanded on the initial biological assessments of 1999. Continued biological monitoring was needed to account for the inherent spatial, seasonal, and life cycle variability of aquatic communities. An expanded assessment was needed for several reasons, which include the (1) proposed addition of two new stream corridor units in the preserve (fig. 1) and a lack of baseline information for these units; (2) regional decline in water quality noted previously; (3) increased population growth and urbanization in the surrounding watersheds; (4) intensive forestry practices and documented noncompliance with forestry best management practices (Roy Zipp, National Park Service, written commun., 2000); (5) increased levels of oil and gas exploration and anticipated development throughout the preserve and adjacent areas; and (6) unknown status and trends of many rare, threatened, and endangered aquatic species.

Specific objectives of this study were to

1. Provide the preserve with detailed baseline data and information on the status of aquatic biota including fish and benthic macroinvertebrates (primarily aquatic insects) and information on stream habitat and land use at the network of 15 USGS benchmark bioassessment sites.
2. Complete seasonal fish and benthic macroinvertebrate community assessment at eight primary sites to improve the accuracy of data on taxa composition and relative abundance for these communities.
3. Determine land uses in the drainage area upstream from each of the 15 benchmark sites for the 1970s and 1990s and the percentage changes during the intervening years.

Purpose and Scope

The purpose of this report is to present the methods of and findings from the biological assessment at 15 benchmark bioassessment sites (stream reaches) in the Big Thicket National Preserve during 1999–2001. Comprehensive fish and benthic macroinvertebrate (primarily aquatic insect) taxonomic data collected in the reaches are tabulated. Statistical and graphical techniques are used to compare fish and benthic macroinvertebrate communities among the reaches. In addition, the relation of the community structure of aquatic biota to stream-habitat conditions and changes in land use in the preserve is briefly addressed.

Acknowledgments

The author thanks the NPS staff of the Big Thicket National Preserve. In particular, Roy Zipp, Natural Resource Specialist with the preserve from 1997 to 2001, assisted with many phases of the project—proposal, project planning and logistics, and field activities.

METHODS OF ASSESSMENT

Geographic Scope and Stream Reach Selection

The study area comprises four preserve units and five corridor units in the Big Thicket National Preserve. Five of the 15 assessment sites are in preserve units, and 10 are in corridor units (fig. 1, table 1). Thirteen of the 15 sites are in the lower Neches River Basin, and two are in the Trinity River Basin (fig. 1). Assessment sites were selected using 7.5-minute USGS topographic maps, digital orthophoto quadrangles, and on-site reconnaissance. Selection was based on the collocation of assessment sites with existing preserve water-quality monitoring sites. For corridor units, emphasis was on the upstream-to-downstream pairing of sites within a corridor unit and the need to provide spatial coverage to sample the majority of preserve and corridor units. Stream size or above-site drainage area was not used as a site selection criterion.

At each assessment site, a sampling reach was selected. The selection criteria for a reach were: (1) the reach could not be within 100 meters downstream from a highway bridge or other in-channel structure; (2) the reach had to be entirely within the Big Thicket National Preserve; (3) the reach had to be at least one full meander in channel length or a minimum of 20 times the wetted channel width; and (4) if the reach was one full meander in channel length, it had to contain at least two of three types of geomorphic channel units—riffles, runs, or pools (Meador and others, 1993). The upstream and downstream boundaries of each reach were marked with permanent monuments and georeferenced by recording

Table 1. Reach ID, name, and location and sampling schedule of fish, benthic macroinvertebrates, and stream-habitat conditions for 15 bioassessment reaches in the Big Thicket National Preserve, Texas, 1999–2001

[NS, not sampled]

Reach ID (preserve or corridor unit; fig. 1)	Reach name	Coordinates for down-stream boundary monument	Fish and benthic macro-invertebrates collected summer 1999	Stream-habitat assessment spring 1999	Fish and benthic macro-invertebrates collected spring and summer 2001
BSC2 (preserve)	Big Sandy Creek at Hwy. 1276 near Camp Ruby, Texas	N 30°40'17" W 94°41'12"	+	+	NS
BSC5 (corridor)	Big Sandy Creek at Hwy. 1276 near Dallardsville, Texas	N 30°34'36" W 94°37'41"	+	+	+
LPIB1 (corridor)	Little Pine Island Bayou at Hwy. 326 near Sour Lake, Texas	N 30°11'21" W 94°23'41"	+	+	NS
LPIB6 (corridor)	Little Pine Island Bayou at Hwy. 69 near Beaumont, Texas	N 30°10'46" W 94°11'11"	+	+	+
MC1 (corridor)	Menard Creek at Hwy. 943 near Segno, Texas	N 30°33'40" W 94°42'05"	+	+	NS
MC4 (corridor)	Menard Creek at Hwy. 146 near Rye, Texas	N 30°28'54" W 94°47'16"	+	+	NS
NR1 (corridor)	Neches River below Steinhagen Lake	N 30°44'54" W 94°07'45"	+	+	+
NR2 (preserve)	Neches River below Steinhagen Lake in Jack Gore Unit	N 30°24'40" W 94°07'08"	+	+	NS
NR3 (preserve)	Neches River in Beaumont Unit near Beaumont, Texas	N 30°12'60" W 94°07'03"	+	+	+
TC1 (preserve)	Turkey Creek on Hwy. 1943 near Warren, Texas	N 30°37'11" W 94°21'29"	+	+	NS
TC2 (preserve)	Turkey Creek on Hester Bridge Road near Warren, Texas	N 30°33'06" W 94°19'58"	+	+	+
VC1 (corridor)	Village Creek on Mustang Trail near Village Mills, Texas	N 30°28'23" W 94°21'53"	+ (fish only)	+	+ (fish only)
VC3 (corridor)	Village Creek on McKinney Bridge Road near Village Mills, Texas	N 30°27'60" W 94°19'21"	+	+	+
VC10 (corridor)	Village Creek on Hwy. 418 near Kountz, Texas	N 30°23'53" W 94°15'56"	+	+	NS
VC11 (corridor)	Village Creek near confluence with Neches River	N 30°14'31" W 94°07'14"	+	+	+

a latitude and longitude for each monument using a hand-held global positioning system (GPS). For those reaches with geomorphic channel units, four transects (each one corresponding to a geomorphic channel unit) also were marked with monuments and georeferenced using the hand-held GPS. Monuments were constructed by driving into the ground 30- by 1.25-centimeter reinforcement-bar stakes and attaching to the top of each an aluminum surveyor’s cap stamped with “USGS.”

Fish Community Assessment

The fish community in each reach was sampled once in summer 1999 (table 1). In addition, the fish community at each of eight reaches was sampled once in spring 2001 and again in summer 2001, to account for seasonal differences in fish distribution and water temperature in the stream. Preserve and USGS staff selected the eight reaches for more intensive assessments that were considered the most important on the basis of historical and ongoing water-quality assessments by the preserve.

Various electrofishing and netting techniques were used to assess fish community composition and structure (Meador and others, 1993; Moring, 2002). Barge electrofishing equipment was used to sample the fish community in each reach. Two electrofishing passes were made per reach, and the time in seconds that the electrofishing unit was operated was recorded to monitor sampling effort. A 7.5- by 3-meter seine (0.64-centimeter mesh) was used to supplement electrofishing sampling, particularly in riffles. At least one seine-haul was completed in each type of geomorphic channel unit present in the reach.

All collected fish were identified to species, and total and standard lengths in millimeters and total weight in grams were recorded (Meador and others, 1993). All minnows and other problematic taxa were fixed in 10-percent buffered formalin and returned to the USGS office in Austin, Tex., for identification. Fish specimens that were difficult to identify and those specimens that required a verification of identification were sent to ichthyologist Dr. Dean Hendrickson, Texas Memorial Museum at the University of Texas, for final identification and permanent storage.

Benthic Macroinvertebrate Community Assessment

Benthic macroinvertebrate samples were collected at 14 of the 15 sampling reaches (table 1) using reach-based compositing methods developed by the USGS National Water-Quality Assessment (NAWQA) program (Cuffney and others, 1993; Moring, 2002). One reach, Village Creek on Mustang Trail near Village Mills (VC1), was not sampled for benthic macroinvertebrates because of budgetary constraints and because of its proximity to the Village Creek on McKinney Bridge Road near Village Mills (VC3) reach. The USGS and NPS assigned higher priority for benthic macroinvertebrate sampling to VC3. Two sample types, a richest targeted habitat (RTH) and a qualitative multi-habitat (QMH) were collected in each reach in summer 1999. Spring RTH and QMH samples and summer RTH and QMH samples also were collected in 2001 in the seven of eight reaches where fish communities were sampled in 2001. As with fish, sampling of benthic macroinvertebrates in two seasons was done to account for differences in species life stages and, consequently, to increase the ability to identify taxa to the lowest taxonomic level. Multiple generations of benthic macroinvertebrates can be collected at the same time in the temperate waters of streams in the Big Thicket National Preserve. Therefore, the two seasonal samplings were done to improve the accuracy of species composition and relative abundance for these reaches.

Five RTH samples were collected in each reach and composited. Each RTH sample was taken by selecting five sampling locations distributed between two or more geomorphic channel units in the reach (for reaches with one full meander). At each of the five sampling locations, a woody snag was located, and a submerged limb of at least 5 centimeters in diameter was selected from the snag for sampling. The limb was held in a Surber sampler with a 425-micron mesh net with a 425-micron dolphin plankton bucket attached to the end of the net. The net was oriented with the mouth directed upstream, and the limb was brushed for 60 seconds to dislodge organisms into the net. The contents of the net and plankton bucket were rinsed into a 19-liter bucket, processed through a 425-micron sieve to remove entrained organic and inorganic debris, placed in a 1-liter polypropylene jar, and fixed with 10-percent buffered formalin (Cuffney and others, 1993).

A QMH sample was collected in each reach by using a 205-micron mesh d-frame net. Multiple habitats in the reach were sampled including riffles, runs, margins of pools, undercut banks, and in stands of aquatic macrophytes in an attempt to collect taxa not expected to be represented by the RTH sample. The QMH sample also was collected to augment the taxa composition or taxa list for each reach. Contents of the d-frame net were placed in a 19-liter bucket, field-processed through a 205-micron mesh sieve, transferred to a 1-liter jar, and fixed with 10-percent buffered formalin.

All benthic samples were shipped to a contract laboratory (Ecoanalysts, Inc., Moscow, Idaho) for identification and enumeration of taxa. If a sample had 500 or fewer organisms, all the organisms in the sample were sorted, counted, and identified. If the sample contained more than 500 organisms, then a 500-count

Table 2. Description of stream-habitat measures and land-use variables for 15 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001

[Land use refers to land use in contributing drainage area above downstream boundary of each reach; GIRAS, Geographic Information and Retrieval Analysis System; NLCD 92, National Land Cover Data 92; --, not applicable]

Stream habitat		Land use	
Measure	**Description of measure**	**Variable**	**Description of variable**
Linear reach length (meters)	Straight-line distance from mid-channel of upstream reach boundary to downstream boundary	Drainage area (square kilometers)	Area within subbasin boundary upstream from the reach
Curvilinear reach length (meters)	Distance from boundary to boundary following channel thalweg	Percentage urban land use (1970)	GIRAS Level II urban land-use data from 90-meter cells
Reach sinuosity	Ratio of curvilinear distance to linear distance	Percentage urban land use (1990s)	NLCD 92 Level II urban land-use data from 30-meter cells
Reach slope	Measured as slope from mid-channel elevation of streambed from upstream to downstream boundary	Percentage agricultural land use (1970s)	GIRAS Level II agricultural land-use data from 90-meter cells
Reach structure index	Ratio of frequency of in-channel structure such as snags and undercut banks to curvilinear reach length	Percentage agricultural land use (1990s)	NLCD 92 Level II agricultural land-use data from 30-meter cells
Bank slope	Slope of bank from thalweg to high-bank terrace	Percentage forest land use (1970s)	GIRAS Level II forest land-use data from 90-meter cells
Wetted channel width (meters)	Distance from left bank water's edge to right bank water's edge along each transect	Percentage forest land use (1990s)	NLCD 92 Level II forest land-use data from 30-meter cells
Bank-full channel width (meters)	Distance from high-bank terrace to high-bank terrace along each transect	Percentage change for each land use from 1970s to 1990s	Absolute difference in land use between 1970s and 1990s for each Level II land-use category
Channel incision	Ratio of bank height divided by bank-full width	--	--
Bank height (meters)	Bank height from channel thalweg to bank-full terrace.	--	--

subsampling routine was used (Lester, 1999). With the exception of some midges and non-insect macroinvertebrates, all taxa were identified to genus. A reference collection with at least one specimen of each taxon identified was provided to the USGS by the contract laboratory.

Stream-Habitat Assessment

Characterization of channel and riparian-zone habitat features (Fitzpatrick and others, 1998; Moring, 2002) can include depth, velocities, bed and bank substrates, and type, frequency and extent of geomorphic channel units (riffles, runs, and pools). Several reach-based and within-reach transect-based measures were taken (table 2). Four channel cross sections extending from the right bank high-bank terrace to the left bank high-bank terrace were selected in each reach (corresponding to the four geomorphic channel units in reaches with one full meander). Many researchers have suggested up to 11 transects per reach (Fitzpatrick and others, 1998). However, for the study described in this report, the selection of four cross sections in each reach was assumed to be sufficient to characterize channel morphology and therefore, variability in stream velocity, depth, and substrate types and distribution. All but one reach, Little Pine Island Bayou (LPIB6), were one full meander in length, with a pair of point bars alternating on each bank. Four cross sections were assumed to be sufficient to characterize gross channel morphology because of the uniformity of the channels for the majority of reaches. In addition, all 15 sites are on low-gradient streams, which facilitates the selection of one full meander of channel length. This approach helped to standardize the reaches among sites for comparison.

A Sokia Leitz™ Set 4A laser-operated total station was used to survey all transects and the entire reach to provide the data needed for many of the reach habitat measures. All survey data were stored on-site in a data logger that was electronically linked to the total station. The data were imported into an electronic spreadsheet and sorted, and computations were done to determine linear reach length, curvilinear reach length, bank height, bank width, bank slope, wetted channel width, and mean depth.

Land-Use Characterization

Land use was characterized for each contributing subbasin upstream from the downstream boundary of each reach. Sixty-meter digital elevation models (DEMs) that were re-sampled from 30-meter DEMs were used to delineate each subbasin for the computation of drainage area. The 1970s land-use data were obtained from the Geographic Information Retrieval and Analysis System (GIRAS) (U.S. Geological Survey [1973–80]), and includes land-use data from 1973 to 1980. The GIRAS 1:250,000-scale blocks used for land-use characterization overlap within the majority of the above-reach drainages. The 1973–80 land-use data will be referred to hereinafter as the 1970s land-use data. The 1990s land-use data were obtained from a USGS dataset called National Land Cover Data 1992 (NLCD 92) (Vogelmann and others, 2001), which was derived from early to mid-1990s Landsat Thematic mapper satellite data. For this report, Anderson Level I and Level II land-use categories including barren, forested, urban or built-up, range, water, and wetland were compared using geographic information system (GIS) technology to yield positive or negative percentage changes in these land uses between the 1970s and 1990s. Percentage changes in selected land-use variables (table 2) were used to explain differences in biological communities or stream-habitat conditions.

Data Management and Analysis

All field data were recorded on waterproof data forms in the field. Recorded data included site name and description, individuals collecting the sample, date and time, weather conditions, sample identification (ID) and description, and any pertinent comments about the reach or sampling effort. Field data forms were reviewed in the field for accuracy and completeness, and a final review was done at the USGS office in Austin, Tex.

After review, all data were keyed into a spreadsheet pending data analysis. Hard copies of the data were printed and filed with the field data forms for each reach. All data were archived in the USGS office in Austin. Benthic macroinvertebrate identification and enumeration data were received from the contract laboratory in a spreadsheet format and stored along with other digital data for the project.

All statistical analyses were done with the Statistica® software package (StatSoft, 1998). Cluster analysis was used to compare overall similarities among fish communities and among benthic macroinvertebrate communities by reach. Cluster analysis is a classification technique that groups like entities (fish or benthic macroinvertebrate communities by reach in this application) into clusters. Similarity among communities by reach is quantified in terms of "linkage distance" (Ludwig and Reynolds, 1988), which can be shown graphically—the more similar the communities in two reaches, the smaller the linkage distance.

The number of fish or invertebrate species collected can be influenced by the number of individuals collected. For two streams of similar size, the number of species generally is proportional to the number of individuals collected but declines asymptotically with increased sampling until no new species are collected with repeated samplings (Nielsen and others, 1989); therefore, unless the asymptote is quantified, the number of individuals collected can introduce bias into the interpretation of biological diversity indexes or other metrics (Ludwig and Reynolds, 1988). In the field effort for the study described in this report, no attempt was

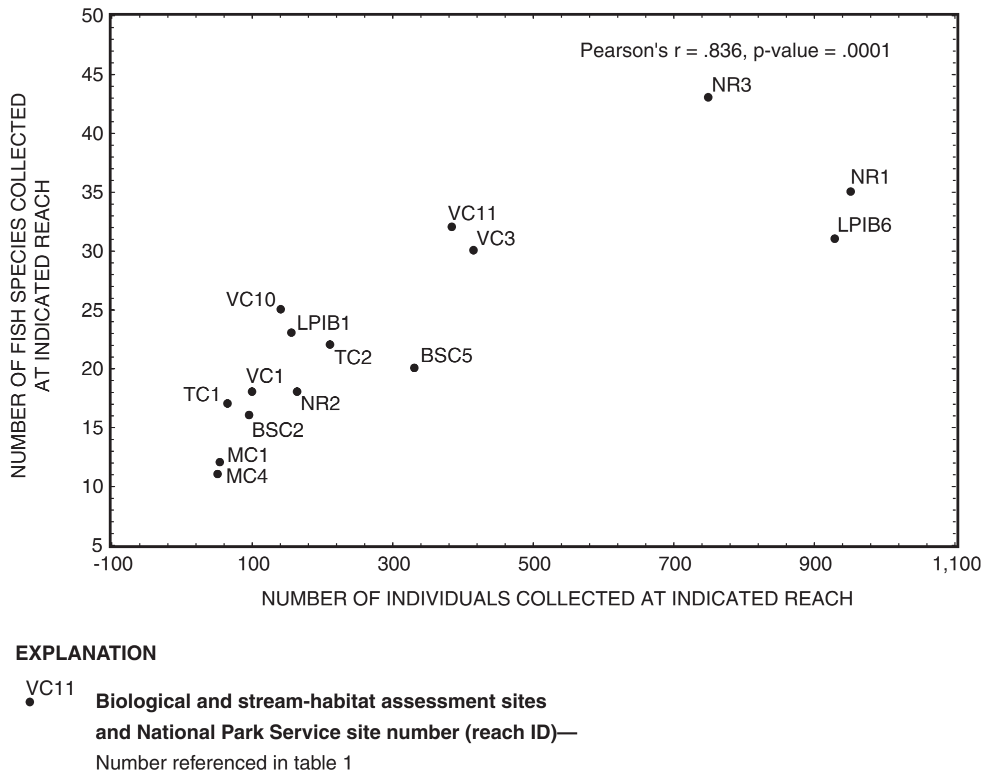


Figure 2. Number of fish species collected relative to number of individuals collected for 15 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001.

made to quantify the asymptote of species richness in any of the reaches. The number of individual fish collected was positively correlated with the number of species (fig. 2) in each reach (Pearson's r = .836, p-value = .0001). Therefore, a technique was required to remove the influence of sample size on the number of species collected.

To remove the influence of fish and invertebrate sample size among reaches, the number of individuals of each species was converted to a "1" or "0" to indicate the presence (1) or absence (0) of a species from the reach. These presence-absence data were used in the cluster analysis to compare the fish and invertebrate community similarity among the 15 reaches.

Another measure of species for comparison among reaches that avoids sample-size bias is Menhinick's species richness (Menhinick, 1964). Menhinick's richness was computed for each reach by dividing the number of species in the reach by the square root of the number of individual fish or invertebrates collected.

Principal components analysis was used as a variable reduction technique to determine those stream-habitat and land-use variables that explain the largest amount of variation among reaches, and in turn, compare those physical variables to selected biological variables using correlation. Principal components analysis is a multivariate statistical technique (Ludwig and Reynolds, 1988) that quantifies the amount of variation (among reaches in this application) explained by each variable in terms of "factor loadings." Stream-habitat and land-use variables (table 2) with factor loadings greater than 0.7 were compared with total number of fish species, total number of aquatic insect species (or genus), and Menhinick's species richness using correlation.

Stream-habitat variables also were compared using correlation with land-use variables to identify those stream-habitat variables, if any, that could be significantly correlated with particular land-use characteristics.

BASELINE ASSESSMENT

Fish Communities

Sixty-eight species of fish were collected among the 15 reaches during 1999–2001 (table 3, at end of report). A total of 4,818 individual fish were collected. Minnows (family Cyprinidae) were the most abundant group with 1,433 individuals collected among the 15 reaches. Of the minnows, the blacktail shiner (*Cyprinella venusta*) was the most frequently collected species (644 individuals). Minnows typically are the most abundant group or family of fishes in streams. They commonly are collected in large numbers with a variety of collection techniques because of the schooling behavior of many species, including the blacktail shiner. The longear sunfish (*Lepomis megalotis*) of the Centrarchidae family was the most frequently collected of all species (761 individuals). The tarpons, family Elopidae, were the least abundant group with seven individuals collected, all of one species, ladyfish (*Elops saurus*). Ladyfish and other tarpons are marine or estuarine species and are not commonly collected in freshwater streams. Four blue suckers (*Cycleptus elongatus*) were collected, all within the reach Neches River below Steinhagen Lake (NR1). The blue sucker is difficult to collect because of its habitat preference for the bottom of deep, fast moving rivers and channels. The blue sucker is listed by the State of Texas as a threatened species and is a "current-loving" or rheophilous species. The four blue suckers were collected in a higher-gradient section of the Neches River in the tailwaters of the Steinhagen Lake Dam. Common carp (*Cyprinus carpio*), an introduced species, was collected in only one reach, Menard Creek at Hwy. 146 near Rye (MC4).

The most fish species (43) were collected in the most downstream Neches River reach, the Neches River in the Beaumont Unit near Beaumont (NR3). This reach is only several kilometers upstream from the tidal break in the Neches River, and several species including ladyfish and atlantic needlefish (*Strongylura marina*) were collected more frequently in this reach than other reaches. In addition, this Neches River reach is longer and wider than the other reaches, and fish species richness generally increases with increasing channel size or stream order (Vannote and others, 1980). The least number of fish species were collected at the two Menard Creek reaches, 12 at Menard Creek at Hwy. 943 near Segno (MC1) and 11 at Menard Creek at Hwy. 146 near Rye (MC4).

The cluster analysis to determine fish community similarity among reaches showed that reaches clustered according to their geographic proximity and that the smaller reaches typically were more similar in overall fish community structure than the larger reaches, with a few exceptions (fig. 3). The two Trinity River Basin reaches, MC1 and MC4, were most similar in species composition. The Little Pine Island Bayou at Hwy. 326 near Sour Lake, Tex. (LPIB1) reach did not cluster with the other reach in the same subbasin, Little Pine Island Bayou at Hwy. 69 near Beaumont, Tex. (LPIB6). Among sites on the same reach, the Neches River reaches had the largest linkage distance (4.45) and, therefore, the least similarity. NR1 and NR3 are more than 48 river kilometers apart, and the more downstream reach, NR3, had several marine or estuarine fish species that the upstream reaches (NR1 and NR2) did not.

Menhinick's species richness ranged from a minimum of 1.016 at Little Pine Island Bayou reach LPIB6 to a maximum of 2.097 at Village Creek reach VC10 (fig. 4). The small richness at Little Pine Island Bayou LPIB6 is influenced by the fact that 47 percent of the individual fish collected at the site were two species of shad, the threadfin shad (*Dorosoma petenense*) and the gizzard shad (*Dorosoma cepedianum*). Shad are pelagic filter feeders, and LPIB6 is a relatively deep channel with little current or in-channel structure such as snags or undercut banks that are characteristic of Village Creek reach VC10 and other reaches that had comparatively larger species richness. The occurrence of snags and other in-channel structure can result in higher species richness because of the variety and greater volume of habitat present.

Another way to assess fish community structure is to compare the relative abundance of major fish families among sampling sites (fig. 5). Relative abundance is less than 100 percent in figure 5 because several families with low relative abundance were omitted. Minnows (family Cyprinidae) and sunfishes (family Centrarchidae) dominated the relative abundance among the 15 reaches. Centrarchid relative abundance was dominated by the longear sunfish (*Lepomis megalotis*), bluegill (*Lepomis macrochirus*), spotted bass (*Micropterus punctulatus*), and largemouth bass (*Micropterus salmoides*). Centrarchids generally had a higher relative abundance in smaller channels such as LPIB1 where there is more in-channel structure in relation to total reach area compared to that of the larger reaches in the Neches River. The total number of

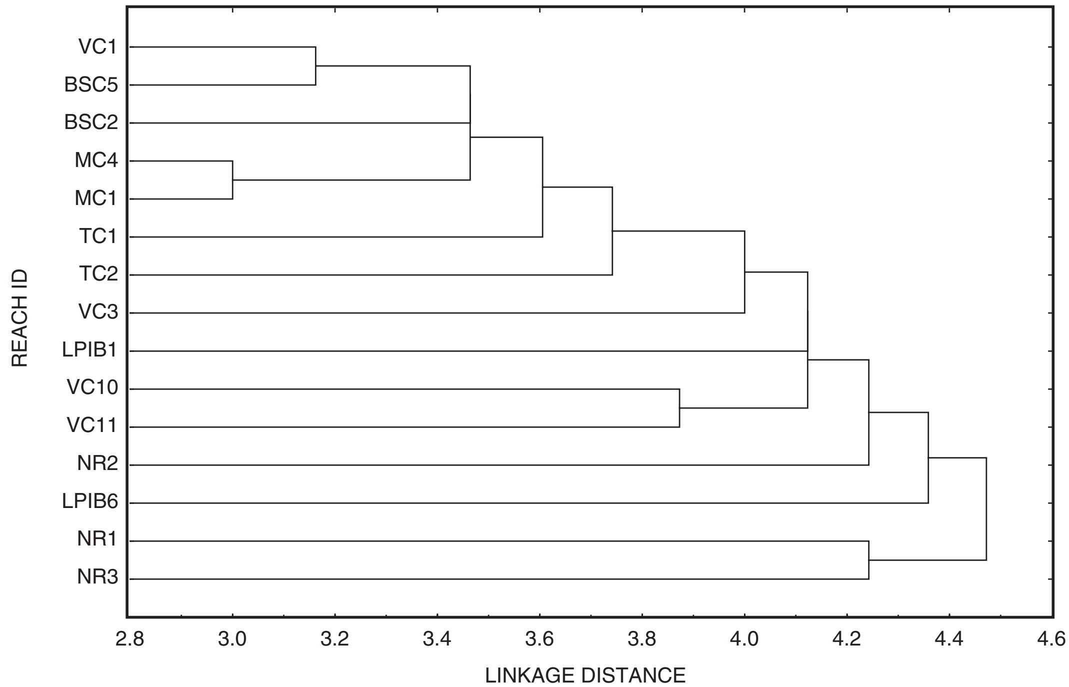


Figure 3. Results of cluster analysis to indicate similarity of fish communities for 15 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001.

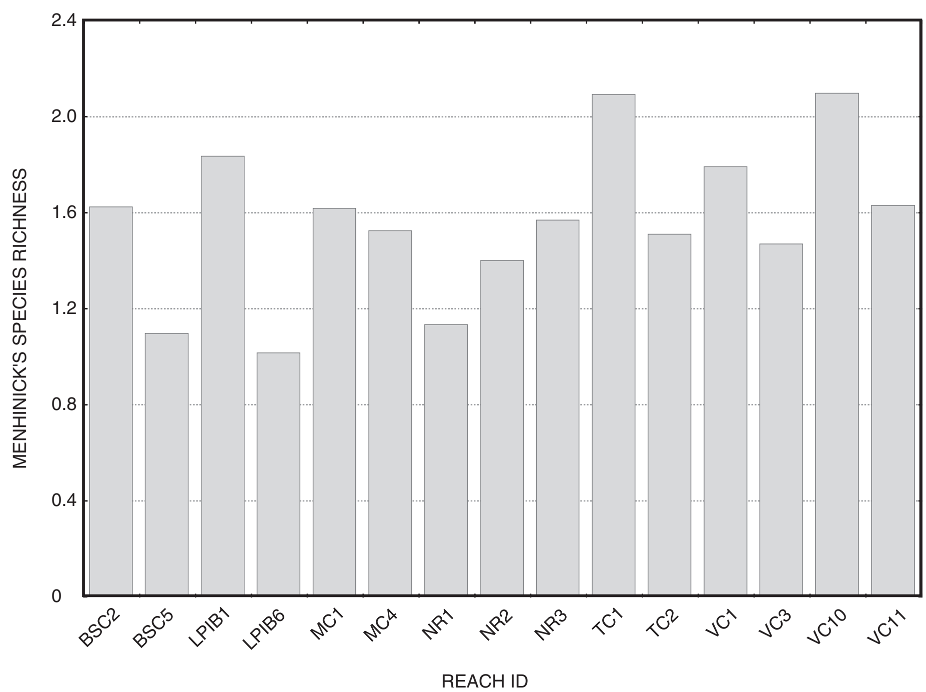


Figure 4. Menhinick's species richness for fish communities from15 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001.

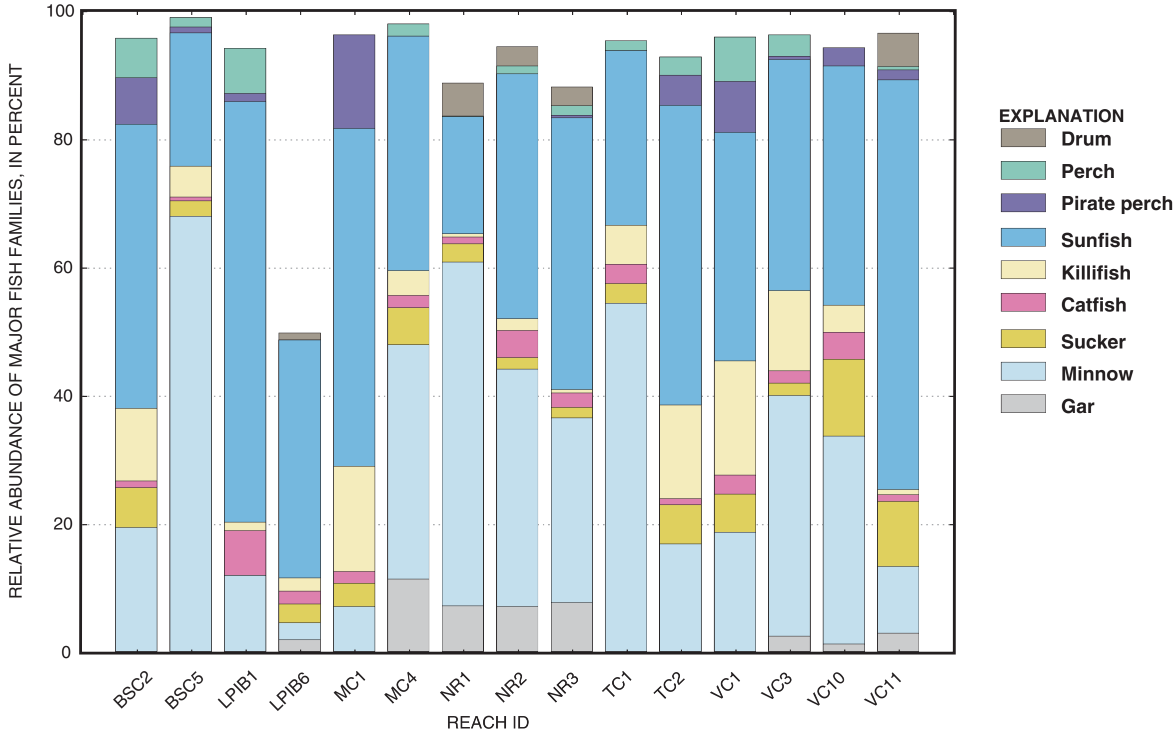


Figure 5. Relative abundance of major fish families for 15 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001.

centrarchids collected was higher at the large channel sites, but the relative abundance was lower. Gars (family Lepisosteidae) are common in large rivers, and gars were relatively the most abundant in the Neches River reaches. Pirate perches (family Aphredoderidae) were most common in the smaller reaches including Big Sandy Creek reach BSC2, Menard Creek reach MC1, Turkey Creek reach TC2, and Village Creek reach VC1. Pirate perches are common in smaller sand-bottomed streams and rivers; *Aphredoderus sayanus* is the only species in the family (Robison and Buchanan, 1984).

Benthic Macroinvertebrate Communities

A total of 9,238 benthic macroinvertebrates that constitute 301 unique taxa were collected among the 14 reaches sampled for invertebrates (table 4, at end of report). Two-hundred forty-two of the benthic macroinvertebrate taxa were aquatic insects, and 59 were non-insect taxa that included freshwater worms (Clitellata), opossum shrimp (Mysidacea), roundworms (Nematoda), snails (Gastropoda), amphipods (Malacostraca), clams (Bivalvia), and water mites (Arachnida). Sampling in this study was intentionally biased for the collection of aquatic insects, and all non-insect taxa were considered incidental collections; therefore, the results discussed below will be limited to aquatic insect taxa among the 14 reaches sampled.

The most frequently collected aquatic insect was the riffle beetle (*Stenelmis* sp.). Of the 10 most commonly collected taxa, six were midges of the family Chironomidae. The most frequently collected midge was *Polypedilum illinoense* gr. Midges often dominate the aquatic insect community in freshwater streams in number of species, number of individuals, and aquatic insect biomass (Resh and Rosenberg, 1984). Other commonly occurring taxa included the filter-feeding caddisfly, *Cheumatopsyche* sp., and the filter-feeding blackfly, *Simulium* sp. The most abundant mayflies were the collector-gatherers *Tricorythodes* sp. and *Pseudocloeon dardanum.*

A cluster analysis using presence/absence data for all of the aquatic insect taxa (fig. 6) showed a very different pattern compared to results of the fish community cluster analysis (fig. 3). Unlike the fish community cluster analysis, the aquatic insect cluster analysis

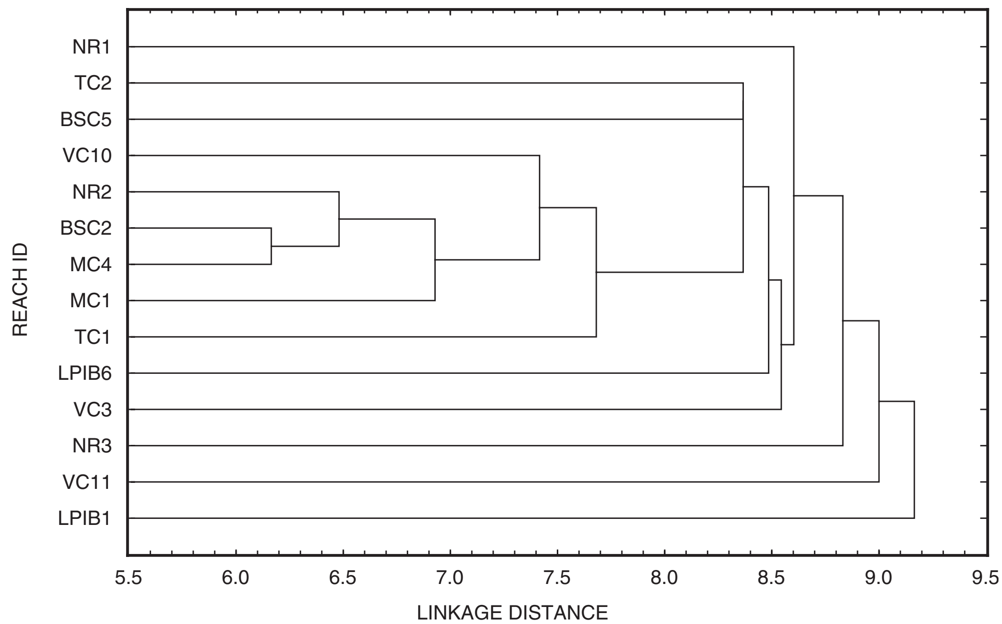


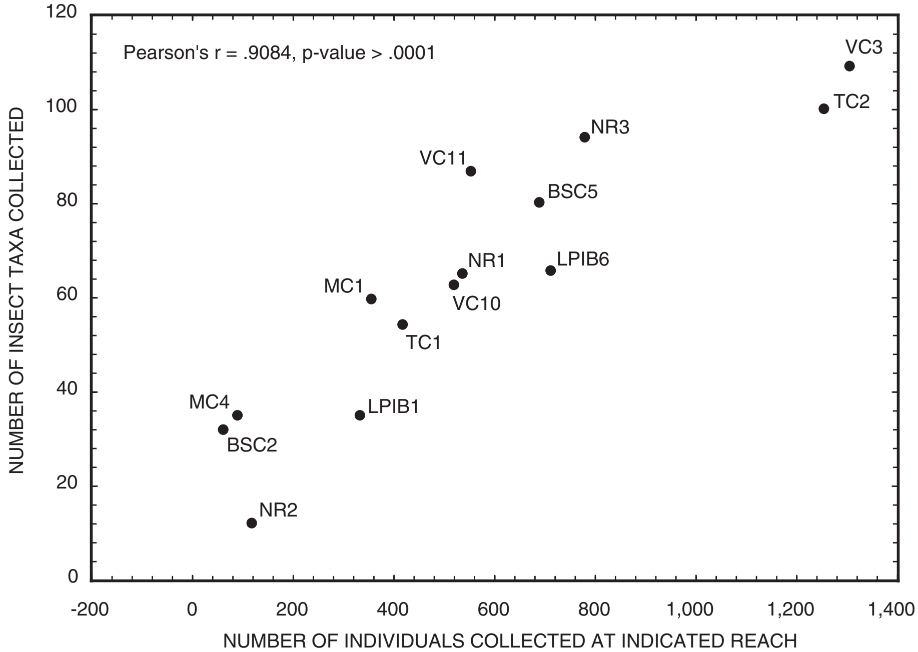
Figure 6. Results of cluster analysis to indicate similarity of aquatic insect communities for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001.

does not indicate a clustering of reaches based on site proximity. For example, the cluster analysis results show the Neches River reach (NR2) to be more similar to a Big Sandy Creek reach (BSC2) and to the Menard Creek reaches (MC1 and MC4) than it is to the other two Neches River reaches (NR1 and NR3). The majority of the linkage distances were 8.0 or higher, which indicates that the aquatic insect communities are more variable and dissimilar than the fish communities among the 14 reaches.

The number of aquatic insect taxa was significantly positively correlated (Pearson's r = .908, p-value = .0001) to the number of individuals collected in the 14 reaches (fig. 7). The Village Creek on McKinney Bridge Road (VC3) reach had the largest number of aquatic insect taxa (108), and the Neches River below Steinhagen Lake in the Jack Gore Unit (NR2) reach had the fewest number of taxa (12).

Menhinick's species richness varied considerably among the reaches (fig. 8). Big Sandy Creek reach BSC2 had the largest species richness (3.9), with a new taxon observed for about every two insects collected in the reach. The smallest species richness (1.09) was for the Neches River reach NR2. The collection of aquatic insect samples in NR2 was difficult because of swift currents and a relatively deep channel. It is likely that the small number of taxa and number of individual insects collected in this reach is at least partially the result of adverse sampling conditions.

The Ephemeroptera, Plecoptera, and Trichoptera (EPT) index commonly is used to assess the ecological health of streams. The EPT index is the sum of the proportion of each of the three orders (mayflies, stoneflies, and caddisflies), and it is expressed as a percentage of all identified taxa; larger scores indicate healthier streams. The index is sensitive to changes in water quality and is less variable seasonally and perennially than other metrics such as species richness (Lenat and Barbour, 1994). The EPT index was largest for the Neches River reach NR1 and smallest for the Little Pine Island Bayou reach LPIB6, one of the two reaches in stream segments in the preserve that are on the State 303(d)list (fig. 9). The EPT index score for NR1 probably is larger than the other index scores because this reach is only a few kilometers downstream from the Steinhagen Lake Dam; and net-spinning caddisflies likely are more common in the reservoir release waters below the dam. Caddisflies respond to increased dissolved oxygen concentrations caused by re-aeration in the tailwaters of the dam. The low index score for LPIB6 might be explained by little or no current at this



EXPLANATION

VC11 **Biological and stream-habitat assessment sites and National Park Service site number (reach ID)—** Number referenced in table 1

Figure 7. Number of aquatic insect taxa collected relative to the number of individuals collected for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001.

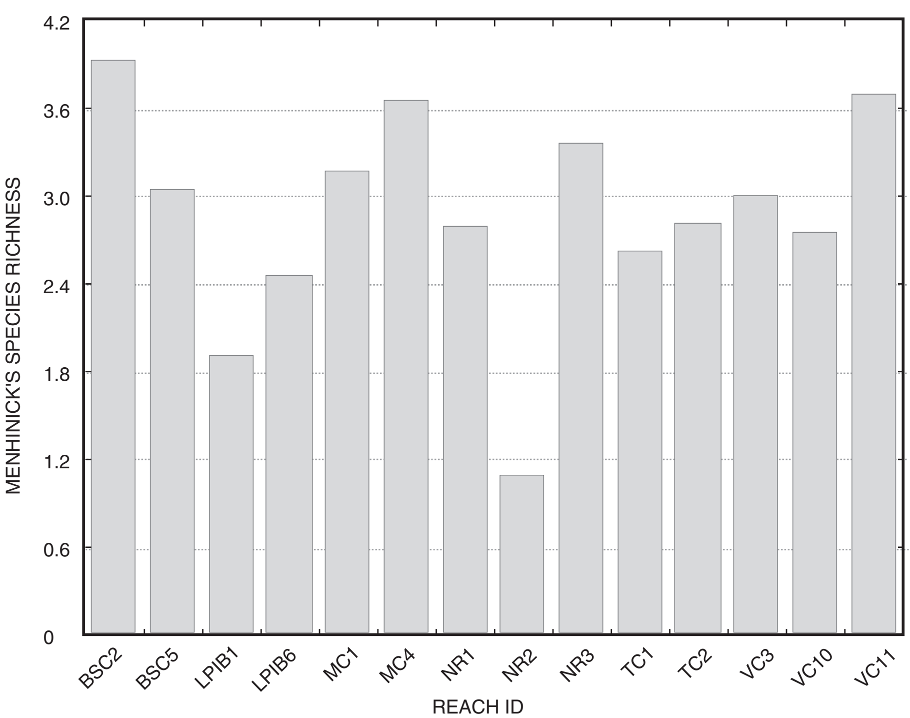


Figure 8. Menhinick's species richness for aquatic insects from14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001.

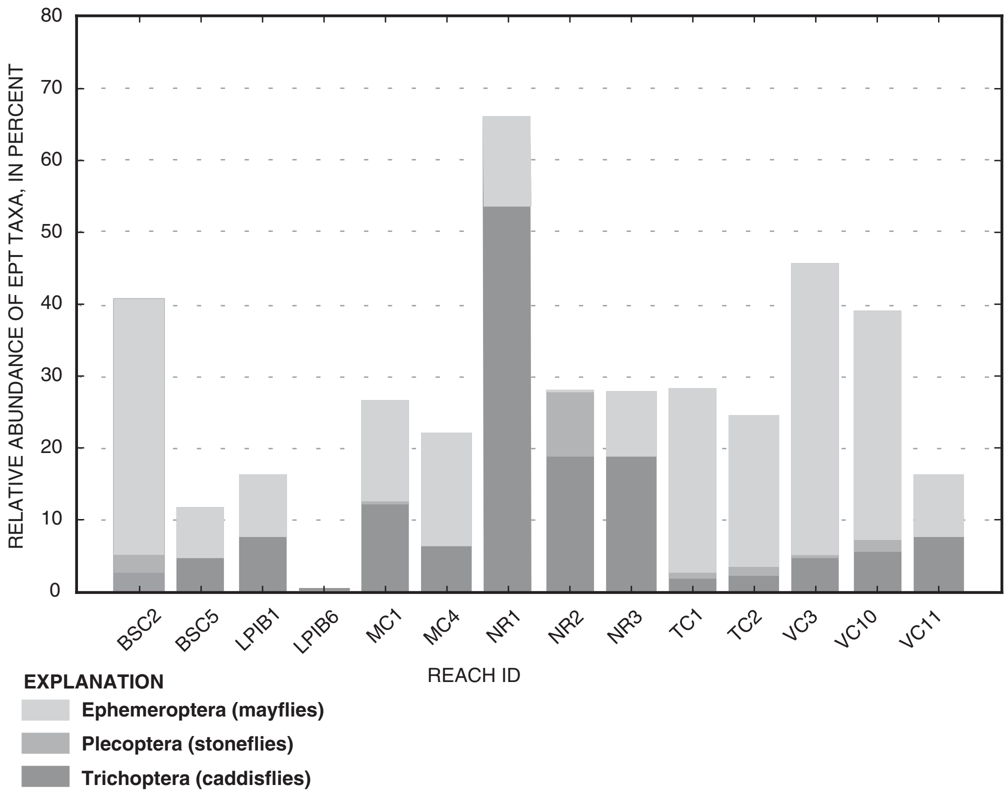


Figure 9. Relative abundance of Ephemeroptera, Plecoptera, and Trichoptera taxa (EPT index) for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001.

reach, possibly lower dissolved oxygen concentrations, and little in-channel structure such as woody snags to provide a substrate and habitat for the EPT taxa. Many of the EPT taxa, particularly caddisflies (Trichoptera), require a current at velocities that facilitate their filter-feeding habits. The mayflies (Ephemeroptera) were a larger percentage of the EPT index at the reaches with smaller channel size, and the caddisflies were a larger percentage of the EPT index in those reaches with larger channel size. Stonefly (Plecoptera) taxa are more depauperate than the mayfly or caddisfly taxa in the Big Thicket National Preserve and are less represented in the EPT index for the 14 reaches.

The trophic structure of aquatic insect communities is influenced by many factors including channel width, depth, velocity, nutrient composition and availability, bed material, and composition and density of riparian vegetation (Hynes, 1970). In low-order (smaller) streams in wooded settings dominated by deciduous riparian species, the amount and composition of input to the stream from leaf- and dead-fall and from overland runoff influences the trophic structure of the aquatic insect community in the stream (Vannote and others, 1980). The river continuum concept of Vannote and others (1980) hypothesizes that the macroinvertebrate community exists in a way that is compatible with its source of nutrition—that is (in the study described in this report), the aquatic insect community in smaller stream channels will be of the type (shredders and scrapers, for example) that can deal with the more coarse particulate matter that tends to be characteristic of smaller stream channels; whereas in larger stream channels in which smaller particulate matter tends to be characteristic, the aquatic insect community will be of the type (filter feeders, for example) that depends on fine particulate organic matter. In general, aquatic insect communities in the Big Thicket reaches fit the river continuum concept. With a couple of exceptions (LPIB1 and NR3), the relative abundance of shredders and scrapers (fig. 10) generally was larger in the reaches with smaller channels (fig. 11a); and, also with a couple

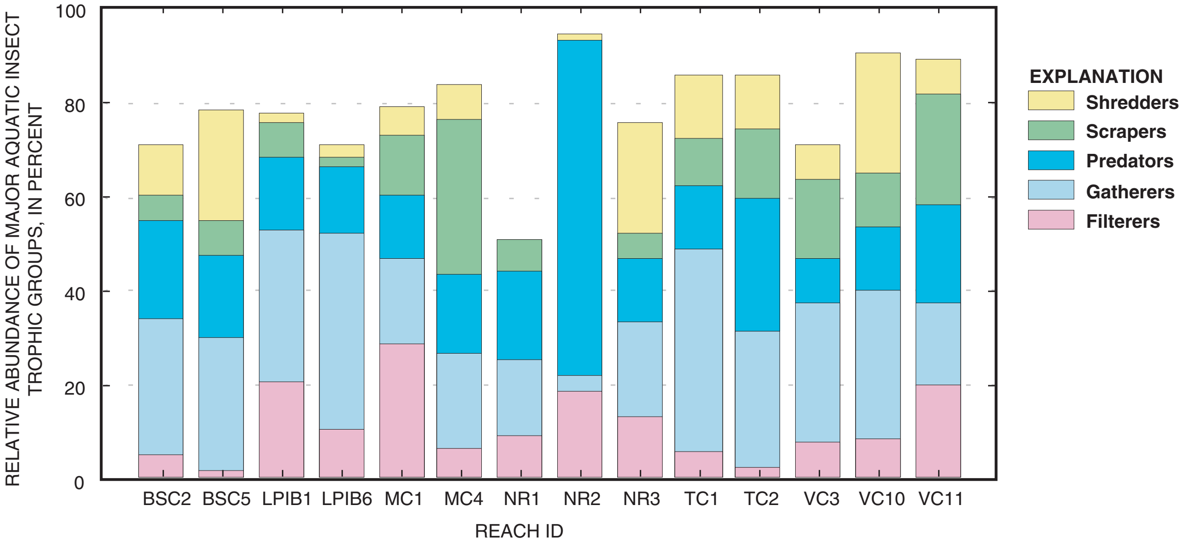


Figure 10. Relative abundance of major aquatic insect trophic groups for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001.

of exceptions (LPIB1 and MC1), the relative abundance of filter feeders generally was larger in the reaches with larger channels (fig. 11b). Relative abundance is less than 100 percent in figure 10 because minor aquatic insect trophic groups were omitted.

Stream Habitat and Land Use

The physical characteristics of the channel of a stream reach and the contributing drainage upstream from a reach (table 5, at end of report) can influence the structure and function of the resident fish and aquatic insect communities (Richards and others, 1996; Allan and others, 1997; Stauffer and others, 2000). Among stream-habitat variables measured for this report (table 2), bank-full channel width, bank height, and curvilinear reach length had principal components analysis factor loadings greater than 0.7; and the 1990s land-use variables percentage agricultural, percentage forest, and percentage urban had factor loadings greater than 0.7. These variables were used for further analysis: correlation with total number of fish species, total number of aquatic insect species, and Menhinick's species richness. None of the selected stream-habitat or land-use variables were significantly correlated with any of these biological measures.

In a comparison of stream-habitat variables with land-use variables using correlation, the percentage of 1990s urban land use in drainage areas upstream from the downstream boundaries of the bioassessment reaches was significantly negatively correlated (Pearson's $r = -.698$, p-value = .012) with the reach structure index, a measure of stable habitat for aquatic biota (fig. 12). (The three Neches River reaches, NR1, NR2, and NR3, were not included in this comparison because of the lack of contributing drainage area downstream from the most upstream reach, NR1, and the large catchment, Steinhagen Lake, upstream from all three sites on the Neches River.) The percentage of urban land use ranged from about 0.6 to about 2.5 percent; however, percentages of urban land use of less than 10 percent in a drainage area have adversely influenced the aquatic insect community (McMahon and Cuffney, 2002).

The drainage areas upstream from each of 13 bioassessment reaches were dominated by forested land use in the 1970s and in the 1990s, although the percentage decreased during the intervening years (fig. 13; table 5). Forested land use in the 1970s ranged from about 84 percent in the drainage area upstream from Little Pine Island Bayou reach LPIB6 to about 98 percent upstream from Little Pine Island Bayou reach LPIB1. By the 1990s, forested land use had decreased to about 77 percent in LPIB6 and to about 92 percent in LPIB1. The percentage of forested lands decreased

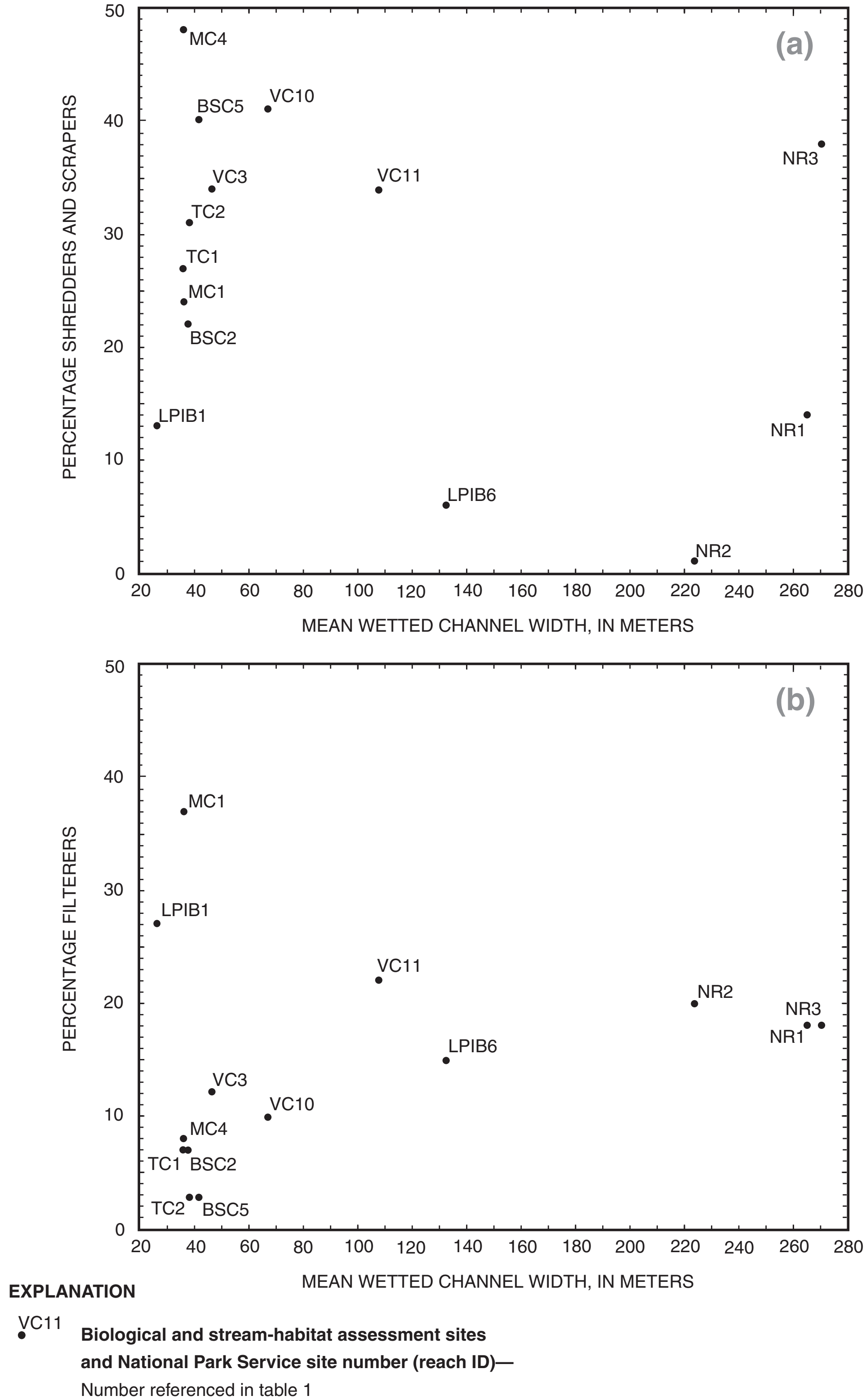


Figure 11. Relation between (a) relative abundance of shredders and scrapers and channel size, and (b) relative abundance of filter feeders and channel size for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001.

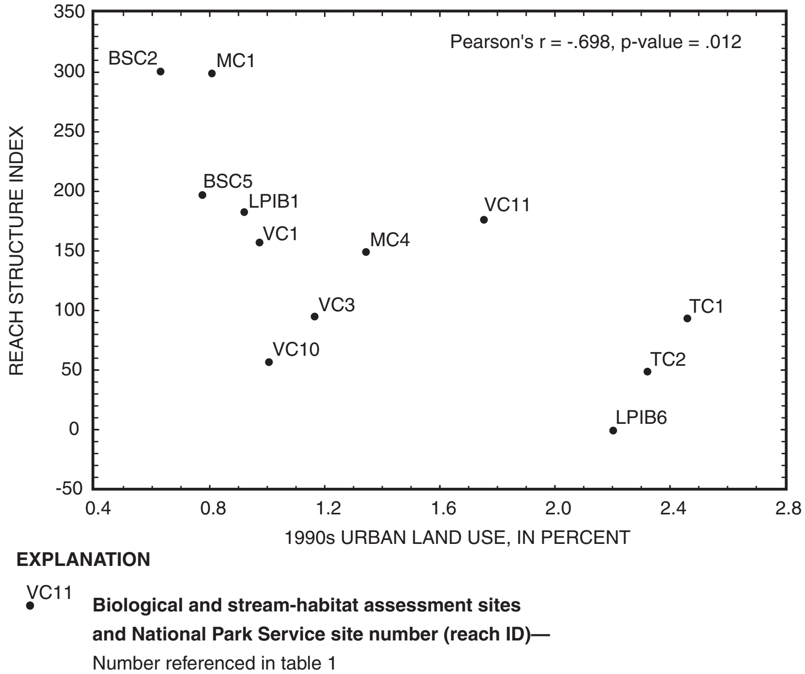


Figure 12. Reach structure index relative to 1990s urban land use in contributing drainage area above downstream boundary of reach for 12 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001.

the most (10.6 percent) in Turkey Creek reach TC1. The percentage of urban land decreased slightly (maximum 0.82 percent for any drainage area) between the 1970s and 1990s for all of the drainage areas upstream from the reaches for which data are available (table 5). However, the percentage of land in agricultural use increased from a minimum of about 0.8 percent in the LPIB1 drainage area for the 1970s to a maximum of about 15 percent in the LPIB6 drainage area for the 1990s. Timber-crop management is common throughout the lands bordering the units of the Big Thicket National Preserve.

SUMMARY OF MAJOR FINDINGS

Often described as the "biological crossroads" of North America, the Big Thicket National Preserve is an important holding of the NPS because of its biological diversity and unique geographic distribution. The USGS, in cooperation with the NPS, conducted a study to establish benchmark biological monitoring stations at 15 sites throughout the preserve from which to assess baseline biological conditions in streams and to supplement historical and ongoing water-quality monitoring at these sites. The establishment of the 15 bioassessment sites, or reaches, in the Big Thicket National Preserve and the baseline data and information on the fish and aquatic insect communities of these reaches summarized in this report constitute a first step toward assessment of the status of aquatic biological resources in the preserve. The principal findings of the study are

1. The fish communities in the preserve were dominated by minnows and sunfishes.
2. The blue sucker, listed by the State as a threatened species, was collected only in one reach, the Neches River below Steinhagen Lake.
3. Fish communities in geographically adjacent reaches in this assessment were most similar in overall community structure.
4. The most frequently collected aquatic insect was the riffle beetle. Of the 10 most commonly collected aquatic insect taxa, six were midges.
5. Aquatic insect communities among reaches did not indicate the same geographically proximate pattern of similarity as did fish communities.
6. The Ephemeroptera, Plecoptera, and Trichoptera (EPT) index was smallest for the Little Pine Island Bayou near Beaumont reach LPIB6, one

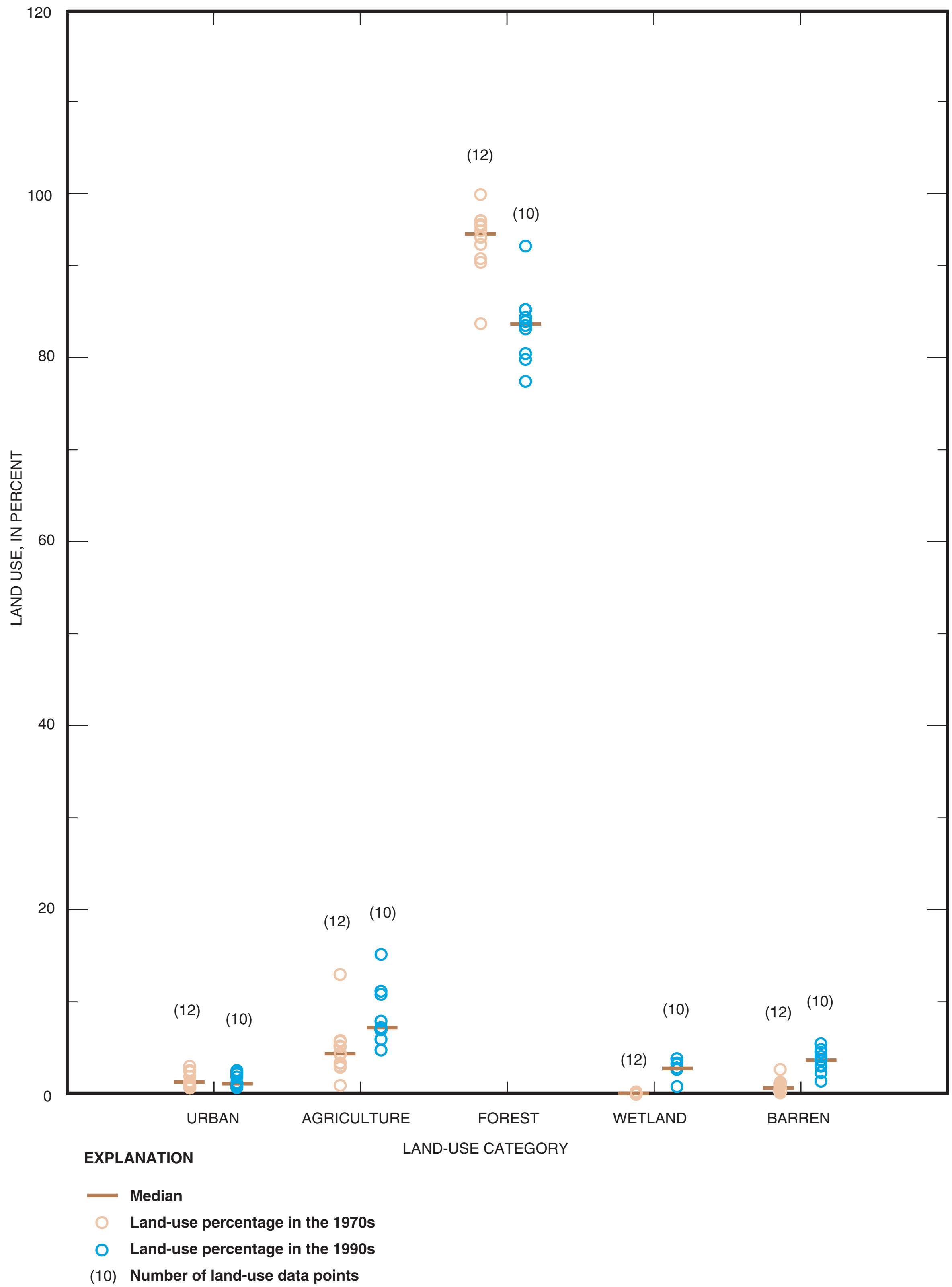


Figure 13. Land use by category in the 1970s and 1990s in the drainage areas upstream of the 15 bioassessment reaches, Big Thicket National Preserve, Texas.

of two reaches in stream segments in the preserve that are on the State 303(d) list.

7. Trophic structure of the aquatic insect communities among the 14 reaches sampled generally is consistent with the river continuum concept, with shredders and scrapers more abundant in reaches with smaller, low-order stream channels and filter feeders more abundant in reaches with larger channels.
8. Stream habitat and land use were not significantly correlated with any of the biological community measures or metrics.
9. The percentage of 1990s urban land use in the drainage areas upstream from 12 bioassessment reaches (three reaches not included in comparison) was significantly negatively correlated with the reach structure index, which indicates less stable habitat for aquatic biota.
10. Between the 1970s and 1990s, the percentage of forested lands upstream from each of 13 bioassessment reaches decreased the most (10.6 percent) in the Turkey Creek near Warren (TC1) drainage area.

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Table 3. Fish taxa and counts of individual fish collected for 15 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001

Group	Family	Species		Bioassessment reach ID															Total
		Scientific name	Common name	BSC2	BSC5	LPIB1	LPIB6	MC1	MC4	NR1	NR2	NR3	TC1	TC2	VC1	VC3	VC10	VC11	
Gars	Lepisosteidae																		
		Lepisoteus spatula	Alligator gar	0	0	0	0	0	0	5	0	6	0	0	0	11	0	0	22
		Lepisoteus oculatus	Spotted gar	0	0	0	3	0	0	35	6	18	0	0	0	0	2	12	76
		Lepisosteus osseus	Longnose gar	0	0	0	11	0	0	35	6	41	0	0	0	0	0	0	93
Herrings	Clupeidae																		
		Dorosoma petenense	Threadfin shad	0	0	0	254	0	0	14	2	14	0	0	0	0	0	0	284
		Dorosoma cepedianum	Gizzard shad	0	0	0	182	0	0	62	7	41	0	0	0	0	0	5	297
Pikes	Esocidae																		
		Esox americanus	Grass pickerel	0	0	2	1	1	0	0	0	0	0	1	1	2	0	2	10
Tarpons	Elopidae																		
		Elops saurus	Ladyfish	0	0	0	3	0	0	0	0	4	0	0	0	0	0	0	7
Minnows	Cyprinidae																		
		Cyprinella lutrensis	Red shiner	1	0	0	0	0	0	150	0	3	0	0	2	0	0	0	156
		Notropis amabilis	Texas shiner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
		Hybognathus nuchalis	Mississippi silvery minnow	0	0	0	0	0	0	0	0	5	0	0	0	0	1	2	8
		Notropis atherinoides	Emerald shiner	0	0	0	0	0	0	1	0	1	0	0	0	10	0	0	12
		Cyprinella venusta	Blacktail shiner	7	10	1	8	4	18	218	35	143	7	10	16	109	27	31	644
		Notropis atrocaudalis	Blackspot shiner	0	0	0	0	0	0	0	3	0	4	2	0	0	0	0	9
		Notropis volucellus	Mimic shiner	4	0	7	0	0	0	0	3	26	12	18	0	0	14	2	86
		Notropis amnis	Pallid shiner	0	12	1	0	0	0	0	0	2	0	0	0	0	0	0	15
		Notropis texanus	Weed shiner	0	0	6	0	0	0	0	0	19	0	0	0	2	2	0	29
		Notemigonus crysoleucas	Golden shiner	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
		Pimephales vigilax	Bullhead minnow	7	204	1	17	0	0	142	20	16	13	6	1	32	1	2	462
		Opsopoeodus emiliae	Pugnose minnow	0	0	2	0	0	0	0	0	1	0	0	0	3	1	0	7
		Cyprinus carpio	Common carp	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
		Ctenopharyngodon idella	Grass carp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Silversides	Atherinidae																		
		Labidesthes sicculus	Brook silverside	0	0	0	2	0	0	0	0	0	0	0	0	6	2	1	11
		Menidia beryllina	Inland silverside	1	0	0	15	0	0	5	0	3	0	0	0	0	0	1	25
Suckers	Catastomidae																		
		Cycleptus elongatus	Blue sucker	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	4
		Minytrema melanops	Spotted sucker	0	0	0	0	0	0	0	0	0	2	1	0	3	6	3	15
		Moxostoma poecilurum	Blacktail redhorse	6	8	0	8	2	3	0	0	1	0	12	6	5	10	1	62

Table 3. Fish taxa and counts of individual fish collected for 15 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001—Continued

Group	Family	Species		Bioassessment reach ID															Total
		Scientific name	Common name	BSC2	BSC5	LPIB1	LPIB6	MC1	MC4	NR1	NR2	NR3	TC1	TC2	VC1	VC3	VC10	VC11	
Suckers—Continued		*Ictiobus bubalus*	Smallmouth buffalo	0	0	0	19	0	0	17	3	8	0	0	0	0	1	30	78
		Carpiodes carpio	River carpsucker	0	0	0	0	0	0	6	0	3	0	0	0	0	0	5	14
Catfish	Ictaluridae																		
		Ictalurus natalis	Yellow bullhead	1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	5
		Ictalurus furcatus	Blue catfish	0	0	0	3	0	0	5	5	8	0	0	0	0	0	0	21
		Ictalurus punctatus	Channel catfish	0	1	0	14	0	1	4	2	6	0	0	0	4	3	4	39
		Pylodictis olivaris	Flathead catfish	0	0	0	2	0	0	1	0	3	0	2	0	1	3	0	12
		Notorus gyrinus	Tadpole madtom	0	0	0	0	1	0	0	0	0	1	0	3	3	0	0	8
		Notorus nocturnus	Freckled madtom	0	1	7	0	0	0	0	0	0	1	0	0	0	0	0	9
Killifishes	Cyprinodontidae																		
		Fundulus olivaceus	Blackspotted topminnow	5	2	0	0	0	2	0	0	0	0	4	2	17	0	0	32
		Fundulus notatus	Blackstripe topminnow	6	14	2	19	9	0	5	3	4	4	27	11	35	6	3	148
		Fundulus chrysotus	Golden topminnow	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5
Sunfishes	Centrarchidae																		
		Lepomis megalotis	Longear sunfish	29	46	55	72	19	12	40	40	111	3	69	27	96	30	112	761
		Lepomis marginatus	Dollar sunfish	0	2	7	1	0	0	0	0	0	0	0	0	5	0	0	15
		Lepomis auritus	Redbreast sunfish	0	0	0	5	3	3	0	0	0	0	0	0	4	0	0	15
		Lepomis microlophus	Redear sunfish	0	0	0	8	0	0	5	0	0	2	4	0	2	2	1	24
		Lepomis punctatus	Spotted sunfish	0	3	2	8	1	2	3	0	1	1	5	1	8	2	1	38
		Poxomis annularis	White crappie	0	0	0	33	0	0	21	0	17	0	0	0	0	2	10	83
		Poxomis nigromaculatus	Black crappie	0	0	0	5	0	0	8	0	1	0	0	0	0	0	0	14
		Micropterus punctulatus	Spotted bass	12	13	3	8	5	2	25	7	23	4	13	5	9	10	40	179
		Micropterus salmoides	Largemouth bass	0	1	0	34	0	0	15	0	78	1	0	2	1	3	15	150
		Micropterus coosae	Redeye bass	0	0	0	0	0	0	2	0	5	0	0	0	0	0	5	12
		Lepomis cyanellus	Green sunfish	0	0	0	3	0	0	1	0	0	0	0	0	0	0	2	6
		Lepomis macrochirus	Bluegill	2	1	19	148	1	0	54	14	76	7	7	0	19	2	54	404
		Lepomis gulosus	Warmouth	0	3	17	12	0	0	0	2	6	0	1	1	2	1	6	51
		Elassoma zonatum	Banded pygmy sunfish	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	8
		Lepomis symmetricus	Bantam sunfish	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	5
Temperate basses	Percichthyidae																		
		Morone chrysops	White bass	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	4
		Morone saxatilis	Striped bass	0	0	0	0	0	0	3	0	1	0	0	0	0	0	1	5
Mullets	Mugilidae																		
		Mugil cephalus	Striped mullet	0	0	0	8	0	0	16	0	15	1	1	0	1	6	3	51

Table 3. Fish taxa and counts of individual fish collected for 15 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001—Continued

Group	Family	Species		Bioassessment reach ID															Total
		Scientific name	Common name	BSC2	BSC5	LPIB1	LPIB6	MC1	MC4	NR1	NR2	NR3	TC1	TC2	VC1	VC3	VC10	VC11	
Pirate perches	Aphredoderidae																		
		Aphredoderus sayanus	Pirate perch	7	3	2	0	8	0	0	0	3	0	10	8	2	4	6	53
Perches	Percidae																		
		Percina sciera	Dusky darter	4	0	7	0	0	1	0	2	6	0	5	4	8	0	2	39
		Etheostoma gracile	Slough darter	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
		Ammocrypta clara	Western sand darter	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	4
		Etheostoma chlorosomum	Bluntnose darter	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3
		Etheostoma proeliare	Cypress darter	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
		Ammocrypta vivix	Scaly sand darter	1	5	0	0	0	0	1	0	5	1	0	3	2	0	0	18
		Percina macrolepida	Bigscale logperch	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Lampreys	Petromyzontidae			0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
		Ichthyomyzon castaneus	Chestnut lamprey	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	4
		Ichthyomyzon gagei	Southern brook lamprey	3	2	0	0	0	0	0	0	6	0	12	3	6	0	0	32
Livebearers	Poeciliidae																		
		Gambusia affinis	Western mosquitofish	0	1	7	1	1	1	0	0	1	2	0	0	0	0	0	14
Drums	Sciaenidae																		
		Aplodinotus grunniens	Freshwater drum	0	0	0	15	0	0	49	5	22	0	0	0	0	0	20	111
Needlefishes	Belonidae																		
		Strongylura marina	Atlantic needlefish	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Number of fish				97	332	157	930	55	46	958	165	756	66	212	101	416	142	385	4,818
Number of fish species				17	19	22	32	12	11	33	18	43	17	22	18	32	25	32	69

Table 4. Taxonomic classification of benthic macroinvertebrates and counts of individual taxa for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001

Class	Order	Family	Genus or species		Bioassessment reach ID														Total
			Scientific name	Common name	BSC-2	BSC-5	LPIB-1	LPIB-6	MC-1	MC-4	NR-1	NR-2	NR-3	TC-1	TC-2	VC-3	VC-10	VC-11	
Clitellata	Arhynchobdellida	Erpobdellidae		Freshwater leeches	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2
	Rhynchobdellida	Glossiphoniidae	*Helobdella* sp.		0	0	0	5	0	0	0	0	0	0	0	0	0	0	5
			Helobdella triserialis		0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
			Placobdella sp.		0	1	0	0	1	0	0	0	0	0	0	0	0	0	2
			Placobdella ornata		0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
			Placobdella parasitica		0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
	Oligochaeta			Aquatic earthworms	0	29	0	197	0	0	7	0	21	0	3	17	0	10	284
	Haplotaxida	Lumbricina			0	0	0	1	0	1	0	0	0	0	0	0	0	0	2
Mysidacea	Mysida	Mysidae	*Taphromysis louisianae*	Freshwater shrimp	0	0	0	23	0	0	1	0	2	0	0	0	0	0	26
Nematoda (phylum)				Roundworms	0	2	0	16	1	0	0	0	3	0	0	2	0	0	24
Gastropoda					0	0	0	0	0	0	0	0	0	0	1	0	0	1	2
	Architaenioglossa	Viviparidae	*Campeloma* sp.	Freshwater snails	0	1	0	0	5	0	0	0	0	0	5	0	0	0	11
			Campeloma decisum		0	2	0	0	0	0	0	0	0	0	2	0	0	0	4
	Neotaenioglossa	Hydrobiidae			0	3	0	17	0	0	0	0	5	0	29	1	0	1	56
			Amnicola sp.		0	3	3	3	10	1	0	0	10	0	0	53	0	4	87
	Basommatophora	Ancylidae	*Ferrissia* sp.		0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
		Lymnaeidae			0	2	0	0	0	0	0	0	0	0	0	0	0	1	3
		Physidae			0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
			Physella sp.		0	0	0	4	0	0	0	0	2	0	0	0	0	0	6
		Planorbidae			0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
		Planorbidae	*Menetus dilatatus*	Freshwater limpets	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
			Menetus sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
Arachnida	Sacroptiformes	Oribatei		Soil mites	0	4	0	16	0	0	5	0	1	0	8	2	0	1	37
	Acari			Mites	0	2	1	5	1	0	1	0	2	1	27	14	6	2	62
	Trombidiformes	Hygrobatidae		Water mites	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
		Hydryphantidae			0	0	0	2	0	0	0	0	1	0	7	0	0	1	11
		Arrenuridae	*Arrenurus* sp.		0	0	0	0	0	0	0	0	1	0	1	3	0	0	5
		Lebertiidae			0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
		Limnesiidae			0	0	0	0	0	0	0	0	2	0	1	1	0	0	4
		Mideopsidae			0	0	0	0	0	0	0	0	0	0	1	13	0	0	14
		Sperchonidae			0	1	0	0	0	0	0	0	0	0	0	12	0	0	13
		Torrenticolidae			0	3	0	1	0	0	0	0	3	0	4	2	0	1	14
		Unionicolidae			0	0	0	0	0	0	0	0	0	0	1	8	0	0	9
		Clathrosperchonidae	*Clathrosperchon* sp.		0	0	0	5	0	0	0	0	1	0	0	0	0	4	10
Turbellaria				Flatworms	0	0	0	0	0	0	1	0	0	0	0	1	0	0	2
Malacostraca	Amphipoda			Amphipods	0	0	0	0	0	0	2	1	3	0	0	0	0	0	6
		Corophiidae	*Corophium* sp.		0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
		Crangonyctidae			0	3	0	0	0	0	0	0	0	0	13	0	1	0	17
			Crangonyx sp.		0	0	0	19	2	1	5	0	4	0	3	0	0	64	98
		Gammaridae	*Gammarus* sp.		0	0	46	4	0	0	0	0	1	2	7	4	0	8	72
		Hyalellidae	*Hyalella azteca*		1	4	0	0	0	4	0	0	0	3	0	0	0	0	12
			Hyalella sp.		0	0	0	6	0	0	124	0	5	0	0	0	0	25	160
	Decapoda	Cambaridae		Crayfishes	1	4	0	0	0	0	0	0	0	0	3	0	0	1	9

Table 4. Taxonomic classification of benthic macroinvertebrates and counts of individual taxa for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001—Continued

Class	Order	Family	Genus or species		Bioassessment reach ID														Total
			Scientific name	Common name	BSC-2	BSC-5	LPIB-1	LPIB-6	MC-1	MC-4	NR-1	NR-2	NR-3	TC-1	TC-2	VC-3	VC-10	VC-11	
Malacostraca—Cont.	Decapoda—Cont.		*Orconectes* sp.	Crayfishes	1	1	0	0	0	1	0	0	0	0	0	0	0	0	3
			Procambarus dupratzi	Crayfishes	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
			Procambarus sp.	Crayfishes	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
		Palaemonidae		Freshwater shrimp	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
			Palaemonetes kadiakensis		7	24	28	11	27	2	16	0	5	0	28	28	3	4	183
	Isopoda	Asellidae	*Caecidotea* sp.	Aquatic sow bugs	0	0	0	10	0	0	0	0	0	0	0	0	0	0	10
			Lirceus sp.		0	0	23	0	3	0	0	0	0	0	0	0	0	1	27
Bivalvia					0	1	0	0	0	2	0	0	1	0	0	2	0	3	9
	Veneroida			Clams	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
		Corbiculidae	*Corbicula* sp.		0	2	0	0	0	0	8	0	1	0	2	2	6	0	21
			Corbicula fluminea	Aisan clams	0	11	0	0	0	0	0	1	1	0	0	1	0	0	14
		Pisidiidae	*Eupera cubensis*	Peaclams	0	0	0	13	0	0	0	0	0	0	0	0	0	0	13
			Sphaerium sp.		0	1	0	0	1	0	0	0	0	0	0	0	0	0	2
		Sphaeriidae		Peaclams	0	1	0	7	0	0	1	0	15	0	12	0	0	0	36
	Unionoida	Unionidae		Unionids (freshwater clams)	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Ostracoda				Ostracods	0	3	0	0	0	0	0	0	5	0	6	23	0	0	37
Insecta	Ephemeroptera	Baetidae		Mayflies	0	0	0	0	3	1	1	0	0	12	0	17	18	0	52
			Acerpenna pygmaea		1	5	8	0	16	0	0	0	0	13	3	19	3	0	68
			Baetis intercalaris		0	42	0	0	0	0	0	0	7	3	28	37	0	0	117
			Baetis sp.		0	1	0	0	0	1	1	0	0	0	1	0	0	1	5
			Centroptilum sp.		0	1	2	0	0	0	0	0	0	4	6	5	15	0	33
			Fallceon quilleri		0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
			Procloeon sp.		0	0	0	0	0	0	0	0	0	3	0	4	13	0	20
			Pseudocloeon longipalpus		0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
			Pseudocloeon propinquum		0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
			Pseudocloeon sp.		0	0	0	0	0	0	0	0	7	0	2	10	0	0	19
			Pseudocloeon dardanum		0	0	0	0	4	0	0	0	13	30	0	88	21	0	156
			Plauditus sp.		0	0	0	0	0	0	0	0	0	0	2	6	6	0	14
		Caenidae			0	0	0	0	0	0	0	0	0	0	0	0	14	0	14
			Amercaenis ridens		0	0	0	0	0	0	0	0	0	0	0	0	4	4	8
			Brachycercus sp.		0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
			Caenis amica		0	0	0	5	0	0	0	0	0	0	0	0	0	0	5
			Caenis hilaris		1	3	0	0	0	0	0	0	0	0	26	8	1	9	48
			Caenis latipennis		2	2	16	0	0	0	0	0	0	0	0	0	0	0	20
			Caenis punctata		0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
			Caenis sp.		1	24	0	2	2	0	2	0	10	2	21	14	0	1	79
		Leptohyphidae			0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
			Leptohyphes sp.		0	0	0	0	0	0	0	0	0	0	0	1	0	0	1

Table 4. Taxonomic classification of benthic macroinvertebrates and counts of individual taxa for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001—Continued

Class	Order	Family	Genus or species		Bioassessment reach ID														Total
			Scientific name	Common name	BSC-2	BSC-5	LPIB-1	LPIB-6	MC-1	MC-4	NR-1	NR-2	NR-3	TC-1	TC-2	VC-3	VC-10	VC-11	
Insecta—Cont.	Ephemeroptera—Cont.		*Asioplax* sp.		0	1	0	0	0	0	0	0	2	21	0	11	15	0	50
			Tricorythodes sp.		7	13	0	0	8	2	9	0	2	11	23	72	23	6	176
		Leptophlebiidae			0	0	0	0	7	5	0	0	0	3	7	1	1	0	24
			Choroterpes sp.		0	0	0	0	5	0	0	0	0	0	8	2	0	0	15
			Paraleptophlebia sp.		0	0	0	0	0	0	0	0	0	0	0	6	0	0	6
			Thraulodes sp.		0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
		Heptageniidae	*Heptagenia* sp.		0	0	0	0	0	0	0	0	7	0	0	0	0	4	11
			Stenacron sp.		0	0	0	0	0	1	0	0	0	0	7	0	0	0	8
			Stenacron floridense		6	0	11	0	0	0	0	0	0	0	0	0	0	0	17
			Stenacron interpunctatum		0	2	0	0	0	0	0	0	0	0	3	0	0	1	6
			Stenonema exiguum		0	0	1	0	1	1	1	0	0	0	1	2	2	0	9
			Stenonema integrum		0	0	0	0	0	0	1	0	0	0	0	1	0	0	2
			Stenonema mexicanum		0	0	0	0	0	0	17	0	3	0	0	3	0	0	23
			Stenonema sp.		3	2	0	0	4	1	0	0	0	3	16	28	20	0	77
		Ephemerellidae			0	0	0	0	0	0	0	0	0	0	0	16	1	0	17
		Ephemeridae	*Hexagenia* sp.		1	0	0	0	0	0	0	0	12	0	4	0	0	0	17
		Isonychiidae	*Isonychia* sp.		5	1	0	0	8	4	1	0	8	5	6	26	15	1	80
	Odonata	Coenagrionidae		Damselflies	0	0	0	0	0	0	3	0	0	0	0	3	0	2	8
			Argia sp.		0	1	0	0	0	0	0	1	0	0	5	4	0	11	22
		Calopterygidae	*Hetaerina* sp.		0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
			Calopteryx sp.		1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		Corduliidae	*Macromia illinoiensis*	Dargonflies	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
			Macromia sp.		0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
			Neurocordulia molesta		0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
			Neurocordulia sp.		0	0	0	0	0	0	0	13	0	1	0	0	1	0	15
		Macromiinae			1	1	0	0	0	0	0	0	0	0	0	0	0	0	2
		Aeshnidae			0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
			Boyeria sp.		0	0	0	0	6	2	0	0	0	0	0	0	0	0	8
			Boyeria vinosa		0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
			Nasiaeschna pentacantha		0	0	0	0	0	0	0	0	1	0	0	0	0	1	2
		Gomphidae			0	0	0	1	2	0	0	0	0	0	2	1	0	0	6
			Hagenius brevistylus		0	0	0	0	0	0	0	0	1	0	1	1	0	1	4
			Progomphus sp.		0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
			Stylurus sp.		0	0	0	0	0	0	0	0	1	0	0	1	0	0	2
			Phyllogomphoides sp.		0	0	3	0	0	0	0	0	0	0	0	0	0	1	4
		Libellulidae			0	0	0	0	0	0	0	0	0	0	1	1	0	2	4
	Plecoptera	Perlidae		Stoneflies	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
			Acroneuria sp.		0	0	0	0	1	0	0	11	0	0	0	2	1	0	15
			Neoperla sp.		2	0	0	0	0	0	0	0	1	3	6	0	8	0	20
			Perlesta sp.		0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
		Taeniopterygidae	*Taeniopteryx* sp.		0	6	0	0	0	0	0	0	0	0	1	0	0	0	7

Table 4. Taxonomic classification of benthic macroinvertebrates and counts of individual taxa for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001—Continued

Class	Order	Family	Genus or species: Scientific name	Genus or species: Common name	Bioassessment reach ID: BSC-2	BSC-5	LPIB-1	LPIB-6	MC-1	MC-4	NR-1	NR-2	NR-3	TC-1	TC-2	VC-3	VC-10	VC-11	Total
Insecta—Cont.	Heteroptera	Corixidae		Water boatman	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
			Trichocorixa sp.		0	0	0	1	0	0	0	0	9	0	0	0	0	6	16
			Palmacorixa sp.		0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
		Gerridae		Water striders	0	0	0	12	3	0	0	0	0	0	0	0	0	0	15
		Veliidae		Broad-shouldered water striders	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
			Rhagovelia sp.		0	0	0	0	0	1	0	0	0	0	0	0	1	0	2
		Naucoridae	*Pelocoris* sp.	Creeping water bugs	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
			Ambrysus sp.		0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
		Nepidae	*Ranatra* sp.	Water scorpions	1	0	0	1	0	0	0	0	0	0	0	0	0	1	3
		Capsalidae	*Trochopus* sp.	Flukes	0	0	0	0	6	0	0	0	0	0	0	0	3	0	9
		Pleidae	*Neoplea* sp.	Pygmy backswimmers	0	0	0	0	0	0	8	0	1	0	0	0	0	2	11
					0	0	0	0	0	1	0	0	0	0	0	0	1	0	2
		Belostomatidae		Gian water bugs	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
			Belostoma sp.		0	0	0	1	0	0	6	0	3	0	0	0	0	1	11
	Megaloptera	Corydalidae		Dobson flies	0	0	0	0	2	0	0	0	1	0	0	1	0	0	4
			Chauliodes sp.		0	0	0	1	0	0	0	0	0	0	0	0	0	1	2
			Corydalus sp.		0	0	0	0	4	3	6	2	1	3	10	4	3	4	40
		Sialidae	*Sialis* sp.	Alderflies	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	Trichoptera				0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
		Hydropsychidae		Caddisflies	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
			Cheumatopsyche sp.		2	1	33	0	7	1	0	0	41	0	6	100	2	5	198
			Hydropsyche bidens		0	0	0	0	0	0	41	0	43	0	0	0	0	0	84
			Hydropsyche mississippiensis		0	0	0	0	0	0	0	0	42	0	0	22	0	0	64
			Hydropsyche simulans		0	4	0	0	10	1	0	0	6	2	0	0	1	0	24
			Hydropsyche sp.		0	0	0	0	0	0	20	0	4	1	1	12	7	0	45
			Macrostemum sp.		0	0	0	0	0	0	1	21	10	0	0	0	4	7	43
			Potamyia flava		0	0	0	0	0	0	9	0	0	0	0	0	0	0	9
			Smicridea sp.		0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
		Brachycentridae	*Brachycentrus numerosus*		0	0	0	0	0	0	0	0	0	1	1	5	0	0	7
			Brachycentrus sp.		0	3	0	0	0	0	0	0	0	0	9	0	0	0	12
		Helicopsychidae	*Helicopsyche* sp.		0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
		Hydroptilidae	*Neotrichia* sp.		0	0	0	0	0	0	0	0	7	0	0	0	0	2	9
			Hydroptila sp.		0	2	0	1	0	0	0	0	5	1	0	8	0	0	17
			Mayatrichia sp.		0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
		Polycentropodidae			0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
			Cyrnellus fraternus		0	0	0	1	0	0	4	0	0	0	0	0	0	0	5
			Neureclipsis sp.		0	0	0	0	0	1	2	0	16	0	2	2	0	4	27
			Nyctiophylax sp.		0	0	0	0	2	1	0	0	0	0	0	6	0	0	9
			Polycentropus sp.		0	1	0	0	0	0	0	0	0	2	9	0	0	0	12

Table 4. Taxonomic classification of benthic macroinvertebrates and counts of individual taxa for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001—Continued

Class	Order	Family	Genus or species		Bioassessment reach ID														Total
			Scientific name	Common name	BSC-2	BSC-5	LPIB-1	LPIB-6	MC-1	MC-4	NR-1	NR-2	NR-3	TC-1	TC-2	VC-3	VC-10	VC-11	
Insecta—Cont.	Trichoptera—Cont.	Leptoceridae			0	2	0	1	0	0	0	0	0	0	1	0	0	0	4
			Oecetis persimilis		0	0	0	0	0	0	0	0	0	1	0	0	1	0	2
			Oecetis sp.		0	0	0	0	0	0	0	0	1	0	12	11	2	0	26
			Nectopsyche candida		0	2	0	0	2	2	0	0	0	0	0	1	0	0	7
			Nectopsyche sp.		0	1	0	0	0	0	5	0	10	0	3	1	1	1	22
			Triaenodes sp.		0	0	0	0	1	0	0	0	0	0	2	0	0	1	4
		Philopotamidae	*Chimarra* sp.		0	1	0	0	26	0	0	2	3	0	7	69	12	4	124
	Lepidoptera			Moths and butterflies	0	0	0	0	0	0	6	0	0	0	0	0	0	0	6
	Coleoptera	Dytiscidae		Predaceous diving beetles	0	0	0	0	0	0	0	0	0	0	0	0	0	25	25
			Coptotomus sp.		0	0	0	0	0	0	0	0	0	0	1	0	1	2	4
			Desmopachria sp.		0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
			Hydrovatus sp.		0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
			Liodessus sp.		0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
			Lioporeus pilatei		0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
			Neoporus sp.		0	0	0	0	0	0	3	0	8	0	2	0	0	116	129
		Hydrophilidae		Water-scavenger beetles	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
			Cymbiodyta sp.		0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
			Derallus sp.		0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
			Enochrus sp.		0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
			Hydrochus sp.		0	0	0	1	0	0	0	0	0	0	4	0	0	0	5
			Tropisternus sp.		0	0	0	1	0	0	1	0	1	0	0	0	0	1	4
			Berosus sp.		0	0	0	0	0	0	0	1	0	0	1	0	0	0	2
			Sperchopsis sp.		0	0	0	0	2	0	0	0	0	0	0	0	0	1	3
		Psephenidae	*Ectopria* sp.	Water-penny beetles	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		Noteridae	*Hydrocanthus* sp.	Burrowing water beetles	0	0	0	0	0	0	13	0	1	0	0	0	0	0	14
			Suphis sp.		0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
		Elmidae		Riffle beetles	4	0	2	1	0	0	0	0	0	0	0	30	4	0	41
			Ancyronyx variegatus		0	2	3	0	0	0	0	0	0	4	11	3	0	2	25
			Dubiraphia sp.		1	18	2	0	5	4	0	0	0	0	27	10	9	14	90
			Dubiraphia vittata		0	1	1	0	1	0	0	0	0	4	47	25	0	0	79
			Macronychus glabratus		4	3	0	1	7	5	0	0	0	3	39	9	0	1	72
			Microcylloepus sp.		0	10	0	0	3	0	0	0	0	13	1	0	0	1	28
			Stenelmis sp.		1	16	28	0	33	29	11	0	5	35	190	71	39	53	511
		Helodidae	*Cyphon* sp.	Marsh beetles	0	0	0	17	0	0	13	0	3	0	0	0	0	29	62
		Gyrinidae	*Dineutus* sp.	Whirligig beetles	2	0	5	0	0	1	4	0	2	0	1	1	0	1	17
			Gyretes sp.		0	2	0	0	2	1	6	0	1	0	1	1	0	0	14
			Gyrinus sp.		0	0	0	0	0	0	12	60	22	0	0	1	0	0	95
		Hydraenidae	*Hydraena* sp.	Minute moss beetles	0	0	0	0	0	0	1	0	0	0	6	0	0	1	8

Table 4. Taxonomic classification of benthic macroinvertebrates and counts of individual taxa for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001—Continued

Class	Order	Family	Genus or species		Bioassessment reach ID														Total
			Scientific name	Common name	BSC-2	BSC-5	LPIB-1	LPIB-6	MC-1	MC-4	NR-1	NR-2	NR-3	TC-1	TC-2	VC-3	VC-10	VC-11	
Insecta—Cont.	Coleoptera—Cont.	Haliplidae	*Peltodytes* sp.	Crawling water beetles	0	3	0	0	1	0	1	0	2	0	0	0	0	4	11
	Diptera	Athericidae			1	0	0	0	0	0	0	0	0	0	1	0	2	0	4
		Ceratopogonidae			0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
		(1)			0	13	4	1	7	2	1	0	15	1	14	3	12	12	85
			Bezzia/Palpomyia sp.	Biting midges	0	3	0	13	0	0	39	0	29	0	5	4	0	14	107
			Culicoides sp.		0	7	0	0	0	0	0	0	1	0	0	0	0	0	8
			Forcipomyia sp.		0	0	0	0	0	0	0	0	0	0	2	0	0	3	5
			Probezzia sp.		0	2	0	12	0	0	1	0	2	0	0	4	0	1	22
			Sphaeromias sp.		0	0	0	1	0	0	0	0	4	0	0	0	0	0	5
		Tipulidae	*Hexatoma* sp.	Crane flies	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2
			Pilaria sp.		0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
		Ephydridae		Brine flies	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
		Chaoboridae	*Chaoborus* sp.	Phantom midges	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
		Empididae	*Hemerodromia* sp.	Balloon and dance flies	0	3	0	0	10	2	1	0	6	0	10	6	1	0	39
		Psychodidae		Moth and sand flies	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
			Pericoma sp.		0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
		Sciomyzidae		Marsh flies	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
		Simuliidae		Blackflies	0	0	0	0	0	1	5	0	1	0	0	3	0	1	11
			Simulium sp.		0	36	0	2	70	0	0	0	27	7	43	10	4	7	206
		Tipulidae			0	1	0	1	0	0	0	0	0	0	1	0	0	0	3
			Tipula sp.		0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
		Chironomidae	*Antillocladius* sp.	Midges	0	0	0	7	0	0	0	0	0	0	0	0	0	0	7
			Cladopelma sp.		0	0	0	3	0	0	1	0	1	0	0	0	0	0	5
			Clinotanypus sp.		1	1	0	0	1	0	0	0	3	0	9	4	0	0	19
			Coelotanypus sp.		0	0	0	0	0	0	0	1	2	0	0	0	0	0	3
			Corynoneura sp.		0	45	2	10	1	0	0	0	7	29	40	16	7	0	157
			Epoicocladius sp.		0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
			Fissimentum sp.		0	0	0	0	0	0	0	0	4	0	0	0	0	0	4
			Harnischia sp.		0	0	0	3	0	0	0	0	4	0	0	0	0	0	7
			Pagastiella sp.		0	0	0	1	0	0	0	0	3	0	3	0	0	7	14
			Parachironomus frequens gr.		0	0	0	3	0	0	0	0	0	0	0	0	0	0	3
			Parachironomus sp.		0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
			Phaenopsectra sp.		0	3	0	0	0	1	0	0	1	0	0	2	0	0	7
			Potthastia longimana gr.		0	1	0	1	0	0	0	0	0	0	0	3	0	2	7
			Radotanypus sp.		0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
			Rheosmittia sp.		0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
			Smittia sp.		0	0	0	4	0	0	0	0	0	0	0	0	0	0	4
			Stempellina sp.		0	18	0	0	1	0	0	0	0	0	51	1	0	5	76
			Synorthocladius sp.		0	0	0	0	0	0	0	0	0	0	0	1	0	0	1

Table 4. Taxonomic classification of benthic macroinvertebrates and counts of individual taxa for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001—Continued

Class	Order	Family	Genus or species		Bioassessment reach ID														Total
			Scientific name	Common name	BSC-2	BSC-5	LPIB-1	LPIB-6	MC-1	MC-4	NR-1	NR-2	NR-3	TC-1	TC-2	VC-3	VC-10	VC-11	
Insecta—Cont.	Diptera—Cont.		*Unniella* sp.		0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
			Zavreliella sp.		0	0	0	3	0	0	0	0	0	0	0	0	0	0	3
		(2)	*Procladius* sp.		1	0	0	4	0	0	2	0	12	0	2	1	5	2	29
		(3)	*Natarsia* sp.		2	1	0	1	0	1	0	0	0	0	1	0	0	0	6
		(4)	*Ablabesmyia* sp.		4	26	9	7	4	2	1	0	8	0	27	17	11	7	123
			Labrundinia sp.		0	5	11	0	10	0	0	0	7	3	6	0	0	2	44
			Labrundinia johannseni		0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
			Labrundinia pilosella		0	0	0	0	0	0	4	0	0	0	0	10	0	11	25
			Larsia sp.		1	6	0	0	0	2	0	0	0	13	66	11	2	0	101
			Nilotanypus fimbriatus		0	0	0	0	1	0	0	0	0	0	0	8	6	0	15
			Nilotanypus sp.		0	0	0	1	1	0	0	0	0	0	0	0	0	0	2
			Pentaneura sp.		0	0	35	0	0	0	0	0	2	26	21	20	1	4	109
			Zavrelimyia sp.		0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
		(5)		Midges	0	0	1	0	0	0	0	0	0	0	0	6	1	2	10
		(6)	*Cricotopus bicinctus* gr.		0	4	0	3	0	0	1	0	8	0	1	10	0	1	28
			Cricotopus sp.		0	64	0	0	0	1	1	0	23	47	24	30	92	4	286
			Lopescladius sp.		0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
			Nanocladius sp.		0	2	4	2	2	0	3	0	8	7	2	5	5	2	42
			Nanocladius (Plecopteracoluthus) sp.		0	0	0	0	0	0	0	0	0	0	0	3	0	0	3
			Nanocladius minimus		0	0	0	0	0	0	6	0	0	0	0	0	0	0	6
			Orthocladius sp.		0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
			Orthocladius (Euorthocladius) sp.		0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
			Parametriocnemus sp.		0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
			Rheocricotopus sp.		0	27	1	0	9	0	0	0	5	19	90	30	2	0	183
			Tvetenia vitracies gr.		0	0	0	0	1	0	0	0	0	0	0	5	0	0	6
			Xylotopus par		0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
			Thienemanniella sp.		0	121	8	16	2	0	7	0	8	13	108	20	5	0	308
			Thienemannimyia gr. sp.		2	0	0	0	2	0	0	0	1	1	2	5	13	9	35
		(7)			1	0	2	2	0	0	0	0	0	1	0	1	1	0	8
			Chironomus sp.		0	0	0	11	0	0	8	0	2	0	0	0	0	1	22
			Cryptochironomus sp.		0	1	1	2	1	3	0	0	4	1	3	7	0	8	31
			Cryptotendipes sp.		0	3	0	0	0	0	0	0	0	0	0	0	1	0	4
			Dicrotendipes sp.		0	6	4	20	0	0	0	0	0	12	1	5	5	16	69
			Goeldichironomus sp.		0	0	0	14	0	0	36	0	2	0	0	0	0	0	52
			Glyptotendipes sp.		0	0	0	7	0	0	0	0	0	0	0	0	0	0	7
			Nilothauma sp.		0	0	0	0	0	0	0	0	0	0	1	5	3	3	12
			Paracladopelma sp.		0	0	0	0	0	0	0	0	0	0	1	4	0	0	5
			Paratendipes sp.		0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
			Polypedilum sp.		0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
			Polypedilum convictum		3	0	4	2	15	2	0	0	15	9	0	0	16	1	67

Table 4. Taxonomic classification of benthic macroinvertebrates and counts of individual taxa for 14 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001—Continued

Class	Order	Family	Genus or species		Bioassessment reach ID														Total
			Scientific name	Common name	BSC-2	BSC-5	LPIB-1	LPIB-6	MC-1	MC-4	NR-1	NR-2	NR-3	TC-1	TC-2	VC-3	VC-10	VC-11	
Insecta—Cont.	Diptera—Cont.		*Polypedilum fallax* gr.		0	3	0	1	0	0	0	1	0	0	0	0	1	2	8
			Polypedilum halterale gr.		0	0	0	68	0	0	3	0	1	0	0	0	0	1	73
			Polypedilum illinoense gr.		0	2	0	344	1	0	0	0	18	0	19	13	0	2	399
			Polypedilum flavum		0	12	0	0	0	0	2	0	17	0	3	27	0	0	61
			Polypedilum scalaenum gr.		0	4	7	1	0	0	0	0	6	0	15	22	28	8	91
			Polypedilum tritum		0	10	7	8	3	3	154	5	44	11	0	7	5	17	274
			Stelechomyia perpulchra		0	0	0	0	1	2	0	0	0	1	1	0	0	0	5
			Stenochironomus sp.		1	1	2	1	3	0	3	0	8	1	11	4	0	9	44
			Stictochironomus sp.		0	0	0	0	0	0	0	0	6	0	0	1	0	5	12
			Stictochironomus caffrarius gr.		0	0	0	0	0	0	0	0	7	0	0	0	0	1	8
			Tribelos sp.		0	3	0	1	0	0	0	0	1	0	0	0	0	1	6
			Tribelos jucundum		0	10	0	0	0	0	0	0	0	0	0	0	0	0	10
			Tribelos fuscicorne		0	0	0	34	0	0	4	3	3	0	2	0	0	0	46
			Xenochironomus xenolabis		0	0	0	1	0	0	0	0	0	0	0	0	0	3	4
		(8)	*Pseudochironomus* sp.		0	6	2	2	1	0	0	0	2	1	1	1	2	1	19
		(9)	*Cladotanytarsus* sp.		0	3	31	11	0	0	0	0	0	2	20	8	2	1	78
			Rheotanytarsus sp.		1	3	15	2	10	1	27	0	85	3	9	85	3	5	249
			Stempellinella sp.		0	16	25	0	10	0	0	0	2	6	23	12	0	4	98
			Tanytarsus sp.		1	20	44	24	4	1	4	0	15	13	21	58	17	27	249
			Parakiefferiella sp.		0	15	0	0	0	0	1	0	17	3	8	11	1	0	56
			Paralauterborniella nigrohalterale		0	0	1	2	0	0	0	0	4	3	0	6	0	3	19
		Dolichopodidae		Long-legged flies	0	1	0	3	0	0	2	0	1	0	0	0	0	0	7
		Tabanidae		Horse and deer flies	0	1	0	0	1	0	0	0	0	0	0	0	0	0	2
Number of benthic macroinvertebrates					76	805	436	1,081	411	105	724	123	882	426	1,426	1,507	543	693	9,238
Number of aquatic insects					66	694	335	716	359	93	544	121	784	420	1,258	1,314	527	555	7,786
Number of aquatic insect taxa					32	79	35	66	60	36	66	12	94	54	99	108	64	86	242

[1] Subfamily Ceratopogoninae.
[2] Subfamily Tanypodinae, tribe Procladiini.
[3] Tribe Natarsiini.
[4] Tribe Pentaneurini.
[5] Subfamily Orthocladiinae.
[6] Tribe Orthocladiini.
[7] Subfamily Chronominae, tribe Chironomini.
[8] Tribe Pseudochironomini.
[9] Tribe Tanytarsini.

Table 5. Stream-habitat and land-use data for 15 bioassessment reaches, Big Thicket National Preserve, Texas, 1999–2001

[See table 2 for data description; m, meters; km^2, square kilometers; NA, not available]

Stream-habitat measure or land-use variable	Bioassessment reach ID														
	BSC2	BSC5	LPIB1	LPIB6	MC1	MC4	NR1	NR2	NR3	TC1	TC2	VC1	VC3	VC10	VC11
Linear reach length (m)	113	75.2	92.4	487	81.2	101	962	639	509	115	107	77.2	161	363	191
Curvilinear reach length (m)	113	117	159	866	104	161	1,170	926	908	161	186	134	241	455	477
Reach sinuosity	100	155	172	177	127	160	121	145	178	140	173	174	149	125	249
Reach slope	1.65×10^{-5}	1.95×10^{-4}	1.34×10^{-4}	1.06×10^{-5}	5.95×10^{-5}	1.43×10^{-4}	5.04×10^{-5}	6.44×10^{-5}	3.20×10^{-5}	6.28×10^{-4}	1.18×10^{-4}	6.95×10^{-5}	1.68×10^{-4}	1.22×10^{-4}	7.79×10^{-6}
Reach structure index	300	197	182	0	300	149	21.4	0	0	93.0	48.3	157	95.5	57.2	176
Mean bank slope	.074	.082	.067	.079	.084	.092	.034	.047	.065	.101	.083	.094	.075	.074	.053
Bank height (m)	3.65	3.30	2.19	7.46	3.54	4.07	10.9	5.97	7.23	3.64	4.26	3.56	4.33	5.62	4.12
Mean wetted channel width (m)	11.8	9.36	5.10	40.9	14.1	15.5	86.1	67.4	96.5	10.7	9.79	8.51	16.7	23.4	41.0
Mean bank-full channel width (m)	21.9	38.7	17.8	58.7	22.2	41.1	103	91.8	88.6	29.5	21.8	23.9	30.4	36.3	78.2
Channel incision	.055	.026	.032	.039	.054	.031	.033	.025	.029	.037	.045	.047	.028	.044	.011
Drainage area (km^2)	280	389	239	1,620	227	391	19,900	20,400	23,600	367	391	700	593	838	1,120
Percentage urban land use (1970)	.68	1.24	.92	3.02	.97	.58	1.95	1.90	1.98	2.49	2.36	1.02	1.27	1.00	1.87
Percentage urban land use (1990s)	.63	.78	.92	2.2	NA	NA	1.83	1.80	1.82	2.46	2.33	.98	1.16	1.01	1.75
Percentage agricultural land use (1970s)	5.65	4.41	.84	12.9	5.79	4.25	25.3	24.7	21.7	5.22	5.05	2.93	3.28	3.27	2.95
Percentage agricultural land use (1990s)	7.89	6.96	4.73	15.1	NA	NA	25.5	25.0	22.6	11.2	10.8	5.92	7.21	6.89	7.19
Percentage forest land use (1970s)	93.1	93.8	97.7	83.7	93.1	92.3	68.7	69.3	72.8	90.4	90.8	94.9	94.3	94.9	94.4
Percentage forest land use (1990s)	83.1	83.5	92.1	77.4	NA	NA	59.4	59.6	62.6	79.8	80.4	85.2	84.0	85.3	84.4