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Stream Habitat Characteristics at Selected Sites in the Georgia-Florida Coastal Plain

By Lori J. Lewis and Michael Turtora

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Conversion Factors

Multiply	By	To obtain
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
square kilometer (km^2)	0.3861	square mile
meters per kilometer (m/km)	5.28	foot per mile

Acronyms and abbreviations used in report

ADAPS	=	Automated Data Acquisition and Processing System
GAFL	=	Georgia-Florida
Facw	=	Facultative wetland
Fac	=	Facultative
Facu	=	Facultative upland
NAWQA	=	National Water-Quality Assessment Program
NWIS	=	National Water Information System
Obl	=	Obligate wetland
TWINSPAN	=	Two-Way Indicator Species Analysis
USGS	=	United States Geological Survey
$\leq$	=	less than or equal to
$>$	=	greater than

Vertical Datum

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Habitat characterization is part of a multi-disciplinary approach to water-quality assessment implemented by the National Water-Quality Assessment Program. Habitat data were collected in the Georgia-Florida Coastal Plain study unit at 24 sites during 1993-95. Data were collected for habitat characteristics at three spatial scales: basin, segment, and reach. Basin data include physiography, land resource provinces, and land use, providing a description of the environmental setting at each site. Segment data include length, gradient, and sinuosity. A Kendall correlation analysis performed on segment characteristics and the log-of-basin area showed a correlation between segment gradient and the log-of-basin area and a correlation between sinuosity and segment length.

Reach data consist of field-collected measurements of both instream and riparian habitats. Sand and detritus were the most common channel-bed substrates among the sampled sites. Measurements of channel width, water depth, and bank width and height were used to create cross-sectional profiles of each sampled area. Elevations of selected durations plotted on cross sections illustrated the percentage of time that the banks were inundated at each site. Sites were divided into two groups based on duration of bank inundation (less than or equal to 1 percent and greater than 1 percent). Bank woody vegetation was also sampled and a clustering algorithm known as Two-Way INdicator SPecies ANalysis (TWINSPAN) was used to analyze these data. TWINSPAN divided the sites into two groups based on their vegetation composition. A statistical comparison of the two types of site groups (duration of bank inundation and vegetation) was performed. The significant association between these groups was consistent with the hypothesis that inundation frequency affected riparian vegetation.

INTRODUCTION

The objective of the National Water-Quality Assessment (NAWQA) Program is to describe the status and trends in the quality of our Nation's water resources and to help provide an understanding of the major factors that can affect the quality of these resources (Hirsch and others, 1988). The program design involves an integrated approach to water-quality assessment which incorporates physical, chemical, and biological components.

Stream habitat evaluation is an intregal part of the biological studies conducted by the NAWQA Program, providing documentation of geomorphic and riparian characteristics that influence the water chemistry and species composition of aquatic environments. The goal of stream habitat characterization within the NAWQA Program is to use the relations among habitat and other physical, chemical, and biological factors to interpret water-quality conditions (Meador and others, 1993).

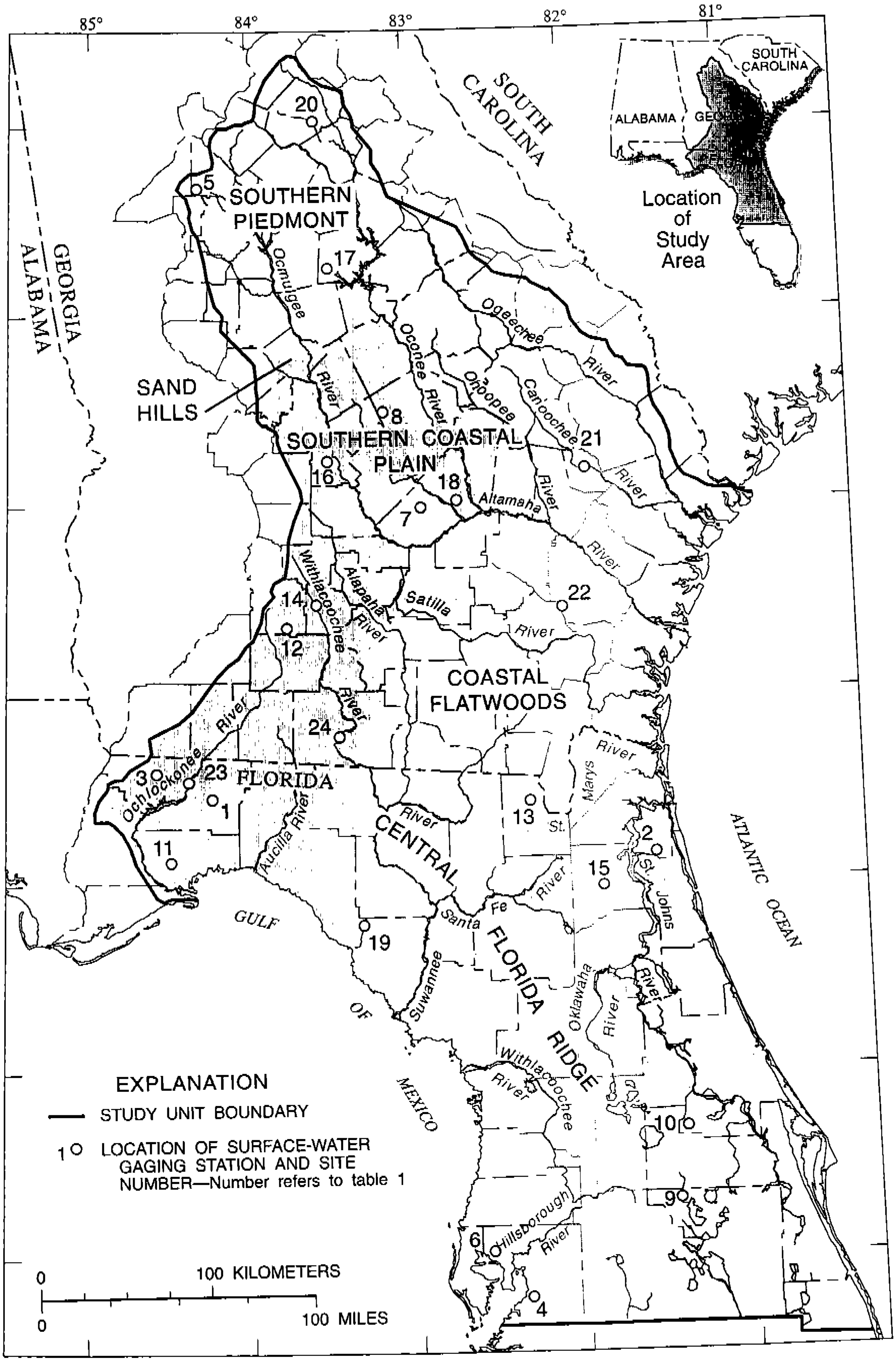


Figure 1. Land resource provinces and locations of sites with habitat data in the Georgia-Florida Coastal Plain Study Unit.

Purpose and Scope

This report presents results from stream habitat characterization of 24 stream sites in the Georgia-Florida Coastal Plain (GAFL) study unit. The objectives of this report are: (1) to describe basin and segment characteristics of the streams, (2) to report data gathered at selected stream reaches, and (3) to present analyses relating the frequency of bank inundation at stream reaches to the species composition of bank vegetation. Habitat characterization of selected sites in this study area began in 1993 and continued through 1995.

Environmental Setting

The GAFL study area is located on the southeastern coast of the United States. It covers an area of nearly 161,000 km^2 and extends from north-central Georgia to central Florida (Berndt and others 1996). The study area is located mostly in the Coastal Plain physiographic province, with only the northernmost part in the Southern Piedmont province.

The GAFL study area is divided into 5 land resource provinces (fig. 1). These provinces were designated based on generalized soil classifications (Berndt and others, 1996). Listed from north to south they are: (1) Southern Piedmont, (2) Sand Hills, (3) Southern Coastal Plain, (4) Coastal Flatwoods, and (5) Central Florida Ridge (fig. 1). The Southern Piedmont covers the northernmost tip of the study area and is characterized by steeply sloped mountain ridges, foothills and narrow valleys. The Sand Hills is a narrow tract separating the Southern Piedmont from the Southern Coastal Plain. The Southern Coastal Plain extends diagonally across central Georgia into a small part of the Florida Panhandle. This area ranges from approximately 80 to 160 km in width and has been described as having broad interstream areas with both gentle and deeply incised valleys (Berndt and others, 1996). The Coastal Flatwoods extends along the coastlines of both Georgia and Florida and inland approximately 8 to 160 km. This province is composed of nearly level plains, marshes, barrier islands and a set of low terraces (Berndt and others, 1996). The Central Florida Ridge includes the middle part of the Florida Peninsula and has a poorly organized drainage system. Known for its karst topography, this province contains many sinks, sinkhole lakes, sinking streams, and springs (Berndt and others, 1996).

The population of the GAFL study area was 9.3 million in 1990 (Berndt and others, 1996). The three largest cities are Jacksonville, Fla., Atlanta, Ga. and Tampa, Fla. (fig. 2). In all, land-use areas classified as urban cover 4.4 percent of the study area. Other significant land uses include forest (48 percent), agriculture (28 percent) and wetlands (16 percent). These land-use statistics from the 1970's were derived using the USGS classification system for land use and land cover (Anderson and others, 1976; Mitchell and others, 1977). Much of the forested lands are private pine plantations. There are also four national forests located in the study area. Agriculture includes both orchards and row crops, as well as cattle and poultry operations. Wetlands are located mostly along the coastlines and in the Okefenokee Swamp.

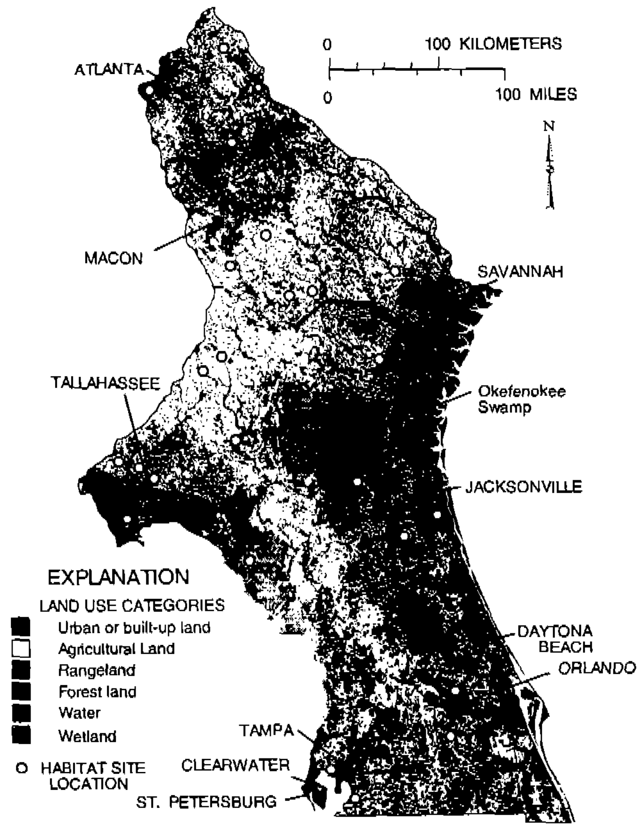


Figure 2. Land use (1972-1976) and locations of sites with habitat data in the Georgia-Florida Coastal Plain study unit.

Acknowledgments

The authors thank the Georgia Agricultural Research Service in Tifton, Ga., for providing gage data for Little River near Tifton, Ga. Appreciation is extended to the following people for their efforts in the data-collection process: Darlene Blum, Wade Bryant, John Byrnes, Thomas Cuffney, Melanie Darst, Lawrence DeWeese, William Fife, Thomas Garside, Steven Goodbred, Lisa Ham, Rupert Heirs, Cliff Hupp, Richard Kelly, Helen Light, Michael Meador, Edward Oaksford, John Pittman, Alan Punshon, and Mark Zucker. The authors also acknowledge the technical guidance offered by USGS reviewers Melanie Darst and Kim Haag.

METHODS

Habitat characterization sites were in close proximity to USGS gaging stations. They represent various land uses, land resource provinces, and basin areas within the study area. Site refers to the location where reach data were collected.

Data were collected in accordance with the NAWQA protocol, "Methods for characterizing stream habitat as part of the National Water-Quality Assessment Program" by Meador and others (1993). The importance of both broad-scale fators and local conditions is reflected in the NAWQA habitat characterization protocol by the recognition of nested spatial scales: basin, segment, and reach (fig. 3).These spatial scales form a hierarchy which provides a framework for data collection and interpretation.

Basins can be characterized by broad-scale factors such as physiography, geology, and land use. These factors influence the long-term development of stream habitats. For example, reach and segment characteristics such as gradient and substrate are often actually controlled by the geology of the basin.

The segment is defined as a section of stream between two tributary junctions or other major discontinuites such as waterfalls, dams, or point sources of pollutants (Frissel and others, 1986). A segment should represent a uniform set of physical, chemical, and biological conditions within a stream (Meador and others, 1993). Characteristics such as stream gradient and sinuosity are relevant at this smaller ecological scale.

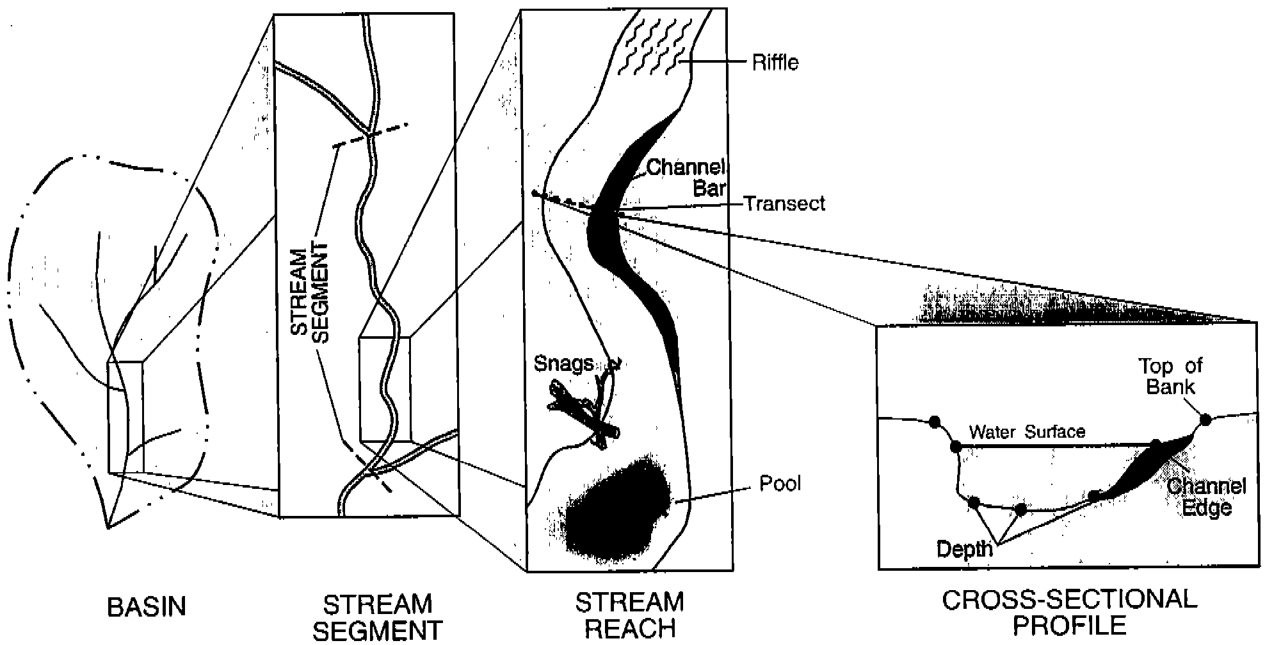


Figure 3. Spatial hierarchy of basin, stream segment, stream reach, and cross-sectional profile.

Segments were further subdivided into reaches based on the distribution of geomorphic channel units such as riffles, pools, and runs. The reach was selected to represent the diversity of geomorphic channel units present (Meador and others, 1993). Ideally, each reach included 2 examples of each geomorphic channel unit in the segment. Reach scale characteristics include channel-bed substrate, channel shape, erosional features, and the occurrence of refugia, such as submerged logs, in addition to geomorphic channel units.

Data Collection

Drainage basin data were compiled using a geographic information system (GIS). Depending on basin size, the drainage basin was delineated on either 1:24,000 or 1:100,000 USGS topographic maps. Lines resulting from these delineations were digitized and the GIS was used to determine basin area and broad-scale geographic features of each basin. These features include physiography (Fenneman, 1938), land-resource provinces (Berndt and others, 1996), and land use (Anderson and others, 1976).

Segment data include segment length, channel sinuosity and segment gradient. Channel sinuosity is the ratio of channel length to the straight-line distance between two points. Segment gradient is the change in elevation per unit channel length. Segment data were measured from 7.5-minute USGS topographic maps using a digitizer.

The reach is the sampling unit for field data collection. Although the primary factor in selecting a stream reach is the presence of two repeating geomorphic channel units (pool, riffle, or run), they are not present in all streams. Most streams in the GAFL study unit are dominated by runs. In these cases, the reach length was set to equal approximately 20 times the channel width with a 500 m maximum length. GAFL study area reaches ranged in length from 89 to 500 meters. At site 7 (Turnpike Creek) data were collected at three consecutive reaches to assess how well measurements at a single reach characterize the segment.

Reach data include instream and riparian characteristics. Data were collected along transects perpendicular to the channel. Six transects were established at 18 of the 24 sites and three transects were established at the other six sites. Data collected included channel width, canopy angle, aspect, and bank characteristics such as height, width, angle, shape, substrate, and erosion. Water depth and channel-bed substrate were also measured at three points along each transect.

Bank woody vegetation (trees and shrubs) data were collected using the point-centered quarter method (Mueller-Dombois and Ellenberg, 1974). These sampling points were established at the tops of both banks for each transect in the reach. Four quarters were delineated by the intersection of two imaginary lines at this center sampling point, one coincident with the transect line and one perpendicular to it (fig. 4). For the tree or shrub nearest to the center point in each quarter, the species, diameter at breast height, and distance to the center point were recorded. Woody vegetation measured in each quarter had to be at least

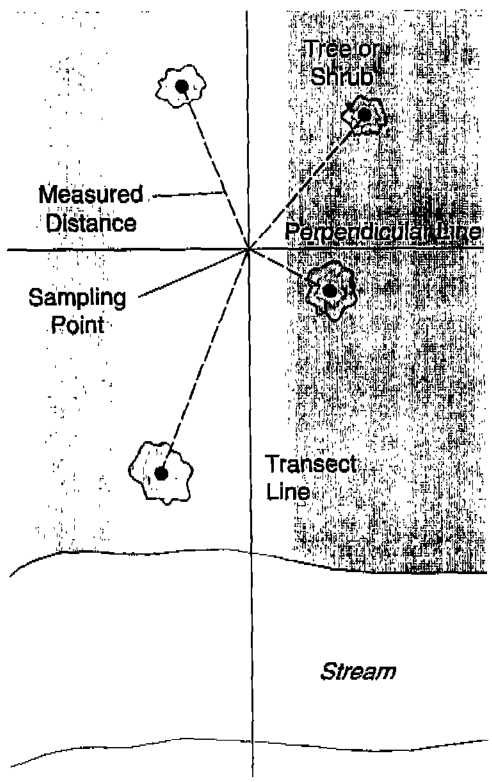


Figure 4. Schematic of point-centered quarter method for woody vegetation (trees and shrubs) sampling.

2 meters tall with a diameter at breast height of at least 3 centimeters. A possible limitation of the point-centered quarter method in relation to characterization of bank vegetation is that measured trees are not limited to the top of the bank. If no tree exists on the top of the bank for a given quarter, a tree may be selected from either the channel edge (for quarters toward the channel) or on the floodplain proper (for quarters toward the floodplain).

Data Analysis

Basin characteristics were considered in conjunction with characteristics from other levels in the spatial hierarchy to describe habitat at the sites. For example, the relations between basin area and segment data were explored. Site numbers were assigned in order of increasing basin area. Segment data were analyzed using scatter plots and correlation analysis. The scatter plot matrix (Chambers and others, 1983) of various segment characteristics provides a graphical means of exploring the multivariate structure of a data set. For each transect at each reach, bank width, bank height, channel width and water depth were used to create cross sectional profiles.

The following process was used to determine the approximate percentage of time the banks were inundated. Daily discharge data at USGS gaging stations were used to calculate flow duration (the percentage of time a given flow was equaled or exceeded). Duration calculations were initially based on discharge because stage data were not available for all stations. For each gaging station, flow duration statistics were converted to stage duration statistics using the most recent rating curve (plot of stage versus discharge) (fig. 5).

Transect measurements of channel geometry were made relative to the water surface at the time of sampling. To relate channel geometry measurements at transects with inundation durations based on stage recorders near the sampling reach, the assumption was made that the water surface slope was zero over the length of the sampling reach. This assumption is reasonable since stream gradients are small relative to river stage fluctuations. Given this assumption and river stage the day of field measurement, the stages for each inundation duration were shifted by subtraction.

Woody vegetation data were analyzed using Two-Way INdicator SPecies ANalysis (TWINSPAN), a polythetic, divisive, hierarchical clustering algorithm (Gauch, 1982). This algorithm classifies sites based on species assemblage and classifies the species based on their abundance at the sites. The TWINSPAN analysis proceeds in a series of steps. For site classification, each step divides a group of sites into two groups based on differences in species occurrence. At each division, species that differ the most between the two groups, termed indicator species, are identified. These indicator species are of two types because different indicator species

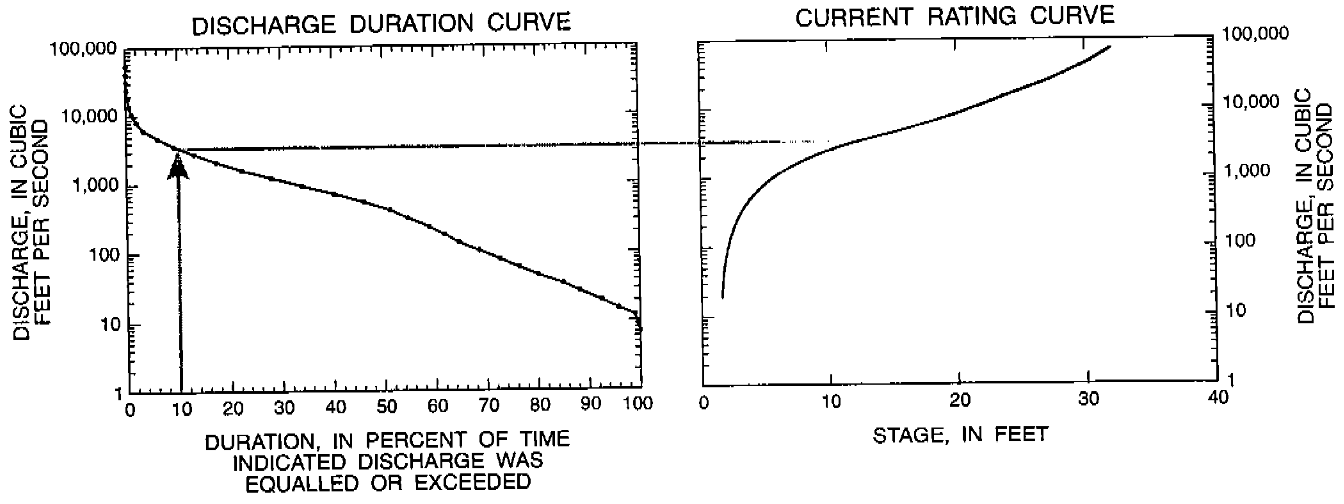


Figure 5. Determination of stage that is equalled or exceeded for a given percentage of time by using the discharge duration curve with the current rating curve at a selected site.

may define one of the two groups either by their presence or by their absence. TWINSPAN results were used to classify reaches based on their species composition and to construct a table of species found at each reach in which sites and species are ordered to emphasize the similarities in vegetation between reaches.

RESULTS OF HABITAT CHARACTERIZATION

Data from the 24 sampled sites are presented by spatial hierarchical level. These data provide a wide range of habitat descriptors, from the broad basin characteristics that control the development of the stream to the local conditions in the reach at the site of biological community sampling.

Basin and Segment Data

Basin and gage data are presented in table 1. The sites are ordered by increasing basin sizes that range from 25 to 3,864 km^2. Pie charts of land use for each basin based on categories described by Anderson and others (1976), and Mitchell and others (1977), are presented in figure 6.

Table 1. Basin and gage data for selected sites in the Georgia-Florida Coastal Plain study unit

[Site no., Site number; USGS, U.S. Geological Survey; km^2, square kilometers]

Site no.	Station number	Station name	Gage type	Period of record	Basin area (km^2)	Land resource province	Land use class
1	02326838	Lafayette Creek at Tallahassee, Fla.	water stage recorder	1979-89; 1993-96	25	Southern Coastal Plain	urban
2	02246150	Big Davis Creek at Bayard, Fla.	water stage recorder	1966-69; 1974-97	37	Coastal Flatwoods forest	forest
3	02329534	Quincy Creek near Quincy, Fla.	discontinued gage	1975-93	44	Southern Coastal Plain	mixed
4	02300700	Bullfrog Creek near Wimauma, Fla.	water stage recorder	1957-59; 1977-97	74	Coastal Flatwoods	mixed
5	02203800	South River at Bouldercrest Rd at Atlanta, Ga.	crest stage indicator	1951-87	101	Southern Piedmont	urban
6	02307000	Rocky Creek near Sulphur Springs, Fla.	water stage recorder	1953-97	109	Coastal Flatwoods	urban
7	02216180	Turnpike Creek near McRae, Ga.	water stage recorder	1983-97	129	Southern Coastal Plain	agriculture
8	02224000	Rocky Creek near Dudley, Ga.	discontinued gage	1951-76	160	Southern Coastal Plain	agriculture
9	02263800	Shingle Creek at Airport near Kissimmee, Fla.	water stage recorder	1959-97	227	Central Florida Ridge	urban
10	02234990	Little Wekiva River near Altamonte Springs, Fla.	water stage recorder	1972-79; 1983-97	239	Central Florida Ridge	urban
11	02327100	Sopchoppy River near Sopchoppy, Fla.	water stage recorder	1964-97	270	Coastal Flatwoods	forest
12	02317870	Warrior Creek near Sumner, Ga.	crest stage indicator	1966-87	283	Southern Coastal Plain	agriculture
13	02229000	Middle Prong St. Marys River at Taylor, Fla.	water stage recorder	1956-67; 1976-97	326	Coastal Flatwoods	forest
14	02317797	Little River near Tifton, Ga.	water stage recorder	1972-97	335	Southern Coastal Plain	agriculture
15	02245500	South Fork Black Creek near Penney Farms, Fla.	water stage recorder	1940-97	361	Coastal Flatwoods	forest
16	02215100	Tucsawhatchee Creek near Hawkinsville, Ga.	water stage recorder	1986-97	420	Southern Coastal Plain	agriculture
17	02221525	Murder Creek below Eatonton, Ga.	water stage recorder	1977-97	491	Southern Piedmont	mixed
18	02216100	Alligator Creek near Towns, Ga.	crest stage indicator		628	Southern Coastal Plain	agriculture
19	02324000	Steinhatchee River near Cross City, Fla.	water stage recorder	1950-97	791	Coastal Flatwoods	forest
20	02217475	Middle Oconee River near Arcade, Ga.	water stage recorder	1987-97	863	Southern Piedmont	mixed
21	02203000	Canoochee River near Claxton, Ga.	water stage recorder	1937-97	1,450	Southern Coastal Plain	agriculture
22	02227500	Little Satilla River near Offerman, Ga.	water stage recorder	1951-97	1,721	Coastal Flatwoods	agriculture
23	02329000	Ochlockonee River near Havana, Fla.	water stage recorder	1927-97	2,951	Southern Coastal Plain	mixed
24	02318500	Withlacoochee River near Quitman, Ga.	water stage recorder	1929-32; 1937-48 1989-97	3,864	Southern Coastal Plain	mixed

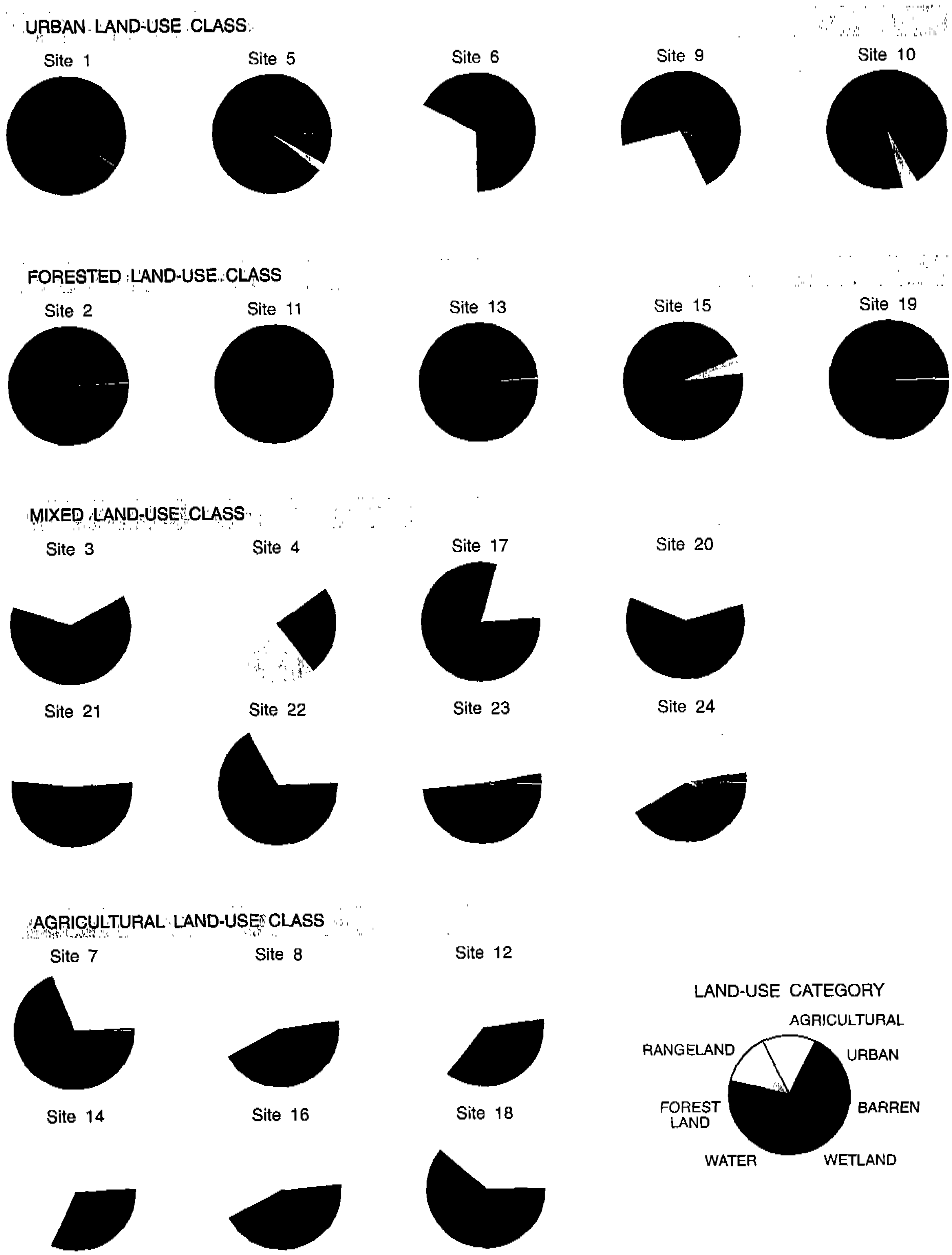


Figure 6. Percentage of basin area in each land-use category grouped by land-use class.

Sites were classified based on basin land use and basin area. Although land use is considered a continuous variable, it is necessary to classify sites based on land use in studies such as this one in which the relatively small number of sites make comparison of continuous variables difficult. A rational classification method depends on an understanding of geography. For example, small watersheds are more likely to have homogeneous land use than large watersheds. Conversely, large rivers tend to integrate the effects of many factors (Gilliom, 1995). Therefore, sites greater than 1,000 km^2 were classified as mixed, regardless of land-use composition.

Land-use intensity was also considered in site classification. Urban land uses are considered to be the most intense.These areas have the greatest road density and the least remaining permeable surface resulting in the likelihood of greater effects per unit area. Agricultural land uses have moderate intensity compared with urban and forested land uses. Therefore, sites were only classified as forested if there was no other land use covering greater than 10 percent of the basin area. Because of differences in intensity, a smaller proportion of urban land use could be expected to influence a basin than agricultural land use. Thus, basins with urban land use greater than 10 percent and less than 30 percent were classified as mixed. Basins with greater than 30 percent urban land use were classified as urban as long as agricultural land use did not exceed 30 percent. Alternatively, basins with greater than 30 percent agricultural land use were classified as agricultural as long as urban land use did not exceed 10 percent. Of the 24 basins, 6 were classified as agriculture, 8 were mixed, 5 were forest, and 5 urban.

The distribution of sites by basin area and land-use class among land resource provinces is illustrated in figure 7. All of the GAFL sites classified as forest were located in the Coastal Flatwoods and all of the sites in the agricultural land use class were located in the Southern Coastal Plain. Two sites were located in the Central Florida Ridge; both were classified as urban and were similar in basin area (table 1).

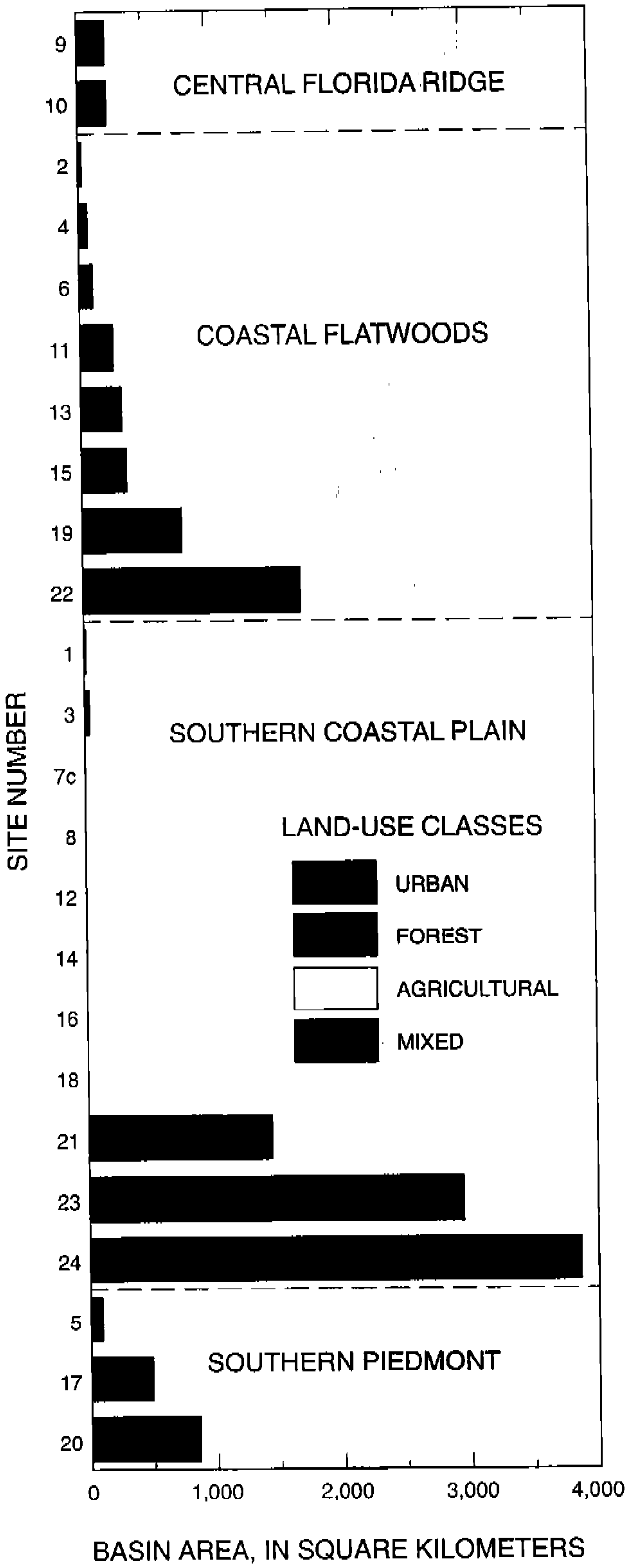


Figure 7. Basin area, land use, and land resource province of each site.

Segments ranged from 0.8 to 15 km in length with an average segment length of 4.14 km (table 2). There was little variation in sinuosity among stream segments. Stream gradients ranged over at least four orders of magnitude, from less than 0.01 to 12.46 m/km (table 2). All possible combinations of segment length, sinuosity, segment gradient, and the log of the basin area were plotted and Kendall correlations were calculated to determine if there were any relations between the variables (fig. 8). The correlation between segment gradient and log of basin area and the correlation between sinuosity and segment length were statistically significant. The negative correlation between segment gradient and log of basin area implies that small streams drain hillslopes and combine to form larger streams with relatively low gradients.

Table 2. Segment data for habitat sites in the Georgia-Florida Coastal Plain study unit

[km, kilometers; m/km, meters per kilometer]

Site number	Station name	Segment length (km)	Channel sinuosity	Segment gradient (m/km)
1	Lafayette Creek at Tallahassee, Fla.	1.9	1.05	12.46
2	Big Davis Creek at Bayard, Fla.	4.0	1.10	1.89
3	Quincy Creek near Quincy, Fla.	1.3	1.15	1.67
4	Bullfrog Creek near Wimauma, Fla.	3.1	1.28	1.13
5	South River at Bouldercrest Rd at Atlanta, Ga.	4.5	1.23	3.07
6	Rocky Creek near Sulphur Springs, Fla.	4.0	1.98	0.85
7	Turnpike Creek near McRae, Ga.	1.6	1.15	0.74
8	Rocky Creek near Dudley, Ga.	1.3	1.11	1.90
9	Shingle Creek at Airport near Kissimmee, Fla.	4.5	1.11	0.86
10	Little Wekiva near Altamonte Springs, Fla.	12.1	1.40	0.42
11	Sopchoppy River near Sopchoppy, Fla.	8.5	1.69	0.49
12	Warrior Creek near Sumner, Ga.	2.4	1.09	0.53
13	Middle Prong near Taylor, Fla.	6.1	1.11	0.85
14	Little River near Tifton, Ga.	1.1	1.14	0.50
15	South Fork Black Creek near Penney Farms, Fla.	1.4	1.23	0.01
16	Tucsawhatchee Creek near Hawkinsville, Ga.	2.6	1.49	0.01
17	Murder Creek below Eatonton, Ga.	1.6	1.10	1.09
18	Alligator Creek near Towns, Ga.	1.3	1.22	0.61
19	Steinhatchee River near Cross City, Fla.	10.5	1.25	0.41
20	Middle Oconee near Arcade, Ga.	1.9	1.19	0.01
21	Canoochee River near Claxton, Ga.	2.6	1.70	0.34
22	Little Satilla near Offernam, Ga.	15.0	1.55	0.43
23	Ochlockonee River near Havana, Fla.	0.8	1.12	0.01
24	Withlacoochee River near Quitman, Ga.	5.3	1.64	0.58
	Mean	4.14	1.30	0.87
	Standard deviation	3.78	0.25	0.80
	Median	2.57	1.21	0.60
	Range	(0.8-15.0	(1.05-1.98)	(0.01-12.46)

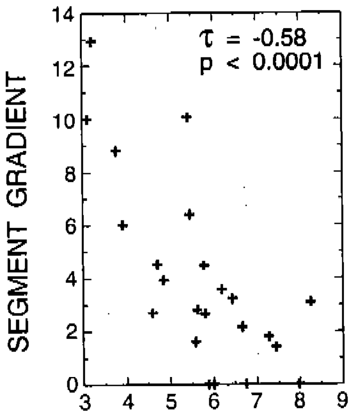
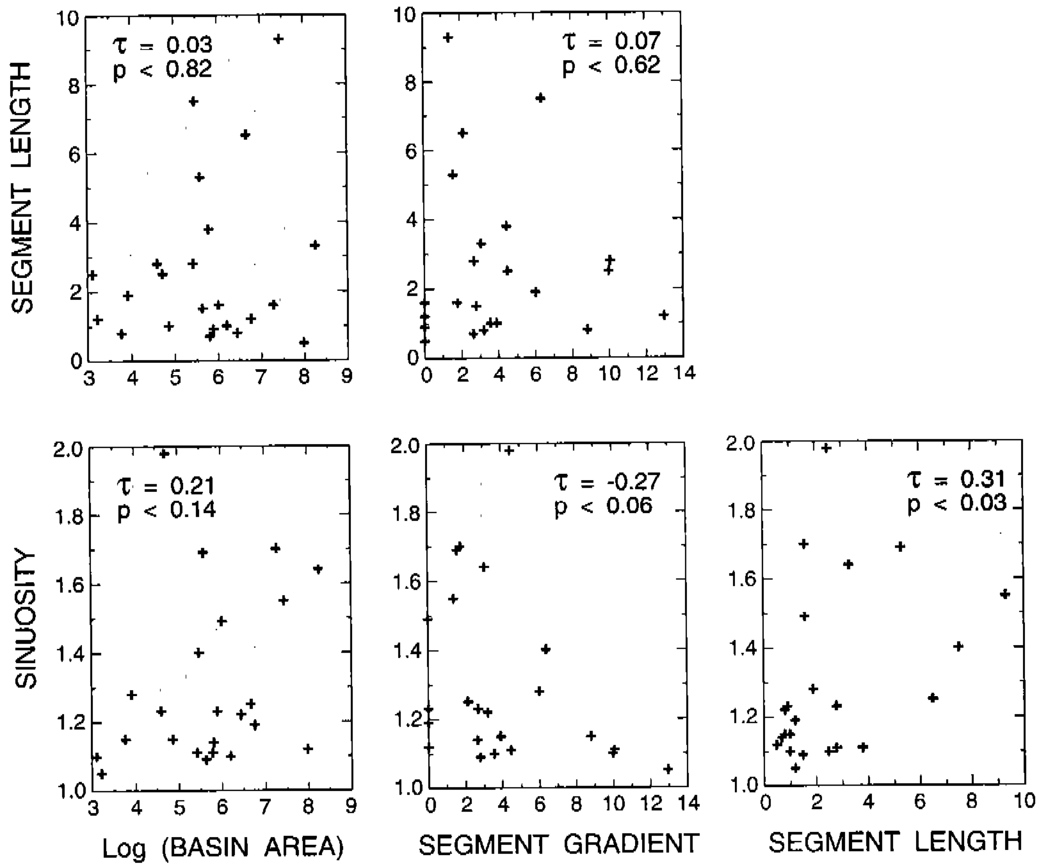


Figure 8. Matrix of segment data for the Georgia-Florida Coastal Plain study area.

EXPLANATION

SIGNIFICANT CORRELATION

NO SIGNIFICANT CORRELATION



Reach Data

Channel-bed substrate and bank woody vegetation are the two reach characteristics described in this section. Instream and riparian measurements were used to construct cross sections of each reach. Because duration of inundation affects the structure of vegetative assemblages (Light and others, 1993), classification of sites based on duration of inundation at top of bank was compared to classification of sites based on riparian vegetation.

Channel-Bed Substrate

Substrate is an important streambed feature that regulates the occurrence and distribution of a variety of fish and benthic invertebrates. Sand was the most common substrate material found in the study area. Sand and detritus occurred most frequently; cobble, gravel, and boulder substrates were rarely encountered. There were only three sites sampled in the study area where sand was not among the dominant bed materials (fig. 9): site 2 (Big Davis Creek), dominated by organic matter and muck, site 8 (Rocky Creek) having both cobble and gravel, and site 19 (Steinhatchee River) where the reach consisted of limestone outcroppings. Limestone is also the predominant substrate at sites 24 (Withlacoochee River), 17 (Murder Creek), and 23 (Ochlockonee River). The bedrock at site 24 (Withlacoochee River) is associated with one of the few riffles among the GAFL sites.

Channel Cross Sections and Duration of Bank Inundation

Cross-sectional profiles allow the comparison of channel shape among sites. Channel shape is a function of the width-to-depth ratio as well as bank angle. Cross-sectional profiles were plotted in three groups based on stream width to maintain similar scales to compare and contrast channel shape (fig. 10). The vertical exaggeration was held constant within each group so that streams with large width-to-depth ratios would appear flatter than streams with small width-to-depth ratios.

Relative elevations of selected inundation durations are shown on the cross sections of the sites that had available gage data. The endpoints of each profile represent the top of the bank (fig. 10), making it possible to approximate the percentage of time that the top of the banks of each transect are inundated. Sampled streams were divided into two groups based on duration of bank inundation: those with bank inundation occurring 1 percent of the time or less, and those with higher durations of bank inundation (fig. 10).

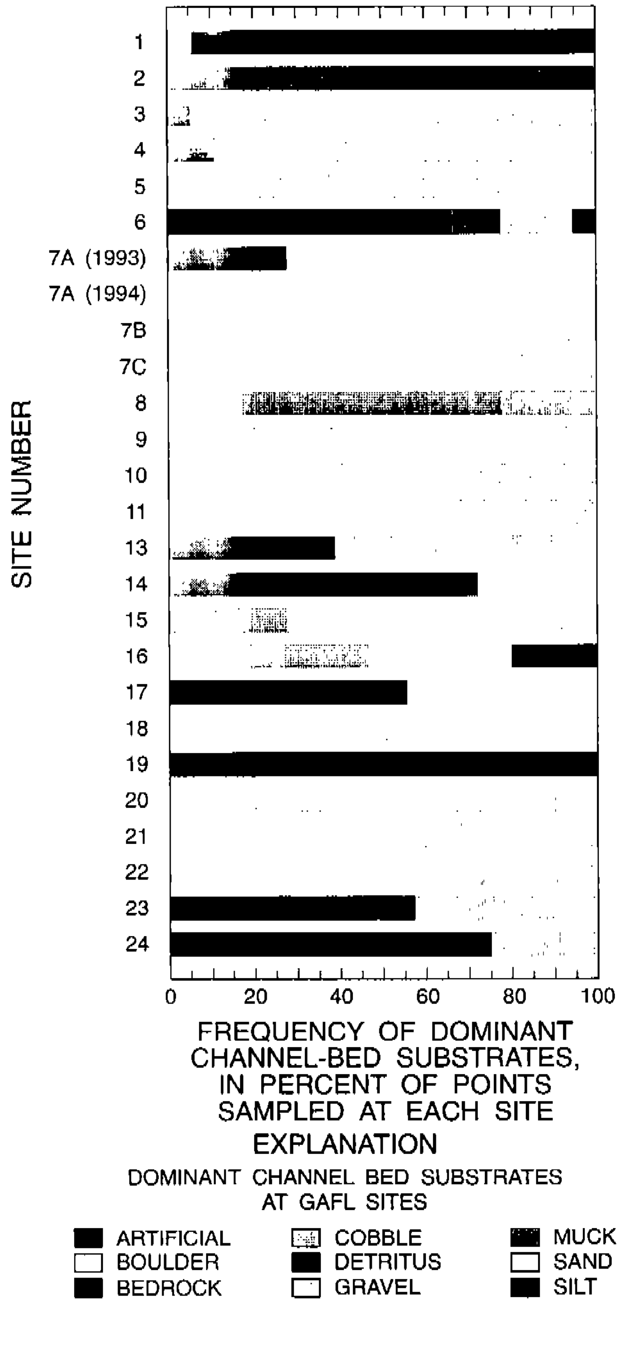


Figure 9. Percentage of occurrence at sampled points of dominant channel-bed substrates at selected sites in the Georgia-Florida Coastal Plain study area.

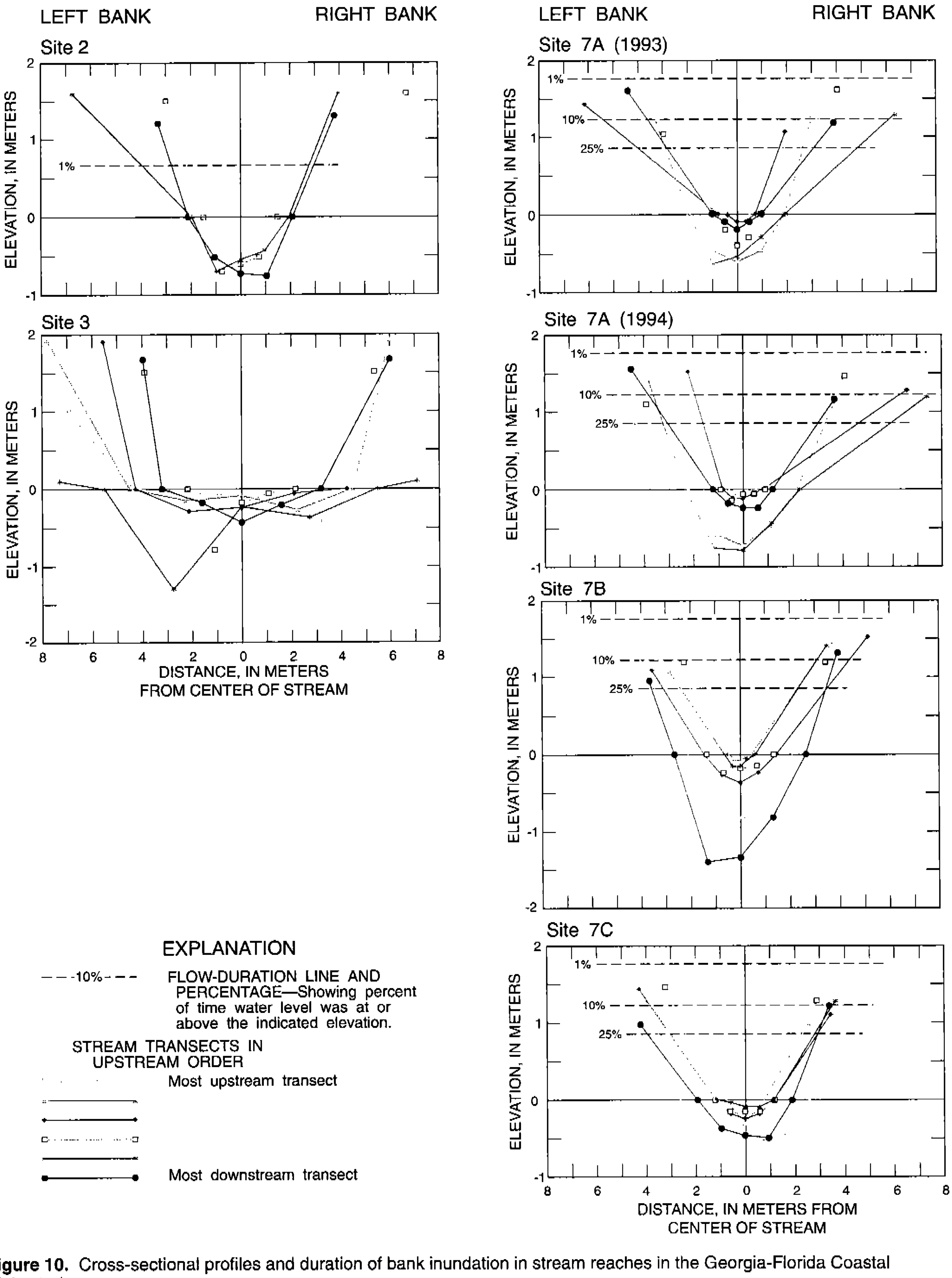


Figure 10. Cross-sectional profiles and duration of bank inundation in stream reaches in the Georgia-Florida Coastal Plain study area.

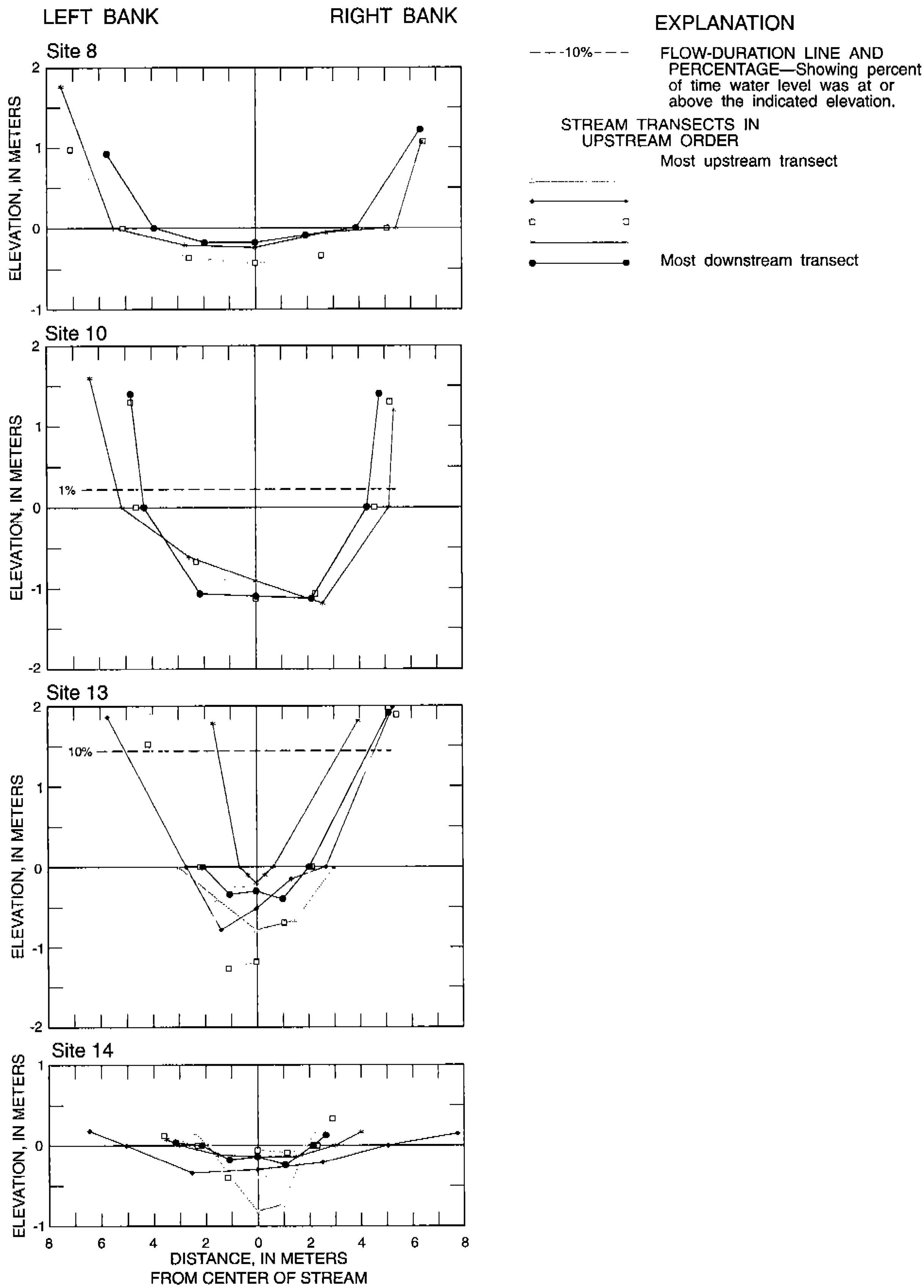


Figure 10. Cross-sectional profiles and duration of bank inundation in stream reaches in the Georgia-Florida Coastal Plain study area--Continued.

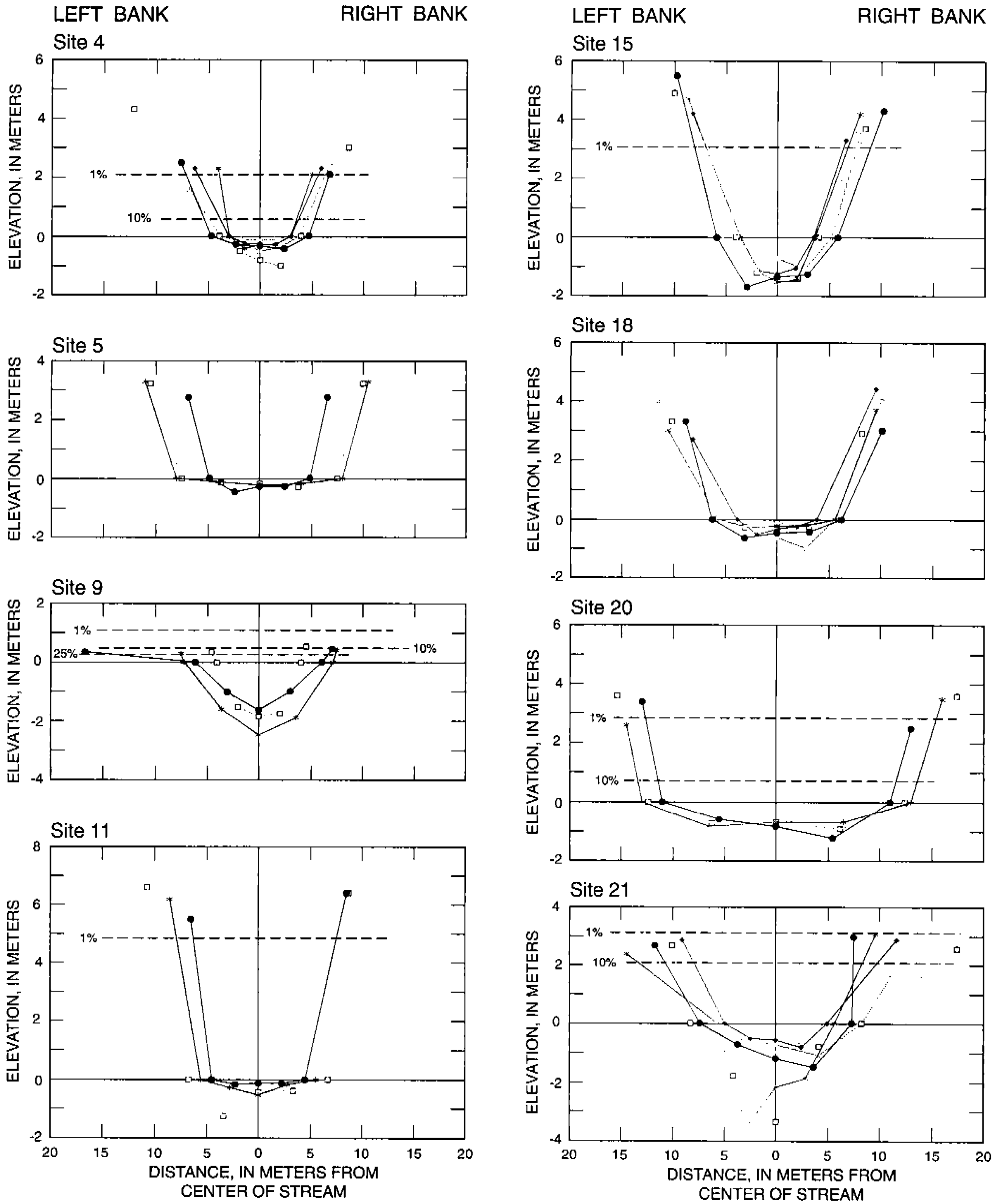


Figure 10. Cross-sectional profiles and duration of bank inundation in stream reaches in the Georgia-Florida Coastal Plain study area--Continued.

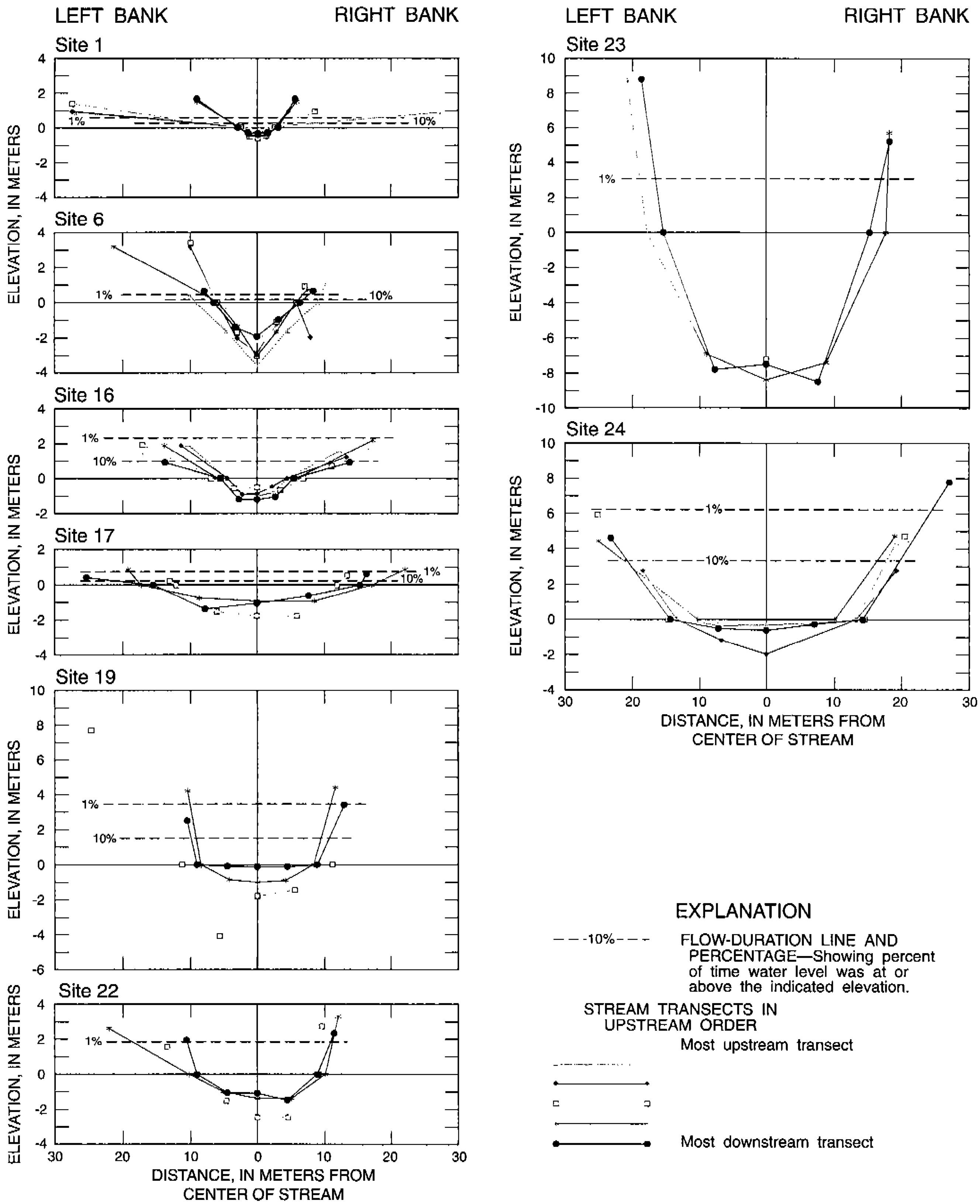


Figure 10. Cross-sectional profiles and duration of bank inundation in stream reaches in the Georgia-Florida Coastal Plain study area--Continued.

If the 1 percent inundation duration is below the top of bank the water elevations are above the top of banks less than 3 or 4 days per year on average. Elevations at the 10 and 25 percent duration levels were also plotted for sites that were categorized as greater than 1 percent to allow an estimation of bank inundation duration.

Comparison of Woody Vegetation at Sites

Seventy-four woody species (trees or shrubs) were identified as a result of quarter- point sampling. *Acer rubrum* (red maple) and *Quercus laurifolia* (swamp laurel oak) were identified at 75 percent of the sites (fig.11). Other common species were *Quercus nigra* (water oak), identified at 65 percent of the sites, and *Liquidambar styraciflua* (sweetgum), identified at 50 percent of the sites (fig. 11). Thirty-seven species were identified at only one site.

When all species were included in the TWINSPAN analysis, two sites (site 5 (South River) and site 4 (Bullfrog Creek)) were separated from the other 25 reaches in the first two divisions, indicating that these sites have unique species compositions. Site 5 (South River) is one of the few stream sites in the Southern Piedmont and is located in a residential neighborhood. Five of the nine species identified at this site were not found at any other site. Three of the nine species were exotic species: *Ailanthus altissima* (tree of heaven), *Broussonetia papyrifera* (paper mulberry), and *Albizia julibrissin* (mimosa).

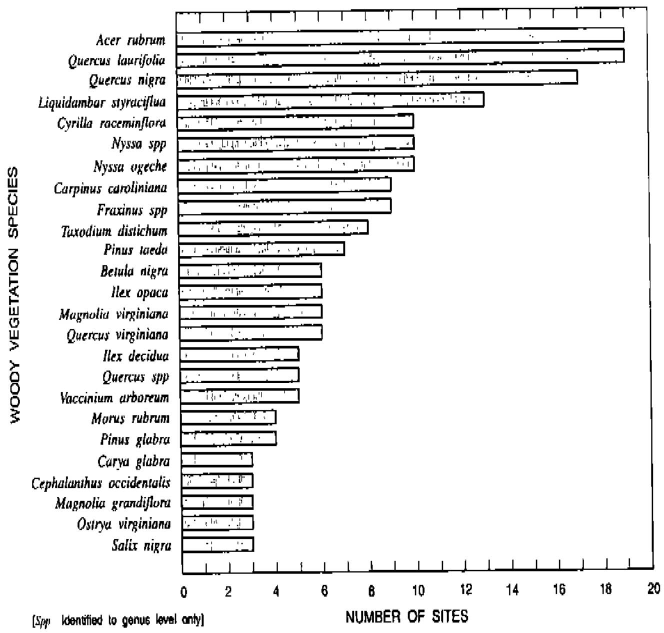


Figure 11. Frequency of occurrence of 25 most commonly identified woody vegetation species. Only species identified at three or more sites are shown.

The other site with a unique species composition, site 4 (Bullfrog Creek), is a subtropical stream located in the Coastal Flatwoods in a mixed land-use setting. The sampled reach borders a recreational park. Only two of eight species identified at this site occurred at more than one other site. Three of the remaining six species were found at only one other site; two of these species are the exotics *Albizia julibrissin* (mimosa) and *Cinnamornum camphora* (camphor).

Exotic species were also identified at two other urban sites. These species were *Sapium sebiferum* (Chinese tallow) at site 1 (Lafayette Creek) and *Cinnamornum camphora* again at site 3 (Quincy Creek). The presence of exotic species at urban streams is consistent with disturbance theory, which predicts that aggressive exotic species are more likely to colonize disturbed habitats than undisturbed habitats.

The species richness (number of species) sampled ranged from five at site 11 (Sopchoppy River) to 18 at site 16 (Tucsawhatchee Creek). Absolute woody species density (number of trees per 100 m^2) was calculated for all sites (table 3). Site 11 (Sopchoppy River) had one of the highest densities whereas site 16 (Tucsawhatchee Creek) had one of the lowest densities. Site 11 (Sopchoppy River) is dominated by small, closely spaced trees and shrubs, mostly *Quercus nigra* and *Lyonia fruticosa* (stagger-bush). Site 16 (Tucsawhatchee Creek) has a mature floodplain forest with a variety of species and large, widely spaced trees.

The sites that had the highest density (about 20 trees per 100 m^2) were site 18 (Alligator Creek) and site 2 (Big Davis Creek). Tree density was lowest (3 trees per 100 m^2) at site 4 (Bullfrog Creek) which may be due to its park location.

Uncommon species may exert a disproportionate effect on multivariate classification methods. Thus, the TWINSPAN analysis was performed on a data set where uncommon species (found at only one or two sites) were removed in order to examine the pattern of variation among the more common species (table 3).

Table 3. Results of TWINSPAN, including species list and relative basal area of species at habitat sites in the Georgia-Florida Coastal Plain study unit; uncommon species excluded

[Groups A and B resulted from first split; sites 4 and 22 removed from Group A and site 5 removed from Group B in second split; %, percent, facw, facultative wetland; obl,obligate wetland; fac, facultative; facu, facultative upland; upl, upland: this category assigned to species that were not in the national list of plant species that occur in Florida wetlanda (Reed, 1988)]

Site number	Wetland fidelity rating	4	22	14	9	7A 1995	7A 1993	7C	12	7B	21	13	23	24	18	15	1	20	17	3	8	16	2	6	11	19	5
Duration category		≤1%	>1%	>1%	>1%	>1%	>1%	>1%		>1%	>1%	>1%	≤1%	>1%		≤1%	≤1%	≤1%	>1%			>1%	≤1%	≤1%	≤1%	≤1%	
Absolute density		3.0	10.5	16.2	9.2	11.0	16.4	14.6	9.2	12.6	16.4	10.7	16.7	16.2	22.4	18.6	13.5	14.3	7.4	18.7	16.6	7.4	20.0	10.2	17.4	7.7	16.4
Species		Group A															Group B										
Cyrilla racemiflora	facw			0.4		0.6	0.3	0.2		0.2		0.3	0.0		2.3	0.1					0.6						
Nyssa ogeche	obl		0.1			2.0	8.4	19.5	8.7	20.8	22.0	22.8		16.5	8.7												
Pinus taeda	fac		54.4			9.5	7.3	6.3				3.0			40.0	22.2											
Magnolia virginiana	facw			9.9		1.3	0.8	0.9		0.2													3.4				
Quercus laurifolia	facw	61.3	3.8	11.0	39.2	71.7	70.1	60.0	74.2	33.3	2.6	21.5	45.4			4.6				0.2		1.5	0.8	6.6	5.6	21.7	
Taxodium distichum	obl			48.6	60.2						11.9	17.1	10.1	29.3	3.9							40.5					
Vaccinium arboreum	facu								0.5				0.3		0.7	0.3						0.9					
Acer rubrum	fac		1.0	1.1	0.3	5.8	8.3	12.8	7.1	31.6	3.1	14.0		7.0	5.8	17.3	3.5	5.0	7.6	0.1	6.1	2.0					
Nyssa group	obl			18.5		8.7			8.9			2.7		0.1		7.8	18.3	0.3	2.4		0.2						
Ilex decidua	facw						0.1						0.1	0.7								0.2				0.1	
Ilex opaca	fac						0.4			2.8					6.1						0.8	0.1				2.0	
Ostrya virginiana	facu												2.2			0.9		3.6									
Quercus species	facu,facw									0.2	0.1				0.8	0.6								4.7			
Cephalanthus occidentalis	obl											0.2								0.1							
Quercus virginiana	facu	33.8	26.4									6.3		18.5										46.4		18.6	
Betula nigra	facw										15.8	8.4		3.9				37.1	21.6								2.8
Fraxinus species	facu,obl			0.1		0.4	0.1						0.1	2.3		0.1		0.1			34.2						0.3
Liquidambar styraciflua	facu		10.1								3.7	3.8		1.4	9.1	4.6	46.3		4.3	6.3	6.8		10.1		6.8	17.2	
Quercus nigra	fac						4.2			0.9	39.7		21.3	14.2	16.6	31.7	2.7	27.2	28.5	38.3	9.8	6.5	29.4	23.1	78.4	17.9	
Carpinus caroliniana	fac										1.1		0.5					2.4	16.5	15.0	17.9	5.7	2.4			1.3	
Magnolia grandiflora	fac																			2.5	1.3	3.3					
Pinus glabra	facw																			20.3	10.1	5.8		2.1			
Carya glabra	facu																					1.7	3.1			15.2	
Morus rubra	fac																8.9		1.2			0.6		10.4			
Salix nigra	obl		4.1														13.7										29.3
		Uncommon species excluded from TWINSPAN Analysis																									
Acer negundo	facw																				2.8						51.0
Acer saccharinum	facw																										9.8
Agarista populifolia	obl																						0.6				
Ailanthus altissima	facu																										1.1
Albizia julibrissin	upl	0.1																									1.1
Alnus serrulata	facw															0.4											
Broussonetia papyrifera	upl																										0.5
Bumelia lanuginosa	facu																					0.3					
Carya cordiformis	fac												0.1					0.3									

Catalpa bignonioides	facw	0.2																			8.1						
Celtis laevigata	facw	0.2																									
Chionanthus virginicus	facu																								0.8		
Cinnamomum camphora	facu																			0.4							
Citrus sirinsus	upl	0.1																									
Cornus species	facu, facw																				0.3						
Crataegus marshallii	fac																								0.1		
Crataegus species	obl, fac														2.5												
Fagus gradifolia	facu																	9.8									
Forestiera acuminata	obl																										4.2
Halesia carolina	facu																			5.5							
Ilex species	facw, fac								0.4																		
Lagerstroemia indica	upl																4.3										
Ligustrum lucidum	upl																			0.1							
Liriodendron tulipifera	fac																			9.2							
Lyonia ferruginea	fac															0.1											
Lyonia fruticosa	fac																								6.7		
Myrica cerifera	fac				0.0																			0.5			
Nyssa aquatica	obl			10.4																							
Pinus echinata	upl												19.5														
Pine species	fac,facw, facu															8.1							43.6				
Planera aquatica	obl													5.9								3.2					
Platanus occidentalis	facw																	1.3	16.5								
Populus deltoides	fac																						0.4				
Diospyros virginiana	fac																						0.9				
Prunus caroliniana	upl																			1.7							
Prunus serotina	facu																0.6										
Quercus alba	facu																	11.8				0.5					
Quercus lyrata	obl																				9.1	18.6					
Quercus phellos	facw							0.3		10.0																	
Sabal palmetto	fac	2.9																								4.6	
Salix caroliniana	obl	1.6																									
Sambucus canadensis	facw																							2.3			
Sapium sebiferum	fac				0.2												1.4										
Serenoa repens	facu																							0.1			
Symplocos tinctoria	fac																			0.2							
Ulmus alata	facu																					0.4					
Ulmus americana	facw																	1.1									
Unknown	n/a				0.1				0.2				0.3		3.4	1.1	0.3						5.4	2.8	2.5	0.3	
Viburnum dentatum	fac																			0.1							
Viburnum obovatum	facw																									0.2	
Number of species		**8**	**8**	**8**	**5**	**8**	**10**	**7**	**7**	**9**	**9**	**11**	**11**	**11**	**11**	**15**	**9**	**12**	**8**	**15**	**13**	**18**	**10**	**9**	**4**	**12**	**9**

The result of this analysis was an initial division of the sites into two groups (group A and group B; table 3) of similar size. *Nyssa ogeechee* (Ogeechee tupelo), *Quercus laurifolia, Cyrilla racemiflora* (titi), *Pinus taeda* (loblolly pine), and *Acer rubrum* were associated with group A, and *Carpinus caroliniana* (ironwood) and *Quercus nigra* were associated with group B.

The next two divisions are of interest because the second division split site 4 (Bullfrog Creek) and site 22 (Little Satilla) from group A based on the presence of *Quercus virginiana* (live oak) at these sites, and the third division split site 5 (South River) from group B based on the absence of *Quercus nigra*. Thus, the distinctive species composition at site 4 (Bullfrog Creek) and site 5 (South River) is apparent even when only common species are considered. Removal of species that occurred at no more than three sites did not substantially alter TWINSPAN results.

The multiple reach data for site 7A,B,C (Turnpike Creek) in the TWINSPAN analysis provided a means of assessing how well a reach represents a segment. The two other reaches at this site were placed next to the duplicate reach in the vegetation data table, indicating that the three reaches are similar. Not only were these reaches placed in the same group at the first division but they remained so after several successive divisions. One of these reaches (7A) was assessed twice, by different people in different years (1993 and 1994) to provide a measure of the replicability of the point-centered quarter method.The TWINSPAN analysis placed these two assessments in the same group and next to each other in the vegetation data table (table 3).

Comparison of Vegetation and Duration of Bank Inundation at Sites

Categories assigned to each species as part of a wetland fidelity rating system of the U.S. Fish and Wildlife Service, National Wetlands Inventory (Reed, 1988) are listed in table 3. These categories are roughly indicative of a species' tolerance of extended periods of inundation. Obligate wetland species (obl) almost always occur in wetlands under natural conditions. Facultative wetland species (facw) usually occur in wetlands but are occasionally found in nonwetland areas. Facultative species (fac) are equally likely to occur in either environment. Species that are more likely to occur in nonwetlands but are sometimes found in wetlands are categorized as facultative upland (facu). Species that were not in the National list of plant species that occur in wetlands (Reed, 1988) were categorized as upland.

The bank duration category for each site is included in table 3 so that it can be compared with the vegetation found at each site. Because sites were divided into two groups ($\leq$1 percent and >1 percent) based on inundation duration at the top of the bank, and because TWINSPAN divided sites into two groups (A and B; table 3) based on vegetation, a statistical comparison of the two classification schemes was performed using chi- square contingency table analysis. Gage data were available at few sites relative to the number needed for a valid chi-square test. Therefore, one site that was missing gage data was placed into the >1 percent class based on its comparatively low banks, and another site was placed into the $\leq$1 percent class based on its high banks. These assumptions seemed reasonable given the broad inundation classification. Whereas all multiple reach data were included in the TWINSPAN analysis, the multiple reach site is represented in the chi-square analysis only once. The chi-square for this analysis was 3.4 ($p < 0.064$), indicating a marginally significant association between the two kinds of categories. Given the small sample size, this result is of interest even though it is above the commonly used criterion of $p < 0.05$ (Miller, 1986).

The indicator species for the first TWINSPAN division, *Nyssa ogeechee, Quercus laurifolia, Cyrilla racemiflora, Pinus taeda*, and *Acer rubrum* were associated with the site group that had >1 percent inundation durations and the indicator species, *Carpinus caroliniana* and *Quercus nigra* were more strongly associated with the site group that had $\leq$1 percent inundation durations.

As noted earlier, the TWINSPAN analysis split site 4 (Bullfrog Creek) and site 22 (Little Satilla) from Group A in the second division based on the presence of *Quercus virginiana,* a facultative upland species. The relative dominance of *Q. virginiana* at these sites was greater than any other group A site. Site 22 (Little Satilla) also had other species in common with sites in group B. Previously discussed limitations with the point-centered quarter method for characterizing top-of-bank vegetation also may have affected these results. Because woody species are not limited to the top of the bank, inundation duration of species may vary from the inundation duration of the top of the bank. Therefore, site 22 (Little Satilla) was reclassified as Group B and the chi-square analysis was recalculated. Site 4 (Bullfrog Creek) was not reclassified, because it had a high proportion of *Quercus laurifolia* (a group A indicator species). The recalculated chi-square of 5.05 ($p < 0.025$) indicates both a statistically significant result and the sensitivity of this analysis due to small sample size. The contingency table showing the number of sites in eachof the two types of groups is presented in table 4.

Table 4. Contingency table of vegetation assemblage and duration of bank inundation categories

Duration category	Number of sites Percentage of sites		
	Group A	Group B	Total
≤1	3 15.00	8 40.00	11 55.00
>1	7 35.00	2 10.00	9 45.00
Total	10 50.00	10 50.00	20 100.00

Of the 11 sites classified as less than or equal to 1 percent duration of bank inundation, 8 sites were in group B (table 4). This is expected because the tops of banks at these sites are drier than the greater than 1 percent sites and the group B indicator species, classified as facultative, can thrive in this type of environment. Similarly, of the 9 sites in the greater than 1 percent duration of bank inundation category, 7 were in group A (table 4). This is also expected because three of the indicator species (classified as facultative-wetland and obligate) are able to tolerate these longer periods of inundation.

Generally, the wetland fidelity categories of the TWINSPAN indicator species are consistent with the conclusion that inundation frequency affects the riparian species assemblage. *Carpinus caroliniana* and *Quercus nigra* are both facultative species and were associated most strongly with sites with inundation frequencies less than 1 percent. *Nyssa ogeechee* (obl), *Quercus laurifolia* (facw), and *Cyrilla racemiflora* (facw) are obligate and facultative wetland species that were indicators for the group with more frequent inundation. Additionally, obligate and facultative wetland species generally appear in group A of table 3, and facultative upland species generally appear in group B.

SUMMARY

Habitat characterizations were conducted as part of the National Water-Quality Assessment Program, a nationwide effort to describe the status and trends in water quality. The Georgia-Florida Coastal Plain study unit is divided into five land resource provinces based on generalized soils maps: Southern Piedmont, Sand Hills, Southern Coastal Plain, Coastal Flatwoods and Central Florida Ridge. Significant land uses in the area include urban, forest, agriculture, and wetlands.

Stream habitats were evaluated at 24 sites during 1993-95 in the study area. This evaluation involved the collection of data at three spatial scales: basin, segment and reach. Basin data, such as land use, land resource province and basin area, were presented to provide a description of the environmental setting of each site. Segment descriptors such as length, gradient, and channel sinuosity (with log-of-basin area) were analyzed using scatter plots and correlation analysis. This analysis showed a correlation between sinuosity and segment length and that segment gradient is inversely proportional to the log-of-basin area.

Reach data included both instream and riparian characteristics. Sand and detritus were the dominant and subdominant channel-bed substrates among the sites sampled. Measurements of other physical characteristics, such as bank width and height, channel width, and water depth were used to create cross-sectional profiles of each reach. Elevations of duration lines were computed from discharge data and plotted on these profiles. The sites were divided into two groups based on duration of bank inundation ($\leq$1 percent and >1 percent).

Woody vegetation (trees and shrubs) sampling resulted in the identification of a total of 74 tree species. The most commonly found tree species among the sampled sites were the red maple (*Acer rubrum*), swamp laurel oak (*Quercus laurifolia*), water oak (*Quercus nigra*), and the sweetgum (*Liquidambar styraciflua*). Vegetation data were further analyzed by using a clustering algorithm called TWINSPAN. When all species were included in the TWINSPAN analysis, the species assemblage at two sites (sites 5, South River; and site 4, Bullfrog Creek) were identified as unique in the first two divisions. When this same analysis was performed on a data set with species identified at two or fewer sites deleted, the result was the initial division of the sites into two groups (A and B). A statistical comparison of these two groups and the two bank-inundation categories ($\leq$1 percent and >1 percent) was performed using chi-square analysis. Analysis of this data resulted in a marginally significant ($p < 0.064$) association between the two groups. Reclassification of one site (using TWINSPAN results) generated a statistically significant result ($p < 0.025$) and showed that the bank-inundation categories and the groupings by species assemblage grouped sites similarly.

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