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FOLLOW-UP EVALUATION OF MITIGATION MEASURES FOR HIGHWAY CONSTRUCTION, STATE ROUTE 29 HAMILTON COUNTY, TENNESSEE

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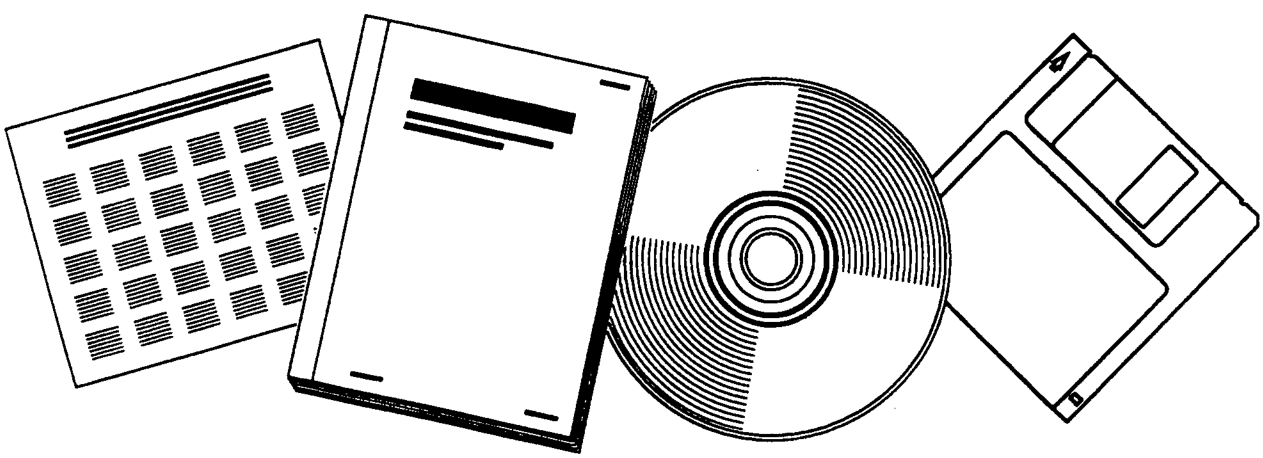

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TENNESSEE
DEPARTMENT OF TRANSPORTATION

Follow-up Evaluation of Mitigation Measures for Highway Construction, State Route 29 Hamilton County, Tennessee

FINAL REPORT

Project Number: TN-RES1042

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U.S. Department of Transportation
Federal Highway Administration

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16. Abstract

A 105-ha section of the floodplain of North Chickamauga Creek in Hamilton County, Tennessee was purchased by the Tennessee Department of Transportation in the late 1970s to mitigate for habitat loss associated with the construction of Tennessee State Route 29. Additional mitigation measures included planting herbaceous and woody vegetation throughout the area and construction of riffle areas and an artificial meander in the creek, three borrow pits of different sizes and designs, and earthen mounds to enhance survival of small animals during flood events. Studies were conducted during the early 1980s to evaluate the effectiveness of mitigation measures and to determine what plants and animals were present on the area. This study was conducted between 1994 and 1996 to determine what changes have occurred since the previous study and to further evaluate mitigation measures.

North Chickamauga Creek was impacted by sediment during construction of the highway. This sediment still covered riffles and other potential substrate for benthic organisms during this study, although this did not affect water quality. Consequently, diversity and abundance of benthic macroinvertebrates and fish were lower than in similar streams without sedimentation problems. Sport fish were moderately abundant in lower stretches of the creek, probably because of low angling pressure and abundant habitat in the form of fallen logs and overhanging banks. Effects on water quality were probably stabilized by 1982-83 and only normal, seasonal fluctuations were observed in this study.

Terrestrial portions of the mitigation site supported a high diversity of plants and animals, primarily because of diverse habitat conditions. Most of the area was covered by mid-successional communities dominated by robust herbaceous plants or woody shrubs or saplings. Two forested areas were present on the site, but both had been selectively harvested before purchase, and the trees were mostly small and of a composition that provided few resources to wildlife. Although mammals and birds were common and diverse throughout the area, several expected species were absent or rare, perhaps a reflection of the successional stage age of the site, its relatively small size, or its close proximity to the highway. Primary differences between this study and the previous study reflected successional changes in plant communities and associated animals that use them. Specific recommendations concerning mitigation measures are included in Chapter 8.

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ABSTRACT

A 105-ha section of the floodplain of North Chickamauga Creek in Hamilton County, Tennessee was purchased by the Tennessee Department of Transportation in the late 1970s to mitigate for habitat loss associated with the construction of Tennessee State Route 29. Additional mitigation measures included planting herbaceous and woody vegetation throughout the area and construction of riffle areas and an artificial meander in the creek, three borrow pits of different sizes and designs, and earthen mounds to enhance survival of small animals during flood events. Studies were conducted during the early 1980s to evaluate the effectiveness of mitigation measures and to determine what plants and animals were present on the area. This study was conducted between 1994 and 1996 to determine what changes have occurred since the previous study and to further evaluate mitigation measures.

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ACKNOWLEDGEMENTS

It is through the efforts of many individuals and organizations that the work presented here has been possible. Our appreciation is extended to all who participated.

Specifically, we wish to thank the Tennessee Department of Transportation (TDOT) and the Federal Highway Administration for financial support of this project. Mr. Ray Brisson and Mr. Mike Presley of TDOT were especially helpful in the administration of the project. The Tennessee Technological University (TTU) Center for the Management, Utilization, and Protection of Water Resources and the TTU Department of Biology provided additional financial assistance and clerical support. The Department of Biology also provided space and assistance in the day-to-day operation of this project, as well as resource personnel as they were needed.

Many TTU students, both undergraduate and graduate, participated in various aspects of this work, from separating benthos samples in the laboratory to collecting water samples and biological data in the field. Without the large number of collective hours they contributed, this project would not have been possible.

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CHAPTER 1

INTRODUCTION

State Route 29 (SR-29) is a controlled access, four lane divided highway constructed in 1977 and 1978. A 105 hectare portion of the North Chickamauga floodplain was designated as an area to research ecological soundness of mitigation techniques often needed for highway construction in floodplains. The original study of this area was conducted in the early 1980s (Coburn et al. 1984). A more recent study of the area began in 1993 and was conducted as a follow-up study to see how the area had changed over time and to evaluate the effectiveness of mitigation measures used.

The research area is a narrow strip between Tennessee SR-29 and Southern Railroad, stretching southerly from Thrasher Pike to a boundary fence 57 m south of Falling Water Creek box culvert. The approximately 105 hectare area is 3.7 km long and ranges from 128 m to 320 m wide, with an average width of 291 m.

Environmental conditions on the area vary. Some portions appear to be relatively undisturbed, others have been disturbed and are undergoing natural succession as evidenced by the plant communities present, and still others continue to be disturbed by anthropogenic activities (e.g., bush-hogging below power lines, off-road vehicle use [Photo, p. 170]). Aquatic systems vary from streams and natural swamps to three different designs of borrow pits. The stream bordering the eastern boundary of the study area, North Chickamauga Creek, has been extensively channelized, rechannelized, and augmented with instream substrate additions. Culverts, both box and round, were introduced to convey water from the western side of SR-29, through the study area, and finally into North Chickamauga Creek.

Complex interactions between these conditions, geomorphology, meteorological conditions, hydrology, and biological principles affect ecological progression in this area. An integrated approach was taken to study the ecological progression. For descriptions of mitigation measures taken at this site and the geomorphology, see the appendix. This section has been excerpted from "Evaluation of highway impacts and mitigation measures on wildlife habitat. Final Report to Appalachian Regional Commission and State of Tennessee Department of Transportation," 1984, C.B. Coburn, Jr., B.L. Ridley, G.K. Ensor, pp. 1-8.

Due to the length of the tables for water quality and benthos data, these are not included in this report, but are available as a separate appendix from Tennessee Department of Transportation. References listed in the discussions of each station (e.g., A1-6, B1) refer to the page numbers of tables and graphs in this separate appendix. Where possible throughout this text, common names for plants and animals are used. Listings of common names with their corresponding species names and family names are provided in the appendix included with this report.

CHAPTER 2

WATER QUALITY

Concerns about water quality along SR-29 have been expressed since the preconstruction phase of this project. For that reason, some stations were established and monitored for physical and chemical parameters during the preconstruction period. Throughout the 1980-83 study on this site, other sampling stations were added and monitored to ascertain effects of the construction activities on water quality.

In this follow-up study, most of the stations established in 1980 were again used as water quality sampling stations. Stations A, B, and C were not sampled in this study as they had been control stations on Falling Water Creek and were not on the study site. Stations E and K had been abandoned during the 1980-83 study due to soil mining along North Chickamauga Creek at those sites and the property owners' objections to our access to these stations. Otherwise, the remaining stations were sampled in as close a proximity to the previous study as was possible.

Stations L, H, Meander A, Meander D, G, and F were located on North Chickamauga Creek and were, therefore, lotic sites. The Large Borrow Pit, Small Borrow Pit, Shallow Borrow Pit, Beaver Pond, and Natural Swamp were characterized as lentic ecosystems. The locations of these stations are shown on Figure 1. Water quality data was collected on these sites in the field, and laboratory analyses were performed on samples from each site. For the culverts (Round Culvert East, Round Culvert West, Box Culvert East, and Box Culvert West), only field data were obtained.

Description of Study Area

Sample sites were located adjacent to SR-29 between Boy Scout Road and Thrasher Pike in Hamilton County, Tennessee. These sites included both lotic and lentic ecosystems, as well as a culvert complex. All lotic sites were subjected to extreme water level fluctuations during this study. The following is a description of each sampling site.

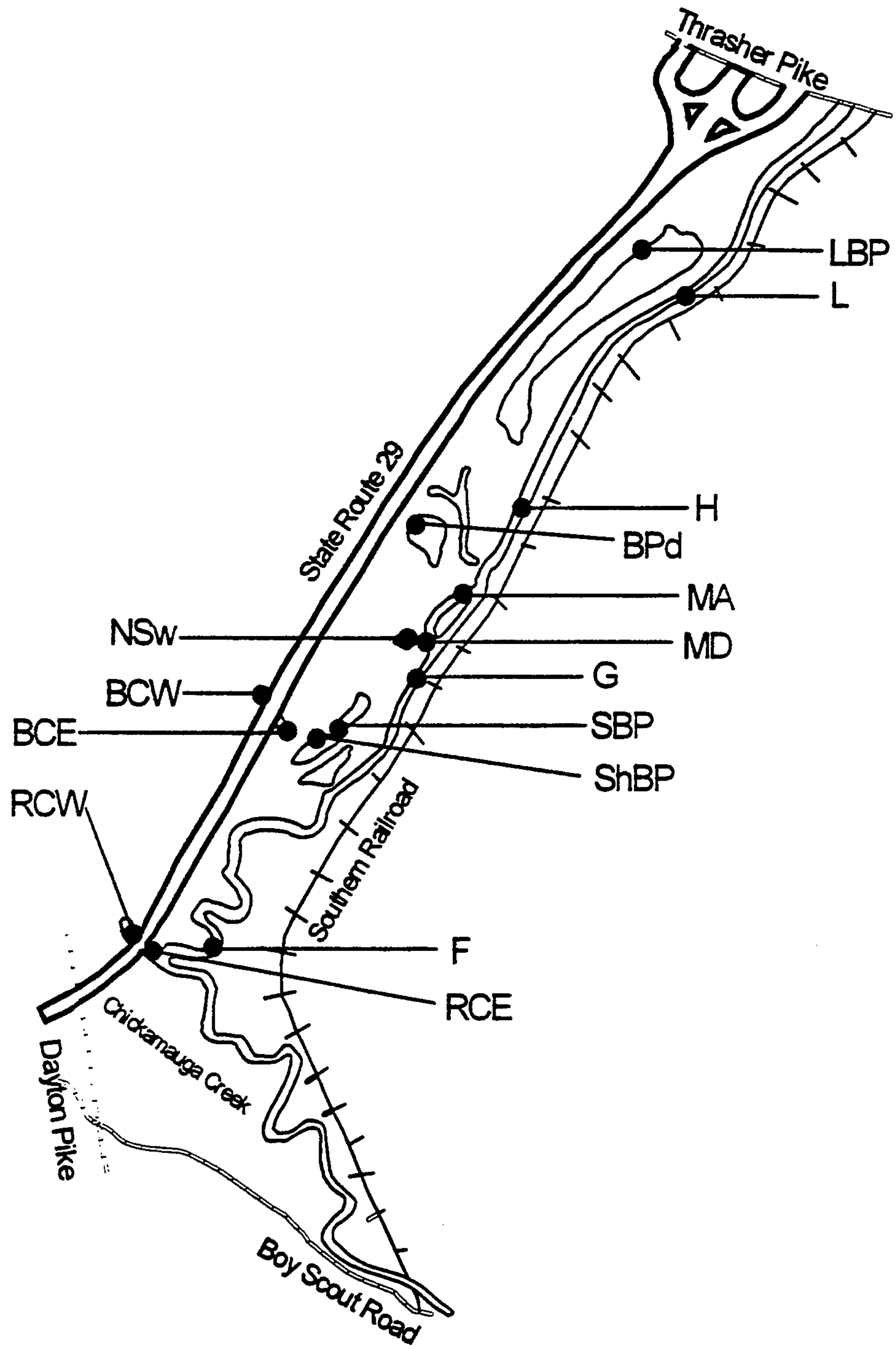

Figure 1. Locations of water quality and benthos sampling sites on SR-29 study site.

North Chickamauga Creek Stations

Station F. This station was the lower-most sample site on North Chickamauga Creek, and, therefore, is characterized as lotic. Habitat type at this site would be technically designated as a pool. Substrate topography was uneven with bars, shallow knolls, and deeper holes. Woody debris, including stumps and logs, were scattered throughout this station. This debris caused flow patterns which created pockets of heavy sedimentation with scattered leaf mats. Bottom substrate was predominantly sand. Very few rooted aquatic macrophytes were found at this site.

Station G. Located approximately 183 meters downstream from the artificial meander, Station G was also lotic in nature since it was on North Chickamauga Creek. This station could technically be classified as a pool habitat at its downstream end, with a slow-flowing run area just upstream. Substrate at this site was primarily composed of silt-covered sand. As at Station F, there was quite a bit of wood debris scattered throughout this sampling site. Turbulence created by this debris had scoured the bottom sediments in some areas to great depths, and some of the riparian zone had been undercut. This resulted in the formation of sand bars in the stream bed, adjacent to the pooled areas. Some emergent macrophytes (*Polygonum* sp.) colonized these sand bars.

Meander D. This site was located at the downstream end of the artificial meander. An extreme amount of fine sediment has been deposited over time at this site. This substrate is unconsolidated and contains organic deposits. What appeared to have once been a slow-moving run or pool area is now an extremely shallow run. The bottom topography at this site was extremely uniform with low habitat diversity. Due to fluctuating water levels, the riparian zone has been undercut in places, providing the only desirable aquatic habitat; however, these banks are not stable and further erosion is expected. No macrophytic growth was evidenced at Meander D.

Meander A. Located just upstream from the entrance to the artificial meander, Meander A could be technically classified as a pool. The bottom at this site is unevenly contoured and the substrate is composed primarily of fine and coarse sand. Extensive amounts of sand have been deposited at the entrance to the artificial meander, near the location of the earthen dam that diverted water from its natural course into the meander. The entrance to the meander contains some debris (tires, metal sheets, wood) that was apparently washed downstream during high flows. This debris has created some diverse habitats due to water turbulence. These habitats include a small riffle area with a cobble substrate, and several small pools with sand substrate. Downstream from this area, the meander is characterized by pools with unconsolidated sand bottoms and of varying depths. Much of the shoreline at this station is steeply banked as a result of excavation to construct the artificial meander. Vegetation on these banks is dominated by button bush. Because of the water depth and subsequent lack of sunlight at the substrate level, no aquatic macrophytes were found at this site. (Photo, p. 164)

Station H. Due to a diversity of habitat types, Station H on North Chickamauga Creek was subdivided into three sample sites: H Above; H Riffle; and H Below. H Above was a slow-moving, cobble-bottomed, wide pool area. Very little woody debris was found at this site, and most of the substrate was covered by filamentous green algae and moss. H Riffle was a constructed riffle area with a rubble and cobble substrate. This constricted area was immediately downstream from H Above. Some wood debris had been deposited in this riffle area; possibly during peak flow periods. This debris created some small islands adjacent to the riffle on which sparse vegetation was beginning to colonize. The streambed at this site also had sand and organic deposits where dense growths of water willow were established. H Below was located downstream from H Riffle. This habitat type could best be described as a run. The substrate at this site was dominated by cobble with some scattered woody debris and sand. Dry sandy areas at H Below also harbored water willow. No submergent macrophytes were found at H Riffle or H Below due to the lack of substrate suitable for plant growth.

Station L. This is the upper-most station on North Chickamauga Creek and is also a constructed site. Station L is a wet-weather station that is only inundated during high water periods. The substrate at this site is dominated by cobble with deposits of sand. Due to the creation of a riffle area, Station L was subdivided into L Above, L Riffle, and L Below. L Above could be classified as a cobble-laden run area that flows into a cobbled riffle area (L Riffle) and eventually enters a cobbled pool at the downstream end of Station L (L Below). Due to the hydrology and the nature of the substrate at this station, no macrophytes were identified.

Lentic Sites

Large Borrow Pit (LBP). The Large Borrow Pit, with a size of 7.4 ha, is the largest of the four lentic sites sampled. This waterbody is bounded on its eastern and southeastern sides by North Chickamauga Creek, and on its northwestern side by SR-29. This pit was originally constructed with steep banks, but, due to sedimentation, the basin has filled in. Much of the sediment is unconsolidated, and thus, the substrate is unsuitable for colonization by most benthic macroinvertebrates. However, buttonbush and black willow have become established in the restricted littoral zone of this basin. These plants provide the only real habitat diversity in this ecosystem. (Photos, p. 165)

Small Borrow Pit (SBP). This borrow pit is approximately 0.65 hectares with an original depth of 5.5 m with steep banks. Due to its location and the surrounding topography, it is judged that very little sedimentation has occurred within the Small Borrow Pit. The steeply-sloped banks in this borrow pit provide an extremely limited littoral zone. Shallow substrates that do exist, consist primarily of organic detritus. No aquatic plants are found within this borrow pit; however, the banks are lined with river birch, red maple, and silver maple. These trees provide a limited canopy to the border of this borrow pit. (Photos, p. 166)

Shallow Borrow Pit (ShBP). This lentic habitat is approximately 1.2 hectares in size and lies adjacent to the Small Borrow Pit. Due to its shallowness, inundation of the Shallow Borrow Pit occurs during winter months through spring. This hydrology has allowed for growth of terrestrial and wetland vegetation. Plants found within the shallow pit include smartweed, false pimpernel, buttonweed, false loosestrife, wood rush, buttonbush, and black willow. The edge of the Shallow Borrow Pit contains river birch, red maple, and silver maple. (Photos, pp. 167-168)

Beaver Pond (BPd). The Beaver Pond historically was a segment of the old North Chickamauga Creek streambed. This particular segment was isolated by private land owners in order to channelize North Chickamauga Creek. The result was a lentic habitat that contained water year round. Water in this pond often appeared turbid, and the substrate was highly organic with a lot of detrital matter. Smartweed, buttonbush, and black willow grow within the Beaver Pond, while the banks are lined with sycamore, river birch, red maple, silver maple, and water oak.

Natural Swamp (NSw). Inundation of this lentic habitat coincided with rain events. The Natural Swamp had a highly organic substrate, composed mainly of leaf litter. This was primarily due to the presence of an extensive canopy over the swampy area. Trees forming this canopy are the same as those bordering the Small Borrow Pit.

Round Culvert East (RCE). This is one half of a culvert complex, with this station located on the eastern side of SR-29. The outfall from this culvert has confluence with North Chickamauga Creek. Fluvial geomorphic processes have created gravel bars, pools, and riffle areas between the culvert and North Chickamauga. These habitat types are characteristic of warmwater lotic ecosystems in the region. Historically, rip rap lined this channel; however, very little rip rap was observed at this site. The current substrate consists of sand and small cobble.

Round Culvert West (RCW). The western end of the round culvert is a lotic system that is extremely different from that on the eastern end. This habitat is classified as slow-flowing pools in a narrow channel. Vegetation lined both sides of the stream. The substrate at this site was dominated by sand and cobble with extensive organic debris deposited in different parts of the stream.

Methods

Field water quality measurements were made using Yellow Springs Instrument Company (YSI) Model 51B Dissolved Oxygen and Model 33 S-C-T meters and Analytical Measurements Model 107 pH meter. Parameters obtained were temperature, dissolved oxygen, conductivity, field pH, and salinity.

Water samples were collected from each station when there was sufficient water. For each site, a 125 ml sample was collected and acidified with nitric acid to be used for metals determinations and 500 ml and 1 L samples were collected and stored on ice to be used in other analyses. If biochemical oxygen demand values were to be determined, a 300 ml BOD bottle was also filled and stored on ice.

The following parameters were determined monthly: suspended solids, total solids, nitrite, nitrate, ammonia nitrogen, phosphate, aluminum, calcium, iron, magnesium, and hardness. On a quarterly basis, these parameters were also determined: alkalinity, sulfate, chloride, BOD, turbidity, and sodium. Table 1 summarizes the methods and instrumentation used for these determinations. In all cases, efforts were made to keep the methods as close to those used in the 1980-83 study as was practical, although some parameters were determined using instrumentation more sensitive than that available in 1980-83.

Table 1. Methods used in determination of water quality parameters.

Water Quality Parameter	Method/Instrumentation Used
Total Solids	Dried at 103-105°C
Total Suspended Solids	Dried at 103-105°C
Nitrite	Nitrite-selective electrode, Orion #95-46[a]
Nitrate	Nitrate-selective electrode, Orion #93-07[a]
Ammonia Nitrogen	Ammonia-selective electrode, Orion #95-12[a]
Phosphate	Stannous chloride method
Aluminum	Flame atomic absorption spectrometry[b]
Calcium	Flame atomic absorption spectrometry[b]
Iron	Flame atomic absorption spectrometry[b]
Magnesium	Flame atomic absorption spectrometry[b]
Hardness	Calculation
Alkalinity	Titration
Sulfate	Turbidimetric method
Chloride	Chloride-selective electrode, Orion #94-17[a]
Biochemical Oxygen Demand	5-Day BOD determination
Turbidity	H-F Instruments, Model DRT 100
Sodium	Flame emission spectrometry[b]

[a] Used with Orion Model 720A pH/ISE/mV Meter

[b] Perkin Elmer Model 3110 Atomic Absorption Spectrometer

Results

Data from water quality measurements are included in Appendix A (on file with TDOT). In order to more easily make comparisons between values from 1980-83 and this study, the data from the previous study are also included. Graphs of data for suspended and total solids and for temperature and dissolved oxygen are presented with rainfall data taken from NOAA monthly precipitation reports. Dayton, Tennessee, values were used since that was the rainfall collection site closest to the SR-29 project area for which continuous data were available. Pairs of graphs were plotted so that seasons for the two sampling periods would match up as closely as possible.

North Chickamauga Creek Stations

The substrate in the section of North Chickamauga Creek that runs through the project area is substantially the same as it was by the end of the 1980-83 study. Cobble and sand comprise most of the substrate's composition for Stations H and L, with Stations F and G consisting of pooled areas with sandy bottoms. The meander has accumulated deposits of fine sand, silt, and organic debris and is probably most different from conditions in the early 1980s.

Station F. Conductivity readings exhibited seasonal fluctuations throughout both study periods. However, readings for the year following construction were somewhat higher and possibly indicate that construction-related influences had diminished after the first two years. Values for suspended and total solids from the two studies were comparable, as were those for phosphate, BOD, sulfate, nitrite, and metals. Nitrate levels were lower in this study, which could have been due to changes in agricultural practices in the vicinity of SR-29 (A1-6).

Station G. A similar trend for conductivity, as seen at Station F, was observed at Station G. Total and suspended solids values fluctuated seasonally, as was the case for the 1980-83 study. Nitrate levels were again lower in the current study, indicating that these effects were consistent in this part of the stream. Other parameters were fairly consistent between the two sets of data (A7-12).

Station H. Conductivity values at Station H also showed the same trend as for the above North Chickamauga Creek stations. Total and suspended solids and turbidity values, however, were elevated in the summer months during the 1980-83 study; this was not observed in the current data. Because Station H is a riffle area, water sample collection during low flow months of the years following construction probably stirred up silt from spaces among the cobble which resulted in the higher values.

Once again, nitrate levels were considerably higher in the summer months of the early 1980s than during the current study. Values for other parameters were fairly consistent (A13-18).

Station L. Water flow at Station L was seasonal, with little or no flow during late summer and early fall. Conductivity readings were consistent with those from the last two years of the 1980-83 study. Levels of pH also seemed to have stabilized and were less acidic than those previously reported.

Values for suspended and total solids and turbidity were not appreciably different from the last two years of the 1980-83 study, and fluctuations were probably due to rain events. Nutrient concentrations (phosphate, nitrite, ammonia nitrogen) varied little and were generally low. Nitrate levels were higher in the summer/fall months of the 1980-83 study, but differences were not so large as those for Stations F and G. Metal concentrations varied slightly with water levels due to concentration effects. Values for other parameters were in line with those of the previous study (A19-24).

Meander A. Water samples for this station were collected near the entrance of the meander where North Chickamauga Creek was diverted into the artificial meander. Because flow is slowed here, large deposits of sand and silt have accumulated. A comparison of values for suspended and total solids seemed to indicate that the substrate has stabilized, as the amounts of solids in water samples collected during this study were consistently less than those of the earlier study. Turbidity values also supported this conclusion.

Nitrate values for this station were again less than those obtained during the previous study. Other values were comparable, showing mostly seasonal fluctuations (A25-30).

Meander D. As with Meander A, values for total and suspended solids and turbidity seemed to indicate stabilization of the substrate in the artificial meander. Conductivity readings were comparable to those found in 1982-83.

Lower nitrate levels were observed here, as at all North Chickamauga Creek stations. Otherwise, most parameters were comparable between both studies, showing mostly seasonal fluctuations (A31-36).

Lentic Sites

Of the five lentic sites sampled on the SR-29 project area, two of these, Beaver Pond and Natural Swamp, were not directly impacted by construction activities. The other three sites, Large, Small, and Shallow Borrow Pits, were constructed in the late 1970s and the surrounding areas have changed dramatically since the study of the early 1980s, primarily in the amount of vegetation present.

Large Borrow Pit. Comparison of data from both studies showed few differences for the Large Borrow Pit. Unlike the stream stations, values for total and suspended solids varied little. Conductivity values were comparable, as were those for nutrients, with the exception of nitrate. Current nitrate levels were less than those found in the previous study, although the variation was not so great as for the lotic sites (A37-42).

Small Borrow Pit. Values for most parameters from the Small Borrow Pit were not very different between the two studies. As in the Large Borrow Pit, total and suspended solids values were comparable. Nitrate levels were again lower in the current study. Other nutrient and metal levels were comparable and fluctuations were mainly seasonal (A43-48).

Beaver Pond. Values for water quality parameters from the Beaver Pond varied little between the previous and current studies, which might be expected since this area was not directly affected by construction activities. Due to stagnant conditions at this site, dissolved oxygen levels were very low during warm months, and conductivity levels and values for total and suspended solids and turbidity were higher here than for other sites. Nitrate levels for the current study were comparable to those of 1980, but considerably less than values for 1981-83 (A49-54).

Shallow Borrow Pit. The Shallow Borrow Pit, by nature of its design, was consistently dry during low rainfall months. This site is entirely different now than after construction in 1980 in terms of vegetation cover, having progressed from nearly open and barren to densely-vegetated. In spite of this immense change in cover, water quality parameters did not vary much between studies. Conductivity, solids, and turbidity value fluctuations were more rainfall-related than influenced by the successional changes occurring at this site. Once again, nitrate levels were considerably less in this study than during the previous one (A55-60).

Natural Swamp. The Natural Swamp is another area not appreciably influenced by construction activities. Data showed few differences other than seasonal fluctuations. Suspended and total solid values for three sampling dates of the 1994-95 study were

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FROM: Mike Presley
Research Coordinator

DATE: December 3, 1997

SUBJECT: *Follow-up Evaluation of Mitigation Measures for Highway Construction State Route 29, Hamilton County*

Enclosed are copies of the approved final report for the subject research project. The research was conducted by the Tennessee Technological University and sponsored by the Tennessee Department of Transportation and the Federal Highway Administration.

If additional information is required, please contact me.

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considerably higher than those observed in the 1980-83 study. A possible explanation would be that sediments were stirred up in the process of collecting water samples during times of low water, giving unusually high values. Nitrate levels were comparable between the current study and the first year of the previous study, but higher in 1982-83 (A61-66).

Discussion

Water quality on the SR-29 site has changed little since the last year of sampling on the previous study (1982-83). Most variations in values for the parameters measured are normal, seasonal fluctuations, primarily related to concentration effects due to low rainfall periods. It appears that any changes as a result of construction effects were minimal, and that water quality values had stabilized part-way through the 1980-83 study.

Two parameters that were noticeably different between the studies were nitrate and chloride, both of which had higher values in the earlier study. As mentioned previously, nitrate levels could have been elevated due to agricultural practices in the area or to fertilizer applications on this site following construction, if such applications occurred. Whatever their source, nitrate levels were not high enough to have posed any health hazard (Hem 1989).

Chloride levels were higher at every station during the previous study, especially during 1981-82. Since the levels did not show peaks that would correspond to winter months, salts used for deicing the road were probably not the source of chloride. Chloride can be leached from sedimentary rocks (Hem 1989), so it is possible that the higher chloride levels of the 1980s were attributable to disturbances on the site and the rock used to build up the roadbed. As with nitrates, the chloride levels were not high enough to have been of concern. Perhaps, though, the lower chloride levels seen in this study also indicate that stabilization has occurred.

CHAPTER 3
BENTHOS AND FISH

North Chickamauga Creek and its surrounding watershed are located within the Tennessee River drainage in the Ridge and Valley Province of southeastern Tennessee (Etnier and Starnes 1993). Small streams in this region are characterized by limestone rubble and bedrock riffles with sandy, pooled areas. This watershed has not been exempt from impacts resulting from anthropogenic activities. Therefore, the biota of North Chickamauga Creek has been extensively monitored for impact detection and the stream's potential recovery before, during, and after road construction activities associated with SR-29.

Although highways and smaller roads occupy only a small percentage of the land in the United States, activities associated with their construction may impact aquatic biological community structure or individual species' reactions to altered habitats (Little and Mayer 1993). Many of these impacts have been detected in aquatic ecosystems. Whitney and Bailey (1959) found reductions in numbers and weights of stream game fish species near a highway construction project. Some of the most obvious effects on aquatic ecosystems, as a result of highway construction activities, include: altered suspended solids, bedload, and water quality; stream bank destabilization; and increased channelization. All of these impacts affect the biotic communities associated with lotic aquatic ecosystems.

Aquatic biological communities that could potentially be affected by highway construction must be surveyed, in conjunction with physical and chemical water quality variables, to determine the existence or extent of negative impacts. The EPA (1989) has described procedures for the biomonitoring of lotic ecosystems to detect aquatic life impairments and their severity. They also have stated that if mitigation measures are taken, biosurveys are important for evaluating the effectiveness of such control measures. Some of the obvious reasons for biological monitoring include: biological communities will reflect ecological integrity; biota integrate stresses over time and thus provide a measure of fluctuating environmental conditions; biomonitoring is relatively inexpensive; and the status of biological communities is of direct interest to the public (EPA 1989).

The intent of this phase of the project was to determine the status of aquatic biological communities in portions of North Chickamauga Creek and associated waters adjacent to SR-29 between Boy Scout Road and Thrasher Pike in Hamilton County, Tennessee. This area was extensively sampled in the early 1980s to determine the status of biological communities before and during construction of SR-29. However, the status of those communities was not monitored for approximately 10 years. Therefore, this phase will document the current status of these communities and compare this status to that of the previous study.

Methods

Benthic Macroinvertebrates

When sufficient water was present, quarterly benthic macroinvertebrate samples were obtained from each sample site. Sampling commenced in June 1994 and concluded in September 1995. All sites were qualitatively sampled using a kick net, ensuring that all accessible habitat types within a site were sampled. The EPA (1989) described procedures such as this for use in their Rapid Bioassessment Protocols.

Once obtained, all samples were placed into individually labeled plastic zip-lock bags, and preserved with 10% buffered formalin. Preserved samples were then transported to the laboratory at Tennessee Technological University, where they were picked and sorted from debris, preserved in 70% ethanol, identified to the lowest practical taxon, and enumerated. References used for identification included Pennak (1978), Merritt and Cummins (1984), and Wiggins (1977).

Data analysis included determinations of taxa richness (number of distinct taxa in a sample), abundance (total number of organisms in a sample), and the EPT Index as a means of assessing water quality by analyzing the proportion of those taxa within the Orders Ephemeroptera, Plecoptera, and Trichoptera to the total taxa richness for the sample. These data were then compared to the historical kick net data from the previous study to determine if the status of benthic communities had changed.

Fish

Fish samples were obtained from each site on North Chickamauga Creek, the Large Borrow Pit, and the Small Borrow Pit during Spring and Fall 1995. North Chickamauga Creek sites were electrofished using a D.C. backpack electrofishing unit, when water depths did not preclude the use of this sampling equipment. When depths were too great, a minimum of four anglers were allowed to fish each site for one hour. This allowed us to determine sport fish species present at each site. The Large and Small Borrow Pits were sampled using a white nylon experimental gill net. This net contained five panels of different mesh sizes to allow for the capture of different sizes of fish. The net was set by using a personal float tube so that the smallest mesh size was close to shore, and the largest in deeper water. Two net sets were made in these waters during Spring 1995, with one net anchored to the bottom and the other net suspended from the surface.

All fish collected were identified using Etnier and Starnes (1993). Prior to their release, all identified fish were measured for total length (mm). Any fish that could not be identified in the field were preserved in 10% buffered formalin and returned to the laboratory for species determination and total length measurements.

Data obtained from fish sampling activities were limited to species richness, total abundance, and total lengths. Species richness and abundance values were compared with data reported in Coburn et al.

Results

Benthic Macroinvertebrates

The following paragraphs describe the results of benthic macroinvertebrate sampling by sample site. For the sake of organization, all lotic sites will be described first, followed by lentic sites, and then the culvert complex. Results of the most recent sampling effort will be described first, and then these results will be compared to those of the previous study. All benthic macroinvertebrate tables and figures are located in Appendix B (on file with TDOT).

Station F. A mean taxa richness value of eight taxa was found for this sample site from June 1994 through September 1995 (B1). The lowest taxa richness (2) was found during the March 1995 sampling data. Only oligochaetes and blackfly (*Simulium)* larvae were collected during this month. The June and September 1995 samples both had taxa richness values of eight. These values were still lower than taxa richness for the months of June and September 1994.

Abundance values for Station F averaged 156 organisms per sample (B1). The greatest abundance at this station occurred during September 1994 (443 organisms). The majority (83%) of these organisms were larval chironomids. The lowest abundance was recorded during March 1995 with only five organisms collected.

Richness and abundance values for Station F are illustrated on the top figure of B9. These values were both found to be greatest during June and September 1994, followed by subsequent decreases in December 1994 and March 1995. The June and September 1995 samples showed signs of recovery with increases evident for both values. This may indicate that the stream's benthic community may have encountered an environmental disturbance which eliminated the least tolerant organisms. If this is true, then it would have potentially occurred during Fall 1994.

EPT Index values provide an indication of water quality problems, since the three orders of insects addressed (Ephemeroptera, Plecoptera, and Trichoptera) are relatively sensitive to environmental perturbations. Index values of 0.50 and greater are indicative of acceptable environmental conditions. Only the December 1994 samples had an acceptable EPT value (0.67) (B1). Although the two previous samples had EPT values less than 0.50, these values were higher than those obtained from samples collected after December 1994. In fact, the March 1995 sample had an EPT value of 0. These results may further show that an environmental impact possibly occurred in North Chickamauga Creek during late 1994.

Historical samples at Station F had a mean taxa richness of 4, and a mean abundance of 15 organisms per sample (B3). Therefore, the more recent samples had higher richness and abundance values than the historical samples. Although historical richness and abundance values were sporadic in nature and no clear trends were detected (B9), the greatest richness values were obtained from samples collected during November 1981 and July 1982 (richness = 10). The largest abundance of organisms was obtained during November 1980 (86), with the majority (79%) of these organisms being larval chironomids. The mean EPT value for the historical samples was 0.21, indicating potentially degraded water quality or some other impacted environmental parameter. Only six of 29 samples had EPT values greater than or equal to 0.50.

Station G. Mean taxa richness for Station G was 7, while mean abundance was 167 organisms per sample (B10). The June 1994 sample had the highest richness value (20), while the March 1995 sample had the lowest (2). High abundances were noted for the months of June 1994 (526), June 1995 (271), and September 1995 (122). Chironomid larvae were the dominant organisms in these samples. The lower figure on page B16 illustrates these trends. As with Station F, it appears that some environmental perturbation may have occurred, perhaps as early as September 1994. The June and September 1995 samples possibly indicate that the benthic community may be recovering slightly from the effects of this event.

The December 1994 sample was the only sample that had an EPT value greater than 0.50 (0.60). During this month, the mayfly, *Ephemerella,* was the most abundant organism collected. Further samples contained no *Ephemerella,* indicating that perhaps this genus was eliminated by some form of environmental disturbance.

Historical kick net samples for Station G had a mean richness value of 3, and a mean abundance of 19 organisms per sample (B12). Although historical richness values were sporadic, abundance values tended to show overall increases during the years 1981 and 1982 (lower figure, B16). The greatest abundance occurred in July 1982 with 227 organisms; however, 225 of these organisms were larval chironomids. When compared to the recent samples, abundance and richness values were historically lower. Only two of 25 historical EPT values were considered acceptable. Both of these values occurred during 1982, which may indicate that this site was beginning to be colonized by more sensitive organisms.

Station H Above. This sample site was not sampled during September 1994 due to low water conditions; the following describes the current results for the remaining five sampling periods. Mean taxa richness for this site was 6 (B17). Richness values were highest in June 1994 and lowest in March 1995. The upper figure on B22 depicts these richness values graphically. An increasing trend in richness is evident during June and September 1995, as compared to March 1995.

Mean abundance for H Above was 63 organisms per sample (B17). The greatest abundance was collected in June 1994, while the lowest was collected in March 1995. An increase in abundance occurred in September 1995, possibly indicating that the benthic community was recovering (B17). Low water conditions encountered during September 1994 may have resulted in the depression of richness and abundance values.

Only one acceptable EPT value was calculated for H Above; 0.50 in December 1994. March and June 1995 samples had EPT values of 0, while the value in September 1995 increased somewhat to 0.20. This indicated that 20% of the taxa collected were from the three environmentally-sensitive orders.

Mean taxa richness for historical data from H Above was approximately 3, while mean abundance was nine organisms per sample (B18). Therefore, richness and abundance values for this site are currently higher. Richness values were historically sporadic, but, although abundance values were also slightly irregular, a general increasing trend in abundance was evident from 1980 through 1982 (B22). Only two of 18 historical samples had acceptable EPT values (March 1980 and February 1982); however, the February 1982 sample only contained one organism, a stonefly (*Isoperla*).

Station H Riffle. A peculiar event occurred during March 1995 at this site. Although a sample was obtained during this month, no organisms were collected, so the results described will not include this sample. One can only speculate why this occurred; however, when considering the results of the downstream stations (F and G), this could be the result of some form of upstream environmental impact in North Chickamauga Creek, coupled with the low water event documented during September 1994 at H Above.

Mean richness for H Riffle was approximately 9, with a mean abundance of 230 organisms per sample (B23). However, the mean abundance is artificially inflated due to large numbers of larval chironomids and black flies (*Simulium*), comprising 89% of the June 1994 sample (N = 1080 organisms). Only the June 1994 sample had an acceptable EPT value. The upper graph on B26 illustrates declines in richness and abundance values after June 1994. From this figure, it does not appear that the benthic community at this site is recovering from its decline. Mean richness for historical samples obtained at H Riffle was approximately 3, while mean abundance was six organisms per sample (B25), demonstrating that H Riffle's current benthic community has higher richness and abundance values than the historical community. The lower figure on B26 reveals that historical richness values remained relatively stable from 1979 to 1982, but abundance values declined during this period. Only three of 13 samples had acceptable EPT values (B25).

Station H Below. No sample was obtained at H Below during September 1994 due to low water, so the following describes results from the other five sampling periods.

Mean richness at H Below was 5 taxa, while mean abundance was 50 organisms per sample (B27). High abundances occurred during the months of June 1994, March 1995, and September 1995. These values were due to large numbers of larval chironomids in June 1994 and September 1995, and oligochaetes in March 1995. In fact, oligochaetes comprised 95% of the March 1995 sample. None of these samples had acceptable EPT values. The upper figure on B32 indicates that the greatest richness value occurred in June 1994, and the remainder were slightly depressed and fairly stable. However, abundance values tended to fluctuate after December 1994.

Mean historical richness was approximately 3, while mean abundance was six organisms per sample (B28). These values were slightly lower than those found for the more recent samples. Historical richness values remained relatively stable, with the exception of a slight richness increase in July 1982 (B28). This particular sample also had an associated elevated abundance (N = 26), with 39% of the individuals as larval chironomids, and was considered to be the most diverse of the historical samples. However, both richness and abundance values substantially decreased in August 1982. Only two of 24 samples had acceptable EPT values, while 20 of 24 had EPT values of 0.

Station L Above. No benthic samples were collected from this site during September 1994 due to extremely low water levels; the following is a description of the remaining five samples obtained between June 1994 and September 1995.

Mean richness for this site was four taxa, while mean abundance was found to be approximately 22 organisms per sample (B33). The June 1994 sample had the greatest richness and abundance values during this sampling period (B33). Richness values following the September 1994 dry period were slightly lower, as were abundance values. High abundances were found to occur during June 1995, due to 88% of the sample being composed of larval chironomids. In fact, the high abundance value in June 1994 was also due to 88% of that sample being larval chironomids. None of the samples had acceptable EPT values; moreover, three of the five samples had EPT values of 0, indicating that no members of these sensitive orders were collected..

Mean historical richness values at L Above averaged three taxa per sample, while mean abundance was eight organisms per sample (B34). These values were both determined to be slightly lower than those found during the most recent sampling effort. Although richness values were found to be relatively stable, abundance values were found to increase between December 1981 and June 1982 (B34). The greatest number of organisms were collected during June 1982 (N = 24), but 88% of this sample was composed of larval chironomids. This is reflective of the benthic community sampled between 1994 and 1995. Only one of the historical samples had an acceptable EPT index value (December 1981), while four of the seven historical samples had EPT values of 0.

Station L Riffle. Only four benthic macroinvertebrate samples were obtained between June 1994 and September 1995. During the months of September 1994 and 1995, no samples were taken due to low water conditions at this site. The March 1995 sample contained no benthic macroinvertebrates; therefore, the following describes only three samples obtained during the most recent sampling period.

Samples from June 1994, December 1994, and June 1995 had a mean richness value of approximately six taxa per sample, and a mean abundance of 27 organisms per sample (B36). The highest richness and abundance values were obtained during both June samples (B38). The June 1994 sample appeared to be the most diverse sample with no one taxon being dominant, but the June 1995 sample was dominated by larval chironomids (67% of the sample). Due to the patchiness of the samples, no clear trends in the data were evident.

Historical data from L Riffle was collected between March 1980 and September 1982 (8 samples). Mean richness for these samples was 3, while mean abundance was six organisms per sample (B37). The greatest richness and abundance values were obtained during March 1981; however, clear trends in the data were not evident (B38). Five of the eight historical samples had acceptable EPT values, and two of these (December 1980 and February 1982) had perfect EPT values of 1.0. This number is deceiving since, in both cases, only one organism was collected in the samples.

Station L Below. Of the six samplings, there were organisms collected only on four occasions. No benthos samples were collected during September 1994 due to low water conditions. For the March 1995 sample, no organisms were present. Therefore, the following results are for the remaining four samples.

The mean taxa richness for L Below was 7, while mean abundance was 85 organisms per sample (B39). Samples from June 1994 and 1995 were the highest in both richness and abundance; however, high abundance values for these samples were due to large numbers of larval chironomids (91% and 92% by number, respectively). Graphic analyses of these data revealed no clear trends (B41). No acceptable EPT values were identified from samples obtained from this station.

Historical data from L Below is limited to four samples collected in 1980 and 1982. Data from these samples indicated that richness and abundance values were lower than the more recent samples (B40). Richness values averaged three taxa per sample, while abundance values averaged five organisms per sample. Although the time frame for these samples excludes the entire year of 1981 and one half of 1982, richness and abundance values appear to have been stable through 1980 (B40). The April 1980 samples had an acceptable EPT value of 0.50, but the other three historical samples did not have acceptable values.

Meander A. Benthic samples from Meander A had a mean richness value of approximately seven taxa per sample, and a mean abundance of 90 organisms per sample (B42). The mean abundance value may be artificially high due to abundances of larval chironomids in two of six samples. Larval chironomids made up 66%, 92%, and 89% of the June 1994, September 1994, and September 1995 samples, respectively. Black fly larvae (*Simulium* sp.) were also abundant in the June 1995 sample, composing 20% of this sample. None of the samples had acceptable EPT values.

The upper figure on B44 indicates that taxa richness values for these samples remained relatively stable. Abundance values were highest in September 1994 and declined after that until September 1995 when a slight increase occurred. Historical data from Meander A were obtained between December 1979 and October 1982. Mean richness for these samples was three taxa per sample, while mean abundance was 16 organisms per sample (B43). From July 1980 through October 1982, larval chironomids dominated the samples; two of these samples (December 1981 and October 1982) were composed entirely of these organisms. These data were slightly reduced from the more recent data collected from this site. Acceptable EPT values were achieved in July 1980 and May 1982.

Historical richness values were consistently low in the samples; however, abundance values increased in a step-wise fashion throughout the historical sampling period (B43). These increases were primarily due to the numbers of larval chironomids collected during the later samples. This trend of large numbers of larval chironomids was carried over into the September 1994 sample.

Meander D. Mean richness for Meander D from 1994 through 1995 was 5, and mean abundance was 285 organisms per sample (B45). Abundance was considered high due to the June 1994 sample containing 1398 individuals. The majority of these organisms were larval chironomids, 97% by number. In fact, the next greatest abundance was collected in September 1995 with 204 individuals, of which 202 (99%) were chironomids.

Richness values for Meander D tended to decline from June 1994 through March 1995, but increased somewhat during June and September 1995 (B47). Abundance values decreased dramatically between June and September 1994 and remained low until a slight increase occurred in September 1995.

Five historical samples were taken at Meander D between December 1979 and May 1982. None of these samples had acceptable EPT values (B46). A mean richness value of four taxa was determined, with a mean abundance of 11 organisms per sample. Richness and abundance values remained relatively low and stable throughout this period (B47).

Large Borrow Pit. Larval chironomids dominated the benthic samples from the Large Borrow Pit. Richness values had a mean of six taxa per sample, while mean abundance was 206 organisms per sample (B49). This high mean abundance value was due to four of the six samples having abundance values greater than 200 organisms per sample. Three of these samples were dominated by larval chironomids: 66%, 89%, and 94% by number for June 1994, September 1994, and September 1995, respectively. The June 1995 sample contained 203 organisms of which approximately 35% were chironomids; however, the dominant organism in this sample was a snail (*Helisoma* sp.), comprising 52% of the sample. EPT values were not found to be acceptable in any of the six samples. The figure on page B49 shows that the greatest richness values occurred during September 1994 and June 1995; however, no clear trends in richness values were evident. Abundance values did show a trend that is common for benthic organisms in lentic ecosystems. These values were elevated during the warmer months, and decreased to low values during the winter and early spring months. Many of the common benthic organisms will be abundant during spring and summer, but will begin to emerge to the adult stage during late summer and fall when they will no longer be part of the benthic community.

Small Borrow Pit. Mean richness of benthic organisms in the Small Borrow Pit was 9 for the most recent samples, while mean abundance was 1,253 organisms per sample (B50). Larval chironomids and oligochaetes dominated the benthic community at this site. These organisms are indicative of silty, organic substrates in lentic ecosystems. No acceptable EPT values were identified in samples collected from this site.

As with the Large Borrow Pit, the benthic community of the Small Borrow Pit behaved typically of a lentic benthos. Richness values were highest during June and September 1994 and June 1995 (B52). Abundances decreased to low levels during December 1994 and March 1995, with the dominant organisms being those that tend to over-winter in lentic ecosystems (Isopods, Amphipods, Oligochaetes, and Chironomids).

Oligochaetes, larval chironomids, and other benthic organisms increased in number and diversity during the warmer months.

The Small Borrow Pit was regularly sampled from February 1980 through January 1983. Mean richness, for these samples, was two taxa per sample, while mean abundance was 12 organisms per sample (B52). These values were lower than those from the more recent samples. Historical richness and abundance values did not reflect those of typical lentic ecosystems (B52). The highest richness value was obtained during January 1983 (7), but this value was lower than the mean richness of the more recent samples. Abundance values peaked in June 1980, drastically decreased in July 1980, remained low until March 1982, and again increased in January 1983. These high abundance values were related to increases in numbers of larval chironomids.

Beaver Pond. Recent benthic samples from the Beaver Pond were dominated by larval chironomids and oligochaetes, resulting in high abundance values. Mean richness was 12, and mean abundance was 481 organisms per sample (B53). The highest richness value was found in the September 1994 sample, while the greatest abundance of organisms was collected during June 1995. Richness values remained fairly stable throughout the sampling period; however, the June 1994 and 1995 samples reflected typical responses of lentic benthic communities (B61). The high numbers of organisms collected during these months appears to show the typical increases in benthic organisms during the warm seasons. However, these results may be somewhat misleading since the most abundant organisms in these samples were oligochaetes, which do not undergo an emergence like that of many aquatic insects. No acceptable EPT values were identified for these samples.

Historical benthic data from the Beaver Pond is described on page B55. Mean taxa richness for these dates was three taxa per sample, and mean abundance was 23 organisms per sample. Dominant organisms in these samples were larval chironomids, and, to a lesser degree, oligochaetes. Richness values remained relatively stable between 1980 and 1983; however, abundance values peaked from spring through summer and into early fall of 1981 and 1982 (B61). The greatest numbers were collected during September 1981 and July 1982. These samples were dominated by larval chironomids. Lower values during late fall and winter were probably due to emergence from this lentic system. The majority of the EPT values for the historical samples were equal to 0.

Shallow Borrow Pit. Only three samples were obtained from the Shallow Borrow Pit between 1994 and 1995 due to low or no water. Water inundated this site from September 1994 through March 1995. Mean richness for this site was eight taxa per sample, while mean abundance was 542 organisms per sample (B62). Domination of these samples varied. The September 1994 sample was dominated by oligochaetes (56%) and larval chironomids (39%). These organisms also dominated the December 1994 sample; however, their numbers were greatly reduced. The March 1995 sample was dominated by the isopod *Lirceus* (57%) and the amphipod *Gammarus* (25%). Due to the low number of samples obtained, trends were not determined for the Shallow Borrow Pit benthic data (B64). The graphic results, however, do illustrate abundance shifts for the dominant organisms mentioned earlier. Richness and abundance values were found to be higher in September and March than in December, which is the typical response of benthic communities in lentic ecosystems. EPT values were not found to be acceptable.

Historical samples from the Shallow Borrow Pit also reflected the ephemeral nature of this site, since low to no water conditions prevented the collection of samples during most summer and fall months of 1980, 1981, and 1982. Mean historical richness for this site was approximately three taxa per sample, while mean abundance was 14 organisms per sample (B64). High abundances were found to occur in May 1980, April 1981, May 1981, February 1982, March 1982, and April 1982 (B64). Larval chironomids dominated the April and May 1981 samples, as well as the April 1982 sample. This is typical for these organisms, since they are abundant during the spring in lentic systems, with emergence occurring later in the season. The May 1980 sample was dominated by the hemipteran, *Palmocorixa*, while the February and March 1982 samples were dominated by the mayfly, *Leptophlebia*. The June 1980 and March 1981 samples had acceptable EPT values of 0.50; however, only two taxa were collected in each of these samples, indicating that, although the values were acceptable, the benthic community was limited.

Natural Swamp. Due to low or no water conditions, no benthic samples were collected from the Natural Swamp in 1994 nor 1995, so no comparisons can be made with historical data from this site. Mean richness, for samples collected between 1980 and 1983, was approximately six taxa per sample, and mean abundance was 67 organisms per sample (B70). Richness values remained relatively stable throughout this period, although several samples showed peaks in abundance (B70). The March 1980 sample contained 105 organisms and was dominated by the amphipod, *Gammarus* (40% by number). *Gammarus* and the fingernail clam, *Musculium,* dominated the March 1981 sample (N = 175) at 32% and 26% by number, respectively. The February 1982 sample (N = 235) was dominated by the mayfly, *Leptophlebia*, representing 52% of the sample by number. This organism also dominated the January 1983 sample, representing 67% of the sample by number.

Round Culvert East. This sample site had a diverse benthic community between 1994 and 1995. Mean richness was 13 taxa per sample, while mean abundance was 725 organisms per sample (B71). Richness values tended to show a slight decreasing trend after the June 1994 sample (27 taxa), but abundance values peaked in June 1994 and June 1995 (B77). The 1994 sample was dominated by larval chironomids and oligochaetes, representing 33% and 31% of the sample, respectively. The June 1995 sample was dominated by the isopod, *Lirceus*, representing 73% of this sample. None of the samples had acceptable EPT values. This, however, would be expected since there is flowing water at this site only during rain events and the organisms which would give an acceptable EPT value would be found only in waters with consistent flow.

Historical samples collected between 1980 and 1983 had a mean richness value of seven taxa per sample, while mean abundance was 36 organisms per sample (B73);

therefore, the historical richness and abundance values were lower than those for the more recent samples. Richness values for the historical samples showed a slight increasing trend, while abundance values were erratic with several distinct peaks occurring in the January 1981, April 1981, August 1982, and November 1982 samples (B77). The January 1981 sample (N = 78) was dominated by the exotic Asiatic clam, *Corbicula*, representing 87% of this sample by number. *Corbicula* also dominated the April 1981 sample, 48% by number. The hemipteran, *Hesperocorixa*, dominated the August 1982 sample (N = 96), representing 35% of the sample. November 1982 (N = 83) was dominated by the mayfly, *Ephemerella*, representing 28% of the sample by number. Only three of 26 samples had acceptable EPT values.

Round Culvert West. The 1994 and 1995 samples from this site had relatively high richness and abundance values; however, none of the six samples had acceptable EPT values. Mean richness for these samples was 13 taxa per sample, and mean abundance was 273 organisms per sample (B78). Richness and abundance values for these samples tended to show decreasing trends after June 1994 (B84). The June 1994 sample had the highest richness value of 27 taxa, and the highest abundance value of 852 organisms. This abundance was dominated by larval chironomids, representing 45% of the sample by number.

Historical benthic samples were obtained from Round Culvert West between 1980 and 1983. Mean richness for these samples was four taxa per sample, and mean abundance was 22 organisms per sample (B80). Five out of 24 samples collected had acceptable EPT values. Richness values fluctuated during this sampling period, with the highest richness obtained during the April 1982 sample (N = 10 taxa) (B88). Abundance values also fluctuated during this time with peak abundances occurring during January 1981, June 1981, and April 1982. The January 1981 sample contained 61 organisms, and was dominated by larval chironomids (41% by number). *Corbicula* dominated the June 1981 sample, comprising 96% of the sample. The mayfly, *Ephemerella*, and oligochaetes dominated the April 1982 sample, each representing 29% of the sample by number.

Fish

Station F. This sample site was too deep to electrofish, so four anglers fished for one hour each using artificial lures. Because of this, all fish collected were sport fish. In May 1995, five species were collected, with the dominant species being redbreast sunfish (Table 4). Total lengths for this species ranged from 123 mm to 198 mm. Spotted bass and rock bass were the next most common species collected, with two specimens of each species collected.

Three species were collected by angling at Station F in October 1995 (Table 5). Smallmouth bass was the dominant species caught with a size range of 144 mm to 169 mm; however, two other smallmouth bass were caught, but not measured for total length. One redbreast sunfish and one rock bass were the only other two fish caught in October.

Station G. Electrofishing was accomplished at this site in May 1995. Bluegill was the dominant species collected (Table 4). Thirteen bluegill were collected, ranging in size from 35 mm to 67 mm. The blackspotted topminnow was the next dominant species with four collected. A total species richness of 5 was collected with green sunfish, smallmouth bass, and redbreast sunfish being the three remaining species collected. A school of common carp was observed while sampling; however, none were collected. In October 1995, this site was too deep to electrofish, and one hour of angling by four people resulted in no fish collected (Table 5).

Station H. Fourteen species were collected by electrofishing this site in April 1995 (Table 3), with a total of 53 fish collected. Redbreast sunfish (N = 19) and banded sculpin (N = 15) were the dominant species collected. Sport fish collected at this site included redbreast sunfish, bluegill, warmouth, and green sunfish. These species represented 49% of the total sample by number.

In October 1995, electrofishing of Station H resulted in 10 species collected (Table 5). A total of 134 fish were collected, with central stonerollers and warpaint shiners being the dominant members of the fish community at this site. Sport fish represented only 11% of the sample and included three species (bluegill, green sunfish, and redbreast sunfish).

Station L. Backpack electrofishing of Station L in April 1995 resulted in the collection of six different species (Table 3). A total of 19 individuals were collected, with green sunfish being the most numerous species, and the only sport fish species collected. Green sunfish had total lengths ranging from 56 mm to 90 mm. Other species present included log perch, northern hogsucker, banded sculpin, snubnose darter, and blackspotted topminnow.

In October 1995, six species were collected from Station L (Table 5). Sport fish species present included bluegill, green sunfish, and redbreast sunfish. Other species collected were snubnose darter, log perch, and central stoneroller. Bluegill were the most numerous (N = 4), with lengths ranging from 34 to 42 mm. Due to their small size, these fish were thought to be from the 1995 year class. Sport fish represented 50% of this sample.

Meander A. A total of seven fish species was collected from Meander A in April 1995 by backpack electrofishing (Table 3). Sport fish species included spotted bass, green sunfish, warmouth, and bluegill. These species represented 38% by number of the entire sample. Banded sculpins were the most numerous fish collected (N = 8), and represented 50% of the sample. A single blueside darter was collected at this site and represented the only individual of this species collected. Another species, least brook lamprey, was sighted, but was not collected.

Meander A was electrofished again in October 1995; however, sampling was restricted to shallow areas only, due to high water levels. Six species were collected and included bluegill, redbreast sunfish, longear sunfish, Tennessee shiner, northern hogsucker, and warpaint shiner (Table 5). A total of 28 fish was collected with bluegill (N = 11) and warpaint shiners (N = 11) dominating the sample. Bluegill, redbreast sunfish, and longear sunfish were the only sport fish species collected. Fifty-four percent of the sample by number was sport fish.

Meander D. Electrofishing of this site was conducted in May 1995. This resulted in three species collected, with bluegill being the dominant species (80% by number) (Table 4). Bluegill ranged in size from 32 mm to 115 mm. The other two species collected were redbreast sunfish and blackspotted topminnow. A gar was observed, but not collected; therefore, the species is unknown.

In October 1995, Meander D was too deep to be electrofished, so five people fished with artificial lures for one hour at this site, but no fish were collected (Table 5).

Borrow Pits. Gill netting of the Small and Large Borrow Pits in May 1995 resulted in no fish collected (Table 4). However, a small sunfish species was observed in the Small Borrow Pit, and several mosquito fish were observed in the Large Borrow Pit.

1994 Angling Sample. In September 1994, a single angling sample was conducted at two sites (Table 2). A reach of North Chickamauga Creek between Meander A and Station H was fished for 75 minutes, with a total of seven fishes being caught. Four largemouth bass ranging in size from 203 mm to 305 mm, one smallmouth bass (229 mm), and two bluegill (165 - 178 mm) were caught.

Angling was also accomplished at Station F for 105 minutes. Three species were collected, including rock bass, bluegill, and yellow perch. Rock bass was the most numerous species collected, and ranged in size from 102 mm to 158 mm. Three bluegill were caught and ranged in size from 127 mm to 178 mm, while one yellow perch was collected (178 mm). Several other fish were observed at this site, including seven largemouth bass, two smallmouth bass, and five bluegill.

Historical Data. Fish surveys were conducted in 1975 from historical Station E on North Chickamauga Creek; this site was abandoned in the most recent study because access to it involved crossing privately-owned property. A total of 16 different species was collected from this site (Table 6). Of these species, 11 were collected during 1994 and 1995, indicating that the fish community has not drastically changed. Species collected only in 1975 included drum, black crappie, golden redhorse, spotted sucker, and chestnut lamprey. The most numerous species collected in 1975 was redbreast sunfish, which remains as an abundant sport fish in North Chickamauga Creek.

Discussion

Aquatic biological communities provide important information that can be used to assess the overall health of aquatic ecosystems. Karr and Dudley (1981) defined biological integrity as a balanced adaptive community of organisms having a species composition and functional organization comparable to that of the natural habitat present. Natural processes, increased turbidity, nutrients, and algal production have a major impact on aquatic biota, and thus, biotic integrity. Other factors which adversely affect aquatic systems are those induced by man. Therefore, aquatic organisms respond to varying degrees of environmental quality.

Benthic macroinvertebrates are particularly suitable as ecological indicators because of their habitat preferences and relatively low mobility. These factors cause them to be directly affected by environmental conditions (Whitton 1975). Environmental variables that regulate the presence and distribution of benthic macroinvertebrates include current speed, season, substrate, and dissolved substances. The presence of one or more unfavorable environmental factors results in observable changes in benthic macroinvertebrate community structure (Wilhm and Dorris 1968). Such changes were evident in North Chickamauga Creek.

Benthic communities in North Chickamauga Creek appeared to have encountered an environmental disturbance in the late summer or early fall of 1994. EPT values remained consistently low throughout the sampling period. Since water quality variables were relatively constant during this time, it was thought that the benthic community changed due to habitat modifications. Ruggiero and Merchant (1978) found that substrate differences were better correlated than water quality with benthic macroinvertebrate density and abundance. These organisms typically have patchy distributions due to their preference for some substrates over others.

The size of particles composing a lotic substrate is usually determined by current velocity. As the longitudinal gradient of a stream decreases downstream, a reduced current velocity results in finer-sized particles forming the streambed. This would tend to increase the uniformity of the substratum. Stations F, G, and Meander D had a relatively uniform substrate composed of fine silt. Additionally, at least one flood or high water event occurred during 1994 and 1995. This event could have carried large amounts of silt or other erosional materials into these stations, as well as temporarily affecting riffle areas at the more upstream stations (L, H, and Meander A). Lotic invertebrates have an inherent need for current, but can be adversely affected by fluctuations in current velocity. These changes, with their resultant deposition of silt and other erosional materials following floods and high waters, can drastically affect an existing invertebrate fauna before it can readjust (Baker 1983). Erosional silt alters the aquatic environment directly by screening out light, by changing heat radiation, by blanketing the streambed, and by retaining organic material and other substances which create unfavorable conditions at the substrate (Ellis 1936).

Riffle areas created at Stations L and H provide beneficial substrates for colonization by macroinvertebrates. However, these areas are still subject to fluctuating water levels. During low water, these sample sites rapidly lose water and provide environmental conditions non-conducive for benthic invertebrates. Likewise, during unusually high water levels, silt and other erosional materials will accumulate, reducing suitable substrates for invertebrate colonization. These factors will remedy themselves through natural flow processes, but recovery of the benthic community is slow. Higher richness and abundance values for all sites, when compared to historical data, indicate that benthic habitats have colonized somewhat, but fluctuating environmental conditions have left the benthic communities unstable.

Channelization of streams often reduces their overall habitat quality, so artificial meanders are often used to alleviate such consequences. However, the artificial meander constructed on North Chickamauga Creek has steep-sided banks and limited substrate diversity. The earthen dam placed in the historical creek channel and used to divert water into the meander causes problems at the substrate level. This dam tends to pool water at the entrance to the meander (Meander A) and the resulting reduction in current velocity allows organic particles and silt to settle out of the water column, covering the substrate. This material is conveyed into the meander and again reduces benthic macroinvertebrate habitat availability. The steep sides of the meander are not conducive to favorable aquatic conditions, as the banks favor erosional activity and the eroded material settles in the meander. Much of this is washed downstream and settles out at the confluence with North Chickamauga Creek (Meander D). Substrate in this area is highly unconsolidated, but is of uniform consistency. Organic materials have been deposited here as evidenced by large amounts of detritus and the occurrence of gaseous deposits in the substrate. This has also resulted in a poor benthic community in the artificial meander. Baker (1983) found similar results.

When compared to other lotic ecosystems monitored, the round culvert complex contained the best benthic macroinvertebrate communities. This area was not subjected to the extremely variable flow regimes that were apparent at the other stations, so the substrate on both ends of the culvert remained relatively stable. This stability allowed for colonization by benthic macroinvertebrates.

Benthic communities in the borrow pits behaved typically of most lentic benthic communities. Although each of these lentic ecosystems was somewhat different in basin morphometry, the benthic communities were typically dominated by oligochaetes and larval chironomids. These organisms are often associated with substrates that are rich in organics and composed of unconsolidated sand or silt. This type of substrate was common in the Large Borrow Pit, Small Borrow Pit, and the Beaver Pond. Due to their ephemeral hydrology, the Natural Swamp and the Shallow Borrow Pit do not maintain consistent benthic macroinvertebrate communities and will not be discussed here.

The Large Borrow Pit was constructed as a deep pit, with steep slopes and very few shallow areas to serve as a littoral zone. Littoral zones are among the most productive areas in lentic ecosystems; the great diversity of aquatic organisms and the high annual production of littoral zones set their communities apart from the benthos in deeper waters (Cole 1979). The sample site for the Large Borrow Pit had a very limited littoral zone with poor substrate which may account for the benthic community sampled. Had benthic samples been obtained from a larger littoral zone with submergent or emergent vegetation and a consolidated substrate, the benthic community may have been more numerous and diverse.

The Small Borrow Pit was similarly constructed as the Large Borrow Pit. Essentially no littoral zone existed in the Small Borrow Pit. Again, the substrate was largely unconsolidated and contained organic debris in the form of leaves. Allochthonous organic matter, mostly leaves and sticks, can serve as a primary source of energy in aquatic systems (Cummins 1974, Anderson and Sedell 1979, Stout 1982). However, organic matter in deep waters decomposes, placing a great demand on dissolved oxygen resources. This restricts the colonization of benthic organisms to the limited shallow areas near the banks of the Small Borrow Pit. Leaf matter in this area can be colonized by some benthic invertebrates, with the leaves serving as a food source (Egglishaw 1964); however, due to this limited productive area, oligochaetes and larval chironomids continued to dominate the benthic community. These organisms tend to colonize silty substrates with organic debris, and have a relatively high survival rate, even in the presence of low dissolved oxygen.

The Beaver Pond, although more shallow than either of the previously described borrow pits, contained an extreme amount of organic debris. The water in this pond was often turbid which would limit primary production, and, therefore, dissolved oxygen content. Due to these factors, the benthic community was dominated by oligochaetes and larval chironomids. Aquatic invertebrate abundances are often limited by dissolved oxygen concentrations; this seems to be evident in the Beaver Pond. Richness and abundance values tended to vary during the year, with the greatest values present during the warmer months of the year. During this time, limited colonization by benthic insects occurred in the Beaver Pond, but emergence of the adult stages reduced these values during the colder months.

Substantial evidence supports the premise that fish communities can be used to assess human influences on the biological integrity of freshwater ecosystems, because fishes are sensitive indicators of the relative health of aquatic ecosystems and their associated watersheds (Hocutt 1981, Karr 1981). The public is much more likely to understand information regarding the condition of a fish community than data concerning benthic invertebrates or water quality. Leonard and Orth (1986) found that fish community structure changes consistently with stream degradation. The results of fish surveys on North Chickamauga Creek indicated that the overall fish community structure changed only slightly between 1975 and 1995.

Station H had the most abundant fish community of all stations sampled. The majority of the fish collected at this site were not sport fish, and were functionally considered to be omnivores. This was not surprising since the benthic macroinvertebrate community at this site was limiting. These fish were apparently feeding on periphyton, as well as benthic invertebrates. The increased oxygen content and larger substrate created by the riffle at this site provided acceptable habitat for these omnivorous fishes.

Other upstream sample sites had limited sport fish populations, although empty bait buckets and foot paths indicated that the public was using these areas for fishing. Fish survey results indicated that sport species did inhabit these areas, but were concentrated in deep pools containing fallen trees within North Chickamauga Creek. Stocking reports from the Tennessee Wildlife Resources Agency indicated that rainbow trout (*Oncorhynchus mykiss*) are stocked here every spring. Fishing activity probably occurred during this time.

The artificial meander contained a very limited fish population. Due to the lack of desirable fish habitat, sport species encountered were few in number and were thought to be temporary members of the meander's fish community. The lack of a dependable supply of macroinvertebrates for food probably limited fish abundance, as much as the lack of suitable habitat.

Due to lack of sufficient electrofishing data at Stations F and G, only the sport fish populations at these stations can be addressed. These stations appeared to support fair sport fish populations, although the benthic macroinvertebrate populations at these stations probably limit fish production. However, the diversity of fish habitat serves to support sport fish populations. Very little indication of fishing activity was noted at these stations, so low fishing pressure will probably enable these stations to maintain their sport fish populations.

Although no fish were collected from either the Large or Small Borrow Pits, visual observations confirmed the presence of fish communities. Due to their steep-sloped construction and limited littoral areas, very little natural reproduction is expected to occur for sport fish species. The benthic macroinvertebrate populations of these waters would also serve to limit fish production. Evidence of fishing pressure on the Large Borrow Pit, however, was noted due to the presence of a makeshift boat ramp and discarded bait buckets. Evidently, this borrow pit has a sport fish population, but, due to our sampling results, we cannot address the population. Had adequate access been available at this site, a boat electrofishing survey could have been conducted.

Age and growth analyses were not performed on fish collected from any of the sample sites. For adequate analysis, a relatively large sample of fish would need to be sacrificed for removal of otoliths and age determinations. Due to the sparseness of the fish communities sampled, this was not considered acceptable. Future studies of the fish community in a larger reach of North Chickamauga Creek could provide age and growth analysis, as well as fish population estimates.

Conclusions

The major conclusion, reached as a result of the aquatic biota monitoring, was that suitable habitat for fish and benthic macroinvertebrates is limited on the study area. The riffle areas created at Stations H and L were positive measures that helped to somewhat enhance these biotic communities; however, due to extreme water level fluctuations, these riffles are not so productive as they could be. A greater diversity in substrate size and composition in these areas, with the construction of intermittent pooled areas, would be advised in future endeavors. Substrate size diversity would increase the chance for scouring forces which would effectively cleanse fine sediments from the larger substrate interstitial spaces during high water. The placement of intermittent pools within the riffle area would provide a complex habitat allowing deep water habitat during low water periods.

The remaining stations on North Chickamauga Creek (F and G) should have increased habitat diversity. These areas are essentially pools and runs, with no riffles. Riffles serve to aerate the water, as well as enhance the scouring forces by increasing current velocity. Scouring forces will cleanse silt-laden areas, providing more acceptable substrates for benthic macroinvertebrate colonization. Placement of instream structures above the deeper pools would create beneficial riffles and provide a diversity of fish habitat. Strategically placed logs and rip-rap would serve to create these riffle habitats.

Although artificial meanders often serve to alleviate channelized stream reaches, construction of this meander caused it to not be productive for aquatic biological communities. The earthen dam at the meander entrance serves to pool water during high flows, with only a slow diversion into the narrow meander. This served to deposit sediments at the entrance, as well as carry and deposit sediments throughout the meander's length. A more gradual diversion from North Chickamauga Creek into the meander would alleviate much of this problem. Also, the steep-sloped banks of the meander were conducive to erosion. Steep banks are common in lotic ecosystems; however, they are typically heavily vegetated to reduce or eliminate erosion. Therefore, revegetation of the banks with trees and herbaceous vegetation would serve to curb erosion. Instream habitat structures would serve to diversify fish and benthic habitat and enhance scouring action in the meander. Streamside bank stabilization structures and created riffle and pool areas in the meander would have been beneficial. No matter which instream structures are used, the entire meander should be constructed to resemble a natural lotic ecosystem.

Littoral zones in lentic ecosystems are most productive habitats. Aquatic vegetation in these areas serves as photosynthetic organisms, as well as biological filters for suspended matter and nutrients, substrate for macroinvertebrate colonization, and cover for fish. Many fish use these productive areas for spawning. The Large and Small Borrow Pits have limited littoral habitat and, therefore, biological communities suffer. A gradual slope of 3:1 is recommended for the creation of littoral zones in constructed lentic ecosystems (Flickinger and Bulow 1993). This means that 1 m of depth will be reached about 3 m from shore. Many desirable species of aquatic macrophytes can be planted on these shallow areas to provide instant habitat. Also, when considering fish populations in these systems, the bottom contour should be irregular, and structures, such as trees and brush, should remain in the water body for habitat diversity.

Implementation of the above recommendations will provide aquatic biological communities with more suitable habitats. Not only will these recommendations help to improve the biological communities, but they will also improve the aesthetic and functional value of these natural and created aquatic ecosystems.

Table 2. Fish sampling data, September 13, 1994, angling survey.

Site	Species	Number Captured	Total Length (mm)	
			Average	Range
Meander A to Station H (75 minutes)	Largemouth bass	3	254	203 - 305
	Smallmouth bass	1		229
	Bluegill	2	172	165 - 178
Station F (105 minutes)	Rock bass	4	135	102 - 157
	Bluegill	3	152	127 - 178
	Yellow perch	1		178

Notes: Water levels at other sites were too low to sample.
Large carp were observed below the confluence of N. Chickamauga with Cave Springs.

Table 3. Fish sampling data, April 7, 1995, backpack electrofishing.

Site	Species	Number Captured	Total Length (mm)	
			Average	Range
Station H	Redbreast sunfish	19	133	42 - 201
	Warmouth	2	44	30 - 58
	Bluegill	1		120
	Green sunfish	4	63	50 - 73
	Logperch	1		135
	Stoneroller	3	132	123 - 139
	Banded sculpin	15	77	51 - 98
	Blackspotted topminnow	2	80	77 - 82
	Northern hogsucker	1		79
	Blueside darter	2	52	43 - 62
	Snubnose darter	1		42
	Rainbow darter	1		42
	Creek chub	1		62
Station L	Logperch	1		127
	Green sunfish	6	69	56 - 90
	Northern hogsucker	1		126
	Banded sculpin	3	78	61 - 89
	Snubnose darter	6	57	52 - 63
	Blackspotted topminnow	2	62	52 - 71

Table 3, cont'd.

Site	Species	Number Captured	Total Length (mm)	
			Average	Range
Meander A	Spotted bass	1		119
	Logperch	1		128
	Banded sculpin	8	65	49 - 84
	Green sunfish	1		58
	Warmouth	1		48
	Bluegill	3	37	31 - 42
	Blueside darter	1		49

Table 4. Fish sampling data, May 1995. Stations F, G, and Meander D were sampled May 10; Station F was sampled by angling (1 hr. by four people) and Stations G and Meander D were sampled by electrofishing. The Large and Small Borrow Pits were sampled May 17 using a 38 m gill net.

Site	Species	Number Captured	Total Length (mm)	
			Average	Range
Station F	Redbreast sunfish	4	158	123 - 198
	Spotted bass	2	252	225 - 278
	Bluegill	1		119
	Green sunfish	1		132
	Rock bass	2	166	150 - 182
Station G	Bluegill	13	46	35 - 67
	Green sunfish	2	70	62 - 79
	Blackspotted topminnow	4	62	48 - 70
	Redbreast sunfish	1		86
	Smallmouth bass	1		83
Meander D	Bluegill	8	54	32 - 115
	Redbreast sunfish	1		120
	Blackspotted topminnow	1		75
LBP	no species collected			
SBP	no species collected			

Table 5. Fish sampling data, October 1995. Stations F, H, and Meander A were sampled October 21; Stations G, L, and Meander D, October 28. Stations F, G, and Meander D were sampled by angling; Stations H, L, and Meander A by electrofishing.

Site	Species	Number Captured	Total Length (mm)	
			Average	Range
Station F	Redbreast sunfish	1		142
	Smallmouth bass	4*		144 - 169
	Rock bass	1		179
Station G	No fish collected			
Station H	Bluegill	10	38	26 - 62
	Stoneroller	77	72	42 - 147
	Warpaint shiner	25	51	40 - 66
	Green sunfish	3	93	80 - 100
	Redbreast sunfish	1		113
	Mottled sculpin	1		67
	Banded sculpin	12	92	79 - 111
	Tennessee shiner	1		44
	Speckled darter	1		55
	Snubnose darter	3	57	50 - 64
Station L	Bluegill	4	37	34 - 42
	Green sunfish	1		50
	Redbreast sunfish	2	46	42 - 51
	Logperch	1		118
	Snubnose darter	3	55	49 - 62
	Stoneroller	3	65	59 - 70

* Includes two fish captured, but not measured

Table 5, cont'd.

Site	Species	Number Captured	Total Length (mm)	
			Average	Range
Meander A	Bluegill	11	51	28 - 118
	Redbreast sunfish	2	60	47 - 72
	Longear sunfish	2	104	93 - 114
	Tennessee shiner	1		53
	Northern hogsucker	1		74
	Warpaint shiner	11	41	31 - 60
Meander D	No fish collected			

Table 6. Fish sampling data, May 1975, Station E.

Species	Number Captured
Bluegill	8
Stoneroller	1
Northern hogsucker	5
Green sunfish	3
Redbreast sunfish	19
Drum	12
Banded sculpin	16
Logperch	4
Yellow perch	1
Rockbass	10
Smallmouth bass	1
Warmouth	17
Black crappie	1
Golden redhorse	2
Spotted sucker	1
Chestnut lamprey	5

CHAPTER 4
TERRESTRIAL PLANTS

The value of an area to most wildlife species can be estimated by evaluation of the plant community because plants are the primary source of food and cover to wild animals. Plants reflect the physical characteristics of a site, and they also provide information concerning habitat conditions. For example, plants are one of the three components used to determine the wetland status at a specific site. Comparisons over time provide information on successional changes in plant communities and corresponding changes in animal composition and modifications to physical characteristics of the environment. This portion of the study focused on vegetation characteristics at various locations on the SR-29 study site and successional changes in plant composition that have occurred on the site during the past 15 years.

Methods and Materials

Plant Community Analyses

The study site was divided into nine different plant communities: South Woods, North Woods, upland scrub, lowland scrub, upland grass, lowland grass, swamp, power lines, and Shallow Borrow Pit (Figure 2). Three vegetative strata (herbaceous, sapling/shrub, and pole/sawtimber trees) were sampled in the mature hardwoods, upland scrub, lowland scrub, and swamp habitats. Herbaceous vegetation only was sampled in the upland grass, lowland grass, power lines, and Shallow Borrow Pit habitats because the other two strata were absent.

Transects, 50 m long, were established in each plant community to sample vegetation. Number of transects varied from 12 in the South Woods to one in the Shallow Borrow Pit. Species observed during fieldwork, but not present in transect samples, were identified and compiled in a complete species list included in the Appendix.

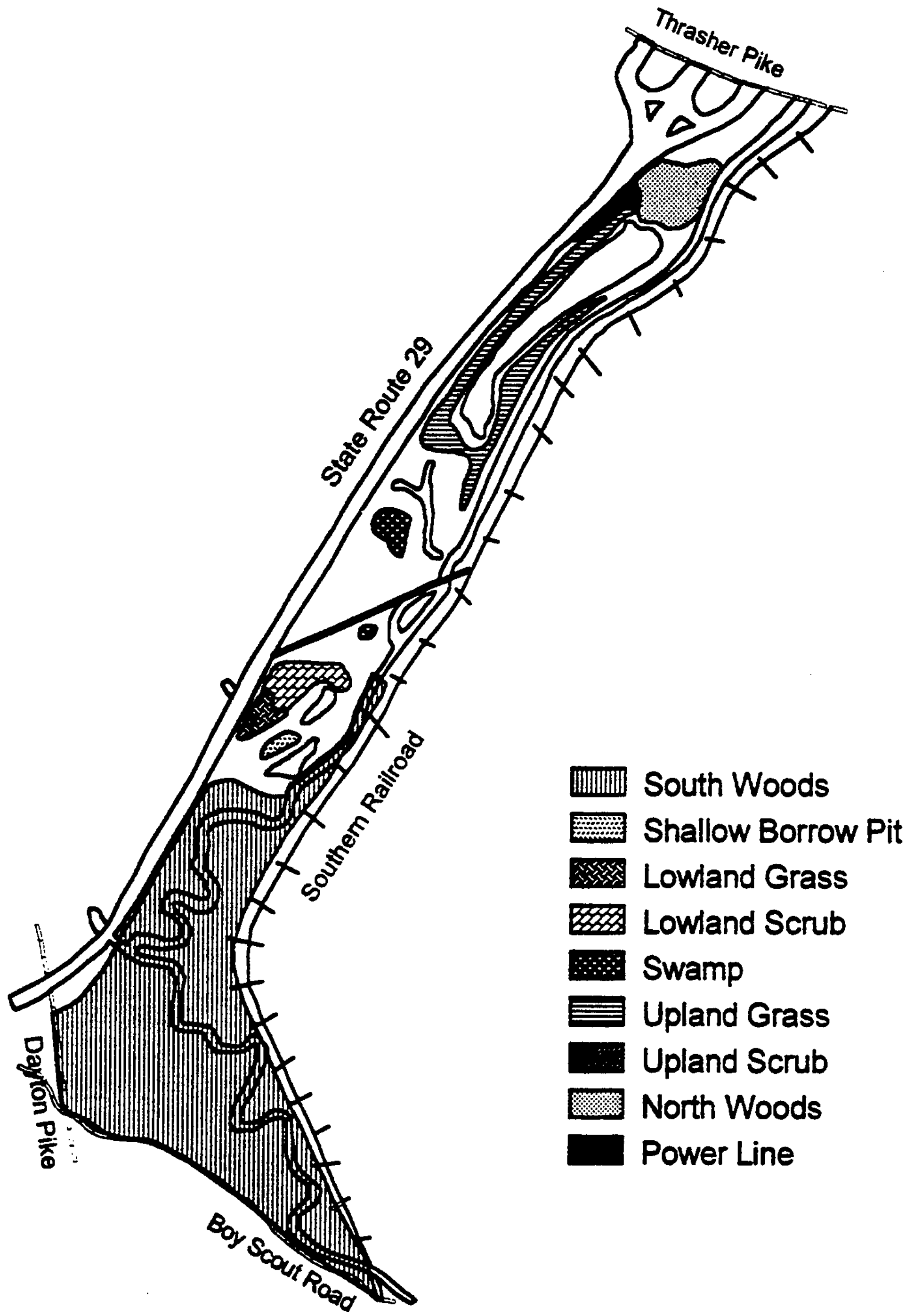

Figure 2. Locations of plant communities on SR-29 study site.

Herbaceous vegetation was assessed using the point-intercept method (Raelson and McKee 1982). A meter stick was dropped perpendicular to the ground at 1 m intervals along each transect, resulting in 50 herbaceous sampling points per transect. Each species touched by the meter stick was recorded, along with its height. Woody vegetation less than 91.4 cm tall was considered part of the herbaceous community. Total percent cover of herbaceous species was calculated by dividing the total number of points at which plants occurred by the total number of points sampled and multiplying the result by 100. Average height of herbaceous vegetation was calculated as the mean of all height measurements, but points at which no plants were recorded were not used. Species richness values were calculated for each habitat type as the average number of species occurring per 50 sampling points.

Sapling/shrub vegetation was sampled within 2.5 m radius circular plots every 10 m along each transect, resulting in 5 plots per transect. Species in each plot were identified and counted. Sapling/shrubs were considered to be woody plants less than 10.2 cm DBH (diameter at breast height measured 1.5 m above the soil surface) and greater than 91.4 cm in height. Total density of saplings/shrub species was calculated on a per hectare basis. Species richness values were determined by averaging number of sapling/shrub species in each transect.

Pole- and sawtimber-sized trees (woody vegetation greater than 91.4 cm tall with a DBH greater than 10.2 cm) were sampled using the point-centered quarter method (Cottam and Curtis 1956) at the same transect points where sapling/shrub plots were centered, and 20 trees were sampled per transect. At each sampling point, the transect line served as the dividing line for two halves, and a compass was used to further divide the area into quarters by running a line perpendicular to the transect line. The nearest tree in each quarter was identified to species, its DBH was measured with a DBH tape, and the distance from the center of the tree to the sampling point on the transect line was measured with a cloth tape. If a tree was forked within 1.5 m of the ground, the nearest fork greater than 10.2 cm DBH was measured.

Data analyses for trees consisted of calculating basal area, density, relative density, dominance, relative dominance, frequency, relative frequency, and importance values for each species in each habitat (Cox 1967). Species richness also was calculated for each vegetative community by averaging number of different tree species present along each transect. Basal area for each tree was calculated by converting DBH to a radius measurement by dividing by 2 and using the area formula of a circle. Average dominance value (Cox 1967) for each tree species was calculated by adding all basal area measurements for that species together and dividing by number of individuals of that species. Unit area used to calculate tree density was 10,000 m^2 because density estimates were per hectare (Cox 1967). Formulas used for calculations of tree measurements are as follows:

$$\text{total density of all species} = \frac{\text{unit area}}{(\text{mean point-to-individual distance})^2}$$

$$\text{relative density} = \frac{\text{number of individuals of a species}}{\text{total number of individuals of all species}} \times 100$$

$$\text{density} = \frac{\text{relative density of a species}}{100} \times \text{total density of all species}$$

$$\text{dominance} = \text{density of species} \times \text{average dominance value for species}$$

$$\text{relative dominance} = \frac{\text{dominance for a species}}{\text{total dominance for all species}} \times 100$$

$$\text{frequency} = \frac{\text{number of points at which a species occurred}}{\text{total number of points sampled}}$$

$$\text{relative frequency} = \frac{\text{frequency value for a species}}{\text{total of frequency values for all species}} \times 100$$

$$\text{Importance Value} = \text{relative density} + \text{relative dominance} + \text{relative frequency}$$

Results

Herbaceous plants

Ninety-five species of herbaceous plants were identified along 40 transects established in nine habitats (Table 7). Several dominant species in various habitats were low-growing woody vines (e.g., Japanese honeysuckle, poison ivy, and blackberry), small shrubs (e.g., pawpaw), or seedlings of trees (e.g., sugar maple); these plants were classified as herbaceous plants by criteria used in this study. Japan grass and Japanese honeysuckle were primary components of the herbaceous stratum of most wooded habitats, and honeysuckle also was abundant along power lines and in the upland grass community. Poison ivy dominated the lowland scrub herbaceous understory and was abundant in the North Woods and along power lines. Blackberry was abundant in scattered locations where sunlight was sufficient, such as openings of the North Woods and along power lines. Other dominant species were habitat specific (e.g., sugar maple was common only in the North Woods, and rush was dominant in the Shallow Borrow Pit). Wetland dependent species dominated in the Shallow Borrow Pit, Natural Swamp, and lowland grass community; whereas upland species or facultative plants (i.e., those that occur in wetland and upland communities) were most abundant in other habitats.

Habitats lacking a woody overstory had a well-developed herbaceous layer that covered most of the ground. Herbaceous coverage was less complete in upland woody communities (i.e., the mature woods and upland scrub community), but over 50% of the substrate in both was covered by herbs. Herbaceous coverage was lowest in the lowland scrub community. Although herbaceous coverage of the Natural Swamp was only slightly lower than that of the North Woods, the swamp estimate was biased upward because only the highest sites in the Natural Swamp were sampled.

Herbaceous plant height was greater in open habitats than in habitats with a woody overstory, with the exception that the Shallow Borrow Pit was dominated by low growing annuals (i.e., mudflat species). Species richness varied among habitats, but upland communities generally were richer than wetland habitats. Also, open communities generally were richer than communities with a woody overstory, except the North Woods were richer and the Shallow Borrow Pit was less rich than expected, based upon this relationship.

Saplings/shrubs

Thirty-one different species of saplings/shrubs were identified in the five habitats with a woody overstory (Table 8). A different species dominated in each habitat, and the sapling/shrub stratum differed greatly among communities. The North Woods and South Woods were most similar among these communities, but sugar maple was much more abundant in the North Woods. Pawpaw was abundant in woodlands at both ends of the study area. The upland and lowland scrub communities were dominated by saplings of early successional tree species, especially Virginia pine in the upland community and winged elm in the lowland community. Buttonbush, an obligate wetland plant, dominated the sapling/shrub stratum of the Natural Swamp.

All five communities had a well-developed sapling/shrub layer, but the density of saplings or shrubs was highest in the lowland scrub community and lowest in the upland scrub community. Species richness was similar among communities.

Trees

Although 33 different tree species of pole or sawtimber size were sampled in the five communities with a woody overstory, early to mid-successional species dominated in all (Tables 9-13). Based on all density and dominance values, sweetgum and yellow poplar were the most important tree species in the North and South Woods (Tables 9 and 10); Virginia pine was most important in the upland scrub community (Table 11); maples, sweetgum, and winged elm were most important in the lowland scrub community (Table 12); and river birch and black willow were most important in the Natural Swamp (Table 13). Few hard mast producing species (i.e., oaks, hickories, and beech) were encountered during tree sampling.

Discussion

Herbaceous plants

Ecological Relationships. Succession is the natural change in plant communities from primarily annual herbaceous plants to perennial herbs and, eventually, woody species. Once woody plants become established, composition of herbaceous plants usually shifts from shade-intolerant to shade-tolerant species, and the density of herbs decreases (Grime 1979). Shading from taller plants and increased leaf litter are the primary factors influencing these changes. These factors are pronounced in mature forests, and the herbaceous layer is almost nonexistent in old growth forests (Grime 1979). The well-developed herbaceous zone in the South Woods of the SR-29 study site provides evidence that the forest was not mature.

The least developed herbaceous layer at the study site was in the lowland scrub plant community, probably because the dense saplings and shrubs created more shade than at other sites. During early spring, a dense layer of onions was present at this location and, had sampling been conducted earlier, percent herbaceous coverage would not have appeared so low. Many herbaceous species in woodlands depend upon spring light before the tree canopy has developed to manufacture most of their food supply for the year; they flower early in spring, and their leaves die before the end of June (Ashby 1961).

Percent herbaceous coverage was lower in the North Woods than in the South Woods, possibly in part because of differences in successional age of forests. Based on tree size and composition, the North Woods appeared more mature than the South Woods (see discussion below), and shading was probably more complete in the North Woods. Human activity also contributed to differences in herbaceous coverage. Pickup trucks, dirt bikes, and ATV's were frequently ridden in the North Woods, denuding vegetation and creating barren areas that were eroding in many places. (Photo, p. 171)

Herbaceous plants along the power line provide an example of a subclimax community, a successional stage that does not change because of events that periodically retard successional progress (Ashby 1961). Regular mowing of the power line suppresses dominant plants (e.g., woody species) and enables plants of smaller stature to regenerate and coexist with more robust species (Grime 1979). This phenomenon probably contributed to the high species diversity of the power line.

Overall, herb diversity was high at the SR-29 study site, primarily because of the diversity of habitat conditions on the area. Variability in water-soil conditions created localized areas ranging from somewhat xeric (dry) to extremely hydric (wet). Light intensity varied from full sunlight in open areas to dense shade in the most mature woodlands. The interaction of these two variables resulted in different habitat conditions, each supporting a different plant community: upland grass (xeric, shade-intolerant species), lowland grass (hydric to mesic, shade-intolerant species), upland scrub (xeric, shade-tolerant species), lowland scrub (mesic, shade-tolerant species), South Woods (mesic, shade-tolerant species), power lines (mesic, shade-intolerant species), swamp (hydric, shade-tolerant species), and Shallow Borrow Pit (hydric, shade-intolerant species).

The diversity of some plant communities is threatened by competition from introduced, exotic species. Japan grass and Japanese honeysuckle were among the most common understory species throughout the study area. Both are shade-tolerant and grow robustly in a wide variety of habitats. Japanese honeysuckle is a climbing or trailing vine that spreads rapidly and eventually dominates an area, eliminating other species through competition for sunlight. Although Japan grass is not so devastating because of its low stature, it competes with other low-growing herbs and sometimes forms thick mats. Kudzu was not very common on the study site, but it has become established at the extreme northern end. Kudzu is well known for its rapid growth rate and ability to eliminate all plants in a given area, including trees. Kudzu is not so shade-tolerant as Japanese honeysuckle, and it does not survive in the understory of mature forests, but it has the ability to climb to the top of trees and to eventually destroy entire forest stands. If these species continue to spread, the plant diversity of the SR-29 site will decline.

Most herbaceous species that had been seeded or planted on the SR-29 site during the early 1980s were found throughout the study site. Fescue had been seeded around the borrow pits and artificial meander to control erosion and is still present in single species mats. Blackberries and bicolor lespedeza had been planted in small patches to reduce erosion and to provide wildlife food and cover. Robust patches of both species are still present at the planted sites; additional blackberry patches have become established throughout the area, probably through the activity of songbirds which feed on the fruit and pass the seeds through their digestive systems. (Photo, p. 169)

The herbaceous layers of the North and South Woods have not changed much since the early 1980s, probably because the successional stage of the forest and amount of shading at that time were similar to those today. As the forests continue to mature, the herbaceous zone should become more sparse, and species composition should shift to more shade-tolerant species. However, latter stages of forest succession take place over several decades, and these changes should occur slowly and require many years to become noticeable.

In contrast, the Natural Swamp has apparently changed substantially over the past 15 years. Shelton reported a robust herbaceous layer in the swamp, dominated by southern watergrass. The herbaceous zone was less robust in this study, probably because of increased shading associated with additional canopy closure, and the primary herb was

Japan grass. It is suspected that Japan grass was misidentified as watergrass during the previous study because the two species are somewhat similar, and watergrass is a coastal plain species that is not known to occur in Tennessee (Godfrey and Wooten 1979, Chester et al. 1993).

Primary differences in herbaceous plant composition between this study and previous studies can be explained by successional changes associated with shifts from open, early successional communities to shrubby, mid-successional communities. For example, fields dominated by aster and beggartick have now become vegetated with later successional herbs and scattered shrubs. Direct comparisons of herbaceous plant composition between studies were limited because previous plant results were presented in general terms and by plant community types, not by specific locations. Plant communities have changed at many locations during the past 15 years (e.g., many open herbaceous communities have become shrub communities), as indicated by the change in the percentage of the area characterized as open fields since the previous study. Thus, the herbaceous composition of the overall SR-29 site has changed substantially since the early 1980s, despite the apparent similarity between plants found in specific habitats.

Wildlife Value. Many wildlife species feed primarily on the fruit, leaves, and underground parts (e.g., tubers and rhizomes) of herbaceous plants. Areas that support diverse communities of herbaceous vegetation provide better food resources than most monocultures. Because monocultural foods are less reliable and more susceptible to catastrophic losses, they are used by fewer types of organisms (i.e., only generalists and those that specialize in that food type), and they often are nutrient-deficient (Fredrickson and Taylor 1982). The diversity of herbaceous plants at the SR-29 site is a good indication that the site is providing excellent food resources for a diversity of wildlife species. The wildlife values of a few of the more common plants on the site are discussed below.

Japanese honeysuckle is considered an excellent plant by some wildlife biologists because it is browsed readily by deer, produces fruit that are readily consumed by quail and songbirds, and provides cover for numerous wildlife species (Stribling 1991). However, Japanese honeysuckle eliminates many native understory species through competition; consequently, many conservationists consider it a noxious weed that should be eliminated if possible and never promoted.

Blackberry, one of the most valuable of all wildlife plants, was locally abundant at the SR-29 site. It is a preferred browse plant by deer (Stribling 1988), its fruit is produced in large quantities and eaten by most wildlife (Stribling 1991), and quail and rabbits use it for cover. Blackberry also provides nesting cover for breeding songbirds; five species of birds breeding along power line corridors in Tennessee appeared to be dependent on blackberry along the edges (Kroodsma 1984).

Lespedeza is a genera of plants within the bean family that is important to wildlife, and various species of lespedeza often are planted for food and cover. Bicolor lespedeza, the species seeded on the SR-29 site, is usually established to provide quail food; its seeds are especially important from December to early spring when seeds from grasses and weeds have often spoiled (Stribling 1991). Other lespedeza species also were identified during this study. Some of them (e.g., serecia lespedeza) provide little food and grow so thick that they are not considered good wildlife plants.

Although tall fescue has been planted as a ground cover at the SR-29 site and many other locations, it does not provide good habitat for wildlife (Quail Unlimited 1992). It grows in thick mats that are avoided by small animals like quail, rabbits, songbirds, and field mice (Quail Unlimited 1992). Some varieties are infected with symbiotic fungi which cause sickness and low conception rates in rabbits and other mammals (Quail Unlimited 1992). Although fescue is useful for erosion control, relatively inexpensive, and easy to grow, native warm season grasses are equally effective and provide better wildlife resources. Many native species are more palatable than fescue, and they provide excellent nesting and brood cover because they form small patches with bare ground between them (i.e., they are bunch grasses) (Capel unknown date). Panic grasses occurred commonly in wet areas of the study site; they also produce abundant, nutritious seeds, and their foliage is dense enough to provide cover, but sparse enough not to inhibit access by small animals (Fredrickson and Taylor 1982).

Broomsedge is a native grass that produces few seeds and is less palatable as a forage crop than other warm season grasses (Capel unknown date). It typically is less dense than fescue and provides excellent cover, especially when it grows in patches among other herbaceous plants (Capel unknown date). Goldenrod, another common plant on the SR-29 site, also provides little food, but is a good cover plant; however, some species of goldenrods grow very tall and can form thick stands that eliminate other useful plants.

Poison ivy, a common plant in many locations of the study area, produces toxic substances that can cause allergic reactions on human skin. Many animals do not react to these substances, and deer readily forage on poison ivy leaves. Poison ivy also produces berries that are consumed by songbirds and other small animals (Martin et al. 1951).

Several different species of rushes and sedges occurred throughout the SR-29 site, most abundantly in lowland habitats. They are of intermediate value to wildlife; although they produce moderate numbers of seeds, the seeds are often small and somewhat difficult to digest (Fredrickson and Taylor 1982). Some species produce larger seeds than others (Godfrey and Wooten 1979), thereby increasing their value as food plants relative to other species. Some species produce underground storage organs (e.g., tubers) that are readily consumed by ducks and other wildlife (Fredrickson and Taylor 1982). Many rushes and sedges have growth forms similar to bunch grasses (Godfrey and Wooten 1979), and they are good cover plants for wetland wildlife species.

Saplings/shrubs

Ecological Relationships. Sapling composition can be used to predict future successional patterns in forests. Although some trees (e.g., dogwood and redbud) are small, shade-tolerant species that will persist in the understory for many years, other species are seedlings or saplings of larger trees and will become a component of the future overstory if environmental conditions allow (Barbour et al. 1987). Pawpaw is a lifelong understory species, and its abundance in the South Woods provided little information concerning successional status of the forest. However, the absence of oaks, hickories, and beeches and presence of earlier successional species (e.g., red maple and sweetgum) in the sapling layer indicated that the South Woods is not a mature forest and is not likely to develop into one in the near future.

Sweetgum, an early successional species, is shade-intolerant, but fast growing; it produces abundant fruit by the age of 25 years (Harlow et al. 1979). Late successional species are long-lived, but slow-growing, whether they are shaded or in full sun (Grime 1979). With intense competition, beeches may only grow to be 2.1 m tall in 25 years, and they do not produce substantial fruit until they are at least 40 years old (Burns and Honkala 1990). White oaks develop slightly faster than beeches, but their acorn production occurs primarily between the ages of 50 and 200 years (Burns and Honkala 1990). Thus, the lack of oaks and beeches in the understory indicates that a mature forest will not develop on the site for many years, unless planting is used to speed succession.

The upland scrub habitat was dominated by Virginia pine, a shade-intolerant species that is considered early successional (Burns and Honkala 1990). Virginia pine often becomes established after fire, or on eroded, nutrient-poor soils. In central Tennessee, Virginia pine out-performs shortleaf and loblolly pine on dry ridges and warm slopes with shallow soils, areas that are considered poor quality (Burns and Honkala 1990). Virginia pine at the upland scrub site of the SR-29 study area appeared to be growing more rapidly than nearby short-leaf and loblolly pines, probably indicating poor site quality, the result of topsoil removal. (Photo, p. 170)

This area was previously referred to as mixed successional land and described as a wet, overgrown field with scattered small trees and shrubs. Sapling species reported for the area included willows, maples, and alder. These species were absent from the upland scrub location during this study and had apparently been replaced by Virginia pine by natural processes which indicates that there has possibly been a change in hydrologic conditions at the upland scrub site; there was no indication that Virginia pine was planted on the site. Although the pines are quite large (230 cm^2 basal area, n=31), they could have become established at the conclusion of the previous study and grown to the current size if they averaged 1.14 cm in diameter growth annually. This growth rate is realistic because Virginia pine grew an average of 0.86 cm annually over a 15 year period in Iowa, a state with less rainfall and a shorter growing season than Tennessee (Snow 1965).

The replacement of previously reported saplings with Virginia pine would probably necessitate a change to dry conditions because Virginia pine does not survive under wet conditions (Burns and Honkala 1990). The upland scrub site may be drier than it was in the early 1980s because the adjacent Large Borrow Pit may be modifying the hydrology of the site. Some wetlands and aquatic ecosystems serve as sources of groundwater recharge (i.e., provide water to the surrounding area), but others discharge groundwater (i.e., absorb water from the surrounding area) (Mitsch and Gosselink 1993). Factors influencing the flow of groundwater to and from wetlands is complex, but include impermeable layers in the soil (i.e., hardpans) which can be created during construction projects using heavy machinery. The Large Borrow Pit may have been constructed in such a way that it receives groundwater from the surrounding area. To test this hypothesis, groundwater wells would have to be placed at locations around the borrow pit and monitored throughout the year.

Silver maple was dominant in the lowland scrub habitat. Silver maple is a bottomland species that grows poorly on dry soils (Harlow et al. 1979). Young silver maples can withstand inundation for several weeks (Harlow et al. 1979), and they are moderately intolerant of shading (Burns and Honkala 1990, Harlow et al. 1979). The other dominant saplings in the lowland scrub community (i.e., winged elm, red maple, and sweetgum) are more tolerant to flooding and slightly more shade-tolerant (Burns and Honkala 1990). All of these species are light seeded and become established quickly in open fields, but are eventually replaced by later successional species, such as oaks. Thus, this community was probably established at the conclusion of the previous study, and the species composition was influenced by periodic, but not prolonged, flooding.

Wildlife Value. Some shrubs (e.g., blueberries and pawpaws) produce fruit that are readily consumed by wild birds and mammals, but saplings are unable to produce fruit because they are young trees that have not reached maturity. Shrubs and saplings both produce browse that are consumed by deer, beaver, and other herbivorous mammals. Most mammals prefer specific types of browse (e.g., beaver prefer silver maple over many other hardwoods) (Nixon and Ely 1969), but most will feed on many different plants if preferred species are limited (Stribling 1988).

For most wild animals, the sapling/shrub layer is more important as a source of cover than food, although it is the most important layer for deer food. Some wildlife species (e.g., the American woodcock) prefer habitats with dense sapling/shrub cover during some times of the year (Robinson and Bolen 1989). Many species use thickets as escape cover when being pursued by predators, but dense sapling/shrub coverage reduces or eliminates the herbaceous layer because of the shading effect.

Trees

Ecological Relationships. This study was consistent with past studies in determining that sweetgum was the most important tree species in both the North and South Woods. Sweetgum is a widespread, moderately-to-rapidly growing tree that is an aggressive pioneer of disturbed sites, particularly old fields (Burns and Honkala 1990). It sometimes forms pure, even-aged stands that can be quite dense (Harlow et al. 1979). It is one of the most adaptable hardwood species in its tolerance to different soil and site conditions (Burns and Honkala 1990), but it is intolerant to shade and is considered an early successional species (Burns and Honkala 1990, Harlow et al. 1979). Its abundance in the South Woods may indicate that the forest is in an early stage of forest development.

Sweetgum was less important in the North Woods than in the South Woods. Beech and sugar maple, the two species with the largest average dominance values in the North Woods, are possibly the most shade-tolerant species of all northern hardwoods (Harlow et al. 1979) and are considered late successional species. The presence of large beeches, medium-sized sugar maples, and small oaks in the North Woods indicates that this forest may have been high-graded in the past. High-grading is the process of removing high quality trees and leaving unmarketable and low value trees. Beeches and small oaks often are of low value and not cut during high-grading operations, leading to a forest dominated by undesirable species (e.g., sweetgum) and supporting scattered, unmarketable individuals of normally valuable species. Although sweetgum was not dominant in the North Woods, its presence and the absence of marketable trees support the hypothesis that high-grading occurred.

Conversely, large beech trees and small oaks were not present in the South Woods, perhaps indicating a different land use practice or successional stage. The South Woods was uniformly vegetated by even-aged sweetgum and yellow poplar trees, indicating that a major disturbance, such as complete clearing, occurred in the past (Harlow et al. 1979). Based on tree composition and size, it is possible that the South Woods was an old field or pasture 40 to 60 years ago, and the forest on the site is much younger than the forest of the North Woods.

The importance of river birch and black willow in the swamp community indicates that this site experiences prolonged flooding. Both species can tolerate up to three months of inundation during the growing season, but they are very shade-intolerant, hence the reason they often are associated with stream banks (Burns and Honkala 1990). Medium-to-large individuals of these species may indicate that environmental conditions are such that more shade-tolerant species cannot become established (i.e., the area is flooded for prolonged periods of time). The swamp community was present during the previous study, and the failure for other species to become established during the past 15 years indicates consistent inundation over that time.

Although not sampled during this study, black willows are now abundant on the banks of the Large and Small Borrow Pits. Some black willows were planted on the edges of the Large Borrow Pit during the early 1980s, but these plantings did not survive. The current size of these willows indicates that they became established soon after the conclusion of the previous study. Willow seeds are very small, wind disseminated, and produced in large quantities (Burns and Honkala 1990). A nearby seed source, perhaps the Natural Swamp, was readily available, or the willow stand would not have become established so quickly.

Wildlife Value. Trees that produce hard mast (i.e., oaks, beech, and hickories) are among the most important of all wildlife plants, but they were scarce on the SR-29 study site. Squirrels, deer, turkeys, and various species of ducks feed heavily on acorns; other species (e.g., small mammals) eat them when preferred foods are not available (Martin et al. 1951). Beech nuts are smaller than acorns and are consumed by smaller mammals and birds. Few animals depend entirely on hard mast because mast crops are variable and almost complete failure occurs in most stands during some years. Hard mast persists longer in the environment than soft mast (e.g., the fruit of maples, elms, and ashes) because soft mast rots more easily. The scarcity of oaks, hickories, and beeches in the forests of the SR-29 site reduces its value as wildlife habitat.

Although hard mast-producing species are considered most important to many wild animals, soft mast-producing species also are important. Soft mast can compensate partially for food loss during years of hard mast failure, and soft mast of some species (e.g., elms and soft maples) is produced during spring when hard mast is not available (Martin et al. 1951). Soft mast also provides nutrients that are deficient in some types of hard mast. Soft mast-producing trees were available at the SR-29 site in good quantities.

Sweetgum was the most abundant tree species on the study area. Although it is considered less valuable to wildlife than many mast producers because of the small size of its seeds, the seeds are produced in quantity and consumed by rodents and songbirds (Burns and Honkala 1990). Beaver regularly browse sweetgum (Burns and Honkala 1990). Virginia pine, the dominant tree in the upland scrub community, also produces seeds that are regularly eaten by squirrels, turkeys, quail, and songbirds (Stribling 1991).

Many wild animals nest or roost in tree cavities, and large trees that regularly form cavities are limiting in some areas. Tree species that most commonly form cavities (e.g., sycamore, elm, sweetgum, and red maple) (Baskett et al. 1980) were common on the SR-

29 site, but they were of insufficient size to have formed cavities large enough for most wildlife. Over time, natural cavities should develop in sufficient amounts to meet the needs of cavity-nesting wildlife on the area.

Table 7. Percent cover of herbaceous or ground level vegetation within plant communities.

Species	South Woods	North Woods	Upland Scrub	Lowland Scrub	Swamp	Upland Grass	Lowland Grass	Shallow Borrow Pit	Power Lines
Acer negundo	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Acer rubrum	0.5	1.7	0.0	0.0	1.0	0.0	2.0	0.0	1.6
Acer saccharinum	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Acer saccharum	0.7	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Allium spp.	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.8
Ambrosia artemisiifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
Ambrosia trifida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.2
Andropogon virginicus	0.0	0.0	2.0	0.0	0.0	0.0	34.0	0.0	0.0
Anisostichus capreolata	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Asimina triloba	2.7	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Betula nigra	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bidens spp.	0.0	0.0	0.0	0.0	0.0	1.0	5.0	0.0	9.2
Boehmeria cylindrica	1.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.4
Calycanthus floridus	6.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Campsis radicans	0.5	1.3	0.0	0.0	0.0	4.5	0.0	0.0	2.4
Carex spp.	0.0	0.0	0.0	0.0	0.0	0.5	47.0	0.0	16.8
Carpinus caroliniana	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carya spp.	0.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cassia fasciculata	0.0	0.0	2.0	0.0	0.0	0.0	25.0	0.0	0.0
Celtis laevigata	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cephalanthus occidentalis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.8
Clematis virginiana	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cornus amomum	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cornus florida	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Cryptotaenia canadense	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cuscuta sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Cyperus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0
Dactylis glomerata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4

Table 7. Percent cover of herbaceous or ground level vegetation within plant communities.

Species	South Woods	North Woods	Upland Scrub	Lowland Scrub	Swamp	Upland Grass	Lowland Grass	Shallow Borrow Pit	Power Lines
Daucus carota	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Desmodium sp.	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Diodia virginiana	0.0	0.0	0.0	0.0	0.0	0.0	0.5	50.0	0.4
Euonymus americanus	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eupatorium spp.	0.3	1.3	0.0	0.5	0.0	0.0	0.5	0.0	0.4
Fagus grandifolia	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Festuca sp.	0.0	0.0	0.0	0.0	0.0	11.5	0.0	6.0	9.2
Fraxinus pennsylvanica	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Galium spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	4.0
Helenium spp.	0.0	0.0	0.0	0.0	0.0	1.0	1.5	0.0	0.4
Hydrangea arborescens	0.0	1.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0
Hypericum mutilum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Hypericum punctatum	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Impatiens capensis	2.0	3.0	0.0	0.5	10.0	0.5	0.0	0.0	0.8
Ipomea spp.	0.7	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Juncus spp.	0.0	0.7	0.0	0.0	0.0	1.0	26.5	0.0	2.8
Laportea canadensis	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lespedeza bicolor	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
Lespedeza cuneatum	0.0	0.3	31.0	0.0	0.0	38.5	24.5	0.0	10.8
Ligustrum sinense	4.3	0.3	1.0	2.5	0.0	0.0	0.0	0.0	0.0
Lindernia anagallidea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0
Liquidambar styraciflua	0.0	0.7	0.0	0.0	0.0	0.0	4.5	0.0	0.0
Liriodendron tulipifera	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lonicera japonica	8.2	9.7	12.0	2.5	0.0	51.5	0.0	0.0	27.6
Ludwigia spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.0	4.8
Luzula sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.0	0.0
Microstegium vimineum	8.5	29.3	45.0	0.0	28.0	2.0	0.0	0.0	0.0
Oxydendrum arboreum	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7. Percent cover of herbaceous or ground level vegetation within plant communities.

Species	South Woods	North Woods	Upland Scrub	Lowland Scrub	Swamp	Upland Grass	Lowland Grass	Shallow Borrow Pit	Power Lines
Panicum spp.	0.2	2.3	2.0	0.0	0.0	6.0	27.0	0.0	6.0
Parthenocissus quinquefolia	3.5	0.7	0.0	3.0	0.0	0.0	0.0	0.0	8.8
Phytolacca americana	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Podophyllum peltatum	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polygonatum biflorum	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polygonum spp.	0.0	1.7	0.0	0.0	9.0	0.0	0.0	22.0	6.4
Polystichum acrostichoides	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prunus serotina	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pycnanthemum tenuifolium	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Quercus phellos	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ranunculus spp.	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Rhus copallina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4
Rhus radicans	36.3	1.0	1.0	19.5	0.0	1.5	6.0	0.0	21.2
Rosa spp.	1.8	0.3	0.0	0.0	0.0	1.5	0.0	0.0	0.0
Rubus spp.	2.0	10.3	4.0	3.5	0.0	7.5	16.0	0.0	29.2
Rumex crispus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Salvia lyrata	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Sambucus canadensis	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sassafras albidum	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scirpus sp.	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
Senecio spp.	0.3	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
Setaria sp.	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Smilacina racemosa	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Smilax spp.	1.8	0.0	1.0	0.0	1.0	6.0	0.0	0.0	0.0
Solanum sp.	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	2.4
Solidago spp.	0.3	2.0	3.0	0.0	0.0	31.5	6.5	0.0	18.0
Staphylea trifolia	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sysrinchium sp.	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7. Percent cover of herbaceous or ground level vegetation within plant communities.

Species	South Woods	North Woods	Upland Scrub	Lowland Scrub	Swamp	Upland Grass	Lowland Grass	Shallow Borrow Pit	Power Lines
Thalictrum thalictroides	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tradescantia virginiana	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trillium cuneatum	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trillium flexipes	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ulmus alata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Ulmus americana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Ulmus rubra	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urtica dioica	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vernonia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4
Viola spp.	7.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vitis spp.	0.5	1.0	3.0	0.0	0.0	0.0	0.0	0.0	4.0
Woodwardia areolata	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified Species	2.5	0.0	0.0	0.5	0.0	2.5	8.5	8.0	9.6
Number of Points Sampled	600	300	100	200	100	200	200	50	250
Total Percent Cover	72.5	63.3	81.0	29.0	56.0	100.0	100.0	98.0	97.2
Species Richness	15.0	12.5	9.0	5.3	5.0	11.8	15.5	9.0	20.6
Average Height (cm)	28.8	29.0	38.3	20.3	24.8	71.6	52.1	19.2	66.1

Table 8. Density of saplings/shrubs per hectare within plant communities, SR-29 study site.

Species	South Woods	North Woods	Upland Scrub	Lowland Scrub	Swamp
Acer rubrum	36	13	51	204	153
Acer saccharinum	0	0	0	178	102
Acer saccharum	153	1388	0	0	255
Albizia julibrissin	7	0	0	0	0
Alnus sp.	7	13	0	0	0
Asimina triloba	342	407	0	0	0
Betula nigra	0	0	0	0	51
Calycanthus floridus	262	38	0	0	0
Carpinus caroliniana	58	51	0	0	0
Carya sp.	0	0	0	0	51
Cephalanthus occidentalis	0	0	0	0	1528
Cornus amomum	0	0	25	76	306
Cornus florida	0	13	0	0	0
Fagus grandifolia	7	25	0	0	0
Fraxinus pennsylvanica	22	38	0	51	0
Gaylussacia sp.	58	25	25	0	0
Halesia caroliniana	0	76	51	0	0
Juniperus virginiana	0	0	76	0	0
Ligustrum sinense	153	166	0	76	0
Liquidambar styraciflua	51	0	127	25	0
Liriodendron tulipifera	7	0	76	0	0
Nyssa sylvatica	7	0	25	0	0
Ostrya virginiana	0	13	0	0	0
Pinus virginiana	0	0	306	0	0
Prunus serotina	0	0	25	0	0
Quercus alba	7	0	0	0	0
Quercus nigra	29	0	0	0	51
Quercus phellos	65	0	0	25	0
Staphylea trifolia	102	0	0	0	0
Ulmus alata	0	0	0	2216	0
Ulmus rubra	160	13	0	76	0
Total Density per hectare	1535	2305	790	2929	2496
Species Richness	5.4	4.9	4.5	5.3	4.5

Table 9. Dominance and density values of pole- and sawtimber-sized trees in the South Woods plant community.

Species	Number of Individuals	Avg. Dom. Value	Density (ha)	Relative Density	Dominance (cm)	Relative Domin.	Freq.	Relative Freq.	Importance Value
Acer negundo	4	149	12.6	1.7	1,877	0.3	0.03	1.4	3.4
Acer rubrum	3	557	9.4	1.2	5,236	0.9	0.05	2.1	4.3
Acer saccharinum	8	1,326	25.1	3.3	33,291	5.9	0.10	4.3	13.5
Acer saccharum	2	165	6.2	0.8	1,032	0.2	0.02	1.4	2.4
Albizia julibrissin	1	243	3.2	0.4	769	0.1	0.02	0.7	1.3
Carpinus caroliniana	7	136	22.0	2.9	2,978	0.5	0.12	4.9	8.4
Carya ovata	2	1,626	6.2	0.8	10,147	1.8	0.02	0.7	3.3
Cornus florida	1	141	3.2	0.4	446	0.1	0.02	0.7	1.2
Fagus grandifolia	1	186	3.2	0.4	589	0.1	0.02	0.7	1.2
Fraxinus pennsylvanica	1	1,452	3.2	0.4	4,589	0.8	0.02	0.7	1.9
Juniperus virginiana	1	340	3.2	0.4	1,074	0.2	0.02	0.7	1.3
Liquidambar styraciflua	121	725	379.0	50.4	274,616	48.4	0.90	38.3	137.1
Liriodendron tulipifera	69	837	216.3	28.8	181,130	31.9	0.72	30.5	91.2
Nyssa sylvatica	1	95	3.2	0.4	300	0.1	0.02	0.7	1.2
Oxydendrum arboreum	1	82	3.2	0.4	258	0.1	0.02	0.7	1.2
Pinus echinata	3	679	9.4	1.2	6,386	1.1	0.05	0.7	3.1
Pinus virginiana	2	944	6.2	0.8	5,889	1.0	0.03	0.7	2.6
Platanus occidentalis	1	6,447	3.2	0.4	20,372	3.6	0.02	0.7	4.7
Quercus nigra	5	856	15.7	2.0	13,403	2.4	0.08	3.5	8.0
Ulmus sp.	6	154	18.8	2.5	2,905	0.5	0.10	4.3	7.3
Totals	240				567,284		2.38		

Table 10. Dominance and density values of pole- and sawtimber-sized trees in the North Woods plant community.

Species	Number of Individuals	Avg. Dom. Value	Density (ha)	Relative Density	Dominance (cm)	Relative Domin.	Freq.	Relative Freq.	Importance Value
Acer negundo	8	398	24.3	6.7	9,660	3.2	0.13	4.3	14.2
Acer rubrum	8	1,230	24.3	6.7	29,884	10.0	0.26	8.6	25.3
Acer saccharinum	1	398	3.0	0.8	1,209	0.4	0.03	1.1	2.3
Acer saccharum	4	2,275	12.1	3.3	27,615	9.2	0.13	4.3	16.9
Betula nigra	1	1,093	3.0	0.8	3,322	1.1	0.03	1.1	3.0
Carpinus caroliniana	4	151	12.1	3.3	1,832	0.6	0.13	4.3	8.2
Carya cordiformis	13	350	39.4	10.8	13,797	4.6	0.23	7.5	23.0
Carya ovata	1	204	3.0	0.8	619	0.2	0.03	1.1	2.1
Celtis laevigata	1	1,855	3.0	0.8	5,639	1.9	0.03	1.1	3.8
Fagus grandifolia	4	3,091	12.1	3.3	37,530	12.6	0.10	3.2	19.1
Fraxinus pennsylvanica	4	1,037	12.1	3.3	12,591	4.2	0.10	3.2	10.8
Halesia caroliniana	18	382	54.6	15.0	20,849	7.0	0.43	14.0	36.0
Liquidambar styraciflua	18	998	54.6	15.0	54,548	18.2	0.43	14.0	47.2
Liriodendron tulipifera	14	827	42.5	11.7	35,139	11.8	0.36	11.8	35.3
Morus rubra	2	100	6.0	1.7	608	0.2	0.06	2.2	4.0
Nyssa sylvatica	2	684	6.0	1.7	4,156	1.4	0.06	2.2	5.2
Platanus occidentalis	6	1,358	18.2	5.0	24,723	8.3	0.16	5.4	18.6
Prunus serotina	2	986	6.0	1.7	5,997	2.0	0.06	2.2	5.8
Quercus alba	1	784	3.0	0.8	2,384	0.8	0.03	1.1	2.7
Quercus nigra	1	370	3.0	0.8	1,124	0.4	0.03	1.1	2.3
Quercus rubra	4	318	12.1	3.3	3,854	1.3	0.10	3.2	7.9
Sassafras albidum	1	387	3.0	0.8	1,177	0.4	0.03	1.1	2.3
Tilia americana	2	148	6.0	1.7	898	0.3	0.06	2.2	4.1
Totals	120				299,155		3.01		

Table 11. Dominance and density values of pole- and sawtimber-sized trees in the upland scrub plant community.

Species	Number of Individuals	Avg. Dom. Value	Density (ha)	Relative Density	Dominance (cm)	Relative Domin.	Freq.	Relative Freq.	Importance Value
Liriodendron tulipifera	5	170	88.0	12.5	14,952	9.9	0.30	18.8	41.2
Pinus echinata	3	144	52.8	7.5	7,609	5.1	0.20	12.5	25.1
Pinus taeda	1	141	17.6	2.5	2,481	1.7	0.10	6.3	10.4
Pinus virginiana	31	230	545.3	77.5	125,485	83.4	1.00	62.5	223.4
Totals	40				150,527		1.60		

Table 12. Dominance and density values of pole- and sawtimber-sized trees in the wet scrub plant community.

Species	Number of Individuals	Avg. Dom. Value	Density (ha)	Relative Density	Dominance (cm)	Relative Domin.	Freq.	Relative Freq.	Importance Value
Acer negundo	5	126	44.7	6.3	5,625	5.5	0.25	8.6	20.3
Acer rubrum	14	132	125.1	17.5	16,516	16.0	0.55	19.0	52.5
Acer saccharinum	20	147	178.7	25.0	26,311	25.5	0.60	20.7	71.2
Celtis laevigata	1	184	8.9	1.3	1,644	1.6	0.05	1.7	4.6
Fraxinus pennsylvanica	6	180	53.6	7.5	9,676	9.4	0.30	10.3	27.2
Juniperus virginiana	1	82	8.9	1.3	730	0.7	0.05	1.7	3.7
Liquidambar styraciflua	16	192	143.0	20.0	27,491	26.6	0.50	17.2	63.9
Ulmus alata	16	102	143.0	20.0	14,571	14.1	0.55	19.0	53.1
Ulmus rubra	1	83	8.9	1.3	745	0.7	0.05	1.7	3.7
Totals	80				103,309		2.90		

Table 13. Dominance and density values of pole- and sawtimber-sized trees in the swamp plant community.

Species	Number of Individuals	Avg. Dom. Value	Density (ha)	Relative Density	Dominance (cm)	Relative Domin.	Freq.	Relative Freq.	Importance Value
Acer rubrum	2	154	33.9	5.0	5,207	2.4	0.20	8.0	15.4
Acer saccharinum	6	188	101.7	15.0	19,141	8.9	0.60	24.0	47.9
Betula nigra	17	334	288.2	42.5	96,312	44.7	0.90	36.0	123.2
Platanus occidentalis	1	163	17.0	2.5	2,760	1.3	0.10	4.0	7.8
Salix nigra	14	389	237.4	35.0	92,271	42.8	0.70	28.0	105.8
Totals	40				215,691		2.50		

CHAPTER 5
REPTILES AND AMPHIBIANS

Approximately 70 species of reptiles and amphibians have ranges that include the SR-29 study site (Conant and Collins 1991). Several of these are habitat specialists and should not occur on the study area because of unsuitable habitat, and others are rare species that were probably extirpated in the distant past. A general survey of common reptiles and amphibians provides information on habitat suitability of specific sites. Many frog populations have declined recently on a worldwide basis, and some biologists have proposed monitoring frogs as an approach to evaluating ecosystem health (Phillips 1994). The purpose of this portion of the study was to develop a species list of reptiles and amphibians on the study site and to evaluate its habitat potential for this faunal group.

Methods

Intensive reptile and amphibian surveys were not conducted in either this study or the previous study, but reptiles and amphibians were captured or observed when conducting other field studies. Most species were found during chance encounters, but some were found by turning over logs or searching ponds at night. Frogs and toads often were identified by calls, but additional sight identifications were made of most of these species.

Results

Twenty-five different species of reptiles and amphibians were captured or observed on the SR-29 study site during this study, and 23 were collected during the previous study (Table 14). Of these, 16 were documented during both studies. Fewer snakes, but more turtles, were captured during the previous study, and frogs were the most commonly encountered group during both studies (Table 14).

Discussion

Although few species of reptiles and amphibians were captured or observed during this survey, many more species are undoubtedly present on the SR-29 study site. Complete survey lists of reptiles and amphibians are difficult to obtain without intensive, long-term surveys because of the relative scarcity and secretive nature of many species. For example, lizards were never observed at the SR-29 site during this study, but the habitat appeared adequate to support fence lizards and several species of skinks (Mount 1975, Conant and Collins 1991); the southeastern five-lined skink was observed during the previous study.

Frogs and toads were the most commonly encountered group on the study area, but many of them were detected because they vocalized, especially on cloudy days and at night. Frogs were most common around and in the Shallow Borrow Pit, but they were present in most habitats with standing water. Toads bred in shallow road ruts at several locations on the study area.

Amphibians and some reptiles can be captured in pitfall traps, and some amphibians were expected in pitfall traps set for small mammals. However, none were captured in pitfalls during this study. Coburn et al. only captured a single amphibian during 3,248 pitfall trap-nights; they explained this low success as due to low populations and dry, hot weather during the period of trapping.

The diversity of habitats at the SR-29 site makes it a suitable area for several species of reptiles and amphibians not observed during this study, but which were probably present. For example, several species of aquatic turtles were probably present in the Beaver Pond, but not observed because they seldom surface, and some species of woodland salamanders for which habitat appeared adequate live in small tunnels beneath the soil surface during most of their lives and can be captured only during their brief breeding seasons (Mount 1975). Consequently, the low number of reptiles and amphibians captured during this study should not be interpreted as low population densities. Frogs and toads, the most easily detected group, were common on the site, and several large, seldom encountered snakes (e.g., corn snake and king snake) were captured, so the study site appeared to provide good reptile and amphibian habitat.

The long, thin shape of the study site and the close proximity to the highway probably detracted from its value as reptile and amphibian habitat. Because of their slow movement patterns and tendency to seek warm surfaces on which to bask, reptiles and amphibians suffer greater road mortality than other vertebrate groups (Mount 1975). Although road mortality was not evaluated in this study, the heavy automobile traffic on SR-29 probably contributes to total mortality of many reptile and amphibian species on the study site and minimizes overland movements to other locations.

Table 14. Comparison of reptiles and amphibians observed on SR-29 study site.

Species	1994-96 Study	1980-83 Study
Marbled salamander	2	0
Two-lined salamander	2	1
Red-backed salamander	1	0
Slimy salamander	1	0
Red-spotted newt	1	0
Northern cricket frog	12	*
Spring peeper	*	*
Gray treefrog	*	2
Upland chorus frog	5	*
Bull frog	8	8
Southern leopard frog	3	2
Wood frog	1	0
Green frog	0	1
Pickerel frog	0	6
American toad	3	*
Fowler's toad	4	*
Snapping turtle	1	6
Eastern box turtle	6	4
Red-eared turtle	3	0
Stink-pot turtle	0	1
Striped-neck musk turtle	0	1
Midland painted turtle	0	1
Eastern painted turtle	0	6
Southeastern five-lined skink	0	2

Table 14, cont'd.

Species	1994-96 Study	1980-83 Study
Black racer	3	2
Corn snake	1	0
Black rat snake	3	2
Black king snake	1	0
Northern water snake	2	3
Brown snake	1	0
Eastern garter snake	7	1
Queen snake	0	1
Eastern worm snake	0	1
Copperhead	1	0

* Calling on area

CHAPTER 6
BIRDS

Birds are an excellent group of vertebrates to survey when evaluating environmental conditions and habitat changes over time. They occur in large numbers and are relatively diverse, they are easily detected and identified (even by vocalizations), and many species are habitat specific (Martin 1995, Rappole 1995). Birding is a popular pastime in the United States, and comparative data have been generated throughout the nation. This portion of the study was designed to determine what species of birds occurred commonly at various habitats of the SR-29 site and how bird densities and diversity have changed since the early 1980s.

Methods

Breeding Bird Transect Surveys and Nest Searches

Breeding birds were surveyed using a fixed-width line transect approach (Wakeley 1987). Observers slowly walked along transects and recorded all birds seen or heard within 50 m on either side of the transect lines. Birds that were detected at distances greater than 50 m were recorded but not used in later analyses. Surveys were conducted during late May and June because non-territorial individuals and migrants were present earlier in the season, and singing activity declined later in summer. Surveys were initiated soon after daylight and continued until mid- or late morning when singing activity declined.

Fifteen transects were located in four different habitats. Fourteen were parallel transects (Figure 3) which connected the road to the creek; these were in close proximity to transects used in the previous study (Shelton 1982). These transects were 200 m apart (i.e., 100 m buffers existed between outer edges of transects) to reduce bias associated with birds being detected from multiple transects (Wakeley 1987). A single 825 m long transect also was located in the old field between and parallel to the creek and borrow pit.

As suggested by Wakeley (1987), multiple surveys were conducted during a two-week period to reduce bias associated with failure to detect birds during individual surveys. Using this approach, the estimated number of individuals of each species per transect is calculated as either the maximum or average number observed during the two-week period. When using the maximum count, one must assume that all individuals of a given species were present on the transect during the entire period, but only detected during the survey of maximum count. This assumption usually is not valid because some mobile, non-breeding individuals often are present temporarily, resulting in an overestimate of bird density. Densities based on both approaches are presented for this study, but the more conservative estimates using average counts probably are more realistic.

Average number of individuals per transect was calculated in this study by taking the median value (i.e., middle value if all data were arranged in numeric order) for each species. For example, if three, three, four, five, and eight tufted titmice were detected on the same transect on five different days, the median number used to calculate density would be four. If an even number of surveys were conducted for a specific transect, the larger of the two middle values was used as the average. Densities (number per ha) for each species were calculated by multiplying median values by 10,000 (the number of m^2 per ha) and dividing the results by the area of the transects (i.e., length times the 100 m width). Total bird densities for each habitat were derived by summing the estimates of individual species.

Attempts were made to locate bird nests by observing territorial individuals and following them to their nest sites. Some searches also were made in likely nesting habitat (e.g., thick shrubs); incubating birds that flushed from these sites often provided the best indication that a nest was nearby. The number of eggs or hatchlings in each nest was recorded, as well as the presence of cowbird young or eggs. Nests containing eggs or young were periodically revisited to determine outcome. Forest-nesting species were not sampled during nest searches.

Winter and Spring Bird Surveys

Winter and spring bird surveys were conducted following procedures used during American Birding Association Christmas Bird Counts. Most of the study area was covered on foot, and all birds observed or identified through vocalizations were recorded. Survey data were tabulated for four sections of the study area: central open habitat surrounding the Large Borrow Pit, the woods on the northern end, the woods on the southern end, and scattered openings in the South Woods (including power line openings). Data generated in these counts probably underestimated actual numbers because many individuals do not vocalize at this time of year and are difficult to detect. Consequently, this approach is useful in determining species lists and relative abundance of various species, but it cannot be used to estimate density.

Results

Breeding Bird Transect Surveys and Nest Searches

Fifteen different 100 m wide transects were surveyed between May 31 and June 14, 1994. Each transect was surveyed one to five times during this period, and most were surveyed at least three times (Table 15). Time of day appeared to be the primary factor influencing the amount of bird activity. Since bird surveys were discontinued once bird activity slowed, the number of surveys differed among transects. Transects varied from 106-825 m long and were classified as being in one of four habitat types (Table 15). Transects covered 8,250 m of field habitat; 9,080 m of wooded habitat (i.e., mid-successional forest); 6,640 m of shrub habitat (i.e., early successional sapling/shrub habitat); and 12,120 m of mixed forest/shrub habitat.

Number of birds detected per transect during individual surveys varied from five to 40, and number of different species detected varied from four to 18 (Table 16). Species composition was consistent among surveys on individual transects (i.e., the same species frequently were observed on different dates at the same locations), but the number of individuals differed among dates (Table 16). A total of 44 different bird species were detected during breeding bird surveys. Of these, 20 were detected on forest transects (Table 17), 25 on the field transect (Table 18), 27 on shrub transects (Table 18), and 38 on mixed forest/shrub transects (Table 19). Birds traditionally associated with open fields or shrubby habitats (e.g., eastern meadowlarks and song sparrows) were seldom detected on forest transects; whereas, birds traditionally associated with forests (e.g., downy woodpeckers and Kentucky warblers) were not observed on transects lacking a forest component (Tables 17-19). A few generalist species (e.g., brown-headed cowbirds, yellow-billed cuckoos, and blue jays) did not appear to have a strong habitat affinity (Tables 17-19).

Density estimates varied from 25-74 passerines (i.e., perching birds) / ha using median counts and 56-164 / ha using maximum counts (Table 20). Based on median estimates, breeding bird density was lowest in open fields and highest in forests and mixed forest/shrub habitat.

Carolina chickadees, blue-gray gnatcatchers, and cardinals were the most abundant breeding species on the study site, followed by red-eyed vireos and indigo buntings (Table 21). Almost half of all chickadees, gnatcatchers, and red-eyed vireos occurred in the forests. Indigo buntings were most abundant in shrubby habitats, and cardinals were equally abundant in forests and shrubby areas. Rufous-sided towhees, field sparrows, yellow-breasted chats, common yellowthroats, and white-eyed vireos were abundant in shrubby and field habitats, but absent from forests; whereas, tufted titmice and Acadian flycatchers were present in moderate numbers in forests but absent from other habitats. Carolina wrens were present in moderate numbers in all habitats but the open field.

Twenty bird nests were discovered on the area (Table 22). Of these, five were empty at the time of discovery, and 15 contained eggs or young. Hatching success was very low, but only two nests contained cowbird eggs. Primarily because these nests were most easily located, most of the nests observed were of species that nest in low shrubs, and over half of these were cardinal nests.

Winter and Spring Bird Surveys

Seventy-five species of birds were detected during winter and spring bird surveys (Tables 23-28). Cardinals, Carolina chickadees, Carolina wrens, and various species of sparrows were the most abundant species detected during winter counts (Tables 23, 24, 27, and 28), whereas species distribution during spring counts (Tables 25 and 26) were similar to breeding bird transect counts (Tables 17-19). Some species (e.g., cedar waxwings and American goldfinches) were encountered only occasionally during winter and spring surveys, but their numbers were relatively high when detected because they are flocking species. Other species (e.g., winter wrens and rufous-sided towhees) were commonly observed but in smaller numbers because they are solitary species.

Discussion

Bird Densities and Distribution

The primary species of birds currently using the SR-29 site are either habitat generalists that use a diversity of habitats or mid-successional species that occur in shrubby habitats. The avian composition reflects the successional stage of the site. The central section of the study area is covered by robust herbaceous plants interspersed with small shrubs and saplings, and the northern and southern ends are covered by forests that, based on tree size and composition, are not successionally mature. Unless disturbed, central sections of the site should become forested in the next few decades, and the North and South Woods should develop characteristics of more mature forests. These changes should result in a shift in avian composition to bird species generally associated with later successional plant communities.

Although passerine densities in forests during this study were high, some species that were expected to occur there (e.g., tanagers, thrushes, and several species of warblers that breed commonly in Tennessee) were noticeably absent or present only in small numbers. These species are neotropical migrants, many of which have declined in recent years; consequently, ornithologists are concerned about their future (Martin 1995, Rappole 1995). One possible cause of their decline is the fragmentation of forests in the United States (Martin 1995), and nationwide studies are currently being conducted to determine the relationship between size of forest blocks and densities of neotropical migrants that are area sensitive.

The SR-29 site is a fragmented landscape, but it is adjacent to a larger forest block, the forested hillside east of North Chickamauga Creek. When considered in conjunction with the hillside, the South Woods should be large enough to support a few pairs of wood thrushes, summer tanagers, and various warblers. Consequently, it is not clear as to why some species were missing from the breeding bird community of the SR-29 site. Possible explanations include the location of the South Woods at the edge of the large forest block, immature stage of forest development, lack of critical forest features (i.e., specific types of trees) caused by past cutting practices (i.e., high-grading), or excessive disturbance caused by highway and railway traffic.

Red-eyed vireos and Acadian flycatchers also are neotropical migrants that are considered to be impacted by forest fragmentation (Martin 1995), but they were moderately common on the study area. The red-eyed vireo is less dependent on large forest blocks than some other species, and it occurs commonly in suburban parks and residential areas, if sufficient tree cover is present (Stevenson and Anderson 1994). Red-eyed vireos were observed in habitats other than forests during this study, but they were always observed in trees and their densities were highest in the South Woods. Red-eyed vireos are among the most abundant of forest-dwelling neotropical migrants (Stevenson and Anderson 1994), and their presence on the study site may have partially reflected this abundance.

Unlike the red-eyed vireo, the Acadian flycatcher was confined to forested habitats in this study, mostly in large trees in close proximity to North Chickamauga Creek. Acadian flycatchers are usually associated with large expanses of mature forests, and they prefer to nest near water (Stevenson and Anderson 1994). Although the South Woods was not expansive nor mature, several large sycamores were present on the creek bank, perhaps remains from a buffer zone immediately adjacent to the creek. These large trees adjacent to water may have been the key feature that provided sufficient habitat to attract breeding Acadian flycatchers.

The brown-headed cowbird is a nest parasite (i.e., it lays its eggs in the nests of other species) and has been implicated in the decline of many forest-dependent neotropical migrants (Lowther 1993, Martin 1995). Cowbirds historically occurred in open habitats adjacent to forests, and it is suspected that cowbirds have increased in recent years because forest fragmentation has resulted in a more open landscape (Lowther 1993). Based on breeding surveys and the low incidence of parasitism of nests discovered on the area, cowbirds were not very common on the SR-29 site during this study, despite the apparent abundance of suitable habitat. Consequently, cowbirds probably had little impact on breeding birds on the study site.

Although they were only occasionally observed from transects, wood ducks were frequently observed along North Chickamauga Creek and in the Beaver Pond and Small Borrow Pit. Wood duck broods were observed on several occasions, and they appeared to be using the study site as nesting and brood-rearing habitat. Wood ducks were uncommon at the turn of the century, primarily because of overharvesting and loss of large trees with cavities needed for nesting (Bellrose and Holm 1994). Populations of wood ducks have increased in recent years, however, partially because conservationists have erected nesting boxes in suitable locations throughout the Southeast (Bellrose and Holm 1994). Several wood duck nest boxes had been erected along North Chickamauga Creek and in the Beaver Pond within the last few years. Although these boxes were not checked for nesting activity during this study, several of them were undoubtedly used because broods were observed often and natural cavities large enough for wood ducks did not appear to be very common.

Several birds detected during breeding bird surveys did not likely breed on the SR-29 site, and, conversely, others probably bred there but were not detected because of the location of transects. For example, great blue herons were observed on several occasions during breeding bird surveys, but they probably did not breed on the site. Great blue herons usually breed in colonies (Butler 1992), but only solitary individuals were observed in this study. Also, great blue heron nests are large and conspicuous (Butler 1992) and should have been observed had they been present. The green heron is a smaller, less conspicuous species that nests solitarily, often in willow thickets (Davis 1994). Although green herons were observed only occasionally near borrow pits, they were more likely to have nested on the study site than great blue herons.

European starlings, house sparrows, and rock doves were not detected on breeding bird transects, and only rock doves were detected during winter surveys. All three are introduced species that now compete with native birds and have contributed to the decline of some species (Stevenson and Anderson 1994). House sparrows mostly breed in urban environments, and rock doves primarily breed on building ledges, under bridges, or in structures associated with agricultural operations, such as silos or barns (Stevenson and Anderson 1994), so these species were not expected on the study area in large numbers. However, starlings are aggressive generalists and nest in a variety of habitats, most commonly in mixed habitats with open fields (their primary feeding habitat) and forests with tree cavities (their primary nest site) (Cabe 1993). The SR-29 study site appears suitable for starlings because cavities are available on the site and feeding locations are available in nearby pastures. Although they currently are not a problem on the area, they may become established in the future and begin to compete with native birds, especially cavity nesters. Starlings were previously reported on the site, but they were only observed during three of 12 months sampled (Shelton 1982); this rarity is consistent with results from this study.

Comparison to Previous Studies at the SR-29 Site

Species detected during breeding bird surveys in this study corresponded closely with those previously reported as occurring on the SR-29 site during the same time of year. Although species lists are available from the previous studies, neither Shelton nor Rice presented complete data on species composition and relative abundance, inhibiting comparison of these parameters among studies. However, circumstantial evidence, presented below, indicated a general shift from a preponderance of early successional species (i.e., grassy field species) to mid-successional species (i.e., shrubby species). This change was expected and reflects successional changes of the plant community.

Both Shelton and Rice indicated that red-winged blackbirds were common on the study site during the early 1980s, but only three individuals were detected on transects during this study. Red-winged blackbirds breed most commonly in dense herbaceous or shrubby vegetation at the edge of wetlands (Yusukawa 1995). Although such habitat was reported as common on the site in the early 1980s, successional changes have now made most of the site less suitable for red-winged blackbirds. For example, the Natural Swamp was surrounded by shrubs and small trees, and common cattail, a favorite cover plant of nesting blackbirds (Yusukawa 1995), occurred in scattered locations in old fields. The Natural Swamp is now surrounded by larger trees, and cattails are no longer present.

Shelton also reported that killdeers and meadowlarks commonly nested along the road edge and were present in open areas on the interior of the site. Breeding killdeers were not detected during this study, and meadowlarks were only commonly heard singing from pastures on the western side of SR-29. Other open habitat birds (e.g., several species of shorebirds) were reported occasionally from the previous study, but were not observed in this study. As succession proceeds, most remaining open habitats will be replaced by herbs and eventually woody vegetation, and habitat for such birds will be minimal on the SR-29 site.

Shelton and Rice reported the presence of a number of species not detected during this study. Most were species associated with short grass or bare ground habitats or spring migrants that occur in southeastern Tennessee only for short periods of time (e.g., Swainson's thrush and Philadelphia vireo). Many of the spring migrants probably were present during this study, but not detected. Most migrants stop temporarily at many locations during migration, often in habitats different from their wintering or breeding sites. Some of these species are present for such short periods that intensive surveys are necessary to document their presence. The more intensive survey approaches used in the previous studies and use of mist nets to capture birds that were not vocalizing provided a more thorough species list than the one produced in this study.

Density estimates of breeding birds were substantially lower during the previous study than those reported here, but Shelton used a different approach in estimating density, a procedure referred to as territorial mapping. In this procedure, the locations of singing males are plotted on a map, and their positions are used to determine territory sizes and the number of territories of each species. Territorial mapping can be effective if the area is covered adequately and exact positions of singing birds can be determined. However, Shelton indicated that he was unable to meet all of the assumptions of the technique and that his estimates were probably biased.

Shelton and Rice also used line transects to estimate bird densities throughout the year on the SR-29 site during 1980-82. Instead of using fixed width transects, as in this study, they estimated flushing distances of birds from transects as they were encountered and averaged these distances to determine the effective width of transects. Although this approach is commonly used, Shelton and Rice treated each survey as a separate data point and averaged these points to derive density estimates, resulting in low estimates. Although density estimates from previous surveys were probably lower than actual densities, estimates from this study were probably too high. Consequently, differences in density estimates between this study and previous studies should be attributed to differences in sampling approaches and not changes in bird density.

Habitat-related trends in density and diversity were similar between this study and previous studies. Shelton and Rice both reported that birds were least abundant and diverse in fields and "old fields" (i.e., shrubby habitats) and that density increased in forests and mixed forest/open areas. In this study and in Shelton's study, species diversity was relatively low in forest habitats, but increased along edges of forests (i.e., in ecotones). Rice, however, reported that diversity was highest in forests and lowest in ecotones. The edge effect, an increase in species density and diversity in ecotones because of increased niches and blending of habitats, is a well-established phenomenon originally described by

Leopold (1933). Consequently, comparisons among habitats in this study and Shelton's study are probably more reliable than those from Rice's study.

Shelton reported that bird density and diversity was highest in natural wooded swamps, and he stressed the importance of swamps as avian habitat. Swamp habitat has changed on the study site since the early 1980s, and much of it has developed into deeper, more permanently flooded areas because of beaver activity. Although swamp habitat was not sampled specifically in this study because of these changes, a few wetland-dependent species not observed elsewhere on the study area (e.g., prothonotary warbler) were observed near wooded swamps. During one survey, a large number of birds were observed in swamp habitat, but most of these were members of a large feeding flock of goldfinches. During most surveys, avian activity was similar between swamps and other forested sites. Consequently, swamp habitat on the SR-29 site should be considered important because of the diversity it contributes to the habitat complex, not because it is better avian habitat than other forested components.

Shelton attributed the low use of the borrow pits by ducks during his study to disturbance from the nearby road, and he promoted the planting of shrubs or trees between the road and borrow pits to reduce this disturbance. The Large and Small Borrow Pits are too deep and too silted to enable the establishment of sufficient emergent or submergent plants to serve as a food resource for ducks. Although various species of ducks undoubtedly rest on the borrow pits for short periods, feeding habitat is not available, and their value to ducks is minimal.

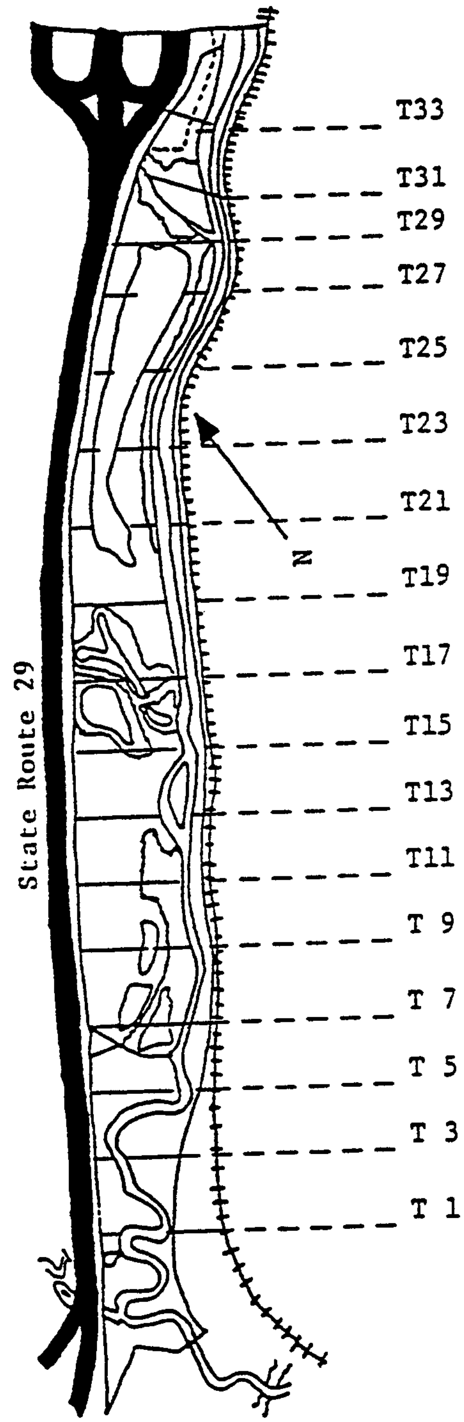

Figure 3. Locations of transects for bird surveys on SR-29 study site.

Table 15. Breeding bird transect descriptions.

Transect Number	Number of Surveys	Length (m)	Habitat
2/3	2	125	Forest
5	2	159	Forest
6/8	1	225	Forest
7	3	251	Forest
9	3	225	Forest/Shrub
11	3	234	Forest/Shrub
13	5	185	Shrub
15	4	284	Forest/Shrub
17	5	222	Forest/Shrub
19	4	228	Shrub
25	1	148	Forest
28	4	247	Forest/Shrub
30	3	145	Shrub
32	3	106	Shrub
FLD	5	825	Field
Totals:	48	3,609	

Table 16. Number of different species and individual birds observed on breeding bird transects during Summer 1994.

Date	Transect No.	# of Individuals	# of Species
05/31/94	5	10	6
06/14/94	5	11	5
05/31/94	7	40	16
06/08/94	7	22	11
06/14/94	7	14	6
05/31/94	9	40	18
06/08/94	9	21	12
06/14/94	9	25	12
06/01/94	11	23	12
06/08/94	11	22	14
06/14/94	11	14	9
06/01/94	13	13	8
06/02/94	13	20	13
06/03/94	13	12	7
06/08/94	13	21	13
06/14/94	13	23	12
06/01/94	15	21	11
06/03/94	15	20	9
06/08/94	15	21	9
06/14/94	15	24	12
06/01/94	17	14	7
06/02/94	17	15	11
06/03/94	17	18	12
06/08/94	17	23	13
06/14/94	17	21	12

Table 16, cont'd.

Date	Transect No.	# of Individuals	# of Species
06/02/94	19	18	11
06/03/94	19	20	6
06/08/94	19	23	13
06/14/94	19	13	9
06/14/94	25	13	8
06/02/94	28	16	10
06/03/94	28	18	12
06/08/94	28	9	5
06/08/94	28	18	9
06/02/94	30	5	4
06/08/94	30	7	6
06/08/94	30	14	8
06/02/94	32	9	6
06/08/94	32	7	5
06/08/94	32	15	7
06/01/94	2/3	17	7
06/08/94	2/3	16	9
06/08/94	6/8	5	4
06/02/94	FLD	29	18
06/03/94	FLD	27	13
06/08/94	FLD	24	11
06/08/94	FLD	25	11
06/14/94	FLD	28	15
Totals:		884	477

Table 17. Estimates of number of breeding birds (maximum and median values) detected along transects in wooded habitat during Summer 1994, SR-29 study site. For transects surveyed once or twice, only maximum values are given.

Species (20)	Transect 2/3		Transect 5		Transect 6/8		Transect 7		Transect 25		Totals	
	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med
Non-passerines:												
Wood Duck			1								1	
Broad-winged Hawk							1	0			1	0
Great Blue Heron	1										1	
Yellow-billed Cuckoo	1										1	
Pileated Woodpecker	1										1	
Common Flicker							1	0			1	0
Red-bellied Woodpecker							1	1			1	1
Downy Woodpecker			1				1	1	1		3	1
Subtotal Non-passerines	3		2		0		4	2	1		10	2
Passerines:												
Acadian Flycatcher	1		1		1		1	1	1		5	1
Tufted Titmouse	2				1		3	1	1		7	1
Carolina Chickadee	4		3		2		7	6	1		17	6
Blue-gray Gnatcatcher	7		6				12	5	4		29	5
Carolina Wren	1						2	1	1		4	1
Red-eyed Vireo	1		1		1		3	2	2		8	2
Kentucky Warbler	1						2	1			3	1

Table 17, cont'd.

Species	Transect 2/3		Transect 5		Transect 6/8		Transect 7		Transect 25		Totals	
	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med
Louisiana Waterthrush							1	0			1	0
Northern Cardinal	1		1				3	2	2		7	2
Brown-headed Cowbird			1				2	0			3	0
Blue Jay	1						3	0			4	0
Indigo Bunting							2	0			2	0
Subtotal Passerines:	19		13		5		41	19	12		109	19
Total:	22		15		5		45	21	13		121	21

Table 18, cont'd.

Species	Transect 13		Transect 19		Transect 30		Transect 32		Transect FLD		Totals	
	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med
Common Yellowthroat	2	1	1	1	1	0	2	1	2	2	8	5
Yellow-breasted Chat	3	2	2	1			3	0	3	2	11	5
Northern Cardinal	3	2	6	2	1	1	3	1	3	2	16	8
Rufous-sided Towhee	1	1	1	0	3	2	2	1	2	1	9	5
Song Sparrow			1	1					2	1	3	2
Field Sparrow	1	0	4	2					6	5	11	7
Common Grackle					1	0			1	0	2	0
Red-winged Blackbird	1	0							1	0	2	0
Brown-headed Cowbird	2	0							1	0	3	0
Eastern Meadowlark					1	0	2	0			3	0
Blue Jay	2	0					1	0			3	0
Common Crow	1	0	1	0	1	0			1	0	4	0
Summer Tanager	1	0	1	0					1	0	3	0
American Goldfinch	1	0	1	0			1	0	1	1	4	1
Blue Grosbeak									1	0	1	0
Indigo Bunting	4	2	4	3	1	0	1	0	4	2	14	7
Subtotal Passerines:	35	14	36	16	17	5	21	8	46	21	155	64
Total:	40	14	39	18	18	6	21	8	51	21	169	67

Table 18, cont'd.

Species	Transect 13		Transect 19		Transect 30		Transect 32		Transect FLD		Totals	
	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med
Common Yellowthroat	2	1	1	1	1	0	2	1	2	2	8	5
Yellow-breasted Chat	3	2	2	1			3	0	3	2	11	5
Northern Cardinal	3	2	6	2	1	1	3	1	3	2	16	8
Rufous-sided Towhee	1	1	1	0	3	2	2	1	2	1	9	5
Song Sparrow			1	1					2	1	3	2
Field Sparrow	1	0	4	2					6	5	11	7
Common Grackle					1	0			1	0	2	0
Red-winged Blackbird	1	0							1	0	2	0
Brown-headed Cowbird	2	0							1	0	3	0
Eastern Meadowlark					1	0	2	0			3	0
Blue Jay	2	0					1	0			3	0
Common Crow	1	0	1	0	1	0			1	0	4	0
Summer Tanager	1	0	1	0					1	0	3	0
American Goldfinch	1	0	1	0			1	0	1	1	4	1
Blue Grosbeak									1	0	1	0
Indigo Bunting	4	2	4	3	1	0	1	0	4	2	14	7
Subtotal Passerines:	35	14	36	16	17	5	21	8	46	21	155	64
Total:	40	14	39	18	18	6	21	8	51	21	169	67

Table 19. Estimates of number of breeding birds (maximum and median values) detected along transects in mixed forest and shrub habitat, Summer 1994, SR-29 study site.

Species (38)	Transect 9		Transect 11		Transect 15		Transect 17		Transect 28		Totals	
	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med
Non-passerines:												
Wood Duck	1	0	2	0	1	0	1	0			5	0
Red-tailed Hawk			1	0							1	0
Bobwhite Quail					1	0	1	0			2	0
Great Blue Heron	2	2									2	2
Ruby-throated Hummingbird							1	0			1	0
Yellow-billed Cuckoo	1	0			1	0	1	0			3	0
Belted Kingfisher							1	0			1	0
Red-bellied Woodpecker	1	1							1	0	2	1
Downy Woodpecker	1	1			1	0	1	0			3	1
Subtotal Non-passerines:	6	4	3	0	4	0	6	0	1	0	20	4
Passerines:												
Eastern Phoebe			1	0							1	0
Acadian Flycatcher	2	1	2	1							4	2
Great crested Flycatcher							1	0			1	0
White-breasted Nuthatch							1	0			1	0
Tufted Titmouse	1	1	1	0			1	0	2	2	5	3
Carolina Chickadee	4	4	4	2	7	1	4	3	6	4	25	14

Table 19, cont'd.

Species	Transect 9		Transect 11		Transect 15		Transect 17		Transect 28		Totals	
	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med
Blue-gray Gnatcatcher	5	5	3	3	7	7	6	1	2	1	23	17
Carolina Wren			2	2	2	2	5	1			9	5
American Robin							1	0			1	0
Brown Thrasher									1	0	1	0
Red-eyed Vireo	3	1	2	1	2	2	2	1	1	1	10	6
White-eyed Vireo	1	0			1	0	2	1			4	1
Yellow-throated Vireo							1	0			1	0
Common Yellowthroat	1	0			1	1					2	1
Louisiana Waterthrush									1	0	1	0
Yellow-breasted Chat	1	0	1	1	1	1	1	1	1	1	5	4
Northern Cardinal	4	3	4	3	4	3	3	2	3	2	18	13
Rufous-sided Towhee	1	0	2	1	1	0	2	2	4	2	10	5
Song Sparrow					1	0	1	0	1	1	3	1
Field Sparrow					1	1			1	1	2	2
Common Grackle	5	1			3	0	1	0			9	1
Red-winged Blackbird			1	0							1	0
Brown-headed Cowbird	1	1	1	1					1	0	3	2
Eastern Meadowlark	1	0			1	0					2	0
Blue Jay			1	0	2	0	1	0	1	1	5	1

Table 19, cont'd.

Species	Transect 9		Transect 11		Transect 15		Transect 17		Transect 28		Totals	
	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med
Common Crow	5	3					1	0	2	0	8	3
American Goldfinch	2	1			1	0					3	1
Blue Grosbeak									2	0	2	0
Indigo Bunting	3	2	3	2	3	2	3	1	3	1	15	8
Subtotal Passerines:	40	23	28	17	38	20	37	13	32	17	175	90
Total:	46	27	31	17	42	20	43	13	33	17	195	94

Table 20. Estimated densities of passerine birds detected along transects in four habitat types on SR-29 study site, Summer 1994, using maximum and median counts.

Habitat Types	Density (birds/ha)	
	Maximum	Median
Field	56	25
Shrub	164	65
Forest	99	76
Shrub/Forest	144	74

Table 21. Estimated densities[a] of bird species commonly observed (≥ 5 individuals) along transects in four habitat types on SR-29 study site, Summer 1994.

Species	Density (birds/ha)			
	Field	Mixed	Shrub	Forest
Acadian Flycatcher	0	2	0	4
Tufted Titmouse	0	2	0	4
Carolina Chickadee	0	12	11	24
Blue-gray Gnatcatcher	4	14	8	20
Carolina Wren	0	4	3	4
Red-eyed Vireo	1	5	3	8
White-eyed Vireo	1	1	5	0
Common Yellowthroat	2	1	5	0
Yellow-breasted Chat	2	3	5	0
Northern Cardinal	2	11	9	8
Rufous-sided Towhee	1	4	6	0
Field Sparrow	6	2	3	0
Indigo Bunting	2	7	8	0

[a] Using median values for transects

Table 22. Bird nests found on SR-29 study site, April 18 - June 28, 1995.

Species	Habitat Type	# Eggs	# Cowbird Eggs	# Young
Northern Cardinal	Upland grass	2	0	0
Northern Cardinal	Lowland grass	3	0	0
Northern Cardinal	Lowland grass	0	0	0
Northern Cardinal	LBP fringe	0	0	3
Northern Cardinal	LBP fringe	2	0	0
Northern Cardinal	LBP fringe	3	0	0
Northern Cardinal	LBP fringe	1	0	0
Northern Cardinal	LBP fringe	2	0	0
Northern Cardinal	North woods	3	0	0
Northern Cardinal	Upland scrub	3	0	0
Field Sparrow	Upland grass	1	2	0
American Robin	North woods	0	0	3
White-eyed Vireo	LBP fringe	0	0	0
Carolina Wren	LBP fringe	1	0	0
Carolina Wren	LBP fringe	2	0	0
Indigo Bunting	LBP fringe	1	1	0
Yellow-billed Cuckoo	LBP fringe	1	0	2
Unidentified	LBP fringe	0	0	0
Unidentified	LBP fringe	0	0	0
Unidentified	LBP fringe	0	0	0

LBP fringe = area around Large Borrow Pit

Table 23. Birds observed on the SR-29 study site on December 27, 1994.

	Central open	North woods	South woods	South open	Total
Mourning Dove	0	0	2	0	2
Belted Kingfisher	1	0	0	0	1
Red-bellied Woodpecker	0	1	6	0	7
Yellow-bellied Sapsucker	0	0	1	0	1
Downy Woodpecker	1	1	3	0	5
Eastern Phoebe	0	0	1	1	2
American Crow	3	0	0	0	3
Tufted Titmouse	4	4	11	0	19
Carolina Chickadee	24	10	9	0	43
Winter Wren	0	2	5	0	7
Carolina Wren	9	8	6	1	24
Golden-crowned Kinglet	2	2	0	0	4
Ruby-crowned Kinglet	8	8	3	2	21
Eastern Bluebird	0	0	0	6	6
Northern Mockingbird	0	1	0	0	1
Brown Thrasher	3	1	0	0	4
Cedar Waxwing	0	0	20	0	20
Yellow-rumped Warbler	0	3	3	3	9
Northern Cardinal	26	9	0	2	37
Rufous-sided Towhee	6	8	0	3	17
Savannah Sparrow	1	0	0	0	1
Song Sparrow	82	14	2	15	113
Field Sparrow	10	2	1	0	13
White-throated Sparrow	10	12	0	3	25
Fox Sparrow	2	0	0	0	2
Swamp Sparrow	24	2	0	0	26
Common Grackle	3	0	0	0	3
American Goldfinch	4	4	11	2	21
Total Individuals	223	92	84	38	437
Total Number of Species	19	18	15	10	28

Table 24. Birds observed on the SR-29 study site on February 24, 1995.

	Central open	North woods	South woods	Total
Great Blue Heron	0	0	1	1
Mallard	0	0	2	2
Wood Duck	0	0	8	8
American Woodcock	0	0	1	1
Turkey Vulture	2	0	0	2
Red-tailed Hawk	1	0	2	3
Bobwhite Quail	0	0	8	8
Red-bellied Woodpecker	0	1	1	2
Yellow-bellied Sapsucker	0	1	1	2
Downy Woodpecker	0	1	1	2
Hairy Woodpecker	0	0	1	1
Blue Jay	0	1	0	1
American Crow	1	0	2	3
Tufted Titmouse	5	0	1	6
Carolina Chickadee	1	8	4	13
Winter Wren	1	2	0	3
Carolina Wren	4	5	3	12
Golden-crowned Kinglet	0	5	0	5
Ruby-crowned Kinglet	0	2	0	2
Hermit Thrush	0	1	0	1
American Robin	0	0	30	30
Brown Thrasher	1	0	0	1
Yellow-rumped Warbler	0	0	2	2
Northern Cardinal	11	3	4	18
Rufous-sided Towhee	5	5	5	15
Song Sparrow	13	6	4	23
Field Sparrow	10	0	0	10
White-throated Sparrow	20	6	18	44
Swamp Sparrow	4	2	8	14
Common Grackle	0	0	2	2
Rusty Blackbird	0	0	12	12
American Goldfinch	5	0	0	5
Total Individuals	84	49	121	254
Total Number of Species	15	15	23	32

Table 25. Birds observed on the SR-29 study site on April 28, 1995.

	Central open	North woods	South woods	South open	Total
Great Blue Heron	0	0	1	0	1
Canada Goose	12	0	0	0	12
Wood Duck	0	0	4	0	4
Turkey Vulture	1	0	0	0	1
Rock Dove	0	1	0	0	1
Mourning Dove	0	2	0	0	2
Yellow-billed Cuckoo	0	0	1	0	1
Chimney Swift	0	0	3	0	3
Ruby-throated Hummingbird	0	1	0	0	1
Belted Kingfisher	0	0	1	0	1
Pileated Woodpecker	0	0	1	0	1
Eastern Phoebe	1	0	0	0	1
Blue Jay	2	0	0	0	2
American Crow	2	0	0	0	2
Tufted Titmouse	1	0	5	0	6
Carolina Chickadee	1	1	4	1	7
Carolina Wren	6	1	5	0	12
Ruby-crowned Kinglet	1	0	0	0	1
Blue-gray Gnatcatcher	8	1	4	0	13
Wood Thrush	0	0	1	0	1
Gray Catbird	1	0	0	0	1
Brown Thrasher	0	2	0	0	2
Cedar Waxwing	10	0	0	5	15
White-eyed Vireo	3	1	3	0	7
Red-eyed Vireo	1	1	13	3	18
Orange-crowned Warbler	0	0	1	0	1
Nashville Warbler	0	0	1	0	1
Chestnut-sided Warbler	0	0	1	0	1
Cape May Warbler	0	0	1	0	1
Magnolia Warbler	0	1	0	0	1
Palm Warbler	3	0	0	0	3
Kentucky Warbler	0	0	2	0	2
Common Yellowthroat	3	0	0	1	4
Yellow-breasted Chat	5	0	0	1	6
American Redstart	0	1	0	0	1
Blue Grosbeak	1	0	0	0	1
Northern Cardinal	2	4	2	1	9
Indigo Bunting	7	2	2	1	12
Rufous-sided Towhee	4	1	1	0	6

Table 25, cont'd.

	Central open	North woods	South woods	South open	Total
Field Sparrow	4	0	0	0	4
White-throated Sparrow	1	2	0	0	3
Swamp Sparrow	2	0	0	0	2
Red-winged Blackbird	1	0	0	0	1
Brown-headed Cowbird	0	0	2	2	4
Scarlet Tanager	0	0	2	0	2
American Goldfinch	4	1	1	0	6
Total Individuals	87	23	62	15	187
Total Number of Species	26	16	24	8	46

Table 26. Birds observed on the SR-29 study site on May 13, 1995.

	Central open	South woods	South open	Total
Great Blue Heron	0	1	0	1
Green Heron	0	1	0	1
Wood Duck	0	6	0	6
Red-tailed Hawk	0	1	0	1
Yellow-billed Cuckoo	0	3	0	3
Ruby-throated Hummingbird	0	3	0	3
Red-bellied Woodpecker	0	1	0	1
Northern Flicker	0	1	0	1
Downy Woodpecker	1	2	0	3
Least Flycatcher	0	1	0	1
Acadian Flycatcher	0	1	0	1
American Crow	0	1	0	1
Tufted Titmouse	0	6	0	6
Carolina Chickadee	0	8	0	8
Carolina Wren	0	7	0	7
Golden-crowned Kinglet	0	4	0	4
Blue-gray Gnatcatcher	0	11	10	21
White-eyed Vireo	0	0	1	1
Red-eyed Vireo	0	6	0	6
Prothonotary Warbler	0	2	0	2
Tennessee Warbler	0	4	0	4
Kentucky Warbler	0	2	0	2
Northern Waterthrush	0	1	0	1
Common Yellowthroat	2	0	2	4
Yellow-breasted Chat	1	0	2	3
Northern Cardinal	0	10	2	12
Indigo Bunting	3	1	2	6
Rufous-sided Towhee	0	1	2	3
Song Sparrow	1	0	0	1
Brown-headed Cowbird	0	3	0	3
American Goldfinch	0	30	0	30
Total Individuals	8	118	21	147
Total Number of Species	5	27	7	31

Table 27. Birds observed on the SR-29 study site on January 28, 1996.

	Central open	North woods	South woods	South open *	Total
Great Blue Heron	0	1	1		2
Canada Goose	0	0	15		15
Wood Duck	0	0	2		2
Turkey Vulture	0	0	1		1
Red-bellied Woodpecker	1	0	0		1
Northern Flicker	2	0	1		3
Downy Woodpecker	1	0	2		3
Eastern Phoebe	0	0	1		1
Blue Jay	1	0	0		1
Tufted Titmouse	0	0	3		3
Carolina Chickadee	2	11	2		15
Carolina Wren	0	2	5		7
Golden-crowned Kinglet	0	1	0		1
Ruby-crowned Kinglet	0	0	1		1
American Robin	0	2	1		3
Eastern Bluebird	0	4	0		4
Northern Mockingbird	1	1	0		2
Brown Thrasher	0	1	0		1
Northern Cardinal	3	0	2		5
Rufous-sided Towhee	1	2	3		6
Savannah Sparrow	4	0	0		4
Song Sparrow	40	0	0		40
Field Sparrow	0	0	20		20
White-throated Sparrow	2	15	4		21
Swamp Sparrow	20	0	0		20
Fox Sparrow	2	0	0		2
American Goldfinch	0	18	12		30
Purple Finch	0	2	0		2
Total Individuals	80	60	76		216
Total Number of Species	13	12	17		28

* No survey due to standing water

Table 28. Birds observed on the SR-29 study site on February 23, 1996.

	Central open	North woods *	South woods *	South open	Total
Wood Duck	2			0	2
Belted Kingfisher	1			0	1
Blue Jay	2			0	2
American Crow	1			0	1
Tufted Titmouse	1			0	1
Carolina Chickadee	7			0	7
Carolina Wren	1			1	2
Northern Cardinal	4			1	5
Rufous-sided Towhee	1			0	1
Field Sparrow	8			3	11
White-throated Sparrow	13			8	21
Song Sparrow	13			7	20
Fox Sparrow	2			0	2
Dark-eyed Junco	1			0	1
Downy Woodpecker	0			1	1
American Woodcock	**				
Total Individuals	57			21	78
Total Number of Species	15			6	16

* No survey conducted in this area

** Not seen, but droppings and probe holes observed

CHAPTER 7
MAMMALS

Mammals are considered one of the most important components of wildlife communities, but many species are difficult to monitor because of their secretive nature and reluctance to enter traps. Small mammals (i.e., mice, rats, and shrews) are more easily captured than larger species because their densities are greater, they are more likely to enter traps than larger species, and the associated traps are less expensive and more easily transported. Small mammals also are easier to handle, mark, and recapture than larger species. This portion of the study was designed to determine the small mammal composition at various habitats on the SR-29 study site and to compare small mammal density and diversity to previous studies on the same area.

Methods

Mammals

Small mammal populations were sampled in five different habitat types: South Woods, lowland grass, upland grass, lowland scrub, and upland scrub (Figure 2). The Natural Swamp, Shallow Borrow Pit, North Woods, and power lines (Figure 2) were not sampled because of the limited number of traps and inundation of the Natural Swamp and Shallow Borrow Pit. Portions of the Natural Swamp that were dry during Spring 1996 were trapped. Trapping was conducted on five occasions (March 1995, May 1995, July 1995, October 1995, and February 1996) for five consecutive nights during each of the four seasons. All five habitats were sampled during every sample period, except the upland scrub habitat was not trapped on March 1995.

Small mammals were trapped using collapsible and non-collapsible standard-length (7.7-cm x 9-cm x 23.1-cm) Sherman live traps. Traps were placed in 18 m x 18 m grids (Schemnitz 1980), all equally spaced 2 m apart; thus, a grid consisted of 100 traps and covered an area of approximately 324 m^2. Traps were baited with a mixture of peanut butter and oatmeal and were checked each morning during sample periods. Small mammals, excluding shrews, caught in live traps were toe-clipped (Schemnitz 1980) for individual identification. Identification number, species, sex, and trap location within grids were recorded before releasing mammals.

Shrews are difficult to capture in Sherman traps because they are carnivorous, so not attracted to the peanut butter/oatmeal bait. Consequently, five sets of 50 pitfall traps (Bury and Corn 1987) were placed in grids of 50 pitfalls in rows of 10, each spaced 2 m apart, in the same habitats. Pitfall traps were 0.95-l plastic cups placed in holes so that the cup tops were flush with the soil surface. Pitfalls were checked each day during trapping periods. Shrews have such a high metabolic rate that, unless they eat almost continuously, they die; consequently, they were dead when the pitfall cups were checked. The dead shrews were returned to TTU for identification. Shrews were preserved in freezers and later soaked in hydrogen peroxide to remove the skin from the skulls. Identification was based on characteristics of teeth when examined under a microscope.

Medium and large mammals were not captured during this study, but observations of individuals or their artifacts (e.g., tracks, scat, dams) were recorded. A listing and a brief discussion of these species are included elsewhere in the text.

Results

Small mammals

Ten species of small mammals were trapped and identified in five different habitat types over a total of 16,374 trap nights (Table 29). The most commonly captured small mammals were four species of mice (63.9% of individual animals captured), but some shrews (23.1%), rats (11.1%), and voles (1.8%) also were sampled. White-footed mice and eastern harvest mice composed 53.7% of all individual small mammals captured.

Some individuals of all species of mice and rats were captured on multiple occasions, but mice were recaptured more often than rats (Table 29). White-footed mice were recaptured most often, followed by house mice and harvest mice. Shrews and voles could not be recaptured because they were dead when discovered in pitfall traps.

More small mammals were captured in upland habitats than in lowland habitats (Table 29). The white-footed mouse was the only species caught in all five habitats, and the meadow vole was the only species caught in only one habitat (i.e., upland grass). The hispid cotton rat was only found in upland habitats, both wooded and non-wooded. Over 95% of eastern harvest mice were captured in grassy habitat, whereas the house mouse was only captured in wooded habitats. More golden mice were caught in the lowland scrub site than in any other habitat. Marsh rice rats were primarily captured during the first winter in lowland grassy areas.

Shrews were caught in every habitat type, but only one shrew was captured in the South Woods (Table 29). Least shrews, the most commonly collected species, were captured in both scrubby and grassy habitats in equal numbers. All short-tailed shrews but one were caught in grassy habitats. The southeastern shrew was collected most commonly in scrubby habitats, but it was the least commonly collected species of the three.

Number of trap nights per small mammal captured was greater during this study than during previous studies on the SR-29 site (Table 30). The ratio of cotton rats to white-footed mice captured on the SR-29 site was less during 1980-81 (Hedges 1985) than during 1981-82 (Skoglund 1982), but proportionately more cotton rats were captured during both previous studies than during this one (Table 30).

Medium-to-large mammals

Eight medium-to-large mammal species were detected on the SR-29 study area, either by sight or artifacts, between March 1995 and June 1996. Most of them were nocturnal or secretive species, and few individuals were actually observed. Some (e.g., the raccoon) were so common that their tracks and other artifacts were detected on most site visits. Domestic dogs also were observed on several occasions.

Swamp rabbits were observed more often than any other medium-to-large mammal species. They were observed throughout the study area, but they occurred most often near flooded areas (e.g., around the Beaver Pond). Eastern cottontails were observed on a few occasions in areas with thick herbaceous cover, but they were less common than swamp rabbits.

Raccoons also were common, but they were never actually observed. Their tracks were abundant throughout the area, especially along North Chickamauga Creek and near standing water habitats (i.e., the Natural Swamp, Beaver Pond, and borrow pits). An attempt was made to trap small mammals near the Natural Swamp during Spring 1996, but raccoons raided almost every trap before small mammals could be captured. They also were a nuisance while trapping small mammals elsewhere, but to a lesser degree.

Beavers were present on the SR-29 study site, and their activities have modified some habitats since the area was established. Beaver dams were located at several locations, especially in the South Woods, and their dam building disrupted several drainage patterns and enlarged the area of standing water in the Beaver Pond and Natural Swamp. Although some trees and saplings that had been gnawed by beavers were observed during this study, beaver damage did not appear excessive at this time. Beavers and muskrats were observed swimming in aquatic habitats created by beaver activity, as well as in nearby sections of North Chickamauga Creek.

Opossum tracks were observed occasionally on the study site, but not so often as those of raccoons. One opossum was captured in a large box trap early in the study before it was decided that trapping of medium-to-large mammals was not feasible because of excessive human activity and the risk of trap loss. Eastern gray squirrels were observed occasionally in the North Woods plant community, but were not common. White-tailed deer also were present on the SR-29 study area, but in low numbers. Three individuals were observed in the upland grass habitat on one occasion, and bedding activity and a few tracks were detected occasionally during this study.

Discussion

Mammals

With the exception of the house mouse, small mammals captured during this study were collected primarily in habitats that are considered typical for those species. House mice usually occur in houses and buildings, abandoned fields, fence rows, weedy roadsides, and cultivated grain fields (Schwartz and Schwartz 1981). House mice were captured in this study in the South Woods and upland scrub plant communities. It is suspected that the house mice recorded as occurring in the South Woods were misidentified because all were from records from the first trapping season when identification skills were weaker. However, house mice did occur in the upland scrub habitat, perhaps because this habitat borders the fence surrounding the study site and functions in some ways as a fence row, a habitat typical of house mice. Other species that occur commonly in weedy roadside edges, such as the eastern harvest mouse and the hispid cotton rat (Schwartz and Schwartz 1981), also were captured in this habitat.

The white-footed mouse is one of the most abundant mammals in wooded regions of North America (Schwartz and Schwartz 1981, McCarley 1954), consistent with collection records from this study. It occurs in almost all habitats but is less common in grassy communities than other species of small rodents (Schwartz and Schwartz 1981). At the SR-29 study site, the white-footed mouse was the most abundant species in every plant community, except in lowland grassy areas where it was partially replaced by the eastern harvest mouse. White-footed mice are among the most docile of all rodents (Schwartz and Schwartz 1981). Consequently, human disturbance (e.g., trapping) probably is less stressful to them and perhaps the reason that so many individuals were captured on multiple occasions during this study.

The eastern harvest mouse was the second most commonly captured mammal during this study. It typically occurs in abandoned fields, meadows, fence rows, weedy roadsides, and marsh borders with dense ground cover (Schwartz and Schwartz 1981). All but one of the eastern harvest mice captured in this study were collected from grassy areas where total percent herbaceous cover was 100%. Harvest mice are less docile than white-footed mice (Schwartz and Schwartz 1981), perhaps explaining why a lower percentage were recaptured.

Marsh rice rats occur in a variety of habitats, but they prefer marshes and wet meadows (Schwartz and Schwartz 1981). Marsh rice rats were collected in wet portions of the South Woods and the lowland grass plant community in this study, consistent with the previous studies. Golden mice also prefer moist or wet habitats, but they occur most commonly in wooded habitats (Schwartz and Schwartz 1981). In this study, golden mice were captured most commonly in the lowland scrub habitat, especially in traps set adjacent to a thicket at one edge of the grid. The relatively low number of these two species captured during this study reflects their general lower abundance, as compared to white-footed and harvest mice (Schwartz and Schwartz 1981), and the low percentage of wetland habitat on the study area.

During this study, the meadow vole was the only small mammal that was captured in a single plant community, the upland grass site. Meadow voles occur in moist, low areas where there is a heavy growth of grasses, or in drier grasslands near streams, lakes, or swamps (Schwartz and Schwartz 1981), a good description of the upland grass plant community. This habitat was sparse at the SR-29 study site, hence the reason that meadow voles were rarely captured.

Cotton rats also occur most commonly in dense grassy fields (Schwartz and Schwartz 1981), probably the reason that so few were captured during this study. Although most of the cotton rats captured during this study were collected from the upland scrub habitat, portions of the habitat are covered with dense grass.

The most often collected shrew species was the least shrew. It is a habitat generalist and occurs in open grassy areas, brush, dry fallow fields, and marshy or timbered locations (Schwartz and Schwartz 1981). At the SR-29 site, least shrews were captured primarily in upland scrub and upland grass plant communities, perhaps indicating that they prefer dry sites more than wet areas. Few least shrews were captured in moist ravines of Savage Gulf in central Tennessee (Todd 1992), further indicating their preference for dry habitats.

Conversely, southeastern shrews prefer wetland habitats and usually occur in bogs, marshy or swampy areas, or habitats with dense ground cover, such as wooded areas with briars and honeysuckle (Schwartz and Schwartz 1981). In this study, southeastern shrews were captured in lowland scrub, lowland grass, and upland scrub habitats. Southeastern shrews were not captured in the Natural Swamp, but it was not sampled adequately because of sampling constraints, and they likely occurred there. The low number of southeastern shrews captured during this study partially reflects the low percentage of wetlands on the study area.

Short-tailed shrews are most common in deciduous woodlands with heavy, moist leaf mold (Hamilton and Whitaker 1979). Short-tailed shrews were relatively uncommon on Unaka Mountain in eastern Tennessee, an area of high shrew density and diversity, perhaps because of low soil moisture (McGimsey 1994). However, they were the second most common species collected in the mature forests and moist ravines of Savage Gulf (Todd 1992). The forests of the SR-29 study site are less mature than those of Savage Gulf, and the substrate is not covered by a thick layer of leaf material, hence the reason that short-tailed shrews were not commonly collected during this study.

Results from this study are similar to small mammal studies conducted on the SR-29 site during the early 1980s. However, Skoglund did not report capturing any eastern harvest mice, and Hedges reported the capture of only two. Conversely, Skoglund and Hedges reported capturing 205 and 102 house mice over 6,240 and 8,684 trap nights, respectively, far more than the number captured in this study. Harvest mice may have been misidentified as house mice in previous studies because they are very similar in appearance and are primarily separated by the presence or absence of grooves on the incisors (Schwartz and Schwartz 1981).

Alternatively, the ratio of house mice to harvest mice may have changed over the past 10 years as successional changes occurred. Grassy communities present immediately after the project site was established, however, have been replaced by shrubby habitats today, and harvest mice should now be less common than 10 years ago. This apparent discrepancy may be explained by competitive interactions between house mice and harvest mice if old buildings (e.g., barns) had been present on the project site shortly before the previous studies. Such buildings may have provided habitat for large numbers of house mice whose population may have declined slowly after the buildings were removed and natural habitats developed on the study site. Records are not available indicating if buildings were present, and remains of old buildings are not apparent in the current environment. Consequently, this hypothesis is less likely than species misidentification.

The change in ratio of white-footed mice (a woodland species) to cotton rats (a grassland species) on the SR-29 site from the early 1980s to today was probably caused by successional changes that have occurred during the past 15 years. The study site was originally unvegetated in many locations, hence the probable reason that cotton rats were not very common initially. As grassy fields developed, cotton rat habitat improved, and numbers increased. These numbers later declined as succession resulted in replacement of grassy fields by shrubby vegetation, areas less suitable to cotton rats and more suitable to white-footed mice. Natural fluctuations in cotton rats, a species known to be cyclic (Schwartz and Schwartz 1981), also may have contributed to ratio differences among studies.

Similarly, succession may have contributed to the loss of habitat for the meadow jumping mouse, a species previously captured on the study site, but not captured during this study. Jumping mice prefer open grassy habitats, but also occur in shrubby or weedy fields (Schwartz and Schwartz 1981). The meadow jumping mouse is an uncommon species throughout Tennessee and has been listed on the state list of "Wildlife in Need of Management" (Eagar and Hatcher 1980). Thus, it may currently exist at the study site in low numbers and not have been captured because of its scarcity.

Skoglund and Hedges also reported that eastern moles were common on the study site during the early 1980s. Mole hills and runways were observed during this study in a wooded area near North Chickamauga Creek, but were seldom observed in this study, probably because they are difficult to observe in tall grass. Also, ecological succession has undoubtedly resulted in habitats less suitable to moles on the SR-29 study site.

Successional changes also may have contributed to differences in trapping effectiveness (i.e., number of trap nights per animal captured) among studies. Grassy habitats generally support larger populations of rats and mice than woody habitats because of the greater amount of available food and cover. It is likely that more rodents were present on the study site during the early 1980s than today because of this difference in habitat.

No voles and only two shrews were captured during previous studies, but Skoglund and Hedges did not use pitfall traps. Although voles can be captured in live traps, the two individuals collected in this study were found in pitfall traps. Shrews are carnivorous (Schwartz and Schwartz 1981) and seldom enter live traps because they are not attracted to the peanut butter and oatmeal bait. Short-tailed shrews are occasionally captured in live traps, and the short-tailed shrew was the species captured during the previous studies.

Five southern flying squirrels were captured during one of the previous studies, but it was not documented in this study. Flying squirrels are common in mature woodlands (Schwartz and Schwartz 1981), and undoubtedly occurred on the SR-29 site during this study. They were not observed because they are nocturnal and seldom seen, even where they are common (Schwartz and Schwartz 1981). Although they are sometimes captured in live traps set on the ground, they are primarily tree dwellers and best captured with traps set in trees (Schwartz and Schwartz 1981). The failure to capture any in this study is not unexpected, but it is surprising that Skoglund captured five. He may have trapped during a year when food supplies were scarce, forcing flying squirrels to feed on the ground, or he may have set his traps in locations more conducive to their capture.

Some mammal species, not observed in this study, were documented as roadkills during the previous studies (i.e., the gray fox, the red bat, and the hoary bat), as well as a few species observed in this study (e.g., the opossum and the raccoon). Although systematic searches of SR-29 were not conducted to document roadkill activity during this study, few dead animals were noticed on the road adjacent to the study site. Previous studies have shown that roadkills occur more commonly in the first few years after road construction, partially because animal populations are higher before vehicular mortality occurs, and partially because individual animals living in the area are initially naive to dangers associated with the road but later adapt to road activity (Oetting and Cassel 1971). However, vehicular activity on SR-29 is much greater today than during the early 1980s, and it undoubtedly influences wildlife populations and activities in some negative ways.

Bats commonly feed on insects over open water (Harvey 1992), and they were observed on several occasions during this study flying over the Shallow Borrow Pit. Attempts were not made to collect bats for identification purposes during this study, but several different species probably occurred on the study area, including some that may be endangered (Harvey, personal communication). Two common species, the red bat and hoary bat, were identified from roadkills during previous studies, and it is likely that these species were still present. Based on the number of observations of feeding bats, the Shallow Borrow Pit serves as an excellent feeding site. The Large and Small Borrow Pits undoubtedly also provided feeding habitat for bats, but recent information indicates that many bats feed more commonly over shallow wetland habitats than large aquatic ecosystems, perhaps because of the greater abundance of invertebrate prey (Harvey, personal communication).

Beavers were an important component of the fauna at the SR-29 study site both during this study and previous studies. Beavers typically live in and along streams, rivers, marshes, and small lakes (Schwartz and Schwartz 1981). The close proximity of North Chickamauga Creek to the SR-29 site probably enhanced beaver habitat by providing a corridor for dispersal to other locations with suitable habitat. Beavers modify the environment more than most other wildlife species by killing trees and damming waterways (Robinson and Bolen 1989). Skoglund reported that beavers were largely responsible for pockets of standing water scattered throughout the SR-29 study site, and he suspected that vegetation changes were occurring in the early 1980s because of beaver activities.

Two large, connected beaver ponds were present in the middle of the SR-29 study site during this study; these ponds were probably the same as those discussed by Skoglund, although Skoglund reported that the ponds were occasionally dry and supported wetland and aquatic plants. These ponds were flooded throughout the length of this study, however, and plants were not observed. Because the water was high in silt, which reduced sunlight available in the water column, and because the area is heavily shaded by the dense canopy, plant growth would be difficult. Siltation is often severe behind beaver dams, and beaver ponds usually are mud-bottomed and commonly support little plant life (Robinson and Bolen 1989). The increased water depth and decline in plants that has occurred in the beaver ponds since the early 1980s is a reflection of natural changes that occur as beaver ponds expand.

Beavers were present throughout the entire SR-29 site during this study, but most of their activity only resulted in runways and small pools that became dry during summer. Although beaver gnawings were observed at various locations, few trees were killed by beavers. Beavers cause substantial damage in some areas (Robinson and Bolen 1989), and it is possible that they will become a problem at the SR-29 site if the population continues to expand.

Although white-tailed deer were present on the study site, they were not very common either in this study or during previous studies. Low deer utilization may be attributed partially to the lack of oaks and other preferred mast producing species (e.g., persimmon). However, preferred browse species (e.g., strawberry bush, Japanese honeysuckle, blackberry, and greenbrier) (Stribling 1988) were common throughout the study site, and food should not have been limiting. Consequently, it is suspected that the study site is avoided by many deer because of its size, shape, and location. The SR-29 study site is an island of habitat, 105 ha in size (relatively small for deer), thin and long, and in close proximity to a busy road and an active railroad track. Although it is suitable for small- and medium-sized animals, it is not suitable for large, wide-ranging species like the white-tailed deer.

Table 29. Number of small mammals trapped from various habitats at SR-29 study site from March 1995 to February 1996.

Species	South Woods		Upland Scrub		Wet Scrub		Upland Grass		Wet Grass			
	No. of Captures	No. of Individ.	No. of Captures	No. of Individ.	No. of Captures	No. of Individ.	No. of Captures	No. of Individ.	No. of Captures	No. of Individ.	Total No. Captures	Total No. Individ.
Short-tailed shrew	1	1	0	0	0	0	6	6	2	2	9	9
Least shrew	0	0	5	5	1	1	5	5	1	1	12	12
Meadow vole	0	0	0	0	0	0	2	2	0	0	2	2
House mouse	3	2	5	2	0	0	0	0	0	0	8	4
Marsh rice rat	2	2	0	0	0	0	0	0	8	6	10	8
White-footed mouse	33	13	19	6	8	4	36	13	1	1	97	37
Golden mouse	1	1	0	0	8	4	2	2	0	0	11	7
E. harvest mouse	0	0	1	1	0	0	19	8	18	12	38	21
Cotton rat	0	0	4	3	0	0	2	1	0	0	6	4
Southeastern shrew	0	0	2	2	1	1	0	0	1	1	4	4
Totals	40	19	36	19	18	10	72	37	31	23	197	108
No. of trap nights	3200		2965		3460		3589		3160			
No. cap./100 tr. nts.	1.25		1.21		0.52		2.01		0.98			
Species Richness	5		6		4		7		6			

Table 30. Number of trap nights per small mammal captured and ratio of white-footed mice to hispid cotton rats on th SR-29 study site in 1980-81 (Hedges 1985), 1981-82 (Skoglund 1982), and 1995-96 (this study).

Species	Skoglund (1982)*	This Study*	Hedges (1985)**	This Study**
Short-tailed shrew	6240	2731	8684	2731
House mouse	30	2731	85	1366
Marsh rice rat	1248	1366	271	1092
White-footed mouse	178	295	140	113
Golden mouse	1040	1561	4342	993
Eastern harvest mouse	- -	520	4342	288
Cotton rat	55	2731	334	1821
Total Density	0.058	0.0082	0.026	0.016
White-footed mice:Cotton rats	1:3	9:1	2:1	16:1

* Based on individuals captured
** Based on number of captures (includes recaptures)

CHAPTER 8
RECOMMENDATIONS

The SR-29 site was purchased by TDOT to mitigate for wetland loss and wildlife habitat destruction. The SR-29 mitigation plan included the creation and manipulation of wetland, aquatic, and terrestrial habitats and the planting of vegetation that was to serve as food and cover for wild animals. This section of the report evaluates the effectiveness of the mitigation measures and provides recommendations as to how the approaches can be modified to be more cost-effective or to better meet the desired goal of providing quality wildlife habitat.

Mitigation and Mitigation Banking

General Considerations of Mitigation

Wetland resources in the United States have declined substantially since settlement by Europeans. Dahl (1990) estimated that from the 1780s to the 1980s, 53 percent of wetlands in the lower 48 states were lost. Tennessee was estimated to have lost 59 percent of its historical wetlands. Almost 95 percent of palustrine wetlands lost in the Southeast from the 1970s to the 1980s were forested, a substantial increase from the 54 percent loss rate from the 1950s to 1970 (Dahl and Johnson 1991). Historical and current wetland acreages specific for Tennessee (Tennessee State Planning Office 1994) provide convincing support that over half of the state's wetland resources have been lost as of the early 1990s. Given the ecological and social significance of wetlands, it is imperative that additional losses be minimized to the extent possible.

The primary regulatory program involving wetlands nationwide results from goals set forth in the Clean Water Act (CWA) of 1977. The CWA was intended to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Waters of the United States protected by the CWA include rivers, streams, estuaries, the territorial seas, and most ponds, lakes, and wetlands. Section 404 of the CWA regulates the discharge of dredged and fill material into waters of the United States, including wetlands. Thus, Section 404 has functioned to slow the rate at which wetlands are lost, but still allows for significant alteration and even filling of wetlands in some instances. As part of the goal of minimizing harm to the country's wetland resources, the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (Corps) signed a memorandum of agreement (MOA) in 1989 regarding the issuance of permits for work in wetlands. The MOA specifies a sequence of steps that should be followed whenever the permitting agency (Corps) receives an application regarding wetland alteration or filling. These steps, which are intended to lessen the impacts of proposed projects involving wetlands, are:

1. avoid impacting the wetland altogether if feasible alternatives are available,
2. minimize the impacts of the proposed action by reformulating the proposed work, and
3. compensate for the loss of the wetland if no viable alternative to the proposed project exists.

The last step involves creating a new wetland or restoring a degraded wetland to compensate for the loss of function performed by the altered or destroyed wetland. The concept of compensation, often referred to as mitigation, provides flexibility in the decision-making process by allowing development that is in the public interest to proceed, while at the same time protecting the overall wetland resource base. The use of compensation in the permitting arena was bolstered by several studies conducted in the 1970s that showed that some types of wetlands could be created successfully (Savage 1972, Woodhouse et al. 1972, Garbisch et al. 1975).

Thousands of wetlands have been created or restored for the purpose of mitigating losses during the past two decades and numerous investigations have been conducted regarding their success. Many of these investigations are summarized in a document edited by Kusler and Kentula (1990). The findings of researchers regarding the degree to which man-made wetlands serve to "replace" natural wetlands that are lost vary, but, in general, it is accepted that some types of wetlands can be approximated and that individual wetland functions may be restored or created.

A relatively new concept in mitigation with considerable potential for enhancing the likelihood that wetland losses can be offset is that of mitigation banking. Following is a brief description of mitigation banking taken from the Institute of Water Resources (IWR 1992). Mitigation banking is defined as the "advanced compensation of unavoidable wetland losses due to developmental activities" that can be achieved through the creation, restoration, enhancement, or preservation of other wetland areas of equivalent value generally located outside the immediate area of wetlands loss or alteration. Wetland mitigation banks are usually relatively large blocks of wetlands with estimated tangible and intangible values, termed credits, that are analogous to cash deposits in a checking account. As anticipated development takes place, credits equivalent to the estimated unavoidable wetland losses are withdrawn or debited from the bank to compensate for the losses incurred. As development continues over time, the credits of banks, which are qualitatively similar and scaled in size to the magnitude of anticipated wetlands losses, are progressively exhausted. When credits are reduced to zero, further mitigation must then be effected by other means or through establishment of new banks.

Mitigation banking can reduce the costs and delays associated with the permit review process, and, in many cases, the large-scale replacement wetlands provided by banks can more effectively maintain ecosystem integrity than several isolated, on-site mitigation projects (IWR 1994a). Recognition of the potential benefits of mitigation banking has led to the recent development of numerous banks, particularly in high-development states such as Florida and California (IWR 1994b). In Tennessee, it is thought that mitigation banks have considerable utility for mitigating small projects where on-site creation or restoration often is not feasible. Agencies, such as the Tennessee Department of Transportation (TDOT), that continually impact small acreages of wetlands through construction activities have the potential to benefit the most from mitigation banks.

While the development of regional mitigation banks in Tennessee seems warranted, they need to be evaluated in the context of the landscape. For example, in the western portion of the state where extensive acreages of alluvial floodplain wetlands formerly existed, the creation of large mitigation banks will result in the replacement of wetlands on a scale appropriate for the region. However, wetlands tend to be much smaller and widely dispersed in much of central and eastern Tennessee. Given this regional perspective, mitigating for losses of small isolated wetlands in a large consolidated bank may not result in the replacement of all landscape functions appropriately. This is particularly true relative to wildlife habitat and the distribution of some animals on a regional scale. For example, amphibian populations, which have declined worldwide in recent decades, probably would benefit more from the creation of small isolated wetlands, (i.e., on-site or near-site mitigation) than from the development of large mitigation banks. An alternative would be to have several different types and sizes of wetlands within a bank. Considerations such as these should be addressed during consultation with the resource and regulatory agencies on a case-by-case basis.

Mitigation Potential of the SR-29 Site

The SR-29 project site has potential to serve as a mitigation bank, but actions taken to date have not been adequate to create a substantial acreage of jurisdictional wetlands. The Shallow Borrow Pit and the northern and southern ends of the Large Borrow Pit are the only wetland areas that were created and thus would be considered as credits within the banking framework. Preservation of existing wetlands typically has not been considered an acceptable method for obtaining bank credits. The total created wetland area is 2.1 ha, a small amount relative to the total project area.

To develop the site into a viable mitigation bank would require additional manipulation of the hydrology in such a way that more of the area meets the criteria for jurisdictional wetlands. Specifically, the site would have to be flooded or have saturated soils for a minimum of 5% of the growing season (i.e., 12 consecutive days at the project site) (USACE 1987). Once wetland hydrology has been established, the site either could be planted with hydrophytes or allowed to develop hydrophytic vegetation naturally.

Manipulation of the hydrology could be accomplished by excavating additional depressions like the Shallow Borrow Pit or by diverting streamflow onto the site for longer periods of time. Portions of the site flood occasionally, but the duration of flooding is not sufficient to create wetland conditions. Excavating depressions is probably preferable over diverting streamflow because of the unpredictability of water flow in North Chickamauga Creek and the difficulty of obtaining permits to fundamentally modify an existing stream course.

The central portion of the SR-29 site in the vicinity of the power line crossings is the most suitable area for creating additional wetlands. The water table already is near the surface at that site, and the elevation is such that water ponds for several consecutive days following significant flood or rainfall events. Constructing shallow depressional wetlands there could be done relatively easily with a minimum of earth moving.

Wetlands such as the Shallow Borrow Pit are considered to be in the depressional class in the hydrogeomorphic classification system (HGM) (Brinson 1993) and perform a multitude of functions described in Brinson (1993) and Smith et al. (1995). HGM recognizes three primary categories of wetland functions: hydrological, biogeochemical, and habitat (Smith et al. 1995). Depressional wetlands perform functions in all three categories and, depending on local and regional considerations, individual wetlands within a mitigation bank could be constructed to maximize the performance of selected high-value functions. Surface water storage, production of organic carbon, and habitat for wildlife and fish are three functions that seem appropriate for consideration at the area. Excellent recommendations for developing wetlands for performing particular functions can be found in Marble (1990).

Future Monitoring

To determine the success of mitigation banks (and any wetland restoration or creation project), it is essential to periodically monitor the developing ecosystem to determine if project objectives are being met (Quammen 1986). If a mitigation bank is developed at the SR-29 site, attaining the proper hydrologic regime is essential for both short- and long-term success. Hydrological monitoring should focus on determining whether the restoration procedures that will be implemented are successful in reestablishing wetland hydrology as defined and described in the Wetland Delineation Manual (WDM) (USACE 1987). Because hydrology is the primary factor responsible for the creation and maintenance of wetlands (Mitsch and Gosselink 1993), failure at this level would preclude the attainment of other project goals. It is reasonable to assume that creating wetland hydrology ultimately would lead to the development of hydric soils and a plant community dominated by hydrophytes. The presence of all three parameters is required for an area to be considered a wetland under current federal guidelines (USACE 1987).

Monitoring the plant community through time provides incremental feedback regarding the success of vegetation establishment, and allows for mid-course corrections regarding choice of species, planting techniques, and hydrologic controls. Critically examining projects that involve forested wetlands is especially important because of our lack of knowledge regarding the long-term success of such efforts. Very few forest restoration or creation efforts are over 20 years old, and it is still too early to judge their ultimate success. Clewell and Lea (1990) examined several projects in the Southeast completed as of the late 1980s and were optimistic that at least some types of southern forested wetlands can be restored.

Monitoring wildlife habitat also is desirable in many situations, especially with mitigation bank projects where creation of habitat typically is one of the principal objectives. Monitoring can be done at various taxonomic levels, but vertebrates, which are higher in the public interest and may represent "an integration of the environmental features over relatively large areas" (Brooks and Hughs 1986), are the most logical group.

Evaluation of Active Management Approaches at the SR-29 Site

Four active management approaches were used at the SR-29 site during the late 1970s to create or enhance wildlife habitat. These approaches were: 1) the creation of borrow pits, 2) the creation of animal flood survival mounds using spoil from the borrow pits, 3) the creation of artificial riffles and an artificial meander in North Chickamauga Creek, and 4) the planting of herbaceous and woody vegetation. The effectiveness of these approaches are evaluated in the following section.

Borrow Pits

Although most borrow pits are constructed to obtain road fill, they provide a diversity of other uses, including fish and wildlife habitat, flood control basins, and recreational opportunities. Borrow pits can be designed in various ways to enhance these secondary benefits. Although some designs are not practical in certain situations because of requirements or constraints associated with specific projects (e.g., a large amount of fill cannot be obtained from a shallow borrow pit), opportunities often are available to construct borrow pits that provide secondary benefits. Fish and wildlife use of various borrow pit designs were investigated in this study.

Man-made wetlands and aquatic environments were created at the SR-29 site by constructing borrow pits of three different designs. The ecological effectiveness of: 1) shape of basins (steepness and slope), 2) size and depth of basins, and 3) proximity to the SR-29 highway were evaluated in this and the previous study. The three borrow pits are referred to as the Large, Small, and Shallow Borrow Pits.

Specific Borrow Pit Recommendations. The Large Borrow Pit is 7.4 ha in size and covers approximately 7% of the SR-29 study site. It is bordered on its northwestern side by SR-29, and it is highly visible to people using the highway. The Large Borrow Pit has a maximum depth of 6.7 m, and it averages 1.8 m in depth. It was designed to create aquatic and wetland habitats by gradually sloping the northern and southern ends and creating steeper slopes on the eastern and western sides. This design resulted in emergent wetlands on the northern and southern ends and aquatic habitat elsewhere. The Large Borrow Pit is much longer (1,600 m) than wide (122 m), and only 0.6 ha of wetlands were created using this approach.

The Large Borrow Pit provides minimal wildlife habitat because of its large, open water surface, lack of emergent and submergent vegetation, and close proximity to the road. Only a few ducks, fish-eating birds, and turtles were observed on the Large Borrow Pit during this study, indicating its low value as wildlife habitat. It provides less than optimum fish habitat because of its high sediment loads and lack of structure.

Although the entire SR-29 area was closed to public access during this study, people regularly fished in the Large Borrow Pit. Some individuals cut the fence to gain boat access, and an unpaved boat ramp had been constructed in the northwestern corner. Fishing and other recreational activities may be the best use of the Large Borrow Pit because of its limited wildlife value. Fishing opportunities can be improved by following recommendations included in the general recommendation section. However, if the Large Borrow Pit is opened for public use, liability responsibilities should be considered because its steep sloping sides make it potentially dangerous to poor swimmers unfamiliar with its design.

The Small Borrow Pit is only 0.6 ha, and trees now surround it, making it not visible from the road. This borrow pit was so steeply sloped that emergent vegetation was essentially lacking. Consequently, wildlife food resources within the borrow pit were restricted primarily to aquatic animals, such as fish, frogs, and invertebrates. The Small Borrow Pit is surrounded by raised spoil banks that theoretically should inhibit sediment buildup from areas outside of the closed system. However, the spoil banks are not vegetated and are so steeply sloped that they are eroding and causing sedimentation problems within the borrow pit. A gently sloping, vegetated bank is a preferable borrow pit design over the design of the Small Borrow Pit.

The Shallow Borrow Pit is a 1.2 ha depressional wetland created by removing topsoil from an area adjacent to the Small Borrow Pit. This borrow pit was graded so that it is inundated from winter to early spring, but dry during summer. The resulting periodic drawdown has resulted in an emergent wetland, supporting an almost complete coverage of herbaceous plants. Small clumps of woody plants are scattered throughout the wetland, and a dense border of maples surrounds the area. Several different wildlife species, especially amphibians which breed in ephemeral pools, were observed on the Shallow Borrow Pit during this study.

If the primary objective when constructing borrow pits is to create wetland wildlife habitat, the shallow borrow pit design is the preferred approach of the three used in this study. The Shallow Borrow Pit provided a higher percentage of wildlife habitat than any other wetland or aquatic area on the study site. The herbaceous plants provided food resources for a diversity of wildlife species, and the scattered woody vegetation provided nest sites for some birds and cover for many wildlife groups. Inland freshwater marshes are the most productive wetland type in North America (Mitsch and Gosselink 1993), and the Shallow Borrow Pit was the best representative of a freshwater marsh on the SR-29 study site.

The value of the Shallow Borrow Pit to wildlife is limited by its small size. Many wildlife species (e.g., ducks) require larger wetlands, and total food resources in such a small area are insufficient to support many individuals. Using the same construction approach as that used on the Shallow Borrow Pit but on a larger area would produce a larger wetland that would be more valuable to wetland wildlife. Alternatively, creating a complex of small wetlands similar to the Shallow Borrow Pit, interspersed with small areas that do not flood regularly, would provide excellent habitat for wildlife species that depend on small ephemeral pools (e.g., many amphibians). The interspersion of shallow emergent wetlands within a forested area would also provide additional edge, thereby enhancing wildlife diversity. A few deeper, permanently flooded ponds within this complex would provide refuge for semi-aquatic animals (e.g., amphibians) during drought conditions.

General Borrow Pit Recommendations. Borrow pits are potentially valuable to many different wild animals, but borrow pit design determines which groups are most likely to use individual ponds. Relatively large, deep borrow pits are more valuable to fish than wildlife, whereas shallow wetlands that are inundated only part of the year are very important to some wildlife groups (e.g., ducks), but of negligible value to fish. Many amphibians breed primarily in ephemeral ponds that do not support fish, thereby reducing predation risks on their aquatic larvae (Mount 1975). To provide maximum fish and wildlife habitat, a diversity of borrow pit designs should be used in developing a mitigation site.

Borrow pits that are designed primarily to provide wildlife habitat, exclusive of human recreation, should be located far enough from roadways to minimize human visitation. In this study, the Large Borrow Pit was highly visible from the road and often used by illegal recreationists, but the Small Borrow Pit was not visible from the highway and was seldom visited. If the shape of the mitigation site is such that a borrow pit must be located near the road (e.g., the long, thin shape of the SR-29 site), vegetation can be planted to reduce the visibility. If the primary purpose of a borrow pit is to provide public recreation, such plantings are not necessary and may be undesirable (e.g., trees around pond edges interfere with bank fishing).

The design of water bodies influences the rate of sedimentation. Steep sloping banks that are not vegetated are eroded by sheetwater washing across the surface during rain events and by wave action produced as the wind blows across lake surfaces. To minimize erosion, shorelines and adjacent littoral zones should be gently sloping and vegetated. Vegetated wetland zones were created on the northern and southern ends of the Large Borrow Pit by gradually sloping the banks. Gentle slopes around the entire Large and Small Borrow Pits would reduce sedimentation and provide fish and wildlife habitat.

Plant roots stabilize the soil and decrease the resuspension of sediments in the lake caused by wave action. Vegetation in the littoral zone also detains sediments washing in from the surrounding drainage basin, thereby reducing the sedimentation rate. The Large and Small Borrow Pits are surrounded by woody vegetation, but unvegetated zones exist between the woody vegetation and the water. Establishment of plants in these zones should reduce sedimentation in the borrow pits and is warranted.

Establishing aquatic and wetland vegetation in the littoral zone of highly silted borrow pits is difficult because water turbidity reduces the amount of light penetrating the water column, thus prohibiting plants from becoming established. Periodic drawdown of aquatic systems promotes substrate oxidation and compaction, as well as the establishment of emergent plants that, when flooded, provide food and cover for fish and wildlife and help reduce sedimentation rates. Low cost / low maintenance approaches are available to provide hydrologic control over water bodies. Stop-log structures or stand pipes at the deepest ends of borrow pits can be used to control water depth, if overflow canals are connected to a permanent water body (e.g., North Chickamauga Creek). Water levels should be lowered during mid-summer to enable emergent plant establishment and raised during fall to flood the vegetation and provide benefits to fish and wildlife (Fredrickson and Taylor 1979).

Active water manipulation as described above would necessitate two site visits per year, but these visits would only involve removal or addition of stop logs or raising or lowering of a stand pipe. If agency personnel are not available to perform these activities, volunteers from local conservation or school groups probably could be identified and trained to manage water levels, especially if they received periodic guidance from wildlife managers or university personnel familiar with water manipulation. Wood duck nesting boxes have been placed throughout the SR-29 site by an unknown conservation group, indicating a desire within the general public to become actively involved in conservation issues.

Wind-caused erosion is more severe in large water bodies because of the greater energy build-up during wave formation. Establishment of vegetated littoral zones in large water bodies helps reduce wind-induced erosion by dissipating wave energy as waves pass through emergent vegetation. However, erosion should be less severe in a complex of small borrow pits than in a single large borrow pit of similar size to the total complex.

Individual borrow pits within the complex could be designed differently (e.g., water depth and drawdown capabilities could vary among units) to provide habitat for various wildlife and fish groups.

Water control structures could be placed among units of the complex to enable hydrologic control of individual units. Managing a complex in a coordinated fashion (e.g., rotational drawdown cycles) would provide maximum water control and should enhance long-term productivity of the system. However, such an approach would require more detailed knowledge of water manipulation and would necessitate periodic advice from personnel with expertise in this management approach.

Borrow pits, when correctly designed and constructed, provide opportunities for fish management. Littoral zones in borrow pits are the most productive component. Aquatic vegetation in these zones serves as biological filters for suspended matter and nutrients, substrate for macroinvertebrate colonization, and cover for fish, as well as the primary source of energy through photosynthetic activity. Many fish species use littoral zones for spawning; however, the Large and Small Borrow Pits have limited littoral habitat. A gradual slope of 3:1 (i.e., 1 m of depth for 3 m distance from shore) is recommended for the creation of littoral zones in constructed lentic ecosystems (Flickinger and Bulow 1993). Aquatic macrophytes can be planted in shallow areas to provide immediate littoral habitat.

When considering fish populations in these systems, the bottom contour should be irregular, and structures (e.g., trees and brush) should be present in the water body to provide habitat diversity. In borrow pits where such structure is not already present, artificial structures, such as weighted Christmas trees and wooden stake beds, can be added as fish attractor devices. Water quality of the borrow pit should be tested to determine its relative fertility and ability to support fish populations. When waters are found to be infertile, liming or fertilization can increase the carrying capacity.

If fish populations do not exist in borrow pits, stocking of desirable species (e.g., bluegill, redear sunfish, and largemouth bass) is recommended to avoid establishment of undesirable invader species (e.g., green sunfish and bullhead catfish). The recommended stocking rate is 250 largemouth bass and 2,500 bluegills or redear sunfish per hectare (Flickinger and Bulow 1993). Sunfish fingerlings should be stocked in the fall and bass during the following spring. This schedule ensures that sunfish have matured and spawned, providing a sufficient prey base for bass by the time that they are introduced. Borrow pits should not be stocked by anglers with wild fish because such stocking destroys the "balanced" fish community and increases the possibility of introducing diseases or undesirable species.

Wildlife Mounds

Soil from borrow pits was used to construct elevated mounds at six locations on the SR-29 study site with the goals of providing refuges for terrestrial wildlife during flood events and enticing burrowing and small mammals away from the highway. Hedges concluded that the mounds were unsuccessful in meeting these objectives because the mounds were inundated during the infrequent flood events. Also, vegetation growth was very limited on the mounds, probably because of soil compaction. By the beginning of this study, herbaceous vegetation had developed on the mounds, but woody vegetation was sparse. Thus, soil compaction may have delayed succession, but it is now proceeding, and the vegetation on mounds should be the same as that of surrounding areas within a few years. During most flood events that occurred in this study, the mounds were above the surface of the flood water, but they were inundated during an unusually high flood event in October 1995.

During this study, a few birds were observed on wildlife mounds, but they did not appear to be attracted or repelled by the mounds. Mammals, reptiles, and amphibians were seldom observed on the mounds, but these groups undoubtedly used them on occasions because the mounds were vegetated and provided suitable habitat. If the mounds were attracting small animals from the nearby highway, higher densities should have been detected during this study. Most small mammals have small home ranges

(Schwartz and Schwartz 1981), and it is doubtful that the presence of mounds would have caused them to modify their distribution.

Small animals, especially those that live in floodplains, are adapted to flood events. Many of them survive short-term events by climbing into living vegetation and debris that accumulate adjacent to streams. Sufficient vegetation and debris are available on the study site to provide refuge during high water. Some small animals survive longer events by leaving floodplains and returning once flood waters recede. Others have high reproductive potential and compensate for flooding mortality through increased natality. Even if wildlife mounds were used by small animals and enhanced survival rates during flood events, a large number of mounds scattered throughout a floodplain would be necessary to provide sufficient refuge to influence population densities. For these reasons, wildlife mounds do not justify the expense of constructing them.

Modifications to North Chickamauga Creek

Aquatic biota monitoring indicated that suitable habitat for fish and benthic macroinvertebrates is limited in many sections of North Chickamauga Creek. Siltation, associated with bank destabilization during previous construction activities, is the primary problem that caused a loss of habitat. These areas contain no riffle habitat and require increased habitat diversity to sustain aquatic biological communities. Riffles help aerate water and enhance scouring forces by increasing current velocities. Scouring forces cleanse silt-laden areas, thereby increasing acceptable substrate for benthic macroinvertebrate colonization. Placing instream structures (e.g., logs and rip rap) above deeper pools at such sites creates riffles and provides fish habitat. Bank stabilization procedures are no longer necessary at most sites on North Chickamauga Creek because banks are now heavily vegetated. However, bank stabilization measures, such as planting cover along banks, should be used at future construction sites to prevent siltation from occurring.

Riffle areas created at Stations H and L provided some habitat for macroinvertebrates, but they were less productive than possible because of extreme water level fluctuations. The riffles were not covered with water during low creek levels and were deeply flooded at other times. Greater diversity in substrate size and composition in riffles and the construction of intermittent pooled areas would enhance productivity of these sites. Substrate size diversity enhances scouring forces which effectively cleanse fine sediments (i.e., silt) from large interstitial spaces during periods of high water. Placement of intermittent pools within constructed riffle areas provides complex habitat, including deep water habitat useful to fish and macroinvertebrates during low water periods.

Although artificial meanders can be used to restore natural hydrology to channelized stream reaches, the meander on North Chickamauga Creek had some significant construction flaws that reduced its productivity. The earthen dam at the meander entrance pools water during high water flow because the meander entrance is too narrow and at a sharp angle from the creek channel. This pooling action deposits sediments at the entrance and throughout the length of the meander. Also, the banks of the meander are so steeply sloped that they erode significantly, further contributing to sediment problems. Establishing vegetation on the banks would reduce this problem, but the banks should have been gradually sloped during construction, and the entrance to the meander more gradually angled, as indicated on original design plans. Instream habitat structure also could have been used to diversify fish and benthic macroinvertebrate habitat and to enhance scouring action in the meander.

Plantings

Specific Planting Recommendations. Tall fescue, bicolor lespedeza, blackberry, wild grape, bush honeysuckle, sassafras, sycamore, yellow poplar, river birch, black willow, white oak, and hickory were planted on the SR-29 study site for erosion control and to provide wildlife food and cover. The success of these plantings was evaluated by referring to a map of proposed landscaping and channel improvements on the project area and searching these proposed planting locations on site. Actual planting records were not available, and the absence of species in locations for which they were proposed may have resulted from modifications to the planting schedule instead of failure to become established.

Although tall fescue was successfully established throughout the SR-29 site to control erosion, it does not provide good wildlife habitat (Quail Unlimited 1992). It grows so densely that it inhibits movements of small animals, and some varieties are infected with symbiotic fungi which cause sickness and low conception rates in rabbits and other mammals. Although fescue is relatively inexpensive, easily established, and does control erosion, native warm season grasses (e.g., big bluestem, little bluestem, Eastern gamagrass, switchgrass, Indiangrass, side-oats grama, and weeping lovegrass) are equally effective and provide better forage and cover for wildlife. Bunch grasses (i.e., those that form small patches) provide excellent cover and also would be preferable over fescue.

Bicolor lespedeza was to have been planted in two plots near the northwestern and southwestern ends of the Large Borrow Pit. A thick patch of bicolor is now established near the northwestern end, and small patches and individual stems are present within 100 m of the original plot. Although four times as many seedlings were planned for the southwestern plot as the northwestern plot, bicolor is absent from the southwestern location. Maintaining bicolor over an extended period often requires periodic disturbance (e.g., burning or bush hogging), but there were no indications of differences in disturbance between the two sites. Differences in shading conditions and flooding relationships between the sites also were not apparent, and it is not clear why only one of the two plots was successful.

Bicolor is a shrubby legume capable of reaching 3.3 m in height (Stribling 1991). Bicolor provides excellent cover, and its seeds are persistent, hard-coated, and readily consumed by wildlife, especially bobwhite quail (Stribling 1991). However, bicolor competes with understory herbs and tree seedlings for sunlight when it invades wooded habitats, especially those that are periodically burned. Bicolor is not native to the United States, and some wildlife biologists consider it a potential problem species. The bicolor planting in the northwestern corner of the borrow pit has provided valuable resources on the SR-29 site, but the planting of bicolor elsewhere should be done cautiously because of its ability to spread.

Most blackberry plantings on the study site have become established and spread from their original locations. Blackberry is one of the most valuable of all wildlife plants. It is a preferred browse plant by deer, and its fruit is produced in large quantities and eaten by most wildlife (Stribling 1991). Blackberry also provides nesting cover for breeding songbirds and escape cover for many diverse wildlife groups (Kroodsma 1984).

Blackberry plantings seldom are justified because it is a plant that becomes established easily by natural distribution of seeds by fruit-eating birds and mammals. However, if nearby patches are not available to serve as an initial seed source, natural establishment is impaired. Blackberry plantings probably were justified at the SR-29 site because it is abundant where it had been planted and absent from several open areas where it had not been planted (e.g., western side of the Large Borrow Pit). Some of these areas have been colonized by less desirable herbaceous plants (e.g., goldenrod and serecia lespedeza), indicating that blackberry can be used to help direct successional changes to better benefit wildlife. Given sufficient time, blackberry probably would have become established naturally throughout the study area, but the plantings provided a valuable resource at an earlier date.

Wild grape is still present at several sites where it had been planted, but it is sparsely distributed within thick patches of other plants (e.g., ragweed, goldenrod, and serecia lespedeza). Although vigorously growing grape vines produce fruit that is valuable to wildlife, fruit was not observed on grapes that had been planted, perhaps an indication of stress associated with competition with more robust herbs. Wild grape usually occurs in wooded habitats, but it was planted in open fields at the SR-29 site, probably the reason that it is being replaced by herbs. Naturally established grape vines are common in the South Woods, and the planting of grape at the study site was not justified.

Five hundred bush honeysuckle plants were to have been planted at various locations on the SR-29 study site, but only a few were located during searches of the area. Coburn et al. did not include bush honeysuckle in their discussion of plantings, and the planting schedule may have been modified to exclude this species. Bush honeysuckle provides cover for nesting birds and produces a small fruit that is consumed by various wildlife species, but many other shrubs provide similar resources. Bush honeysuckle also has formed dense thickets in some locations that have resulted in the elimination of other, more valuable plants. Thus, other plants besides bush honeysuckle would have been more appropriately planted at the site.

Sassafras seedlings were planted at various locations, primarily between the Large Borrow Pit and SR-29. Sassafras trees were observed throughout the study area; some occurred naturally, and others probably were planted. Sassafras is a small, understory tree that provides some browse for deer (Burns and Honkala 1990). Although birds readily consume the fruit, it is not considered very valuable because it does not produce abundant fruit (Martin et al. 1951). Sassafras probably would have become established throughout the area by bird dissemination, and planting of this species on the area was not necessary.

Sycamore, yellow poplar, river birch, and black willow were planted extensively throughout the SR-29 site; all four are found abundantly throughout the area. They all produce an abundance of small seeds that are wind disseminated, and most individuals on the study site probably are progeny of mature trees found elsewhere. All four occur commonly along stream banks, and large individuals were present on the banks of North Chickamauga Creek, thus providing a seed source. Consequently, the planting of these species on the study site was not necessary.

Of these species, only the seeds of yellow poplar are consumed readily by wild birds, and its fruit is less valuable than that of many other southern trees (Martin et al. 1951). Willows and birches are valuable to browsing wildlife in the northern United States, but they are less important in the Southeast because of the greater diversity of browse plants (Martin et al. 1951). Large (>50 cm DBH) sycamores and river birches often form cavities and provide nesting and escape cover for many wild animals;

establishment of these species for this purpose may be occasionally justified if a seed source is not nearby. In Tennessee, planting of any of these four species is rarely justified because of their relatively low wildlife value and widespread distribution.

Trees that produce hard mast (i.e., oaks, beech, and hickories) are among the most important of all wildlife plants (Martin et al. 1951). Squirrels, deer, turkeys, and various species of ducks feed heavily on acorns; other species (e.g., small mammals) eat them when preferred foods are not available. Beech nuts are smaller than acorns and are consumed by smaller mammals and birds. Few animals depend entirely on hard mast because mast crops are variable, and almost complete failure occurs in most stands during some years. Hard mast persists longer in the environment than soft mast (e.g., the fruit of maples, elms, and ashes) because soft mast rots more easily. Large oaks and beeches also are valuable to cavity-nesting birds and mammals (Baskett et al. 1980). The scarcity of oaks, hickories, and beeches in the forests of the SR-29 site detracts from its value as wildlife habitat, and the planting of oaks and hickories on the area was justified.

Although white oak was to have been planted at several locations throughout the study area, very few individuals were ever located during this study. Most of those that were observed were large individuals that must have been present before the project site was established. White oak is a tree that grows best on well-drained, upland soils, and white oak seedlings and saplings are less flood tolerant than many other oak species (Burns and Honkala 1990). Extensive flooding of the project site during the early 1980s probably resulted in the death of most white oaks that were planted.

Twelve species of oaks occur commonly in wetlands in Tennessee (Reed 1988). Some of these (e.g., overcup and Nutall oak) usually occur in poorly drained sites that are flooded for extended periods, whereas others (e.g., cherrybark and water oak) grow best on wetland fringes that are flooded infrequently during the growing season. Some oaks (e.g., swamp chestnut, pin, and willow oak) grow best in areas intermediate between these two conditions. Planting a diversity of oak species on sites that match their flood tolerance would more likely succeed and provide valuable resources for wildlife, especially during years of mast failure of one or more species. White oaks should only be planted on the highest sites (e.g., on wildlife mounds and small ridges).

Two sawtooth oaks were observed on the wildlife mound in the upland grass community between the Large Borrow Pit and North Chickamauga Creek. Sawtooth oak is a non-native species that often is planted because it produces acorns at a younger age than many native species (Stribling 1991). Planting records did not include sawtooth oak, and the origin of these two individuals is unknown. However, they probably were planted because natural establishment of the species rarely, if ever, occurs in Tennessee. Both individuals appeared to be dying during Summer 1996, perhaps reflecting an inability to adapt to habitat conditions at the SR-29 site.

Few oaks are present in the forests on the northern and southern ends of the SR-29 study site, probably because of selective logging in the past. Although oaks should eventually become established through secondary succession, the speed at which this occurs can be enhanced by planting oaks in openings in the forests. Oak seedlings and saplings are not very shade-tolerant, and oaks planted in dense sections would suffer high mortality and low growth rates. Thus, to improve the wildlife value of the forests on the SR-29 site, selective thinning of less valuable trees would be necessary to complement planting of oaks in the forests. This approach would be very labor intensive and less cost effective than planting oaks in open sites (e.g., areas around the Large Borrow Pit) and is not recommended.

Only four species of hickories occur commonly in wetlands in Tennessee (Reed 1988), and two of these, bitternut and shellbark hickory, were observed on the project site. Some hickories observed during this study may have been planted, but the success of hickory plantings cannot be evaluated because the specific species planted was not included on planting records. Hickories are less valuable than oaks because many wild animals that readily consume acorns will not eat hickory nuts (Martin et al. 1951). Planting a few hickories to supplement oak plantings is justified, but species should be selected that will thrive on sites where they are to be planted. American beech could also be planted on the SR-29 area, but only on the highest sites because beech, like white oak, is not flood tolerant (Burns and Honkala 1990).

General Planting Recommendations. Establishing vegetation on a project site can be very costly and require extensive labor. Therefore, careful consideration should be used in developing a plan with clearly defined objectives and procedures that help ensure success. The following steps are suggested for evaluating planting needs on project sites:

1. Determine primary and secondary objectives; objectives may vary among project sites. Tree or acorn planting on open sites is necessary when the primary objective is to provide forest habitat, but maintaining open areas probably is justified in other situations (e.g., when providing habitat for early successional species). Plantings that are directed at erosion control should consist primarily of herbaceous plants because they are more effective in meeting the objective than woody plants.
2. Inventory existing vegetation on the project site and nearby locations. A species list can help determine potential seed sources for natural establishment and what plants would probably vegetate the area if planting did not occur. Planting of such species is not cost-effective. A plant list also can be used to determine site conditions (e.g., flooding relationships) necessary to predict the likely survival of planted stock.
3. Create a list of desirable plant species that are not likely to become established without planting. Concentrating on native species will enhance the chance of successful establishment and reduce the chance of exotics reaching nuisance levels.
4. Evaluate each proposed species as to the specific objectives and ecological relationships among species. Species that are extremely shade-intolerant should be planted in open areas, whereas species that are shade-dependent should be planted only in wooded environments or near other planted stock. Species that have seeds that are wind disseminated are more likely

to become established evenly across an area than species that are animal disseminated, thereby influencing planting distribution.

5. Develop a list of potential species to be planted by eliminating species from the list that do not meet the objectives, species that have a high probability of becoming established through natural regeneration, and species that are not likely to survive on the specific site.

6. Determine the costs and benefits of proposed plantings. Although some costly plantings may provide valuable wildlife resources, natural regeneration may produce a plant community that is almost as valuable for a fraction of the cost. When planting oaks and other trees, the planting of small seedlings or direct seeding is generally more cost effective than planting large saplings because far more stock can be planted for the same amount of money. The greater stock rate more than compensates for the lower survival rate of smaller plants.

7. Plant vegetation only when it is determined that it is necessary to meet the desired objectives. On many sites, plants will become established through natural processes very quickly. In most cases, planting should be small scale, such as establishment of small patches that will serve as a seed source for natural spread to adjacent areas. Extensive planting usually is not justified, but may be necessary in some cases (e.g., converting open habitats to oak-dominated forests or establishing wetland plants in created wetlands where seedbanks are not already present).

8. Plant vegetation using approaches that will maximize survival rates. Plant each species in the appropriate site conditions and during the season recommended for its planting. For example, trees should be planted from late fall to early spring because mortality rates increase when trees are planted in the summer.

CHAPTER 9
SUMMARY

- Evaluation of borrow pit construction, wildlife mounds, modifications to North Chickamauga Creek, and vegetation plantings are addressed in the recommendation chapter of this report.

Water Quality

- Data showed few differences for water quality on the SR-29 site between the two studies. Construction activities seemed to have had minimal long-term effects on water quality in either lentic or lotic sites.

- Overall stabilization of water sampling sites, except for flood events, had probably occurred by 1982-83.

Fish and Benthos

- Mean richness and abundance values of benthic macroinvertebrate samples from North Chickamauga Creek were greater during this study than during the early 1980s, indicating additional colonization since the previous study.

- Created riffle areas at Stations L and H provided substrates conducive to benthic macroinvertebrate colonization; however, these populations were impacted by widely fluctuating water levels.

- Macroinvertebrate populations in lower reaches of North Chickamauga Creek and in the Artificial Meander were affected by deposited silt and other erosional materials on substrates suitable for invertebrate colonization.

- Benthic invertebrate communities in the borrow pits were composed of organisms that commonly inhabit unconsolidated silt substrates and showed seasonal fluctuations in richness and abundance typical of lentic ecosystems.

- Fish communities in North Chickamauga Creek were most abundant at the constructed riffle areas; however, lower reaches appeared to support fair sport fish populations because of the presence of diverse fish habitat and low fishing pressure. Lotic fish populations were limited by available habitat and benthic macroinvertebrate populations.

- Fish were not collected from the borrow pits, but fish were present in both the Large and Small Borrow Pits, as evidenced by visual observations and the presence of discarded bait buckets.

Plants

- Nine different plant communities were identified on the SR-29 site. Most were early (i.e., herbaceous) or mid-successional (i.e., sapling / shrub) communities.

- Overall, herb diversity was high at the SR-29 study site, primarily because of the diversity of moisture and light conditions on the area. Japan grass and Japanese honeysuckle, exotic species, may threaten this diversity in the future by competing with native plants.

- Most herbaceous species that had been seeded or planted on the SR-29 site were commonly observed during this study, and several patches had spread. Some tree species that had been planted (i.e., black willow, yellow poplar, river birch, and sycamore) were so abundant on the area that it was evident that most had become established naturally.

- Although 33 different tree species were sampled in the five communities with a woody overstory, early- to mid-successional species dominated in all.

- Based on density and dominance values, sweetgum and yellow poplar were the most important tree species in the North and South Woods, indicating an early stage of forest succession or selective cutting practices in the past. These explanations are supported by the small size of overstory trees and the well-developed herbaceous layer in wooded habitats. The North Woods appeared more mature than the South Woods.

- Although a diversity of understory plants valuable to wildlife were documented on the SR-29 site, valuable tree species (e.g., oaks, hickories, and beeches) were noticeably absent, and trees large enough to provide other than very small cavities were rare.

- The herbaceous layer of the North and South Woods had not changed much since the early 1980s, probably because the successional stage of the forest and the amount of shading at that time were similar to those of today. In contrast, the Natural Swamp and open habitats in the central portion of the study area have apparently changed substantially; open fields have been replaced with robust herbaceous communities interspersed with shrubby vegetation, and the canopy of the swamp has closed.

- Changes in plant composition indicate that hydrology has changed on some sites since the early 1980s.

Reptiles and Amphibians

- Intensive reptile and amphibian surveys were not conducted in this study, but 25 species were captured or observed when conducting other field studies. Many more species were undoubtedly present on the SR-29 study site, but they are difficult to detect because of their relative scarcity and secretive nature.

- The diversity of habitats at the SR-29 site makes it a suitable area for several species of reptiles and amphibians not observed during this study, and the low number of reptiles and amphibians captured during this study should not be interpreted as low population densities.

- Frogs and toads were the most commonly encountered group on the study area, and many of them were detected because they vocalized, especially on cloudy days and at night. Frogs were most common around and in the Shallow Borrow Pit, but they were present in most habitats with standing water.

- The long, thin shape of the study site and close proximity to the highway probably detracted from its value as reptile and amphibian habitat because of high road mortality rates.

Birds

- The bird community at the SR-29 site was moderately diverse. The most common species were habitat generalists and species associated with shrubby fields, a reflection of habitat conditions at the site.

- Breeding bird density was lowest in open fields and highest in wooded habitats and ecotones between the woods and open fields. Although bird density was high in the North and South Woods, diversity was lower than in other habitats.

- Several species of forest-dwelling birds expected to breed in the North and South Woods were absent or rare, perhaps because of the location of wooded habitat at the edge of a large forest block, the immature stage of forest development, lack of critical forest features (i.e., specific types of trees) caused by past cutting practices (i.e., high-grading), or excessive disturbance caused by highway and railway traffic.

- The brown-headed cowbird, a nest parasite, and the European starling, an exotic species that competes with native species for nest sites, were uncommon at the SR-29 site and probably had little influence on bird density and diversity at the site.

- Wood duck broods were observed commonly at the study site, and the Beaver Pond, the Natural Swamp, and North Chickamauga Creek appear to provide good brood-rearing habitat. Nesting boxes have been placed at several locations in these habitats and are the probable nesting sites of wood ducks. The Large and Small Borrow Pits are too steeply sloped to provide habitat for ducks, and the Shallow Borrow Pit is too small.

- Minor changes in bird composition since the early 1980s are attributable to successional changes from open, grassy fields to robust herbaceous communities, interspersed with shrubby zones.

- The SR-29 site provides important resources for migrating birds, and a large diversity of species occur on the area for short periods of time during fall and spring migrations.

Mammals

- Ten species of small mammals were trapped from five different habitats. White-footed mice and eastern harvest mice composed 53.7% of all small mammals captured. White-footed mice are generalists and were captured in all habitats, but the other species were more specific to individual habitats.

- Number of small mammals captured per trap night was less during this study than during previous studies on the SR-29 site, and the ratio of white-footed mice to cotton rats increased since the early 1980s. Successional changes during the past 15 years from open, grassy fields to robust herbaceous communities probably caused these differences.

- Bats were observed on several occasions feeding over the Shallow Borrow Pit. The Large and Small Borrow Pits also provided feeding habitat for bats, but invertebrate prey are more abundant in shallow wetland habitats.

- Eastern gray squirrels were uncommon in the North and South Woods, probably because of the low number of mature oaks and hickories.

- Raccoons and swamp rabbits were common on the study area, but white-tailed deer were only occasionally detected. The long, thin shape of the SR-29 site, and its close proximity to the highway and railroad track perhaps make it more attractive to mid-sized mammals than to larger species.

- At least one family of beavers was present on the site, and their dam building activities have enlarged the Beaver Pond since the early 1980s. Although some gnawed trees and saplings were observed during this study, beaver damage did not appear excessive.

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APPENDIX


Artificial Meander - July 1980


Artificial Meander - September 1995

North end of Large Borrow Pit - August 1980

North end of Large Borrow Pit - July 1995

Small Borrow Pit - February 1980

Small Borrow Pit - June 1996

Shallow Borrow Pit from SR-29 - April 1980

Shallow Borrow Pit from SR-29 - August 1990

Shallow Borrow Pit from SR-29 - September 1995

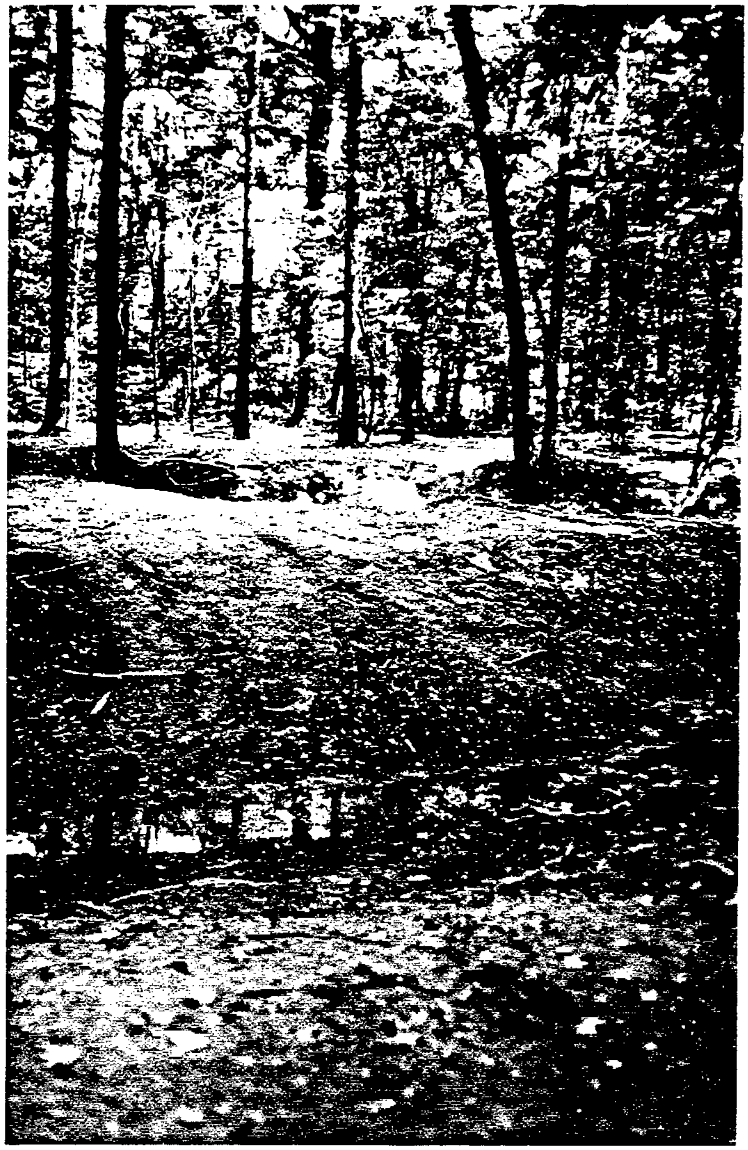
Shallow Borrow Pit during low water period - July 1995

Vegetation between Large Borrow Pit and SR-29 - July 1980

Vegetation between Large Borrow Pit and SR-29 - July 1995

Pine saplings that have naturally seeded in drier locations of SR-29 study site - May 1996

Road made through SR-29 study site by off-road vehicles - July 1995



Erosion in North Woods caused by off-road vehicle use - June 1995

Taxonomy of Identified Fish Species, SR-29 Study Site

Family	Scientific Name	Common Name
Catostomidae	*Hypentelium nigricans*	Northern hogsucker
	Minytrema melanops	Spotted sucker
	Moxostoma erythrurum	Golden redhorse
Centrarchidae	*Ambloplites rupestris*	Rock bass
	Lepomis auritus	Redbreast sunfish
	Lepomis cyanellus	Green sunfish
	Lepomis gulosus	Warmouth
	Lepomis macrochirus	Bluegill
	Lepomis megalotis	Longear sunfish
	Micropterus dolomieu	Smallmouth bass
	Micropterus punctulatus	Spotted bass
	Micropterus salmoides	Largemouth bass
	Pomoxis nigromaculatus	Black crappie
Cottidae	*Cottus bairdi*	Mottled sculpin
	Cottus carolinae	Banded sculpin
Cyprinidae	*Campostoma anomalum*	Stoneroller
	Cyprinus carpio	Common carp
	Luxilus coccogenis	Warpaint shiner
	Notropis leuciodus	Tennessee shiner
	Semotilus atromaculatus	Creek chub
Cyprinodontidae	*Fundulus olivaceous*	Blackspotted topminnow
Percidae	*Etheostoma caeruleum*	Rainbow darter
	Etheostoma jessiae	Blueside darter
	Etheostoma sinoterum	Snubnose darter
	Etheostoma stigmaeum	Speckled darter
	Perca flavescens	Yellow perch
	Percina caprodes	Logperch
Petromyzontidae	*Ichthyomyzon castaneus*	Chestnut lamprey
	Lampetra aepyptera	Least brook lamprey
Poeciliidae	*Gambusia affinis*	Mosquito fish
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum

Taxonomy of Identified Plant Species, SR-29 Study Site

Family	Species	Common name
Acanthaceae	*Justicia americana*	Water willow
Aceraceae	*Acer negundo*	Box elder
	Acer rubrum	Red maple
	Acer saccharinum	Silver maple
	Acer saccharum	Sugar maple
Alismataceae	*Sagittaria sp.*	Arrowhead
Amaryllidaceae	*Narcissus poeticus*	Daffodils
Anacardiaceae	*Rhus copallina*	Winged sumac
	Rhus glabra	Smooth sumac
	Rhus radicans	Poison ivy
	Rhus typhina	Staghorn sumac
Annonaceae	*Asimina triloba*	Paw paw
Apiaceae	*Cicuta maculata*	Water hemlock
	Cryptotaenia canadensis	Honewort
	Daucus carota	Queen anne's lace
Apocynaceae	*Amsonia tabernaemontana*	Blue star
Aquifoliaceae	*Ilex spp.*	Holly
Araceae	*Arisaema dracontium*	Green dragon
	Arisaema triphyllum	Jack-in-the-pulpit
Araliaceae	*Aralia spinosa*	Devil's walking stick
Aristolochiaceae	*Aristolochia macrophylla*	Dutchman's pipe
	Hexastylis arifolia	Wild ginger
Aspidiaceae	*Onoclea sensibilis*	Sensitive fern
	Polystichum acrostichoides	Christmas fern
Asteraceae	*Achillea millefolium*	Yarrow/milfoil
	Ambrosia artemisiifolia	Ragweed
	Ambrosia trifida	Ragweed
	Bidens spp.	Beggar ticks
	Carduus nutans	Nodding thistle
	Chrysanthemum leucanthemum	Oxeye daisy
	Coreopsis tripteris	Tall coreopsis
	Erigeron philadelphicus	Common fleabane
	Eupatorium perfoliatum	Upland boneset
	Eupatorium spp.	Joe-pye-weed

	Gnaphalium spp.	Rabbit tobacco
	Helenium spp.	Sneezeweed
	Krigia virginica	Dwarf dandelion
	Lactuca spp.	Lettuce
	Pyrrhopappus carolinianus	Similar to dandelion
	Senecio spp.	Golden ragwort
	Solidago spp.	Goldenrod
	Taraxacum officinale	Common dandelion
	Vernonia altissima	Ironweed
Balsaminaceae	*Impatiens capensis*	Spotted touch-me-not
Berberidaceae	*Podophyllum peltatum*	May apples
Betulaceae	*Alnus serrulata*	Tag alder
	Betula nigra	River birch
	Carpinus caroliniana	Iron wood
	Ostrya virginiana	Hop hornbeam
Bignoniaceae	*Anisostichus capreolata*	Cross vine
	Campsis radicans	Trumpet creeper
Blechnaceae	*Woodwardia areolata*	Netted chain fern
Boraginaceae	*Mertensia virginica*	Virginia bluebells
Brassicaceae	*Cardamine concatenata*	Cut-leaved toothwort
	Lepidium virginicum	Peppergrass
	Thlaspi perfoliatum	Penny-cress
Calycanthaceae	*Calycanthus floridus*	Spice bush
Campanulaceae	*Lobelia cardinalis*	Cardinal flower
	Lobelia inflata	Indian tobacco
	Specularia perfoliata	Venus looking glass
Caprifoliaceae	*Lonicera japonica*	Japanese honeysuckle
	Sambucus canadensis	Elderberry
	Viburnum cassinoides	Viburnum
Caryophyllaceae	*Cerastium spp.*	Mouse eared chickweed
	Dianthus armeria	Deptford pink
	Stellaria pubera	Star chickweed
Celastraceae	*Euonymus americanus*	Strawberry bush
Clethraceae	*Clethra acuminata*	Sweet pepperbush
Commelinaceae	*Commelina communis*	Asiatic day flower
	Tradescantia subaspera	Spiderwort
Convolvulaceae	*Cuscuta sp.*	Dodder
	Ipomoea pandurata	Wild potato vine

Cornaceae	*Cornus amomum*	Silky dogwood
	Cornus florida	Flowering dogwood
Cupressaceae	*Juniperus virginiana*	Eastern red cedar
Cyperaceae	*Carex spp.*	Sedge
	Cyperus spp.	Sedge
	Elocharis sp.	Spike-rush
	Scirpus sp.	Bulrush
Dioscoreaceae	*Dioscorea villosa*	Wild yam
Ebenaceae	*Diospyros virginiana*	Persimmon
Ericaceae	*Gaylussacia sp.*	Huckleberry
	Kalmia latifolia	Mountain laurel
	Oxydendrum arboreum	Sour wood
	Rhodendron canescens	Rhodendron
Euphorbiaceae	*Euphorbia corollata*	Flowering spurge
Fabaceae	*Albizia julibrissin*	Mimosa
	Apios americana	Ground nut
	Cassia fasciculata	Partridge pea
	Cercis canadensis	Redbud
Fabaceae	*Desmodium sp.*	Beggar's ticks
	Lathyrus hirsutus	Pea plant
	Lespedeza bicolor	Bicolor lespedeza
	Lespedeza cuneata	Sericea lespedeza
	Pueraria lobata	Kudzu
	Trifolium campestre	Yellow clover
	Trifolium pratense	Red clover
	Trifolium repens	White clover
	Vicia angustifolia	Vetch
	Vicia dasycarpa	Smooth vetch
Fagaceae	*Castanea pumila*	Allehgany chinquapin
	Fagus grandifolia	Beech
	Quercus acuminata	Sawtooth oak
	Quercus alba	White oak
	Quercus falcata	Southern red oak
	Quercus nigra	Water oak
	Quercus phellos	Willow oak
	Quercus rubra	Northern red oak
	Quercus shumardii	Shumard's oak
	Quercus stellata	Post oak

Geraniaceae	*Geranium carolinianum*	Geranium
	Geranium maculatum	Wild geranium
Haloragaceae	*Proserpinaca palustris*	Mermaid weed
Hamamelidaceae	*Hamamelis virginiana*	Witch-hazel
	Liquidambar styraciflua	Sweetgum
Hydrocharitaceae	*Andropogon gerardi*	Big bluestem
	Andropogon scoparius	Little bluestem
	Bouteloua curtipendula	Side-oats grama
	Eragrostis curvula	Weeping lovegrass
	Panicum virgatum	Switchgrass
	Sorghastrum nutans	Indiangrass
	Tripsacum dactyloides	Eastern gamagrass
Hydrophyllaceae	*Phacelia bipinnatifida*	Scorpion weed
Hypericaceae	*Hypericum mutilum*	Dwarf St. John's wort
	Hypericum punctatum	Spotted St. John's wort
Iridaceae	*Sisyrinchium angustifolium*	Blue eyed grass
Juglandaceae	*Carya cordiformis*	Bitternut hickory
	Carya ovata	Shagbark hickory
Juncaceae	*Juncus spp.*	Rush
Lamiaceae	*Glecoma hederacea*	Mint
	Monarda clinopodia	Basil balm
	Prunella vulgaris	Heal-all
	Pycnanthemum tenuifolium	Narrow leaved mint
	Salvia lyrata	Lyre leaved sage
	Scutellaria integrifolia	Hyssop skullcap
Lauraceae	*Sassafras albidum*	Sassafrass
Liliaceae	*Allium canadense*	Wild onion
	Erythronium americanum	Trout lily
	Polygonatum biflorum	Solomon's seal
	Smilacina racemosa	False solomon's seal
	Smilax rotundifolia	Greenbrier
Liliaceae	*Smilax spp.*	Greenbrier
	Smilax tamnifolia	Greenbrier
	Trillium cuneatum	Trillium
	Trillium flexipes	Trillium
	Yucca filamentosa	Bear-grass
Magnoliaceae	*Liriodendron tulipifera*	Tulip poplar
Melastomataceae	*Rhexia mariana*	Maryland meadow beauty
Menispermaceae	*Menispermum canadense*	Moonseed

Moraceae	*Morus rubra*	Red mulberry
Nyssaceae	*Nyssa sylvatica*	Black gum
Oleaceae	*Fraxinus pennsylvanica*	Green ash
	Ligustrum sinense	Privet
Onagraceae	*Ludwigia alternifolia*	Seedbox
	Ludwigia palustris	Water purslane
Oxalidaceae	*Oxalis rubra*	Purple wood sorrel
	Oxalis stricta	Yellow wood sorrel
	Oxalis violaceae	Purple wood sorrel
Passifloraceae	*Passiflora incarnata*	Maypops
	Passiflora lutea	Maypops
Phytolaccaceae	*Phytolacca americana*	Pokeweed
Pinaceae	*Pinus echinata*	Short leaf pine
	Pinus taeda	Loblolly pine
	Pinus virginiana	Virginia pine
	Tsuga canadensis	Eastern hemlock
Plantaginaceae	*Plantago lanceolata*	English plantain
Platanaceae	*Platanus occidentalis*	Sycamore
Poaceae	*Agrostis stolinifera*	Redtop
	Andropogon virginicus	Broomsedge
	Arundinaria gigantea	Switch cane
	Dactylis glomerata	Orchard grass
	Elymus spp.	Rye grass
	Festuca spp.	Fescue
	Microstegium vimineum	Japan grass
	Panicum spp.	Panic-grass
	Phleum pratense	Timothy grass
	Setaria spp.	Foxtail grass
Polemoniaceae	*Phlox amoena*	Purple phlox
	Phlox maculata	Wild sweet william
Polygonaceae	*Polygonum hydropiperoides*	Knotweed
	Polygonum pensylvanicum	Pink knotweed
	Polygonum persicaria	Long bristle knotweed
	Polygonum sagittatum	Knotweed
	Rumex acetosella	Sheep sorrel; sour grass
	Rumex crispus	Curly dock
Portulacaceae	*Claytonia virginica*	Spring beauty
Primulaceae	*Lysimanchia spp.*	Fringed loostrife

Ranunculaceae	*Anemonella thalictroides*	Rue anemone
	Clematis virginiana	Virgin's bower
	Ranunculus abortivus	Kidney-leaved buttercup
	Ranunculus hispidus	Buttercup
	Ranunculus recurvatus	Hooked crowfoot
	Ranunculus septentrionalis	Swamp buttercup
Rhamnaceae	*Rhamnus caroliniana*	Carolina buckthorn
Rosaceae	*Crataegus sp.*	Hawthorn
	Potentilla simplex	Five fingers
	Prunus serotina	Black cherry
	Rosa spp.	Rose
	Rubus spp.	Blackberry, dewberry
Rubiaceae	*Cephalanthus occidentalis*	Button bush
	Diodia virginiana	Buttonweed
	Galium asprellum	Rough bedstraw
	Galium spp.	Bedstraw
	Galium triflorum	Bedstraw
	Houstonia caerulea	Bluets
	Houstonia purpurea	Bluets
Salicaceae	*Populus deltoides*	Cottonwood
	Salix nigra	Black willow
Saururaceae	*Saururus cernuus*	Lizard's tail
Saxifragaceae	*Hydrangea arborescens*	Hydrangea
	Tiarella cordifolia	Foam flower
Scrophulariaceae	*Chelone sp.*	Turtlehead
	Linaria canadensis	Toad flax
	Lindernia anagallidea	Lindernia
	Paulownia tomentosa	Princess tree
Solanaceae	*Solanum carolinense*	Horse nettle
Staphyleaceae	*Staphylea trifolia*	Bladdernut
Styracaceae	*Halesia carolina*	Silverbell tree
Tiliaceae	*Tilia americana*	American basswood
Ulmaceae	*Celtis laevigata*	Hackberry
	Ulmus alata	Winged elm
	Ulmus americana	American elm
	Ulmus rubra	Slippery elm
Urticaceae	*Boehmeria cylindrica*	False nettle
	Laportea canadensis	Wood nettle
Valerianaceae	*Valerianella radiata*	Corn salad

Violaceae	*Viola blanda*	White/purple violet
	Viola eriocarpa	Yellow violet
	Viola papilionacea	Blue violet
Vitaceae	*Parthenocissus quinquefolia*	Virginia creeper
	Vitis spp.	Grape vine

Taxonomy of Identified Reptile and Amphibian Species
SR-29 Study Site

Family	Scientific Name	Common Name
Ambystomatidae	*Ambystoma opacum*	Marbled salamander
Bufonidae	*Bufo americanus*	American toad
	Bufo woodhousei	Fowler's toad
Chelydridae	*Chelydra serpentina*	Snapping turtle
Colubridae	*Carphophis amoenus*	Eastern worm snake
	Coluber constrictor	Black racer
	Elaphe guttata	Corn snake
	Elaphe obsoleta	Black rat snake
	Lampropeltis getulus	Black king snake
	Nerodia septemvittata	Queen snake
	Nerodia sipedon	Northern water snake
	Storeria dekayi	Brown snake
	Thamnophis sirtalis	Eastern garter snake
Emydidae	*Chrysemys picta marginata*	Midland painted turtle
	Chrysemys picta picta	Eastern painted turtle
	Chrysemys scripta	Red ear pond slider
	Terrapene carolina	Box turtle
Hylidae	*Acris crepitans*	Northern cricket frog
	Hyla crucifer	Spring peepers
	Hyla sp.	Gray treefrog
	Pseudacris triseriata	Upland chorus frog
Kinosternidae	*Sternotherus minor*	Striped-neck musk turtle
	Sternotherus odoratus	Stinkpot turtle
Plethodontidae	*Eurycea bislineata*	Two-lined salamander
	Plethodon cinereus	Red-backed salamander
	Plethodon glutinosus	Slimy salamander
Ranidae	*Rana catesbeiana*	Bull frog
	Rana clamitans	Green frog
	Rana palustris	Pickerel frog
	Rana pipiens	Leopard frog
	Rana sylvatica	Wood frog
Salamandridae	*Notophthalmus viridescens*	Red-spotted newt
Scincidae	*Eumeces inexpectatus*	Southeastern five-lined skink
Viperidae	*Agkistrodon contortrix*	Copperhead

Taxonomy of Identified Bird Species, SR-29 Study Site

Family	Scientific Name	Common Name
Accipitridae	*Buteo jamaicensis*	Red-tailed hawk
	Buteo platypterus	Broad-winged hawk
Alcedinidae	*Megaceryle alcyon*	Belted kingfisher
Anatidae	*Aix sponsa*	Wood duck
Apodidae	*Chaetura pelagica*	Chimney swift
Ardeidae	*Ardea herodias*	Great blue heron
	Butorides striatus	Green heron
Cathartidae	*Cathartes aura*	Turkey vulture
Columbidae	*Zenaida macroura*	Mourning dove
Corvidae	*Corvus brachyrhynchos*	American crow
	Cyanocitta cristata	Blue jay
Cuculidae	*Coccyzus americanus*	Yellow-billed cuckoo
Fringillidae	*Cardinalis cardinalis*	Northern cardinal
	Carduelis tristis	American goldfinch
	Guiraca caerulea	Blue grosbeak
	Melospiza melodia	Song sparrow
	Passerina cyanea	Indigo bunting
	Pipilo erythrophthalmus	Rufous-sided towhee
	Spizella pusilla	Field sparrow
Hirundinidae	*Hirundo rustica*	Barn swallow
Icteridae	*Agelaius phoeniceus*	Red-winged blackbird
	Molothrus ater	Brown-headed cowbird
	Quiscalus quiscula	Common grackle
	Sturnella magna	Eastern meadowlark
Mimidae	*Dumetella carolinensis*	Gray catbird
	Mimus polyglottos	Northern mockingbird
	Toxostoma rufum	Brown thrasher
Paridae	*Parus bicolor*	Tufted titmouse
	Parus carolinensis	Carolina chickadee
Parulidae	*Geothlypis trichas*	Common yellowthroat
	Icteria virens	Yellow-breasted chat
	Oporornis formosus	Kentucky warbler
	Protonotaria citrea	Prothonotary warbler
	Seiurus motacilla	Louisiana waterthrush

Phasianidae	*Colinus virginianus*	Northern bobwhite
Picidae	*Centurus carolinus*	Red-bellied woodpecker
	Colaptes auratus	Northern flicker
	Dryocopus pileatus	Pileated woodpecker
	Picoides pubescens	Downy woodpecker
	Picoides villosus	Hairy woodpecker
Sittidae	*Sitta carolinensis*	White-breasted nuthatch
Sturnidae	*Sturnus vulgaris*	European starling
Sylviidae	*Polioptila caerulea*	Blue-gray gnatcatcher
Thraupidae	*Piranga rubra*	Summer tanager
Trochilidae	*Archilochus colubris*	Ruby-throated hummingbird
Troglodytidae	*Thryothorus ludovicianus*	Carolina wren
Turdidae	*Hylocichla mustelina*	Wood thrush
	Turdus migratorius	American robin
Tyrannidae	*Empidonax virescens*	Acadian flycatcher
	Myiarchus crinitus	Great crested flycatcher
	Sayornis phoebe	Eastern pheobe
	Tyrannus tyrannus	Eastern kingbird
Vireonidae	*Vireo flavifrons*	Yellow-throated vireo
	Vireo griseus	White-eyed vireo
	Vireo olivaceus	Red-eyed vireo

Taxonomy of Identified Mammal Species, SR-29 Study Site

Family	Species	Common name
Canidae	*Canis domesticus*	Domestic dog
Castoridae	*Castor canadensis*	Beaver
Cervidae	*Odocoileus virginianus*	White-tailed deer
Cricetidae	*Microtus pennsylvanicus*	Meadow vole
	Mus musculus	House mouse
	Ondatra zibethicus	Muskrat
	Oryzomys palustris	Marsh rice rat
	Peromyscus leucopus	White-footed mouse
	Peromyscus nuttalli	Golden mouse
	Reithrodontomys humulis	Eastern harvest mouse
	Sigmodon hispidus	Cotton rat
Didelphiidae	*Didelphis marsupialis*	Opossum
Leporidae	*Sylvilagus aquaticus*	Swamp rabbit
	Sylvilagus floridanus	Eastern cottontail
Procyonidae	*Procyon lotor*	Raccoon
Sciuridae	*Sciurus carolinensis*	Eastern gray squirrel
Soricidae	*Blarina brevicauda*	Short-tailed shrew
	Cryptotis parva	Least shrew
	Sorex longirostris	Southeastern shrew

Excerpt from "Evaluation of highway impacts and mitigation measures on wildlife habitat. Final Report to Appalachian Regional Commission and State of Tennessee Department of Transportation," 1984, C.B. Coburn, Jr., B.L. Ridley, G.K. Ensor, pp. 1-8.

GEOMORPHOLOGY

The headwaters of the North Chickamauga Creek and its tributaries are the forested shallow soils covering Pennsylvanian and Upper Mississippian sandstone atop Walden Ridge. As the stream descends 1000 feet (305 m) to the floodplain along State Route 29, it traverses several Pennsylvanian and Upper Mississippian sandstone and clay shale layers. The sandstone boulder-strewn bed descends at an average rate of 1.7 feet per 100 feet (0.52 m per 30.5 m) to the Upper Mississippian Newman limestone valley floor. The average fall rate in the valley floor is 0.35 feet per 100 feet (0.11 m per 30.5 m).

During high flow, Falling Water Creek water has a similar history. However, at low flow, the water has percolated through Silurian Rockwood formation and/or Mississippian Fort Payne chert and into Mississippian Newman limestone before upwelling into the Newman limestone floor.

Historically and hydrologically, the North Chickamauga Creek basin was formed in a trellis pattern. As the basin matured, relatively young tributaries (Poe Branch, Falling Water Creek, and, more recently, the present headwater for North Chickamauga Creek) were formed. The mechanical and chemical erosion and deposition brought about by these new steams changed the flow characteristics of the basin.

Degrading along the channel, now known as the North Chickamauga Creek headwaters, was primarily mechanical. With a gradient of 2 feet per 100 feet (0.6 m per 30.5 m), the water flow was turbulent and rapid, thus carrying large quantities of suspended solids to the basin. At the juncture, the velocity and turbulence were greatly reduced and solids were deposited forming natural levees. With this rise in land, most of the area north of this juncture flowed into the Tennessee River via Sale Creek, the exception being Poe Branch which had previously developed a spit and bar which had sheltered it from early deposition of the North Chickamauga Creek.

At that time, the entire basin began to aggrade. Hydrologic competency changed as the water proceeded down the basin and deposited larger particles near its confluence and smaller particles farther down the basin. Very small particles were deposited as the stream approached the longitudinal gradient which had been previously elevated by the natural alluvial levee of Falling Water Creek. Because of this rise in the basin, heavy rainfalls resulted in flooding and consequent deposition of fine particulates which covered the early alluvium.

As a result of the early differential deposition, the particulate composition of the underlying strata between Thrasher Pike and the confluence of Falling Water Creek has a gradient from cobble to fine silts rich in organic matter. These physiomorphological differences influence subsurface water quality.

Water flow in the basin north of a point approximately halfway of the north borrow pit is normally subsurface except during periods of high rainfall. The flow beyond this is derived from springs and seeps. Basically, these subsurface waters result from the headwaters of North Chickamauga Creek and Poe Branch going underground into cobble rich strata at their confluence with the basin and from percolation of vadose water. The exception is Cave Springs which flows out of the west side of Cave Springs Ridge. Water from Cave Springs is probably a combination of percolation through Newman limestone on Cave Springs Ridge and subterranean flow of North Chickamauga Creek.

Due to the aggrading, the transverse profile was elevated and the longitudinal profile became less steep between the present Thrasher Pike and the levee of Falling Water Creek. During normal flow, little channel erosion would occur. However, during high rain periods, velocity and content of molar agents would increase, resulting in channel erosion. Meanders would form, become oxbow lakes, and silt in.

In the vicinity of Falling Water Creek's confluence, the terrain is rather flat as a result of siltation by the two streams. Also, the two streams are in continuous flow at this location. These stream dynamics result in a braided stream pattern. South of Falling Water Creek, the North Chickamauga Creek assumes a steeper grade with a rather consistent channel, resulting in less dramatic fluvial dynamics.

Activity of man in the last couple decades has significantly altered the fluvial dynamics between Thrasher Pike and Falling Water Creek. Agricultural practices have added sediments to the stream in runoff from small rains. Of most importance was channelizing the stream along the eastern side of the basin. The straight, narrow channel was dug down to the base rock on a terrace of the original basin. During rainy seasons, the flow was rapid and laminar scouring of the bed and banks resulted. The lack of substrate and low quantities of dissolved material in the water provided for very low biological productivity.

Channelization also produced several artificial lakes of the dammed loops in the old stream bed. Sediments from periodic flooding of the basin and from leaf fall have settled to the bottom filling these lakes at an average rate of 0.80 inches (2.0 cm) per year before the construction of State Route 29 through the basin. This rate accelerated after construction began.

The drainage area for North Chickamauga Creek and its tributaries is primarily medium aged mixed-mesophytic forest with some pastureland. The valley floor is predominantly pastureland and the sprawling Soddy-Daisy community of 8000 people. Streams are riparian communities vegetated with an overstory of sycamore, poplar, oak, and hickory, and a dense understory dominated by river birch, pawpaw, and sassafras. Abandoned fields in various stages of succession are throughout the valley.

Major weather influences on the area are from the northwest from November through March and from the southwest from April through October.

Floodplain soils are derived from cumulative overbank deposition of material by a stream system during flood stage. This material is composed of organic and mineral matter and is transported primarily by the processes of suspension and siltation with running water as the fluid transport medium. The gross amount of material that a given volume of running water can transport over a period of time is referred to as a stream's capacity and is directly related to the velocity of the moving water. The size of particles that a stream can transport at a given time is referred to as the stream's competency and is directly related to the velocity of flow and inversely related to the density of the transported particles. Velocity of flow is determined by stream gradient, amount of water, and the degree of friction exerted by the stream channel. Friction increases with the unevenness of the stream channel and increases with the ratio of solid surface area to the volume of the channel. When running water leaves the stream channel during flood and moves out onto a floodplain, the surface area-to-water volume ratio increases greatly and velocity of flow is reduced.

Deposition occurs when the stream loses its capacity to transport solid material due to a reduction of velocity. As velocity declines over time, the larger and heavier particles will be deposited first, followed by progressively smaller particles as gravity exceeds the competency of running water to transport them. In general, the farther the flowing water is from the stream channel, the lower its velocity and competency, and deposition will be of finer particle size. As a stream meanders away from a particular site of deposition, the overwash will consist of progressively smaller particles. In general, a profile will consist of coarser material at the bottom grading progressively finer upward. Due to the great variability in the magnitude of floods, this vertical grading of sediment particle size can be said only to illustrate a general trend over time.

Floodplain soils are ecologically important due to the fact that they are usually level, deep, well-drained, and have a high capacity to supply water and nutrients to plants.

MITIGATION MEASURES

Construction of a highway through a floodplain will disrupt terrestrial and wetland habitats, impact the stream, and create new habitat. Various citizen action groups stated that one or more of these alterations would adversely affect the ecology of an area. The departments of transportation have tried to compensate by mitigation or creating substitute habitats. There was considerable disagreement within and among these groups on effects and benefits resulting from construction and operation practices in the floodplain. The controversy was based on lack of research data to support the claims of harm or benefits of a given allegation. To scientifically test many of these, the Tennessee Department of Transportation designed a floodplain management plan to include tested and untested mitigation techniques for ameliorating terrestrial and aquatic habitat disruption. The ecological soundness of these was investigated over a three year period.

Terrestrial mitigations included taking much of the floodplain out of cultivation and pastures to revegetate with erosion-resisting vegetation that can stand short term flooding. Native trees, berry, and grape species were planted in selected areas to provide canopy and a nucleus for accelerated succession. High mound areas were constructed to entice small mammals and burrowing mammals away from the highway. These were variously vegetated.

Three types of borrow areas were constructed. A large borrow pit (approximately 20 acres or 8.1 ha) was constructed with shallow ends and steep sides with a year-round pool maintained by having been constructed into the ground water table. The steeper east and west sides were planted in river birch, willow, blackberry, and muscadine grapes. Outlying areas were seeded with fescue and bicolor lespedeza to prevent sheet erosion. A small (approximately 1 acre or 0.4 ha), circular, deep (15 feet or 4.6 m) borrow pit was also constructed into the water table and willow was planted along the water's edge. This borrow pit was flanked by high mound areas separating this borrow pit from a shallow borrow pit which was not deep enough to be in the water table during summer months. Water stood in it during winter and spring months and it dried during summer and fall, thus mimicking a natural slough that was adjacent to it.

Stream mitigations included replacement of substrate in previously rechanneled areas. Artificial pools and riffles were also constructed with extraneous substrate. An artificial meander was constructed. Even though this meander was designed to the physiomorphology of natural meanders, the actual construction was aberrant.

GLOSSARY

abundance: total number of organisms collected in a sample

allochthonous: refers to something formed elsewhere and transported to the site in question

alluvial soils: soils deposited by running water

anthropogenic: has an origin due to the activities of man

basal area: amount of a defined area covered by tree trunks, usually measured at 4.5 ft above the ground

benthos: aquatic, bottom-dwelling organisms

biogeochemical: processes involving the interaction of biological organisms, geologic formations, and chemical reactions

biosurvey: systematic listing of living organisms in a defined area

biota: living things (animals, plants, bacteria, fungi, etc.)

BOD: biochemical oxygen demand; an indicator of oxygen used in decomposition of organics in the water

community: all of the organisms within a defined area

DBH: diameter at breast height; diameter of a tree at 4.5 ft above the ground

detritus: dead organic matter and its associated bacterial organisms

dominance: measurement of the importance of individual species within a community

ecotone: an ecological community of mixed vegetation formed by the overlapping of adjoining communities

ephemeral: temporary in nature

EPT Index: proportion of those invertebrate species within the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) in a sample when compared to total number of organisms in the sample. EPT values of 0.5 or greater indicate acceptable water quality.

extirpate: eliminate a species from an area in which it formerly occurred

facultative plants: plants that are found commonly in both wetland and upland habitats

fauna: all animal life within a defined area

fluvial: referring to streams

geomorphology: an earth structure

habitat: place where an organism lives and its surroundings

herbaceous vegetation: plants that lack woody tissue; sometimes defined as plants shorter than a specific height

herbivorous: a species that primarily consumes plant material

hydric: wet or moist

hydrophyte: plants that grow only in wet (flooded or saturated) conditions

importance value: an expression of the relative importance of a species in a community

kick net sample: sample of bottom-dwelling aquatic organisms that is obtained by kicking the bottom sediments to dislodge the organisms into a net

lentic: referring to standing water

littoral: a shore region of a body of water, often containing rooted aquatic plants

lotic: referring to flowing waters

macroinvertebrates: animals without backbones that are large enough to be seen without the aid of a microscope

macrophyte: aquatic - rooted vegetation in an aquatic ecosystem

emergent - that portion of rooted aquatic vegetation that lies on or above the water's surface

submergent - that portion of rooted aquatic vegetation that grows completely underwater

mast: fruit of trees (e.g., acorns) used as a food source by animals mesic: moderately moist; intermediate between hydric and xeric

mitigation: efforts to moderate in force or intensity; alleviate or compensate

monoculture: plant community or portion of a community consisting of a single species

morphometry: shape

neotropical migrants: birds that migrate between North America and South America

obligate plants: plants that occur almost entirely in hydric conditions

omnivore: organism that eats plants and animals

otolith: ear bones of bony fishes that are commonly used to determine the age of fishes

palustrine: shallowly flooded and/or supporting hydric vegetation

passerine: perching birds (i.e., most song birds)

periphyton: attached to submersed surfaces

pitfall trap: plastic cups or similar structures placed in the ground that capture small animals that fall into them

pool: a segment of a stream with reduced flow that is often deeper than other stream segments

population: a group of organisms of the same species in a given location

productivity: rate of accumulation of living material at a location

richness: total number of different groups (taxa) of organisms

riffle: a shallow segment of a stream with rapid/turbulent flow over gravel or rock substrate

riparian: referring to the banks of a stream/river

run: stream habitat type where water is moving, but not turbulent

subclimax community: plant community that is late in a successional sequence, but not in the final (i.e., climax) stage

substrate: a foundation on which organisms live symbiotic fungi: fungi that grow in association with certain species of plants; often the plant and fungi are dependent upon each other for survival

taxa: a group of closely related organisms as defined by an approved classification system

transect: sampling line from which various data (e.g., bird and plant data) are collected

trap night: measurement of trapping effort (i.e., one trap set for one night)

turbidity: measurement of the degree of cloudiness in water as caused by suspended materials

unconsolidated: soupy; not solid

vegetative strata: structural plant zones within a community usually based largely on height above ground

woody vegetation: plants containing woody tissues (i.e., trees, shrubs, and many vines); sometimes defined as plants taller than a specific height

xeric: dry

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