INVESTIGATION OF THE RELATIONSHIP BETWEEN FLOODPLAIN

GEOMORPHOLOGY AND RIPARIAN SONGBIRD COMMUNITIES

By

Stephanie Nicole Hyder

(Under the direction of Drs. C. Rhett Jackson and Robert J. Cooper)

ABSTRACT

Riparian forests support diverse songbird communities. Many species that breed in riparian forests are considered 'area sensitive', meaning that they are usually not found in areas less than 100 hectares. Neotropical migrants make up a large portion of this group. This research attempted to identify relationships between stream and valley characteristics and associated riparian bird communities. We selected forty sites in the Piedmont region of Georgia, which varied in channel and floodplain characteristics. Songbird counts were conducted from May to June of 2000 and 2001 using transect counts.

Using Canonical Correspondence Analysis and Logistic Regression we attempted to determine which variables were most strongly correlated with the songbird community. We found that riparian songbird communities are generally unresponsive to stream and floodplain geomorphology. Stream order is also generally unimportant to the bird community. Large and small order streams play an equally important role in providing habitat to riparian songbirds.

INDEX WORDS: Riparian forests, Neotropical migrant, Stream, Floodplain, Geomorphology, Canonical Correspondence Analysis

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DEDICATION

I dedicate this work to my parents, Brian and Anne Hyder. Thank you for your guidance, support and encouragement. Without it, I could not have come so far.

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I want to first thank the two people who made this project possible: Rhett Jackson and Bob Cooper. Rhett- thank you for your open door, your patience, and most of all, your friendship. Bob- your sense of humor, encouragement and confidence in my work has made this experience very rewarding. Thank you both for all of your advice and hard work. I feel very lucky to have you as mentors!

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CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

During his travels through Georgia, William Bartram used words like “pure”, “transparent,” “clear” and “crystal” to describe Piedmont streams (Harper, 1958). Settlers described bottomland soils as “dark and uniform in texture”, indicating that conditions had been stable for a long period of time. From these descriptions made during colonial times, we know that streams of the Piedmont were once relatively sediment-free. But, due to poor agricultural practices, this region experienced severe erosion from 1830-1930. It is estimated that 7.5 inches of topsoil was eroded from the Piedmont during this period, due to cotton cultivation. Erosion resulted in the formation of gullies and rills, which washed large amounts of sediment directly into streams and rivers (Trimble, 1974). This upheaval of Piedmont floodplains can be seen today in floodplain soils that retain years of deposition and erosion and streams that are no longer “clear” or “transparent”.

Much of this cultivated land began as riparian forests, which covered nearly 30 million acres across the southeastern United States. Today, only an estimated forty percent of that area remains of this unique ecosystem (Mitsch and Gosselink, 1993). Losses of these forests began in the early 1800’s and reached rates as high as 430,000 acres per year from 1965-1975, largely due to cropland conversion, which was mostly concentrated in the Mississippi Valley (Mitsch and Gosselink, 1993). Riparian forests of the Southeastern Piedmont have been diminished by urbanization, agriculture and clearcut timber harvests that sometimes leave narrow buffers along streams. The effects of poor agricultural practices of the past century are still impacting our streams and rivers. Since 1930, much floodplain farmland has reverted to hardwood forests and sometimes pine plantations.

Characteristics of bottomland forest such as floodplain size, soil type, wetness, flora and fauna, are defined by their geomorphology and hydrology, with basin area having a major influence on hydrology. The hydroperiod of floodplain inundation is defined by seasonal timing, frequency, duration, and depth of flooding events, as well as, climate, topography, channel slope, groundwater storage and geology (Mitsch and Gosselink, 1993). In turn, the hydroperiod plays a major role in determining the plant community of a forest. Floodplain geomorphology can encompass a variety of features including natural levees, terraces, back swamps, sloughs and oxbow lakes. All of these features impact the structure of the system through control of the velocity and volume of water movement. This in turn, influences the slope, terrace formation, degree of erosion and deposition of nutrients and sediment (Sharitz and Mitsch,1993).

Riparian forests serve a critical role within a watershed by shading channels, stabilizing streambanks, providing organic input to the aquatic system and connecting terrestrial and aquatic ecosystems. In addition, they greatly reduce the risk of flooding to downstream communities by providing areas to store floodwater (Guilfoyle, 2001). The bottomland hardwood forest ecosystem is a complex response to terrestrial and fluvial interactions.

Bottomland hardwood habitat is a unique forest habitat. It is linear, and often comprises large tracts of contiguous land surrounded by urban or agricultural settings.

Therefore, it serves as important refugia for 'area sensitive' species (Brinson et al., 1981). Area sensitive species are not found in fragments smaller than 100 hectares and are considered of special concern because of their habitat requirements (Cooper and Ford, 1994). Avian species make up a large percentage of 'area sensitive' species, many of which utilize bottomland forests in abundance, particularly during the breeding season. There are approximately 70 species of birds that breed in riparian forests, 30 of which are neotropical migrants (Kilgo et al.,1998). These migrant birds breed and fledge young in North America during spring and summer and spend winter in the tropical climates of Mexico, the Caribbean, Central and South America (Cooper and Ford,1994).

It is not a coincidence that many songbird populations have been declining as their primary riparian forest breeding habitat diminishes. Askins et al. (1990) recognized the correlation between dramatic population declines during 1940-1980 and the rapid conversion of riparian forest to agricultural and urban development. In particular, urbanization is occurring at high rates in the southeastern United States, where many neotropical migrants are considered species of special concern (Pashley and Barrow,1992; Hamel et al.,1996).

Our goal in this project was to determine the relationship between songbird populations that occupy riparian forests and stream and valley geomorphology. We hypothesized that differences in stream habitat and floodplain wetness would affect the macroinvertebrate prey base for songbirds and thus affect songbird communities. We focused on geomorphic variables generally considered to affect macroinvertebrate productivity and community structure. Specifically, we analyzed variables such as percent fines in channel substrate, amount of riffle habitat, woody debris loading, depth to floodplain water table, floodplain soil chroma and texture and vegetation structure and species composition. We believe that it is imperative to understand the habitat requirements of a group of species that are facing nationwide, regional and local population declines (Askins et al.,1990; Robbins et al.,1989). Such information is needed to guide habitat management and restoration policies. If we determine that certain species are associated with particular stream types, we will be better able to determine how to maintain and manage this habitat.

The objectives were:

(1) Relate songbird communities to stream and floodplain geomorphology and floodplain vegetation through the use of canonical correspondence analysis (CCA).

(2) Evaluate songbird presence or absence along gradients of stream or valley characteristics using relationships suggested by CCA. We expected to find a gradient of moisture conditions on our sites due to past land use practices that led to a variety of floodplain and channel features.

(3) Compare songbird richness and abundance between streams with full riparian forests, streams within buffered clearcuts and beaver swamps.

LITERATURE REVIEW

The importance of stream and floodplain geomorphology has been well documented for aquatic invertebrates and fish (Shields et al., 1994; Wallace et al.,1997; Hawkins and Sedell, 1980; Karr, 1991). For these species, biotic indices have been created to determine the effect that management practices and land use changes involving stream and floodplain geomorphology have on river and stream taxa (Murphy et al., 1981; Newbold et al., 1980). Stream health is estimated from these indices and data collected during stream habitat assessments (Poff, 1997; Maddock, 1999).

Many studies involving riparian and aquatic species conclude that converting or intensively managing bottomlands often increases sediment loads to the stream or river, leading to channel simplification, such as decreasing the amount of riffle habitat (Davies and Nelson, 1994). Aquatic invertebrate communities may shift from shredders- which utilize coarse particulate organic matter, to collectors- which filter or gather fine particulate matter. Fish populations may also shift in response to changes in their habitat and a reduction in food resources for insectivorous and piscivorous species (Vannote et al., 1980).

Data have been collected that document declines in numbers of neotropical migrants. This includes the Breeding Bird Survey (BBS), the breeding bird census, radar monitoring during migration and a series of long term research projects. Declines have been documented for 107 species, one-third of all neotropical migrants (DeGraaf and Rappole, 1983). Many studies conclude that nearly all species with significant declines are forest-interior, 'area sensitive' species. Warblers make up a large portion of this group. Other 'area sensitive' species, such as most vireos and flycatchers, are interior-edge neotropical migrants. These groups are found breeding in abundance in riparian forests throughout the eastern United States. They are particularly vulnerable to nest predation and brood parasitism because they prefer to nest near or on the ground in open cup nests, rather than cavities. They also typically have a lower reproductive rate and smaller clutch size than resident or short-distance migrant species (Askins et al.,1990; Robbins et al.,1989). Results of several studies have concluded that migrant songbird populations are declining, while resident species are maintaining stable or increasing numbers (Askins et al.,1990; Robbins, 1989; Hunter, 1999).

Migration is the obvious difference between these groups of species, and it is the migrant group, for the most part, which is facing the largest declines. Riparian areas provide habitat for many species of migrating birds. For example, many species fly nonstop across the Gulf of Mexico in spring, often landing inland along riparian systems (Smith et al., 1993). River systems may be used as landmarks for aid in orienteering during migration to breeding grounds. Associated forests along these rivers may be significant for successful migration for many species. Extensive loss of riparian forests may increase mortality for some species and lack of available high quality stopover habitat may be a factor contributing to their declines (Moore et al.,1995).

In recent years, biologists and land managers have tried to gain a better understanding of how management practices affect resident and migrant populations. To do this, it is necessary to understand the habitat requirements of these species. Using stream and channel variables to predict the "health" of a system is common for species such as aquatic invertebrates or fish (Maddock, 1999). This system has only recently been attempted for avian species. It seems practical to use stream and floodplain characteristics to predict the presence of an avian community and understand their habitat requirements.

Two studies, in particular, have measured stream or floodplain characteristics in respect to the avian community in the area. Meiklejohn and Hughes (1999) used stream order to address this question in a study in Maine. Their objective was to explore the extent to which bird communities in riparian buffer strips downslope of large clearcuts resembled communities in riparian zones with intact forests. They compared bird use of buffers along main stem rivers, tributaries and reference zones with intact forest. Neotropical migrants were significantly more common than residents or short-distance migrants in all site types. Bird community composition differed between buffered and reference streams and between the main stem and tributaries. Reference sites along tributaries and main stem rivers were dominated by interior species (Ovenbird, Bay-Breasted Warbler, Black-Throated Green Warbler, Cape May Warbler, Blackburnian Warbler and Golden-Crowned Kinglet [See Appendix E for scientific names]). Main stem buffers had equal number of edge and interior species, while buffered tributary sites were dominated by edge species (Chestnut-Sided Warbler, Common Yellowthroat, White-Throated Sparrow, Blue Jay and American Crow). While vegetation structure and composition was similar among all sites and species richness, density and diversity varied little, the community composition varied considerably.

In the second study, Buckton and Oremerod (1997) developed a River Habitat Survey in a study in Wales, England to predict the habitat of river birds. Using five common river birds they were able to predict the distribution of these species along river systems. They measured vegetation, sediment size, number of structures along river and flow regime of each river in the study. The species of consideration were typical river birds: Dippers, Wagtails, Mallards, Goosanders and Common Sandpiper. Using multiple discriminant analysis, they were able to predict the presence of these birds 50-80% of the time.

Neotropical migrants are a very diverse group of species with a range of habitat preferences. Yet, studies have arrived at the same conclusion—bird community composition is predictably different in forest patches of different sizes (Askins et al., 1990). By far, the most common songbird studies involve the effects of timber harvest, buffer width and patch size on songbird abundance, species richness and nesting success.

Timber companies and private landowners are using streamside management zones, or riparian buffers, in increasing fashion. Many states require a minimum buffer when cutting near streams or rivers and others simply suggest their use as a part of a "Best Management Practice"(BMP), which were first introduced as part of the Erosion and Sedimentation Act of 1975. One of the most important roles of buffers is to protect and improve water quality by intercepting nonpoint source pollutants in surface and subsurface flows (Fischer et al., 2000). Healthy buffer strips may stabilize the stream channel, provide a means of erosion control and water temperature control through shading. Buffer zones provide essential habitat for resident and migratory songbirds. The question looms: How wide should the buffers be and do they really provide enough adequate habitat for area sensitive species?

A study by Thurmond et al. (1995) assessed population data within streamside management zones and intact forests of first and second order streams in South Carolina. They found an increase in neotropical migrant abundance with increased buffer width, although densities were similar among all width classes.

An increase in the number of neotropical migrant species with forest width was also reported by Keller et al.(1993) in a study in Maryland and Delaware. Their objective was to establish the effectiveness of riparian buffers as habitat for migrant species. Ten species significantly increased in probability of occurrence as stand width increased. These were: Acadian Flycatcher, Red-Eyed Vireo, Wood Thrush and Kentucky Warbler, all of which are considered ‘area sensitive’. They found that resident species abundance was unaffected by stand width. In the Piedmont of Georgia, Acadian Flycatcher, Northern Parula, Red-Eyed Vireo and White-Eyed Vireo had an increased probability of occurrence as stand width increased (Hodges and Krementz 1996).

Darveau et al. (1995) found that in forests of varying width, the median width sizes had the highest densities of birds. Forest-dwelling and ‘area sensitive’ species were less abundant in narrow strips. They estimated that 60-meter buffer widths are necessary for to sustain forest dwelling songbird communities.

Kilgo et al. (1998) and Triquet et al. (1990) reported similar findings. When comparing bird abundance and richness among stands of various widths, abundances were highest in the median stand widths. Acadian Flycatcher, Wood Thrush and Louisiana Waterthrush abundances were highest in the small width class. All of these species are considered ‘area sensitive’. In these studies, it seems that territory sizes are compacted into smaller areas, thereby increasing bird abundance, but not species richness. Both studies found higher species richness in wide stand widths. Edge species and early succession species benefit from buffer strips and adjacent disturbed habitat.

Blake and Karr (1987) conducted a similar study with various stand widths and concluded that width was an important variable in explaining the number of migrants and interior species, but less important for resident species.

Timber management and agricultural practices have improved greatly over the past decade. Yet, these practices cannot be held responsible for species declines. Urbanization and habitat fragmentation, rather than agriculture and forest management, are considered the primary reason for species decline and extinction in the United States

(DeGraaf and Rappole, 1983). Declining trends in songbird abundance do not have to be permanent. Site regeneration allows intensively managed forests to recover, and with time many species will return to the area (Darveau et al., 1995). Agricultural fields with adjacent forest tracts benefit both early succession and forest interior species. A multilayered, contiguous forest tract can support a maximum diversity of birds, because they provide a variety of seres, including early successional patches in areas where trees have been removed in small patch cuts (Cooper and Ford, 1994).

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CHAPTER TWO

INVESTIGATION OF THE RELATIONSHIP BETWEEN FLOODPLAIN GEOMORPHOLOGY AND RIPARIAN SONGBIRD COMMUNITIES

Hyder, S.N., C.R. Jackson and R.J. Cooper. To be submitted to *Wetlands.*

ABSTRACT

Riparian forests support diverse songbird communities. Stream size, channel slope and velocity of flow, soil moisture and vegetation contribute to the unique qualities of bottomland hardwood forests. Many species that breed in riparian forests are considered ‘area sensitive’, meaning that they are usually not found in areas less than 100 hectares. Neotropical migrants make up a large portion of this group. This research attempted to identify relationships between riparian forest area, stream and valley characteristics and associated riparian bird communities.

We selected forty sites in the Piedmont region of Georgia, which varied in channel and floodplain characteristics. Each stream and valley was surveyed for specific variables that described the qualities of that site. Songbird counts were conducted from May to June of 2000 and 2001 using transect counts.

Canonical Correspondence Analysis and Logistic Regression were used to determine which variables were most strongly correlated with the songbird community. We found that riparian songbird communities are generally unresponsive to stream and floodplain geomorphology. Variables such as percent riffle or bank incision were not as important to the birds as percent canopy cover or floodplain width. However, stream order may be important to the bird community. Large and small order streams appear to play an equally important role in providing habitat to riparian songbirds. Therefore, protection of small order stream habitat may be essential to the songbird community.

INTRODUCTION

Neotropical migrants are western hemisphere species, all or part of whose populations breed north but winter south of the Tropic of Cancer. Population declines are not well understood and it may be difficult to distinguish large-scale trends from local fluctuations. Declines may be due to many reasons: loss of breeding ground, habitat fragmentation, breeding ground habitat changes, contaminants, wintering ground habitat loss, stopover habitat loss, depredation, brood parasitism or normal population fluctuations. Subtle habitat changes can be beneficial or detrimental to many species. Broken forest tracts result in an increase of generalists and predators, such as cats, raccoons, snakes. But, rates of population change in North America are slow compared to the tropics (DeGraaf and Rappole, 1983).

Bottomland hardwood forests are the breeding habitat for many of these species (Askins, 1990). Our objectives in this study were to determine whether features unique to riparian forests, other than vegetation, are important to songbirds. Specifically, we measured many geomorphologic features of forty Southern Piedmont streams, rivers and beaver impoundments in order to determine whether they were correlated with the songbird community inhabiting the area. Determining habitat preferences is important to land managers wanting to maintain or improve existing habitat.

A review of the life histories of riparian songbirds suggests that floodplain geomorphology may be important to some species. Because many of these birds will forage on aquatic insects or floodplain vegetation, it was hypothesized that floodplain and stream geomorphology would affect food and habitat availability in ways that affected songbird community structure. All species are insectivorous during the breeding season and will feed opportunistically on suddenly abundant food sources like hatches of aquatic insects. Some species switch in part or completely to fruit in the fall (Gill, 1990). Southeastern Piedmont riparian songbird communities include Acadian Flycatcher, Louisiana Waterthrush, Eastern Wood-Pewee, Wood Thrush and Red-Eyed Vireo.

During the surveys, a total of 38 species were observed (see Appendix E). We selected eleven species as “target species” for analysis. These eleven were selected because of their habitat preferences or their detection rate in this study. They range from early succession species, meaning they prefer open, disturbed habitats while others are classified as interior or interior edge. For example, we did not include in our group of ‘target species’, generalists such as Northern Cardinal, American Crow or Mourning Dove. We did not include species that were detected at all or nearly all of our sites. These included Acadian Flycatcher, Carolina Wren, Tufted Titmouse, and most woodpecker species. By the same account, we did not include species such as Prairie Warbler or Golden Crowned Kinglet that we detected at only one or two sites. This elimination process left us with a group of eleven birds, which we used for analyses.

SPECIES ACCOUNTS

Early Successional Species

Indigo Bunting

Indigo Buntings are early-succession species, typically absent in urban areas, dense forest or intensively cultivated land. Their habitat is predominantly abandoned fields or roadsides, brushy, weedy habitats, riparian habitats or open deciduous woods within clearings. Nests are found most often in low branching vegetation. As a population they are increasing in range and density the eastern United States (Payne, 1992). Indigo Buntings are the only early succession species within our group of target species. We detected them more frequently in buffered sites and beaver impoundments (Figure 2.39). Throughout the southeast (Figure 2.1), these birds are increasing, although not significantly (trend 0.09, p>0.1). In Georgia, this species is increasing in the central portion of the state (trend 0.3, p=0.7). The Breeding Bird Survey, Patuxent Wildlife Center, Washington, DC, calculated the trends, which are an estimate of the percentage of population increase or decrease.

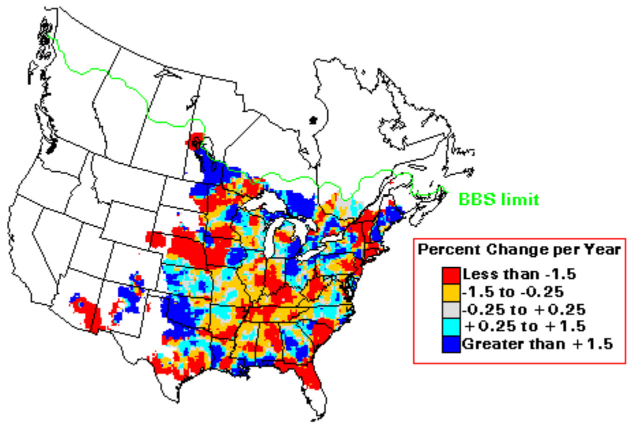

Figure 2.1. Breeding Bird Survey Population Trend of Indigo Bunting (Sauer et al., 2001).

Interior-Edge Species
Summer Tanager

Summer Tanagers are commonly found in pine-oak forests near gaps or edges. They prefer short tree height and open canopy cover. Tanager nests are typically found in branch forks, overhanging a roadway or treefall gap (Robinson, 1996). In the Southeast, Summer Tanagers are increasing (trend 0.3, p>0.1). Populations in Georgia are declining at a rate of –0.7 percent (p=0.41) per year.

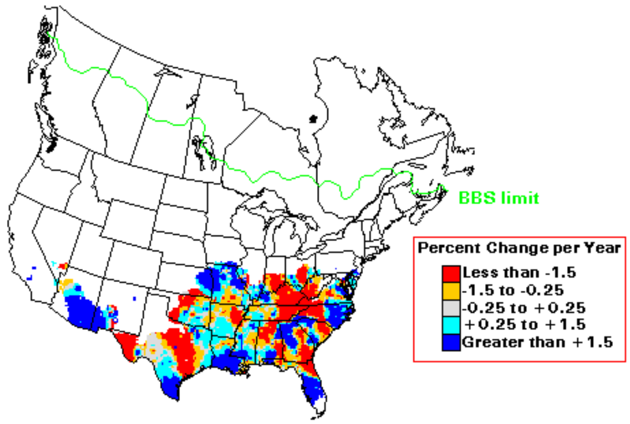

Figure 2.2. Breeding Bird Survey Population Trend of Summer Tanager (Sauer et al., 2001).

Wood Thrush

Wood Thrush populations have decreased significantly since the 1970's, and are facing declines throughout the Southeast (trend –1.5, p<0.1) and Georgia (trend –1.0, p=0.31; Figure 2.3). Their habitat requirements include a shrub subcanopy, dense canopy cover, moist soil and leaf litter. Wood Thrush breed in the interior and edge of deciduous and mixed forests. Nests are located low in shrubs and small trees. Species decline is due to destruction and fragmentation of breeding and wintering grounds as well as nest predators and brood parasites. They are considered a species of concern in the Southeastern United States (Roth, et al., 1996).

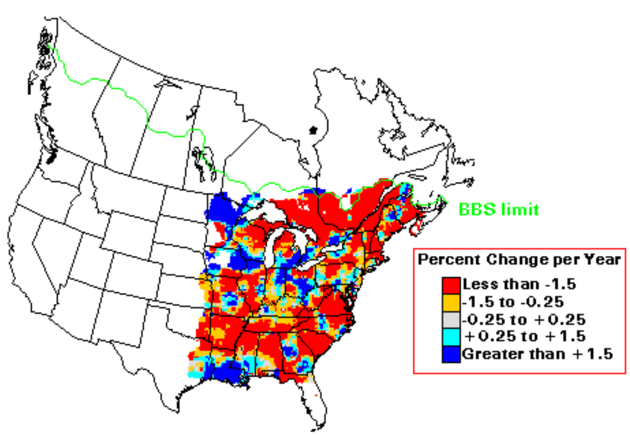

Figure 2.3. Breeding Bird Survey Population Trend of Wood Thrush (Sauer et al., 2001).

Eastern Wood-Pewee

The Eastern Wood-Pewee is ubiquitous across a gradient of forest communities-often found in wooded habitats, urban parks, roadsides, woodlots, orchards or open pine woodlands. These birds use edge and interior habitat and do not seem to be affected by fragmentation. Typically, they are absent in areas of high canopy cover. They feed primarily on flying insects. Pewee nests are located in small trees or saplings. The BBS has documented a recent decrease in population size (McCarty, 1996). It is an interior/edge species, distributed across the central and eastern United States. In the Southeast, BBS reports a significant population decline (trend –1.3, p<0.1).

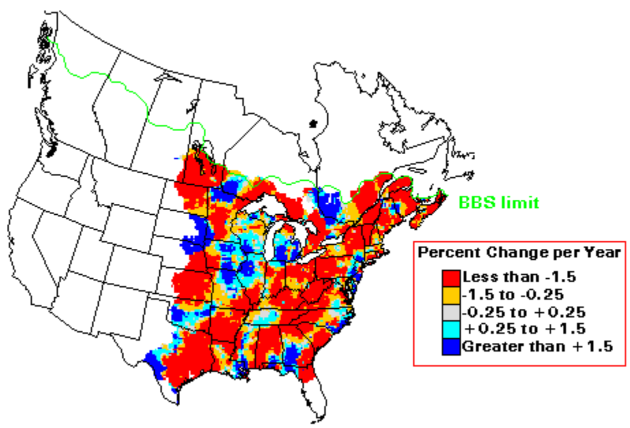

Figure 2.4. Breeding Bird Survey Population Trend of Eastern Wood-Pewee (Sauer et al., 2001).

Georgia trends are also declining, although the trend is not significant. From 1966-2000, BBS documents a –0.6 percent decline (p=0.37) (Sauer et al., 2001).

White-Eyed Vireo

White-Eyed Vireos are common in secondary deciduous scrub, wood margins, overgrown pastures and streamside thickets. Like Wood Thrush, they are heavily parasitized by Brown-Headed Cowbirds. White-Eyed Vireos nest in Y-shaped branches low to the ground (Hopp et al., 1995). Populations are increasing throughout the Southeast (trend 1.2, p>0.1), while decreasing in Georgia (trend –0.5, p=0.3; Figure 2.5).

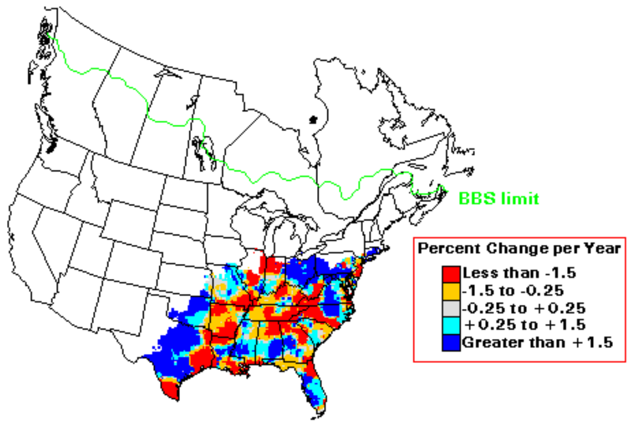

Figure 2.5. Breeding Bird Survey Population Trend of White-Eyed Vireo (Sauer et al., 2001).

Great Crested Flycatcher

These birds are commonly found in mixed woodlots, at the edge of clearings or in open deciduous forests. Although, these are their preferred habitats, they will occupy most any including agricultural and urban settings. They are unique in that they are secondary cavity nesters, the only cavity-nesting flycatcher in eastern North America, and may compete with other species such as Eastern Bluebirds or European Starlings, an exotic species (Lanyon, 1997). This species is an interior/edge species, preferring fragmented forests. The BBS reports a stable long-term trend for these species (Lanyon, 1997). In the Southeast, (Figure 2.6) BBS documents an increasing population (trend=1.4, p<0.1). Populations are also increasing in Georgia, (trend=1.4, p=0.07).

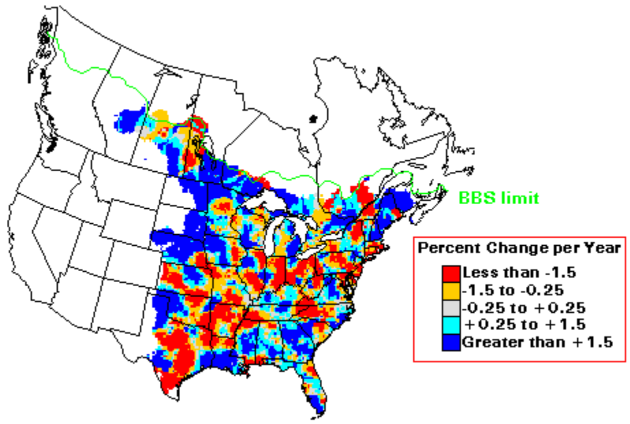

Figure 2.6. Breeding Bird Survey Population Trend of Great Crested Flycatcher (Sauer et al., 2001).

Interior Species
Pine Warbler

These birds are generally classified as 'area sensitive' interior species, requiring large tracts of uneven aged pine forests. Pine Warblers nest high in pine trees, which makes their nesting and breeding behavior difficult to study. Three habitat characteristics have been associated with Pine Warblers: percent canopy closure, successional stage of the stand and percent dominant canopy pines with deciduous understory. This forest type is decreasing with the increase in plantation pine forests in the southeast (Rodewald et al., 1999). Pine Warbler breeding density is inversely related to the percentage of deciduous vegetation in the canopy. Populations are increasing in the Southeastern United States. They typically have a negative association with stream presence (Rodewald et al., 1999). Throughout the Southeast, their populations are increasing or stable (Figure 2.7). In Georgia, they are also increasing through most of the state (trend 1.1, p=0.2).

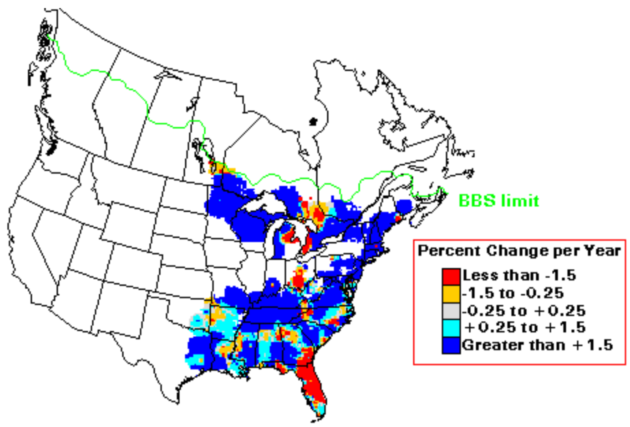

Figure 2.7. Breeding Bird Survey Population Trend of Pine Warbler (Sauer et al., 2001).

Kentucky Warbler

Kentucky Warblers prefer bottomland hardwood forests, with dense understory, near streams. Surveys have documented decreasing trends in the eastern United States (McDonald, 1994). In the Southeast (Figure 2.8), they are declining, although not with a significant trend (-0.09, $p>0.1$). Georgia populations are increasing through most of the state (3.3, $p=0.1$).

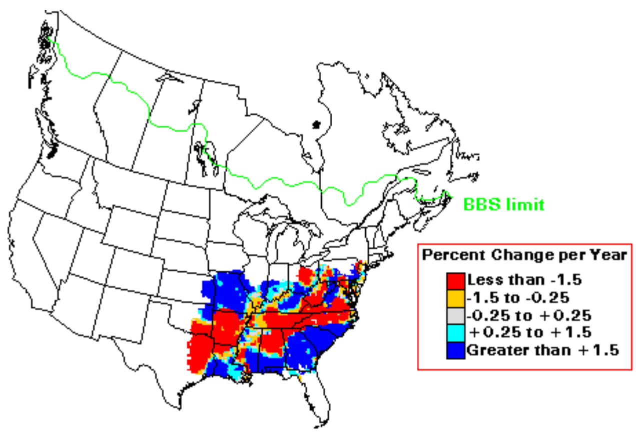

Figure 2.8. Breeding Bird Survey Population Trend of Kentucky Warbler (Sauer et al., 2001).

Hooded Warbler

Habitat preferences for Hooded Warblers are mixed hardwood forests, where they prefer a shrub understory, moist woodlands and mature forests with significant tree fall gaps. Local populations may experience declines as the shrub layer disappears. Nests are common in small shrubs or saplings. Hooded Warblers are considered 'area sensitive', found in large tracts of mature forest and are threatened by fragmentation (Ogden and Stutchbury,1994). Despite some localized declines, their populations are increasing throughout the Southeast (Figure 2.9), although not significantly (trend 1.9, p>0.1). Populations are increasing throughout Georgia, as well (trend 1.9, p=0.18).

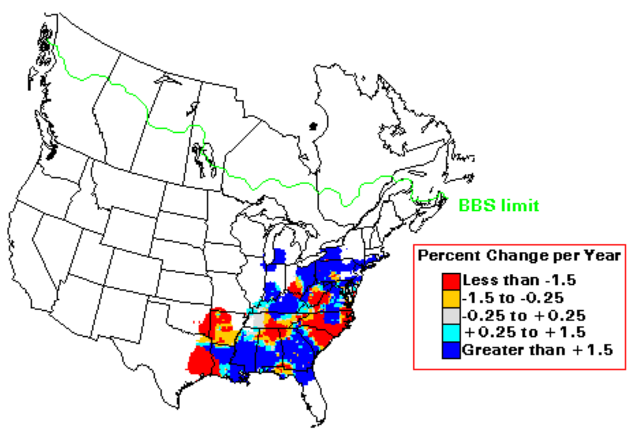

Figure 2.9. Breeding Bird Survey Population Trend of Hooded Warbler (Sauer et al., 2001).

Louisiana Waterthrush

Habitat preferences of Louisiana Waterthrush are riparian habitats in deciduous forests. They prefer streams with gravel or cobble substrate and feed mainly on aquatic insects and other invertebrates. They favor extensive bottomland forests, where they nest under roots, banks, over or near water (DeGraaf and Rappole, 1983). The BBS documents long-term population declines. Suggested management is protection of forest tracts and water systems (Robinson, 1995). They are showing increasing populations throughout the Southeast (trend 4.2, p<0.1; Figure 2.10). In Georgia, the trend is similar (trend 7.6, p=0.14).

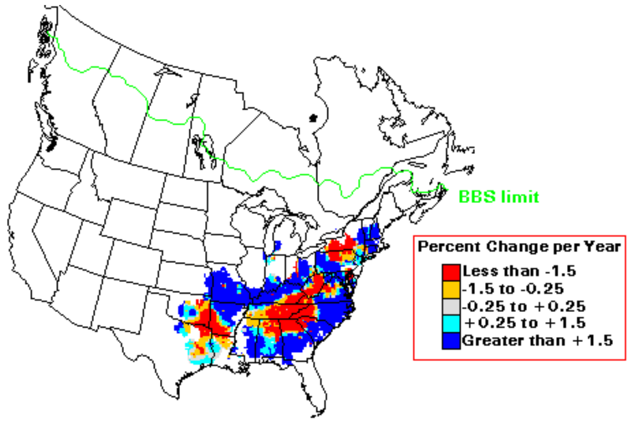

Figure 2.10. Breeding Bird Survey Population Trend of Louisiana Waterthrush (Sauer et al., 2001).

Red-Eyed Vireo

Red-Eyed Vireos prefer open deciduous or mixed forests, with a moderately dense understory. Their nests are commonly located in forked branches. Populations are increasing in the eastern United States (DeGraaf and Rappole, 1983). Throughout the Southeast (trend 2.5, p<0.1) and Georgia (trend 0.7, p=0.37) populations are increasing (Figure 2.11).

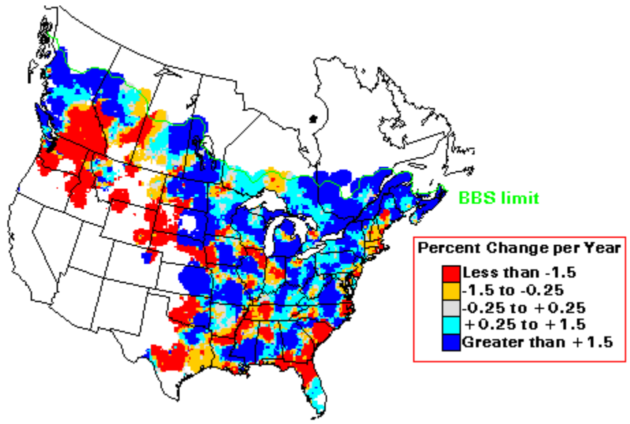

Figure 2.11. Breeding Bird Survey Population Trend of Red-Eyed Vireo (Sauer et al., 2001).

METHODS

Site selection and description

Forty streams were chosen for this project based on location and access, stream and floodplain characteristics. Our goal for site selection was to be able to sample streams with different geomorphic features. In the past century, Piedmont riparian zones were severely altered. Some streams are gullied and terraced, while others are not. Soil texture and moisture also differ due to erosion and aggradation from agricultural practices of the past century.

The selected sites were located in six Piedmont Georgia counties (Figure 2.12). During the 2000 field season, 30 sites were used. An additional 10 sites were added for the 2001 field season. They were within Oconee National Forest, Piedmont National Wildlife Refuge, Hitchiti Experimental Forest, Weyerhaeuser, The Timber Company and International Paper lands. Eleven sites were on managed land, twenty-six sites were on intact forest and three were beaver impoundments. Characteristics of the 37 stream sites are presented in Table 2.1.

Using map and ground-truthing methods, we selected streams that met our criteria of unique stream and floodplain geomorphology. Streams ranged from first to sixth order (Table 2.1) and floodplain width varied from 16-350 m. The median substrate particle size (D50) ranged from 2mm- 27mm. Basin area for each site ranged from 0.114 sq. miles to 397 sq. miles.

Stream Habitat Surveys

We used a modified Hankin and Reeves (1998) method to survey each stream habitat. A given reach length was determined for each stream, using the formula:

mean channel width x 20= reach length

Along this distance, we quantified many geomorphologic variables. These included: habitat types (pool, riffle and glide); length, width and depth of each habitat unit; and width to depth ratio of the channel. The substrate composition within each habitat unit was determined by placing particles into size categories: sand, silt or clay. We tallied all large woody debris in the channel and noted whether each piece was functionally contributing to the channel shape. We placed the bank slope in three categories: vertical, undercut or moderate/slight. A modified Wolman (1954) pebble count was used to calculate the median particle size (D50) of the channel. A spherical densiometer was used to determine percent canopy cover. Channel slope was estimated with a clinometer. Basin area was estimated for each site using topo maps.

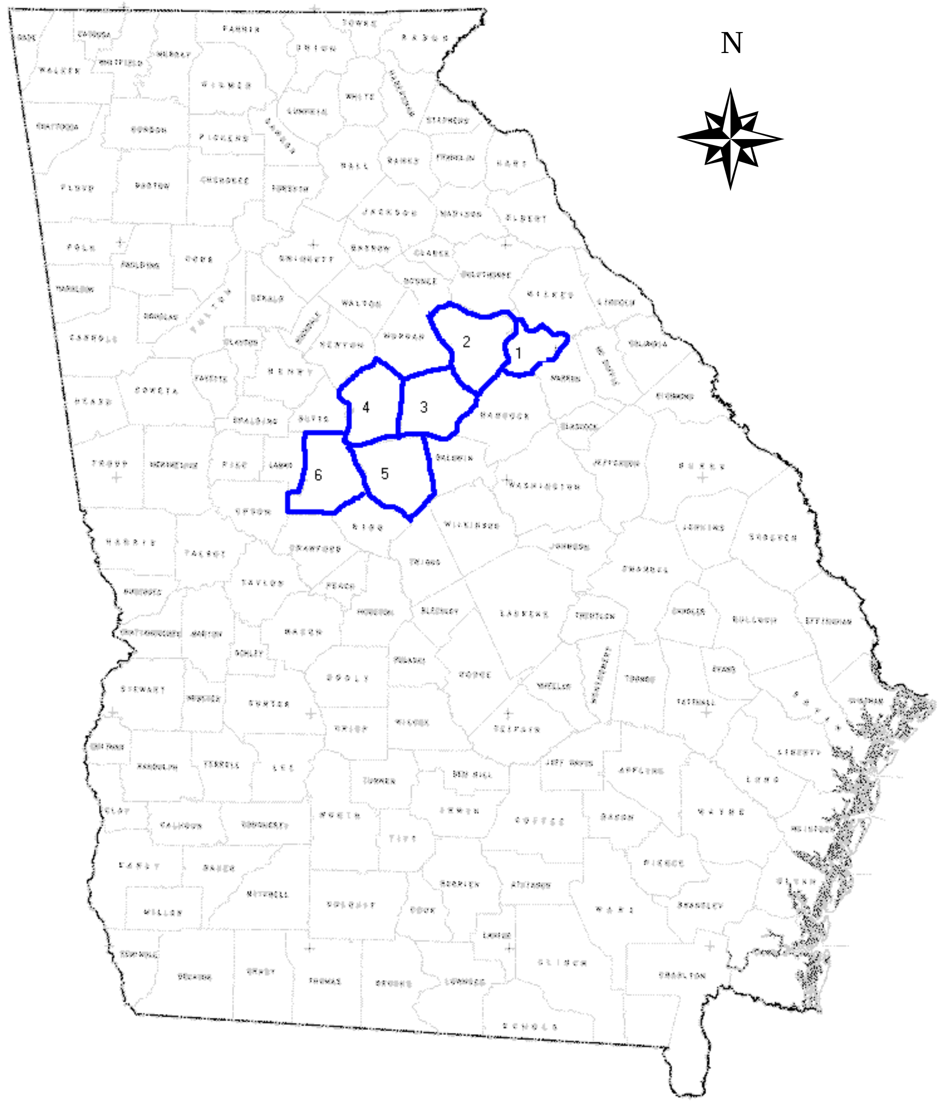

Figure 2.12. Location of forty study sites used for the evaluation of songbird-stream habitat relationships. The pictured counties are: (1) Taliaferro, (2) Greene, (3) Putnam, (4) Jasper, (5) Jones and (6) Monroe.

Table 2. 1 Characteristics of the 37 stream sites used to evaluate the relationship between songbird use and stream characteristics in the Georgia Piedmont. The beaver impoundments are not included in this table.

Site Number	Site Name	Site Type[a]	Basin Area (sq. mi.)	Stream Order	D50[b] (mm)	% Riffle	Floodplain Width (m)	Channel Slope (%)	Qbf[c] (cfs)	Canopy Cover (%)
1	1234B Forest	F	0.1375	1	2	0	42	1	3.90	58
2	1234B Marsh	F	0.172	2	2	0	61.3	1	4.77	23.82
3	1266	F	3.32	2	2	9.8	57.4	1	3.11	41.33
4	626	B	0.513	2	2	6	32	1	3.22	86.48
5	625	B	0.798	2	3	0	60	2	4.44	66.03
6	1231D	F	0.307	2	2	15.8	170	0.5	4.1	66.17
7	684	F	0.586	3	27	0.2	56	1	2.61	58.57
8	702	F	1.72	2	2	83.6	62	1.5	1.76	65.33
9	707A	B	1.08	2	2	8	49	1	1.73	57.36
10	758A	B	0.45	1	2	37.75	50	0.5	1.2	62.61
11	787	B	0.283	1	2	20	75	1	0.51	57.53
12	BFG Pine	F	0.388	1	27	10	57	1.5	1.66	79.72
13	BFG Forest	F	0.416	1	3	24	61	0.5	0.41	12.47
14	Cedar Creek	F	133	4	2	0	350	1	18.16	21
15	Fishing Cr eek	F	13.14	4	2	0	80	1.5	61.09	6
16	Falling Creek	F	72.2	4	2	0	55	2	181.4	13
17	Glades	F	2	1	2	17	36	2	4.13	50.77
18	Murder Creek1	F	190	5	3	19	97	2	359.3	21
20	Hadaway W	B	0.603	1	2	0	44.2	1	2.73	93.07
21	Little Glady	F	5.2	3	3	4	75	2.5	23.65	17.61
22	Little River1	F	156	5	3	24	62	3	110.82	8
24	Old Penfield	F	1.97	2	2	3	80	0.5	1.84	64.03
25	OD Moore 1	B	0.671	2	9.5	24	36	1	2.49	86.57
26	OD Moore 2	B	0.285	1	19	31	16	2.5	1.56	82.78
27	Oconee River1	F	397	6	2	0	280	2	118.94	8
29	Rock Eagle 1	F	0.332	1	19	36	66	2	5.79	48.69
30	Rock Eagle 2	F	2.69	2	2	16	67	2	11.08	13.26
31	Pippin Rd	F	1.07	2	2	4	100	1.25	5.99	93.5
32	Reids Rd	B	0.391	1	6	0	26	0.5	0.12	77.64
33	Ruark 1	B	0.261	1	2	0	20	1	3.9	89.08
34	Ruark 2	B	1.42	2	2	0	20	1.25	2.72	91.33
35	Towns Creek	F	12.28	3	2	0	250	1.5	16	68
36	Whitehall 1	F	0.114	1	2	17	50	0.5	0.351	96.62
37	Whitehall 2	F	0.165	1	2	0	18	0.5	0.38	93.93

[a]Site Type F=forested, B=buffered. [b]D50 refers to the median particle size of the channel substrate.
[c]Qbf is the velocity in cubic feet per second at bankfull stage.

Floodplain surveys

Using a standard level and stadia rod, we surveyed each floodplain to estimate width and topography. On the harvested sites, total buffer width was measured. Bridgham et al. (1991) determined that steel oxidation rods could be used to estimate depth to the water table, thereby giving an estimate of soil moisture during a given time period. During spring 2001, we inserted three oxidation rods at each site. These rods were 120 cm steel welding rods placed in three randomly chosen locations along each transect. The rods were left in the soil for six weeks. After six weeks the rods were removed, and the depth to the rust line measured, if it was present. This allowed us to estimate depth to the water table as well as soil moisture properties.

Soil texture and redoximorphic properties were determined from soil samples taken at the same location as the oxidation rods. Surface samples were collected at a depth of 10 cm. All soil properties were estimated during the spring of 2001 in order to determine the soil characteristics available to the vegetation, and therefore songbird food sources.

Vegetation Surveys

We sampled vegetation along a 400 meter transect, running parallel to each stream study site. This transect was broken into 50 meter segments. Nested quadrats located every 50 m along the transect were used to measure vegetation properties. In sampling, we used a 10m x 10m plot for trees, 5m x 5m plot for shrubs and 1m x 1m plot for herbaceous ground cover (James and Shugart,1970; Noon, 1970). All tree species were identified to species, diameter at breast height (dbh) was measured and total number of trees per plot was tallied. All shrubs were identified to species and stem number was tallied. All herbaceous vegetation was identified to species and percent ground cover within the plot was estimated visually. Vegetation surveys were conducted before songbird surveys began.

Songbird Surveys

From May thru June of 2000 and 2001, we surveyed all birds using a belt transect method. Counts were conducted from 0600 to 1000. Each site had a 400-meter transect for songbird and vegetation surveys. The transects ran parallel to each stream, offset approximately ten meters from the stream edge. We did not center the transect on the stream to avoid the potential effect that running water has on detection probability. We used only one bank of each stream for our surveys. In some instances, streams were too wide to detect birds on the opposite bank, or the banks were located on private property. Birds were counted if they were seen or heard within 50 meters of the transect line. Thus, the stream channel always was located in the survey area. We also recorded any birds flying over but not using the plot. Spot mapping was used to ensure that birds were not counted twice (Noon, 1970).

Statistical Analysis

The 2000 and 2001 songbird survey data were averaged to give us a mean abundance and species richness score for each site. We then compared species richness and abundance among forested sites, buffered sites and beaver swamps. These calculations were made using PC-Ord (1999). To estimate abundance we used the number of birds detected per site. Species richness was defined as the number of species detected per site. Diversity was calculated using Shannon's diversity index:

$$H' = -sum\ [Pi*ln(Pi)].$$

We used Student's t-test and confidence intervals to test overall abundance and species richness differences among the three site types. In order to determine whether clearcut harvest practices affected a species habitat choice, we used a Fisher Exact test for nonparametric data to test for differences in an individual species site preference. We used presence or absence of an individual species to compare forested and buffered sites.

Analysis of Variance (ANOVA) was used to test the 'target species' habitat preferences among the three site types. Using species abundance, we were able to determine whether an individual species was detected more frequently in a particular habitat type.

We used Canonical Correspondence Analysis (PC-Ord ,1999) to relate songbird communities to stream and floodplain geomorphology and floodplain vegetation. CCA allowed us to examine the relationship between the measured stream and floodplain variables and songbird species composition of the site (ter Braak,1986; Palmer, 1993). CCA is a multivariate, direct gradient analysis method. The advantage of using this method is the ability to simultaneously plot species and site scores as points in an ordination diagram called a joint plot. Lines or arrows represent environmental variables, while species and site scores are represented by symbols. Unlike many multivariate statistical methods, CCA has the ability to deal with nonnormal and collinear data. We used the Pearson-Kendall statistic to determine the correlation between axes and variables.

We also used logistic regression to evaluate species presence or absence with regard to a specific variable suggested by CCA. Variable means were tested between groups using a Student's t-test. This allowed us to determine the strength of the relationship between an individual species and the variables used in CCA.

RESULTS

Stream Habitat Surveys

The stream surveys allowed us to determine the basic geomorphic differences in our sites. We concluded that the sites we selected varied in substrate composition, bank incision and channel habitat. Channel slope did not differ widely from site to site. Slope ranged from 0.5 to 3 % and averaged 1.2%. The habitat distribution was predominantly glide. Glides made up 64.3% of our habitat types. Appendix A illustrates the habitat distribution for each site. The eleven sites that are not diagrammed were uniform 'glide' habitat.

Sediments, less than 2mm in size, dominated the particle size distribution. Appendix B lists each site, the size class distribution for that site, the number of particles per size class and the percent of particles finer than that size class.

Floodplain Surveys

Within the Piedmont of the Southeastern United States, the typical floodplain has many features. These include sloughs, back swamps, natural levees, terraces and oxbow lakes. In this study, most of the sites were very simplistic, having only a few of these features. Particularly with smaller order streams, floodplain geomorphology becomes very basic. We did not measure levee height or width. We also did not count the number of sloughs that were encountered. Rather, we surveyed the topography and found that our sites did differ in their general appearance. The floodplain survey results are seen in Appendix C. Soil samples gave us an indication of soil moisture and depth to the water table. Our larger order streams did have wider floodplains and a few sites had a back swamp area. Floodplain widths ranged from 18m to 350m (mean 72m). In other physiographic regions, the floodplain geomorphology may be more complex than what we encountered during this study. This may influence the songbird community in the Piedmont region, where they find similar floodplain characteristics across a wide landscape.

Vegetation Surveys

The simplicity of our floodplain features most likely influenced the vegetation. The nine vegetation plots found on each transect, were averaged in order to get a mean for each species that occurred. All vegetation species were classified into five categories: upland, facultative-upland, facultative, facultative-wetland, and obligate (USFWS). The facultative/facultative-wetland species dominated each site. Appendix D lists all species that were found on the sites during the 2000 and 2001 field season. The percent canopy cover distribution for each sites can be seen in Table 2.1. We found that vegetation was very similar from site to site. This is most likely due to the similarity in soil texture and moisture as well as basic floodplain geomorphology. Because the sites were so similar, combined all species to determine which indicator type was most common (Figure 2.13).

Songbird Community

All species detected during the 2000 and 2001 surveys are listed in Appendix E. Diversity ranged from 2.079 to 2.996 (Table 2.4). The highest diversity values were found on three sites: a beaver impoundment, Oconee River 2 and Site 625. Although diversity was highest on these sites, they were very different in stream and valley geomorphology. Site 625 was a second order buffered site, with a 60 m buffer and no riffle habitat. The Oconee River is a sixth order river with little canopy (8%) cover and a wide floodplain (280 m). Both of these sites differed greatly from the beaver impoundment (Table 2.1). Although diversity scores were high on these sites, the songbird community was different. The lowest diversity score (2.079) was a beaver impoundment site.

Species richness (S) was defined as the number of species detected per site. Richness was highest on five sites: beaver impoundment, Ruark 2, Oconee River 2, OD Moore 1 and 625. Three of these stream sites were buffered sites, while the last is a large sixth order river (Table 2.1). Richness and diversity provide a means of quantifying the overall songbird community, but provide little information on the birds that make up the community of each site. These indices should be referred to with caution when used to identify the "health" of a system. A better indicator might be the early succession species richness score for buffered sites or the interior richness score for forested sites.

The eleven "target species" that we selected for our analysis were found in highest numbers on six sites: 625, 684, BFGForest, Cedar Creek, Towns Creek and Little Glady Creek: two small second order streams, three larger streams and one buffered site.

Overall species richness and abundance (Figures 2.14 and 2.15) for the three site types varied little. Mean richness for the forested sites (10.21), buffered (11.27) and beaver impoundments (10.0) did not differ significantly when tested with a Student's t-test (Table 2.2). Abundance values similarly were not significantly different when compared with a t-test (Table 2.3). Forested sites had a mean abundance of 16.07 birds, 16.82 for buffered sites and 12.16 for beaver impoundments.

All birds detected during the surveys were categorized into four guilds: interior, interior/edge, generalist and early succession (Askins, et al., 1990; Robbins et al., 1989).

Mean abundance and species richness within these categories is illustrated in figures 2.16-2.21. The forested sites had a relatively equal abundance and richness of interior and interior/edge species. Generalists were less common and early succession species were not detected. The buffered sites had higher abundance and richness values in the interior/edge guild. There were equal numbers of interior and generalist species and a few early succession species. The beaver impoundment sites were similar—predominantly interior/edge and generalist species. Using these data, we eliminated the more common species and generalists from our analysis and focused on the eleven species mentioned previously.

Table 2.2. Results of Student's t-test to compare species richness means among the three site types. There is not a significant difference between site types when comparing species richness (p>0.05). The 95% confidence interval is placed around the difference between the means of the two site types considered in the test.

Site	P	t	Df	95% C.I.
Buffered/Forested	0.716	-0.366	35	-11.251 7.811
Buffered/Beaver	0.623	0.543	12	-15.489 24.809
Forested/Beaver	0.752	0.221	27	-21.231 29.051

Table 2.3. Results of Student's t-test to compare abundance means among the three site types. There is not a significant difference between site types when comparing abundance of birds (p>0.05). The 95% confidence interval is placed around the difference between the means of the two site types considered in the test.

Site	p	t	Df	95% C.I.
Buffered/Forested	0.915	-0.108	35	-14.856 13.356
Buffered/Beaver	0.623	0.504	12	-15.489 24.809
Forested/Beaver	0.752	0.319	27	-21.231 29.051

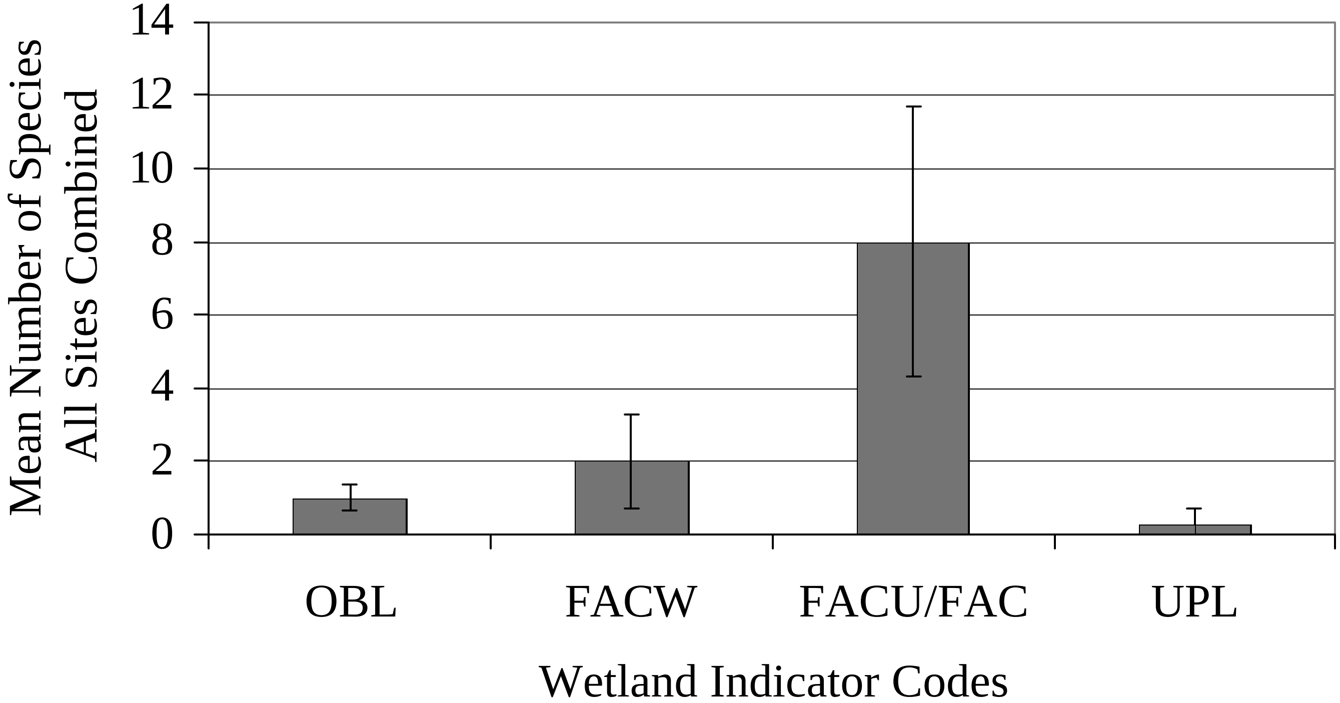

Figure 2.13. Number of tree, shrub and herbaceous species within each wetland vegetation category for forty riparian sites in six Piedmont counties in Georgia.

Table 2.4. Songbird species diversity (H')[a] and richness (S)[b] among forty Piedmont Georgia sites during 2000-2001.

Site	H'	S
1234B Forest	2.773	16
1234B Marsh	2.708	15
1266	2.89	18
626	2.89	18
625	2.996	20
1231D	2.398	11
684	2.89	18
702	2.797	9
707A	2.565	13
758A	2.639	14
787	2.485	12
BFG Pine	2.485	12
BFG Forest	2.833	17
Cedar Creek	2.773	16
Fishing Creek	2.565	13
Falling Creek	2.485	12
Glades	2.565	13
Murder Creek1	2.639	14
Murder Creek2	2.833	17
Hadaway W	2.565	13
Little Glady	2.833	17
Little River1	2.639	14
Little River2	2.485	12
Old Penfield	2.639	14
OD Moore 1	2.996	20
OD Moore 2	2.565	13
Oconee River1	2.303	10
Oconee River2	2.944	19
Rock Eagle 1	2.773	16
Rock Eagle 2	2.833	17
Pippin Rd	2.565	13
Reids Rd	2.833	17
Ruark 1	2.773	16
Ruark 2	2.944	19
Towns Creek	2.303	10
Whitehall 1	2.485	12
Whitehall 2	2.639	14
BFG Beaver	2.303	10
1234 Beaver	2.079	8
Penfld Beaver	2.944	19

[a]Diversity was calculated using Shannon's diversity index: *H?= -sum [Pi*ln(Pi)].* [b]Species Richness is the number of species detected per site.

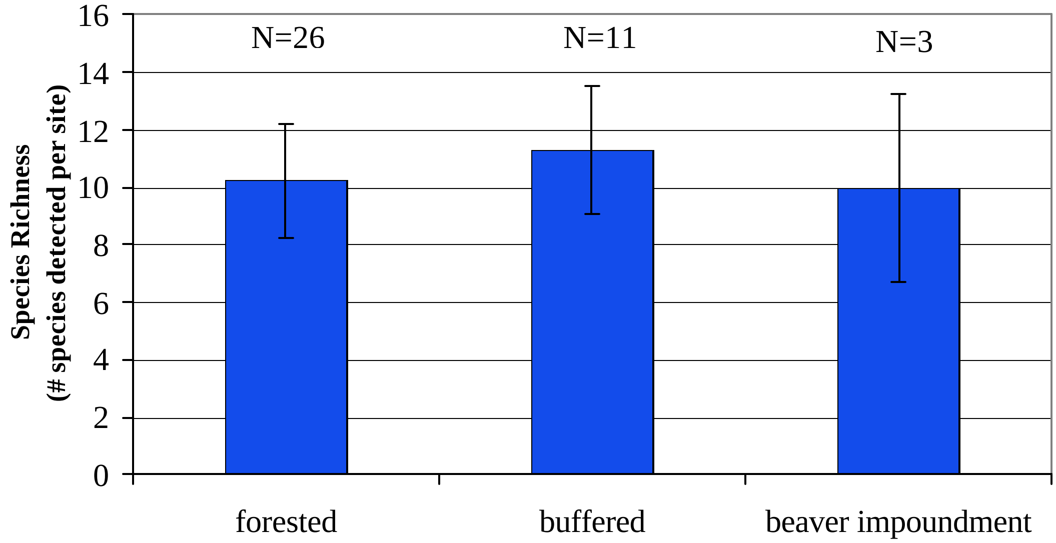

Figure 2.14. Species richness among three riparian site types in the Piedmont region of Georgia. Sites did not differ significantly.

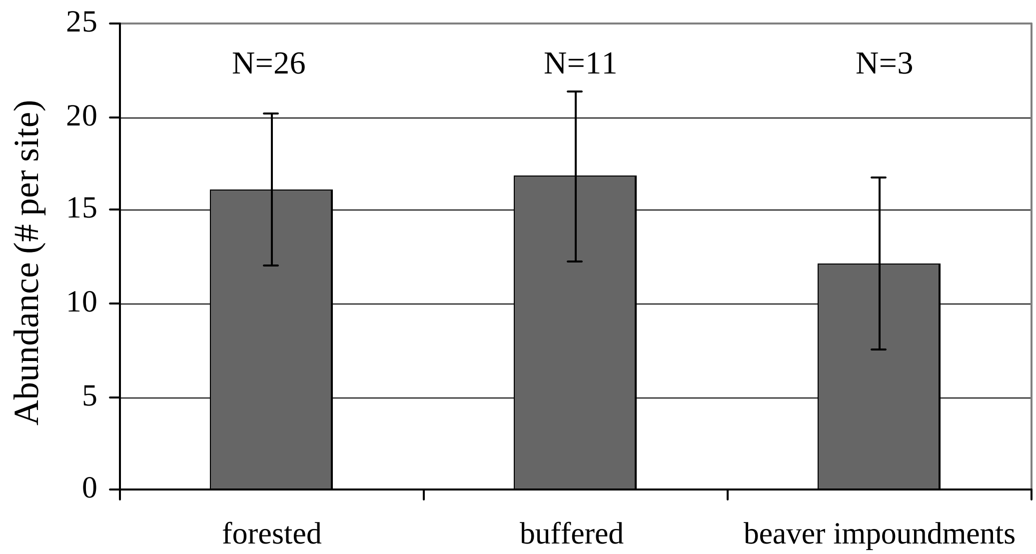

Figure 2.15. Songbird abundance for three riparian site types in the Piedmont region of Georgia did not differ. Sites did not differ significantly.

Site Differences

Using a Fisher Exact Test for nonparametric data, we compared the presence or absence within buffered and forested sites for the eleven target species (Table 2.5). Four species were found significantly more often in one site versus the other. Wood Thrush (p=0.036) were detected in 5 of 11 buffered sites and 16 of 26 forested sites. Acadian Flycatchers were found in every forested site in the study and within 8 of 11 buffered sites (p=0.01). Summer Tanagers were detected in 6 of 11 buffered sites and only 6 of 26 forested sites (p=0.018). Indigo Buntings were detected in 5 of 11 buffered sites (p=0.001) and never detected within the forested sites.

Table 2.5. Results for Fisher Exact Test for eleven target species compared across three habitat types in the Georgia Piedmont. Four species (Wood Thrush, Acadian Flycatcher, Summer Tanager and Indigo Bunting) were found significantly more often in buffered or forested habitat.

Site	**df**	**p**	**Common habitat: forested or buffered**
Kentucky Warbler	1	0.576	ND
Wood Thrush	1	0.036	Forested
Louisiana Waterthrush	1	1.0	ND
White-Eyed Vireo	1	0.732	ND
Red-Eyed Vireo	1	0.410	ND
Summer Tanager	1	0.018	Buffered
Hooded Warber	1	1.0	ND
Great Crested Flycatcher	1	0.398	ND
Pine Warbler	1	0.688	ND
Eastern Wood Pewee	1	0.542	ND
Indigo Bunting	1	0.001	Buffered

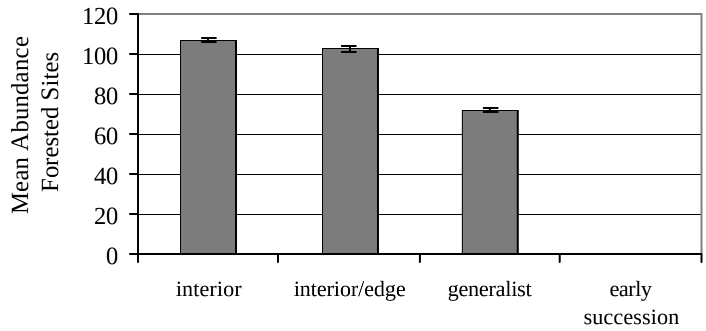

Figure 2.16. Abundance (# per site) of four songbird guilds in 26 forested sites within the Piedmont region of Georgia.

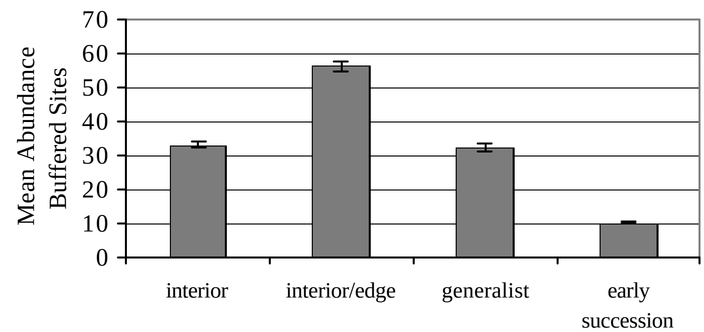

Figure 2.17. Abundance (# per site) of four songbird guilds in 11 buffered sites within the Piedmont region of Georgia.

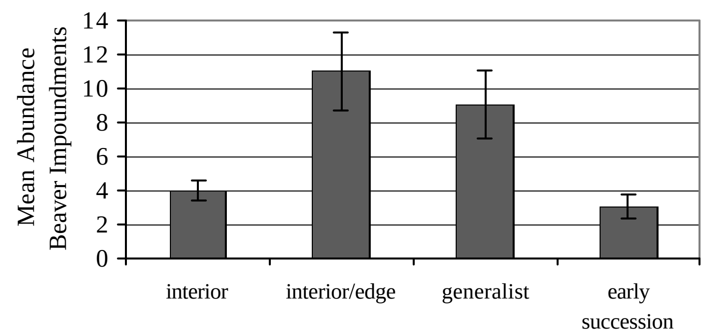

Figure 2.18. Abundance (# per site) of four songbird guilds in three beaver impoundment sites within the Piedmont region of Georgia.

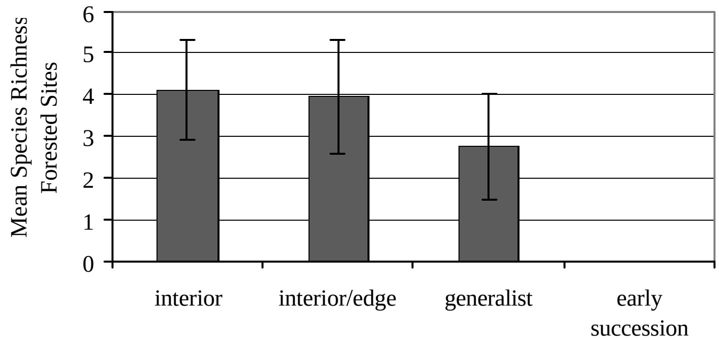

Figure 2.19. Species richness (# species per site) in four songbird guilds in 26 forested sites within the Piedmont region of Georgia.

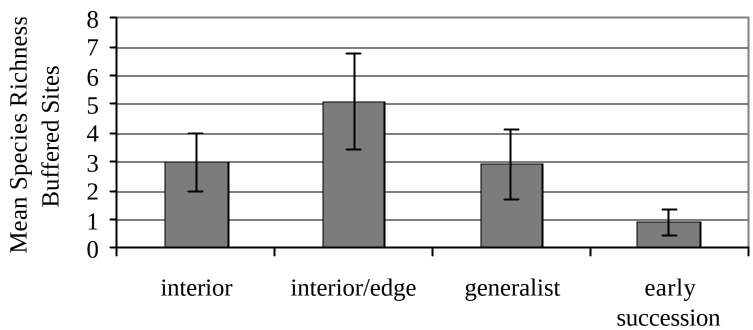

Figure 2.20. Species richness (# species per site) in four songbird guilds in 11 buffered sites within the Piedmont region of Georgia.

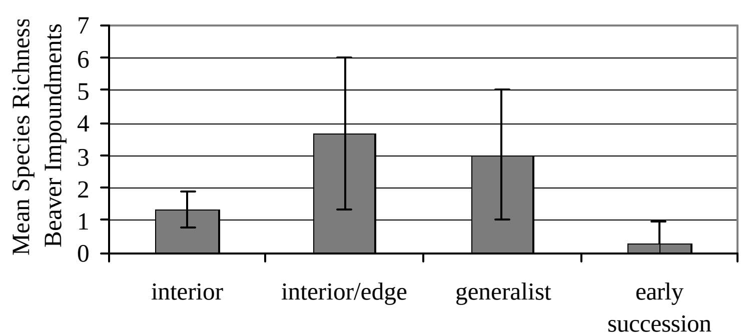

Figure 2.21. Species richness (# species per site) in four songbird guilds in three beaver impoundment sites within the Piedmont region of Georgia.

Canonical Correspondence Analysis

We completed two analyses—one with forested and buffered streams only and a second with all forty sites, including the beaver impoundments. For the first analysis, we used 37 sites, 14 variables (Table 2.7) and 11 species. Stream order was used as a categorical variable for plotting purposes, the results did not change when order was classified as quantitative. Figures 2.22-2.24 illustrate the resulting three axes. Other studies using CCA to investigate community dynamics have results with clear grouping of species and site variables. These studies involved plant communities (ter Braak,1987), algal communities (van der Meer, 1991; Hill et al., 2000) and fish populations (Weigel and Sorensen, 2001), where species are clearly distributed along a gradient of site characteristics. Our results did not have distinct groupings of species or site scores. However, we detected trends that were important in explaining the presence of particular species. In the first CCA, Axis 1 was defined by canopy cover (0.778) and floodplain width (-0.453). Axis 2 was defined by percent riffle (-0.695) and floodplain width (0.408). Axis 3 was defined by channel slope (0.397). Table 2.6 lists the Pearson-Kendall correlations with the ordination axes and the environmental variables. The r^2 values for our variables are very low. Canopy cover and percent riffle were the only variables with significant r^2 values.

Table 2.6. Pearson-Kendall Correlations with the CCA Ordination Axes. Each axis is defined by a combination of variables. These variables are defined in Table 2.7.

	r^2	r^2	r^2
Axis:	**1**	**2**	**3**
FINES	0.061	0.056	0.087
RIFFL	0.0	0.569	0.074
TLWD	0.095	0.093	0.004
CHSLP	0.197	0.027	0.119
FPWDT	0.210	0.121	0.002
BA	0.001	0.035	0.087
CANCOV	0.612	0.040	0.001
CANE	0.038	0.196	0.024
H-OBL	0.00	0.038	0.007
H-UPL	0.111	0.011	0.085
S-OBL	0.088	0.017	0.028
T-UPL	0.004	0.066	0.000
T-OBL	0.041	0.014	0.012

Table 2.7. List of variables and the codes used in the Canonical Correspondence Analysis.

Variable	**Code**
Percent of fine sediments	FINES
Percent of riffle habitat	RIFFL
Total number of large woody debris pieces	TLWD
Channel Slope	CHSLP
Floodplain Width	FPWDT
Total Basal Area of Site	BA
Percent canopy cover	CANCOV
Number of cane (*Arundinaria gigantea*) stems	CANE
Number of obligate herbaceous species	H-OBL
Number of upland herbaceous species	H-UPL
Number of obligate shrub species	S-OBL
Number of obligate tree species	T-OBL
Number of upland tree species	T-UPL
Stream Order	ORDER

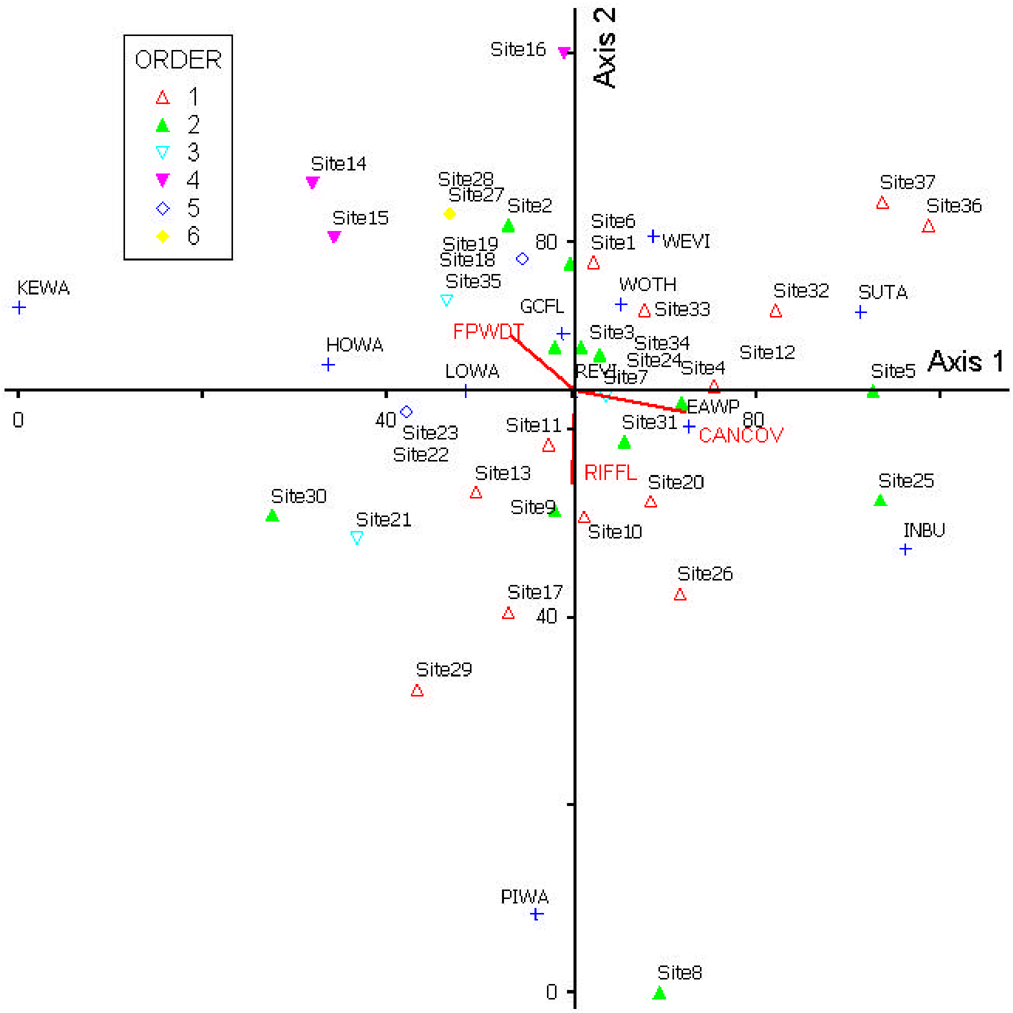

Figure 2.22. Canonical correspondence axes 1 and 2. These axes are defined by floodplain width, percent riffle and percent canopy cover. All sites (colored shapes) are categorized by stream order, species (blue crosses) are listed by species code and variables are indicated by red lines.

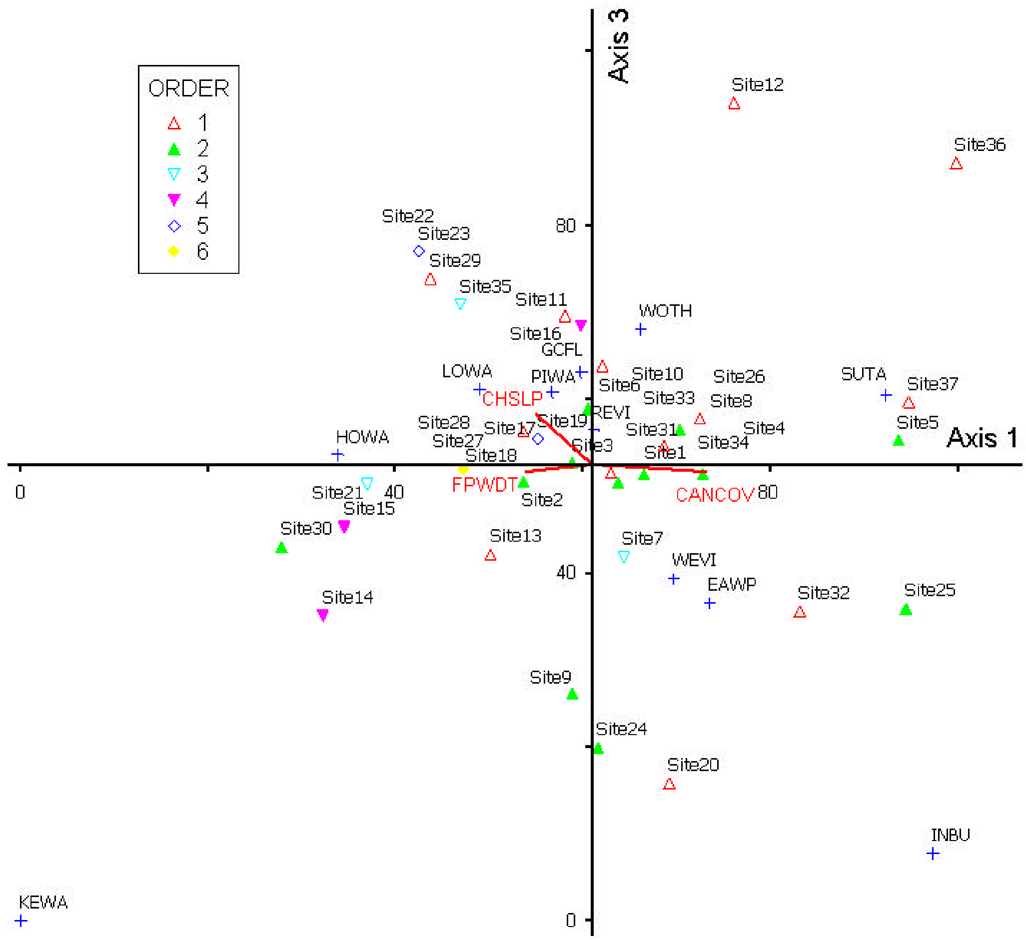

Figure 2.23. Canonical correspondence axes 1 and 3. These axes are defined by floodplain width, percent canopy cover and channel slope. All sites (colored shapes) are categorized by stream order, species (blue crosses) are listed by species code and variables are indicated by red lines.

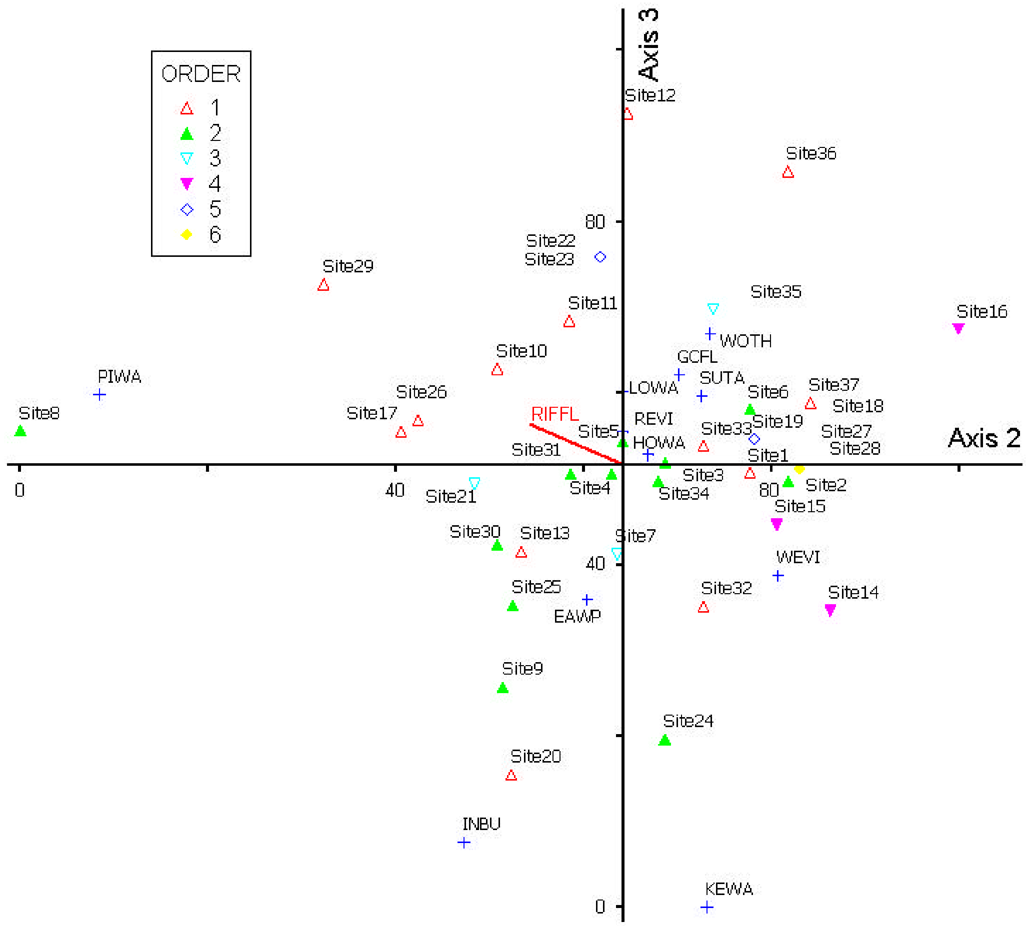

Figure 2.24. Canonical correspondence axes 2 and 3. Axis 2 was defined by percent riffle. All sites (colored shapes) are categorized by stream order, species (blue crosses) are listed by species code and variables are indicated by red lines.

The second CCA incorporated all 40 sites and a reduced set of environmental variables, excluding floodplain width, number of cane stems and stream order. We added percent of pool habitat to the list of variables included in our stream analysis. We included two additional bird species: Belted Kingfisher and Wood Duck. Figures 2.25-2.27 illustrate the results of the second CCA. Axis 1 was defined by the percent of pool habitat (-0.802), slope (0.50), obligate herbaceous species (-0.828) and obligates shrub species (0.505). Axis 2 was defined by percent canopy cover (0.693). Axis 3- percent fine sediments (-0.488) and percent riffle (0.796). Table 2.8 lists the Pearson-Kendall correlations with the ordination axes for this dataset. Again, our r^2 values were very low for most of the variables. Similar to the first analysis, canopy cover, percent pool and percent riffle had the highest correlations.

Table 2.8. Pearson-Kendall Correlations with the Ordination Axes. Each axis is defined by a combination of variables. These variables are defined in Table 2.7.

	r^2	r^2	r^2
Axis:	**1**	**2**	**3**
FINES	0.114	0.095	0.083
POOL	0.650	0.090	0.093
RIFFL	0.056	0.00	0.621
TLWD	0.045	0.046	0.107
CHSLP	0.366	0.079	0.022
BA	0.092	0.005	0.004
CANCOV	0.091	0.583	0.049
H-OBL	0.690	0.012	0.000
H-UPL	0.014	0.102	0.000
S-OBL	0.301	0.042	0.000
T-UPL	0.020	0.001	0.057
T-OBL	0.005	0.014	0.006

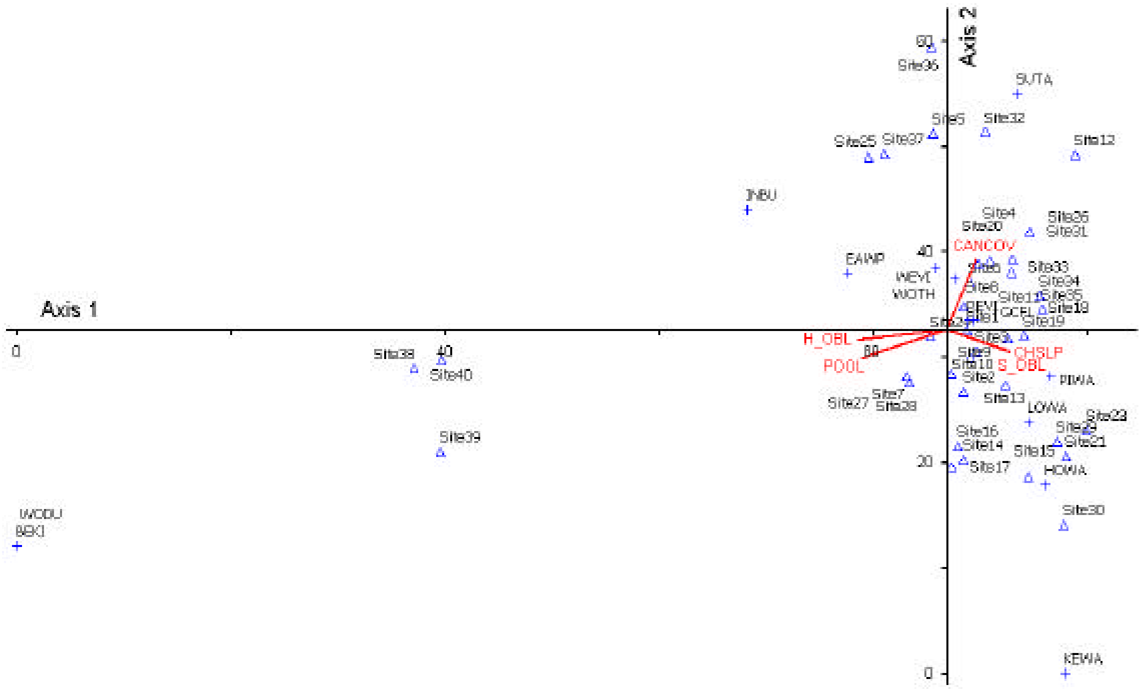

Figure 2.25. Canonical correspondence analysis Axes 1 and 2. These axes are defined by percent canopy cover, channel slope, percent pool, herbaceous and shrub obligate species. All sites (colored shapes) are categorized by stream order, species (blue crosses) are listed by species code and variables are indicated by red lines.

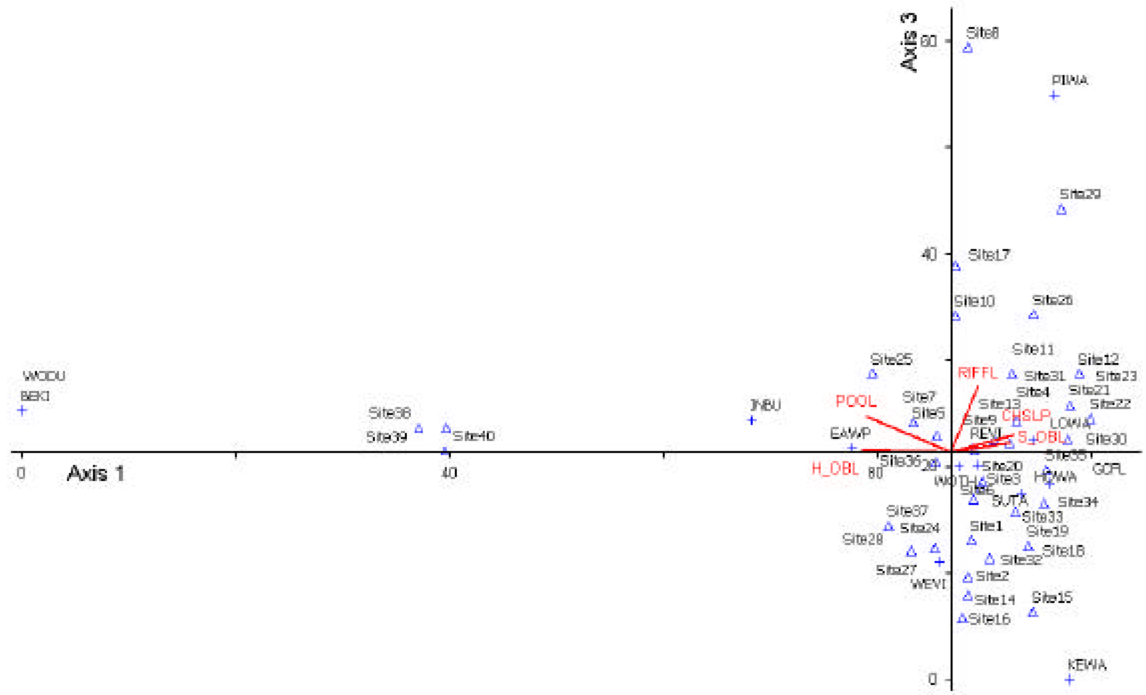

Figure 2.26. Canonical correspondence analysis Axes 1 and 3. These axes are defined by percent pool, percent riffle, channel slope, shrub and herbaceous obligate species. All sites (colored shapes) are categorized by stream order, species (blue crosses) are listed by species code and variables are indicated by red lines.

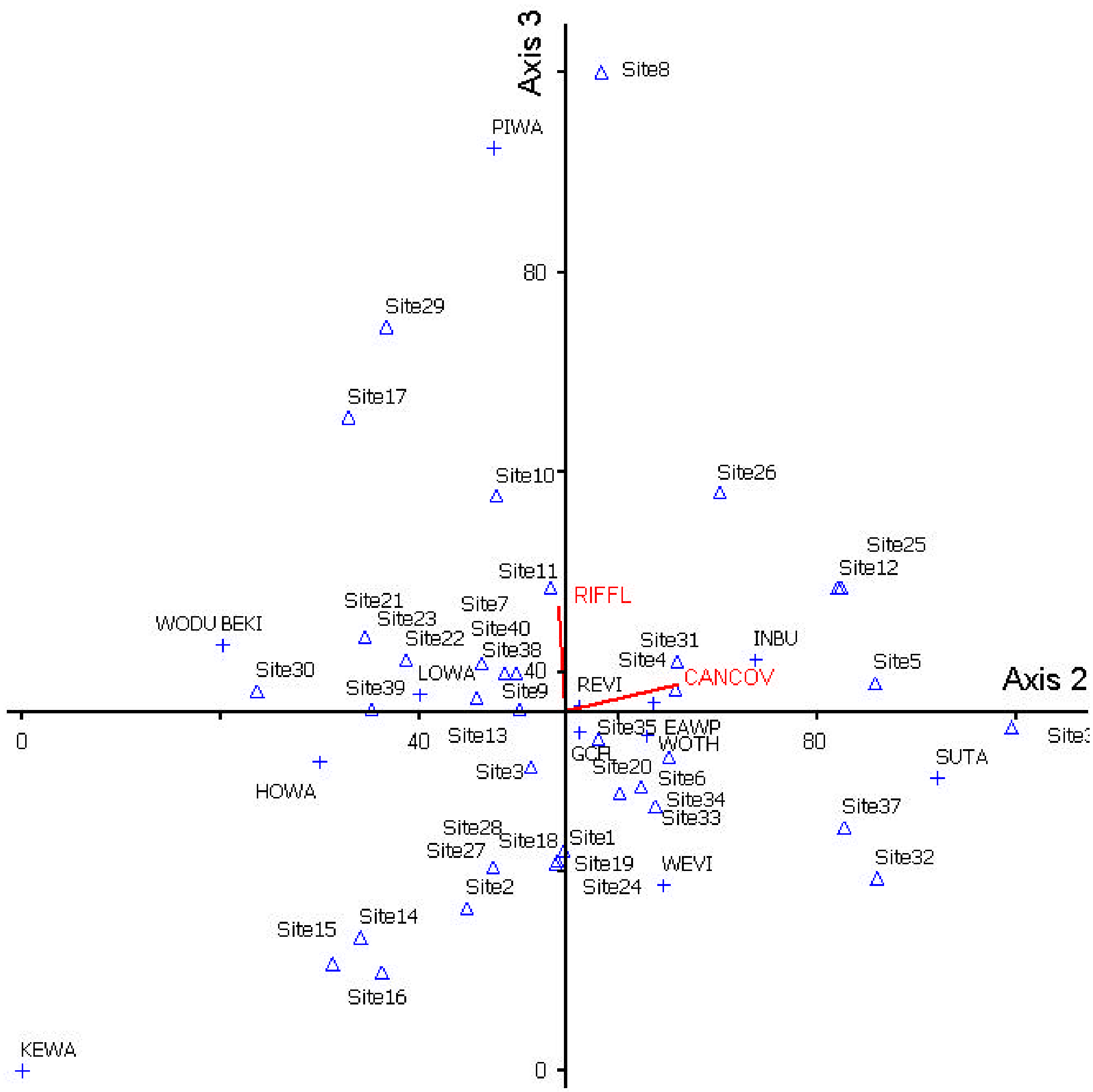

Figure 2.27. Canonical correspondence analysis Axes 2 and 3. These axes are defined by percent canopy cover and percent riffle. All sites (colored shapes) are categorized by stream order, species (blue crosses) are listed by species code and variables are indicated by red lines.

Target Species Results

Using ANOVA, we found significant differences (p<0.05) in target species abundance among all site types (Table 2.9).

Eastern Wood Pewees were detected in buffered sites more frequently than forested or beaver impoundments in this study (Figure 2.28). The results of our correspondence analysis (Figures 2.22-2.27) suggest relationships between low channel slope, dense canopy and obligate herbaceous vegetation and Pewee presence. We used logistic regression to predict the presence or absence of the species in relationship to specific variables. Canopy cover (p=0.06) and slope (p=0.455) were not significant when compared to an alpha of 0.05. However, Pewees are associated with dense canopy, intermediate aged forests, with some degree of openings, gaps or clearings (McCarty, 1996), alluding that canopy cover and herbaceous ground cover are important variables for this species.

Correspondence analysis found relationships between increasing channel slope and floodplain width (Figures 2.22-2.27) and presence of Great Crested Flycatcher. Using logistic regression, we found no significant trends with these variables (slope p=0.938; floodplain width p=0.768). We detected this species significantly more frequently in forested sites (Figure 2.29). The presence of snags is likely one of the most important habitat requirement for this species, which could have a higher probability of occurrence in larger floodplains. Channel slope only varied slightly in this study and was probably associated by chance.

Our analysis found correlations between large floodplains and low canopy cover and presence of Hooded Warblers (Figures 2.22-2.27). These results are not surprising, considering their preferences for large tracts of shrubby habitat (Ogden and Stuchbury, 1994). Using logistic regression, we tested these correlations and found significant results with percent canopy cover (p=0.027). Using a t-test to compare means (t= -2.427, p=0.021), we found a significant relationship between Hooded Warbler presence and low canopy cover. Hooded Warblers were detected more often on forested sites in this study (Figure 2.30).

We found that the Indigo Bunting was associated with decreasing channel slope and obligate herbaceous vegetation (Figures 2.22-2.27). Channel slope varied only slightly in this study, therefore it is difficult to make any correlations. We also could not use the number of obligate herbaceous species in our regression, because they were present in very low numbers (Figure 2.31). As an early succession species, Indigo Bunting would be expected in habitats with more shrub and herbaceous vegetation.

We detected Kentucky Warblers at seven forested sites within our study (Figure 2.32). Because of this low detection rate, they were not associated with any variables in our analysis (Figures 2.22-2.27).

We found correlations between Louisiana Waterthrush presence and increasing channel slope, low canopy cover, high percent riffle and shrub obligate species (Figures 2.22-2.27). We tested these relationships using logistic regression. Canopy cover (p=0.075), riffle percent (p=0.927) and obligate shrub species (p=0.029) were associated with Waterthrush presence. These birds are ‘area sensitive’ interior species, feeding on aquatic invertebrates and nesting near streams. We found no significant relationships between species presence and these variables using a t-test to compare the means of these variables. We detected Louisiana Waterthrush at most of our forested sites (Figure 2.33).

Pine Warblers were not associated with any variables in our analysis (Figures 2.22-2.27), which could be due to their habitat preferences (pine stands) or our low detection rate. We detected few birds in our forested sites and none in the buffered or beaver sites (Figure 2.34.

Red-Eyed Vireos were detected in all habitats in this study, but they were most abundant in the forested sites (Figure 2.35). This species is consistently found at the origin on each joint plot. They were not correlated with any of the variables that we measured (Figures 2.22-2.27).

Our analysis found correlations with dense canopy and Summer Tanager presence (Figure 2.22-2.27). We found nonsignificant trends using logistic regression and then t-tests to compare means. We detected this bird in buffered sites more often than in forested (Figure 2.36).

White-Eyed Vireo was detected in all site types (Figure 2.37). Our analysis suggested correlations between White-Eyed Vireo presence and low percent riffle (Figures 2.22-2.27). Using logistic regression, we found an insignificant relationship ($p=0.113$).

Our analysis (Figures 2.22-2.27) found no relationship between Wood Thrush presence and the variables measured. We detected this species most frequently in our forested sites (Figure 2.38).

Table 2.9. Analysis of Variance (ANOVA) results comparing target species abundance among the three site types. YES indicates a significant difference ($p<0.05$) in abundance among the habitat types. NO indicates a nonsignificant difference.

Species	Forested vs. Buffered	Forested vs Beaver	Buffered vs Beaver
Eastern Wood Pewee	YES	YES	YES
Great Crested Flycatcher	YES	YES	YES
Hooded Warbler	YES	YES	YES
Indigo Bunting	YES	YES	YES
Kentucky Warbler	YES	YES	NO
Louisiana Waterthrush	YES	YES	YES
Pine Warbler	YES	YES	YES
Red-Eyed Vireo	YES	YES	YES
Summer Tanager	YES	YES	YES
White-Eyed Vireo	NO	YES	YES
Wood Thrush	YES	YES	YES

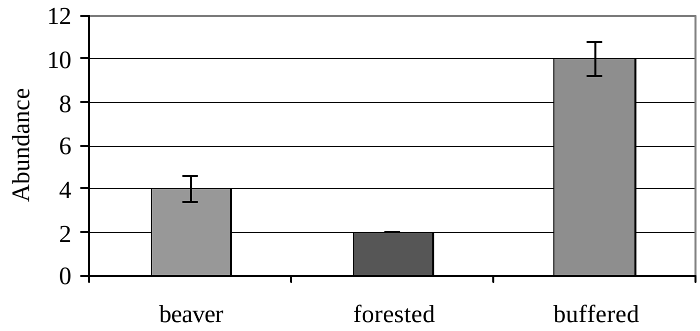

Figure 2.28. Abundance of Eastern Wood-Pewee in three habitat types.

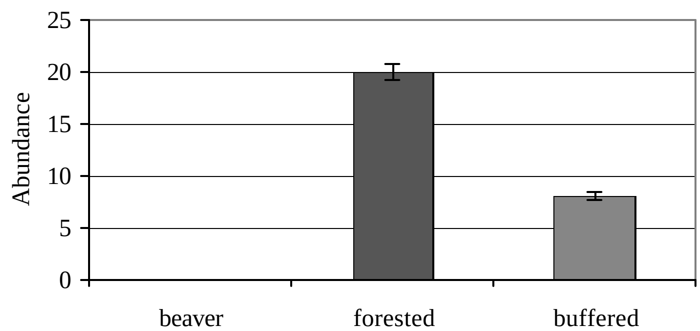

Figure 2.29. Abundance of Great Crested Flycatcher in three habitat types.

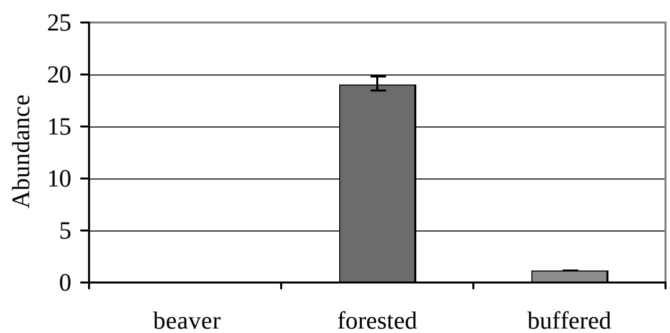

Figure 2.30. Abundance of Hooded Warbler in three habitat types.

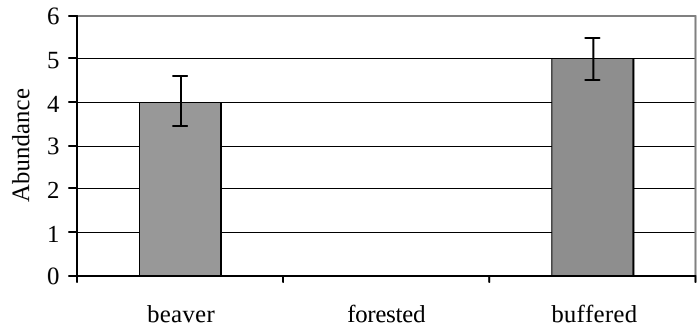

Figure 2.31. Abundance of Indigo Bunting in three habitat types.

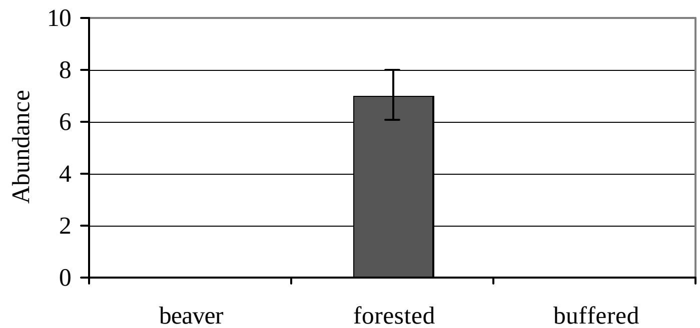

Figure 2.32. Abundance of Kentucky Warbler in three habitat types.

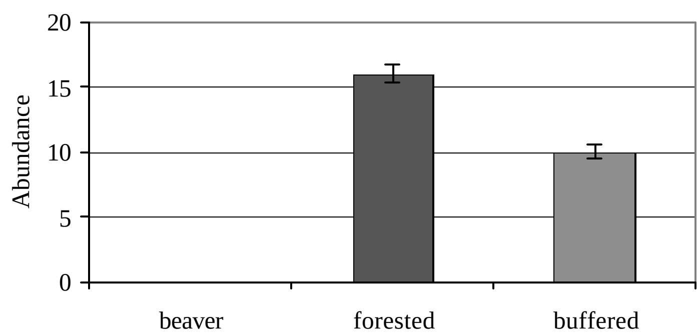

Figure 2.33. Abundance of Louisiana Waterthrush in three habitat types.

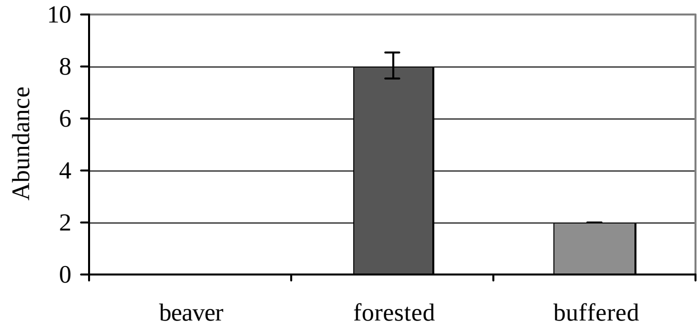

Figure 2.34. Abundance of Pine Warbler in three habitat types.

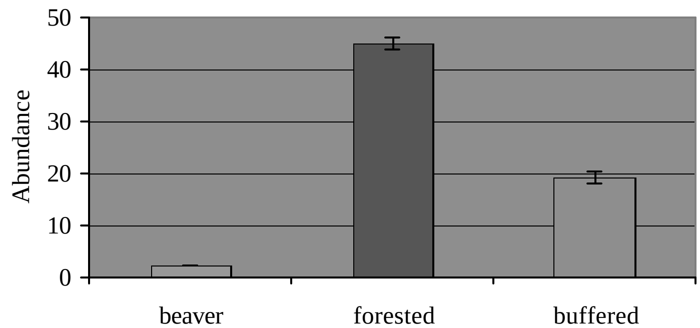

Figure 2.35. Abundance of Red-Eyed Vireo in three habitat types.

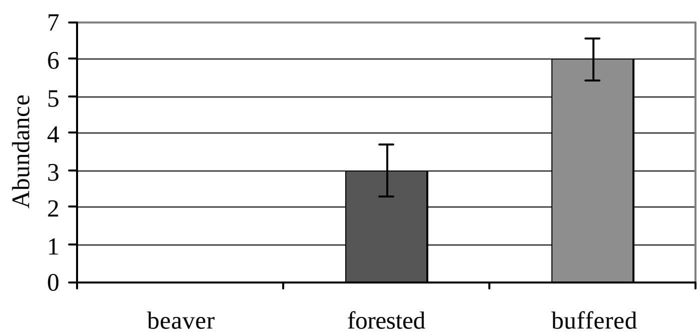

Figure 2.36. Abundance of Summer Tanager in three habitat types.

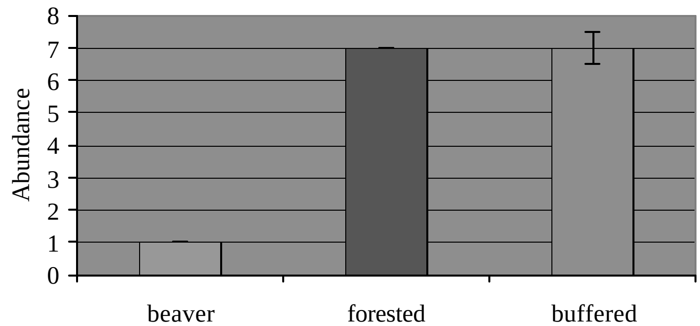

Figure 2.37. Abundance of White-Eyed Vireo in three habitat types.

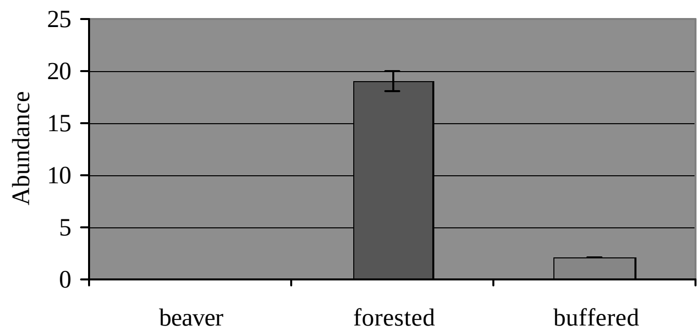

Figure 2.38. Abundance of Wood Thrush in three habitat types.

DISCUSSION

The objectives of this project were (1) relate songbird communities to stream and floodplain geomorphology and floodplain vegetation through the use of canonical correspondence analysis (CCA), and (2) evaluate songbird presence or absence along gradients of stream or valley characteristics using relationships suggested by CCA. We found that Piedmont songbird communities were generally unresponsive to differences in stream and valley geomorphology and were poorly correlated with variables selected to describe these differences. Specifically, woody debris, percent pool and riffle, bank features and substrate composition which were considered likely to influence abundance of aquatic invertebrates and floodplain width, wetness and vegetation characteristics which are important to bird communities, were evaluated and found to be poorly correlated with songbird abundance. This is likely due to the overall similarity of floodplain geomorphic features and vegetation of Piedmont streams and rivers.

Songbird Community

Our third objective was to compare songbird richness and abundance between streams with full riparian forests, streams within buffered clearcuts and beaver swamps. We accomplished this by dividing all birds detected in the surveys into four guilds: interior, interior-edge, generalist and early succession. It is common for particular guilds to inhabit particular site types. Meiklejohn and Hughes (1999) found that their reference sites were dominated by interior species and buffered sites by edge species. Within our sites, we saw a similar pattern. Interior and interior-edge species were detected more frequently within the forested sites (figures 2.16 and 2.19) while generalists and interior-edge species were most common along the buffered streams (figures 2.17 and 2.20). We found that sites with highest species richness scores were very different geomorphically (Table 2.4).

These numbers may be misleading for several reasons. We did not determine breeding success rates for any of the species in this study, and therefore we have no way of knowing how many of these birds nested successfully within these habitats each year. Many of our "forested" sites were in close proximity to roads or agricultural areas, therefore an edge effect may have existed. We may have observed more interior-edge species at some sites for this reason.

By grouping species into guilds, we were also able to narrow our focus to several species. These "target species" were of interest to us because of their habitat preferences, their population status or their detection rate in this study. The majority were interior species that prefer large tracts of contiguous forest for breeding and fledging young. Wood Thrush, Hooded Warbler, Great Crested Flycatcher and Louisiana Waterthrush were encountered predominantly around forested sites, while Summer Tanager and Eastern Wood-Pewee were detected more often along buffered sites. These detections rates are similar to those documented by Keller et al. (1993). These investigators also found an increased probability of detection for Red- Eyed Vireo, Kentucky Warbler and Wood Thrush as stand width increased and a negative probability for Eastern Wood-Pewee. Indigo Buntings were never detected in our forested sites and were seen in small numbers within the buffered sites. We also had very low detection rates for Kentucky Warbler and Pine Warbler. The pine stands within our study were mainly plantation stands, which may explain the low number of Pine Warblers present.

Canonical Correspondence Analysis

Figures 2.22-2.27 show the sites we selected positioned somewhat randomly in the ordination space, indicating that our goal of surveying across a gradient of geomorphologic variables was achieved. It has been shown that there is a distinct association between geomorphic variables and aquatic insect or fish populations (Hankin and Reeves, 1998; Weigel and Sorenson, 2000). In this study, we did not see this association between geomorphic variables and bird species. Clear groupings of species or variables were not produced by CCA. Thus, our analysis indicates that geomorphic variables play only a small role in riparian songbird communities.

Several correlations between target species and variables exist. Hooded Warbler and Louisiana Waterthrush were negatively correlated with percent canopy cover, while Eastern Wood-Pewee were positively correlated with canopy cover. Although channel slope appears in our analysis, it only varied slightly from site to site. It is likely that this variable was only associated by chance with many of these species.

Variables that were used to define CCA axes were predominantly related to patch size and vegetation. Percent riffle, floodplain width, canopy cover and channel slope defined the axes in the ‘no beaver’ analysis. On figures 2.22-2.24, there are a few distinct outliers that can be explained. Site 8 had an unusually high percent riffle (Table 2.1) and therefore is always separated away from other sites. Indigo Bunting, Pine Warbler and Kentucky Warbler were only detected on seven sites out of 37. Therefore, they were also separated from other species and sites.

The only axes where we saw clear groupings of species and sites were in the beaver impoundment group. These axes were defined by percent pool, and shrub and herbaceous obligate species. Sites 38, 39 and 40 were the three beaver sites and were found close together along the axis. Wood Duck and Belted Kingfisher were only detected at beaver impoundments, and were also grouped together along the axis (figures 2.25-2.27).

Most of our target species were associated with canopy cover and floodplain width. Louisiana Waterthrush also showed a correlation to percent riffle, although our regression analysis found it to be insignificant. We can conclude from the canonical correspondence analysis that most neotropical migrants are associated with floodplain width and vegetation characteristics of riparian forests. These habitat parameters should be conserved and maintained throughout riparian forests.

By comparing figures 2.39 and 2.40, the importance of small order streams becomes clear. Abundance and species richness were distributed across stream order, indicating that habitat along forested, low order streams was as important as habitat as along large rivers. Using ArcView, we were able to determine that our six county study area has 6302 km of “minor” streams. When combined, these small order streams make up a large amount of habitat available to wildlife. Larger order streams obviously carry a greater amount of water and therefore a higher flow velocity than smaller order streams. These differences in stream order do not seem to affect the songbird community, again leading us to believe that geomorphologic variables are not the most important aspects of songbird habitat. We conclude that habitat management and protection efforts are as important along small streams as large.

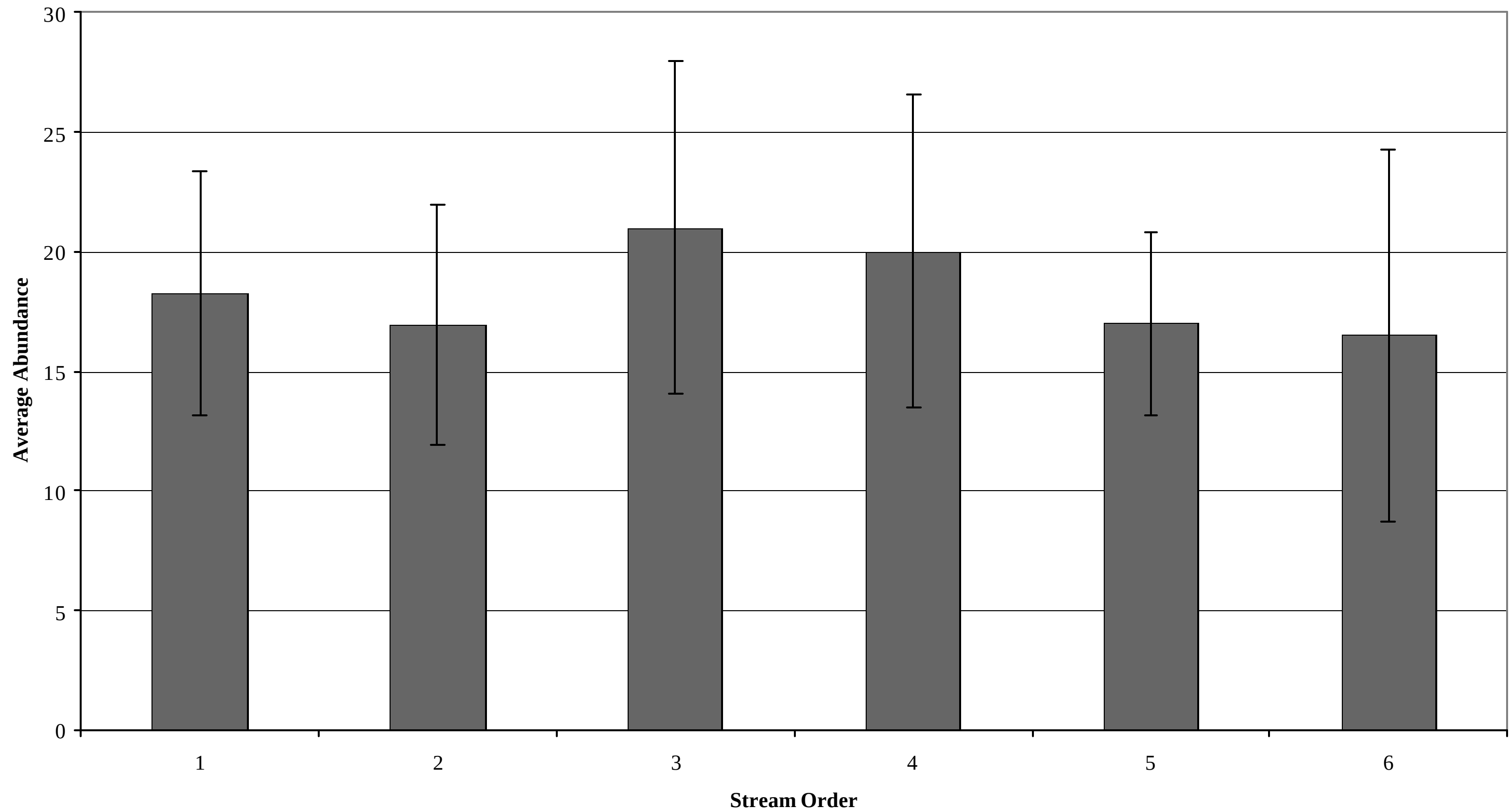

Figure 2.39. Distribution of songbird abundance across six stream orders.

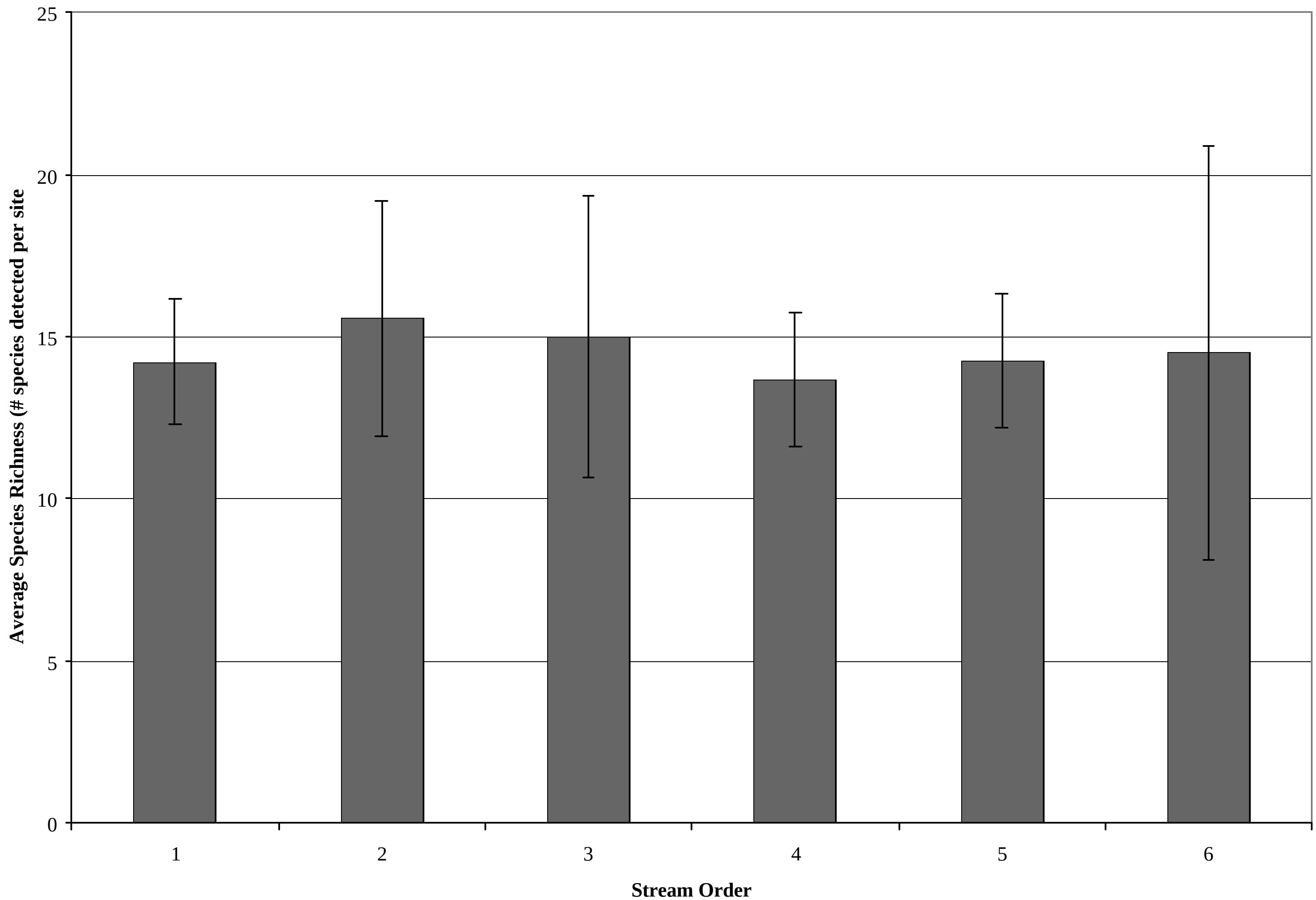

Figure 2.40. Distribution of songbird species richness across six stream orders.

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CHAPTER THREE

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Generally, relationships between avian use, stream characteristics and valley geomorphology were poor and not statistically significant. The buffered sites within our study were occupied by a variety of songbird species, including many neotropical migrants. The buffer widths within this study ranged from 30m to 150m total. We detected many songbirds, including area sensitive species within our narrow buffer widths. We did not, however, measure nesting success rates. Therefore, we cannot conclude that these sites provide adequate habitat. Harvesting affects songbirds in many ways, not only by creating an edge effect, thereby increasing the chances for predation and nest parasitism. Food resources, such as mast and invertebrates are reduced. The amount of ground level vegetation is reduced as well as snags or cavities (Wigley and Roberts, 1994). However, when using small patch cuts, this type of disturbance can be very beneficial to most birds.

Although we did not find direct ties between geomorphology and the songbird community, floodplain width and canopy cover are tied to geomorphology in many ways. Therefore, we can assume that there are many *indirect* ties between stream characteristics and the breeding birds in the surrounding area. Several species depend on aquatic invertebrates as a food source. These insects are dependent on specific channel and flow characteristics. The types of vegetation growing along floodplains are dependent on the moisture regime of the soils. Mast, fruit and berry production are all influenced by the hydrology of a site. Tree species that are resistant to flooding events will dominate frequently inundated sites, thereby influencing canopy cover.

An important finding was the relatively high use of small order streams by songbirds. Small first and second order streams are often neglected in harvest planning and left without buffers. Many assume that these tributaries are not important to species, such as birds, fish and mammals. We found that birds used small order streams, at the same rate as higher order streams. Since small streams dominate the total stream mileage, most songbird habitat is along small streams. Landowners and managers should be encouraged to protect and maintain habitat surrounding these small order streams in a manner similar to that of larger streams.

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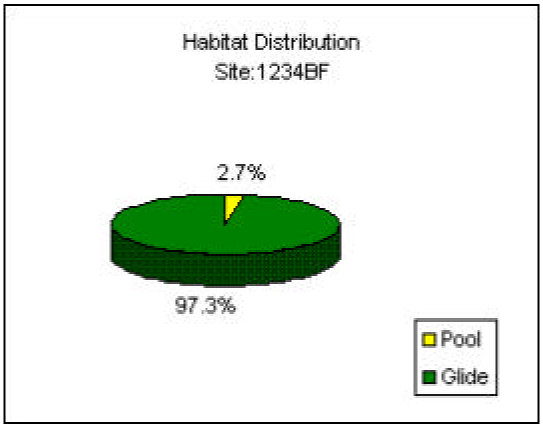
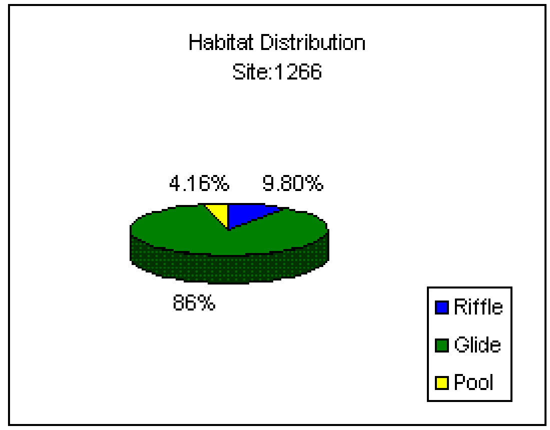
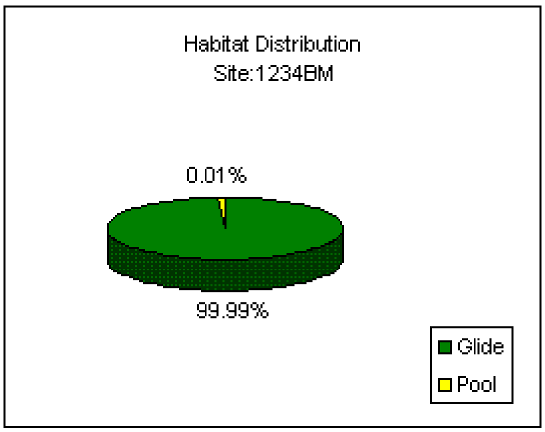
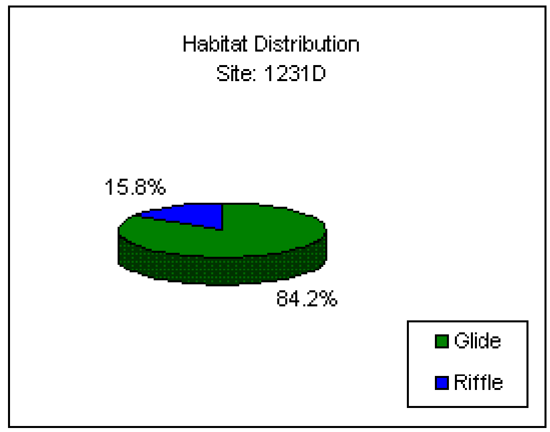
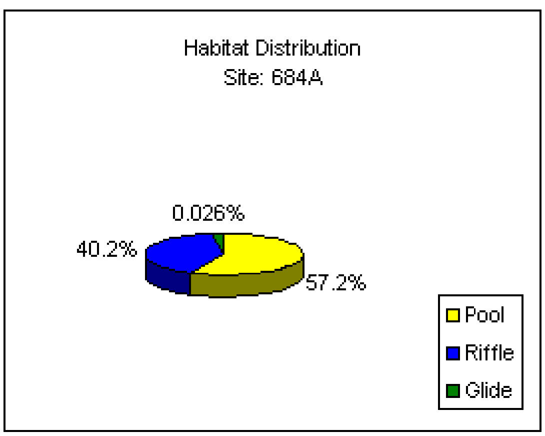
APPENDIX A. Habitat distribution for 26 sites. The remaining sites were either beaver impoundments or streams with 'glide' habitat only.

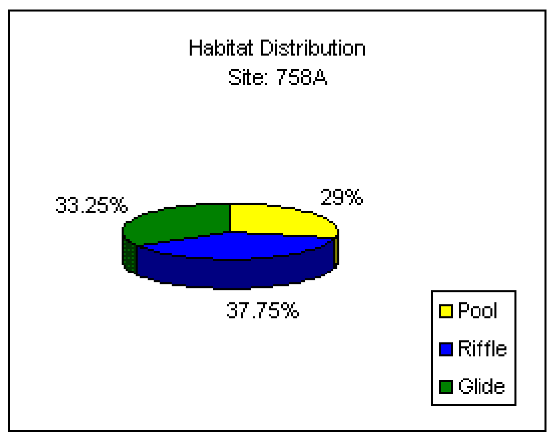












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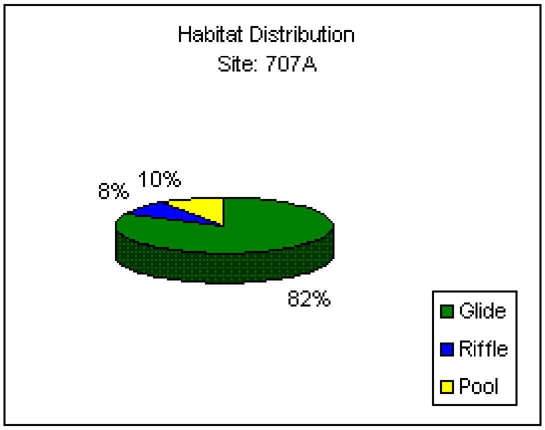

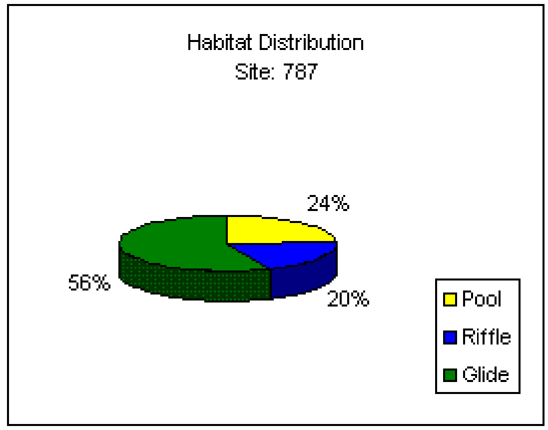

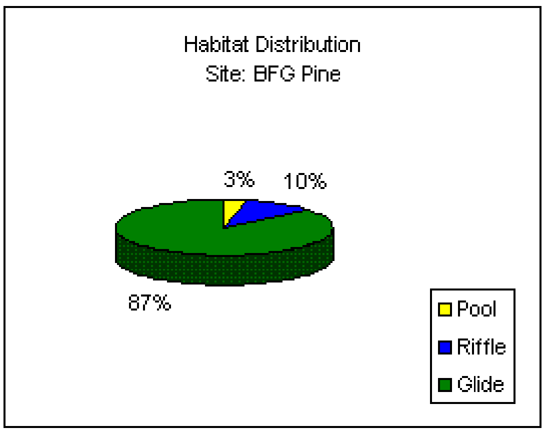

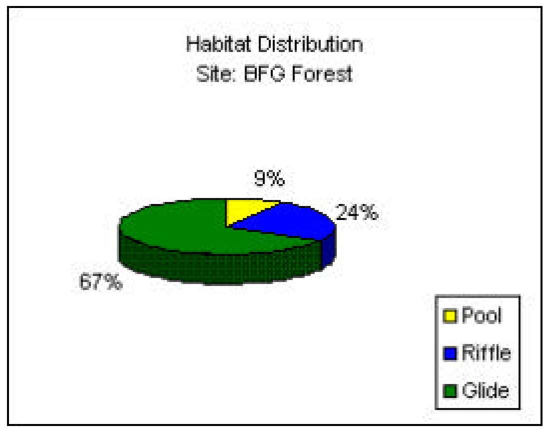

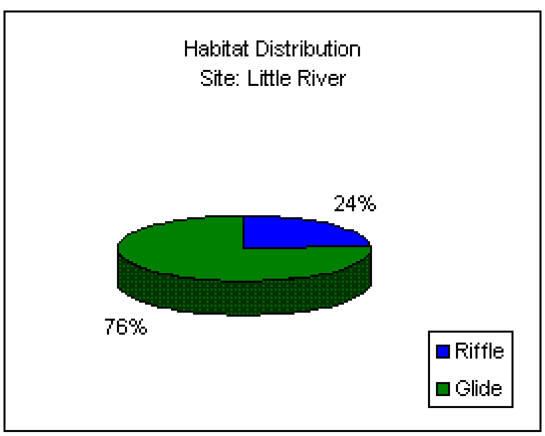

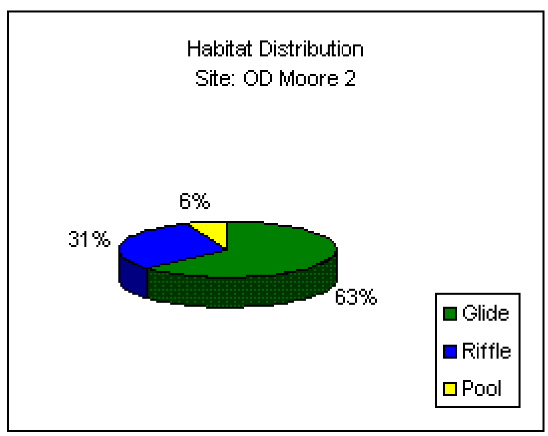

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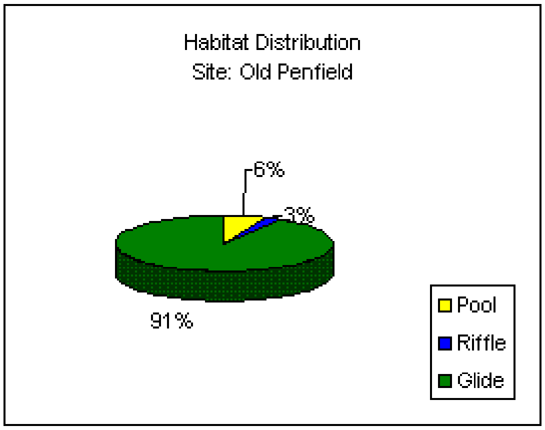

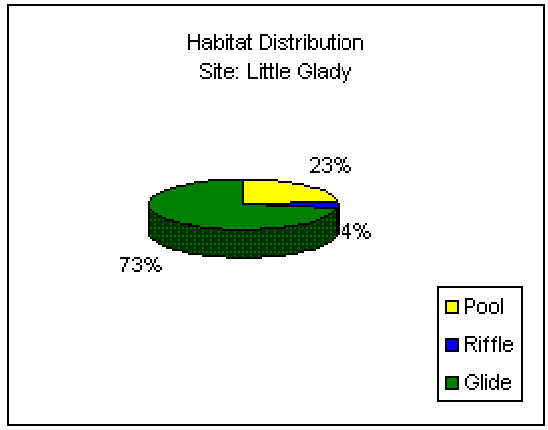

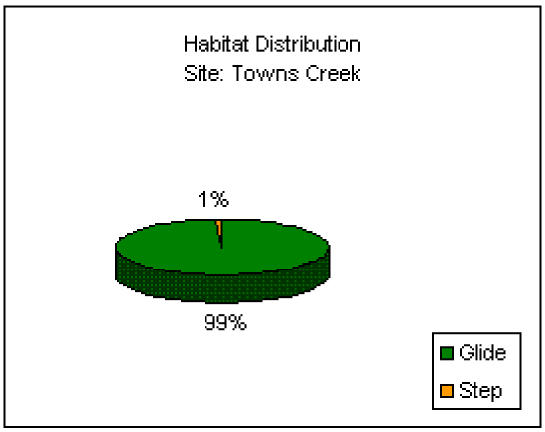

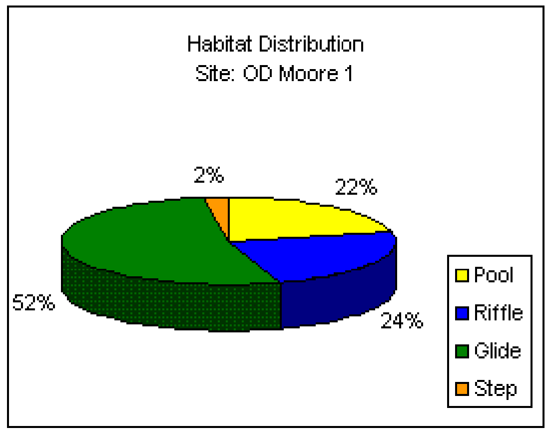

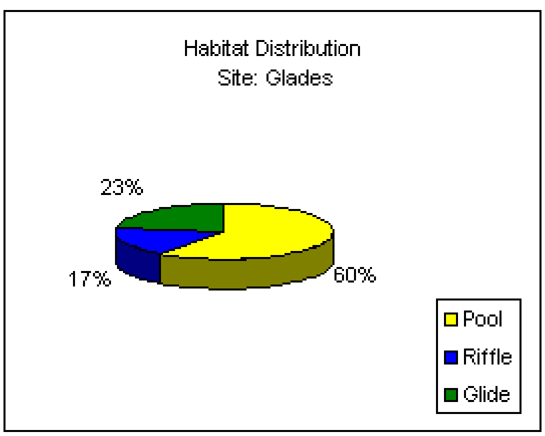

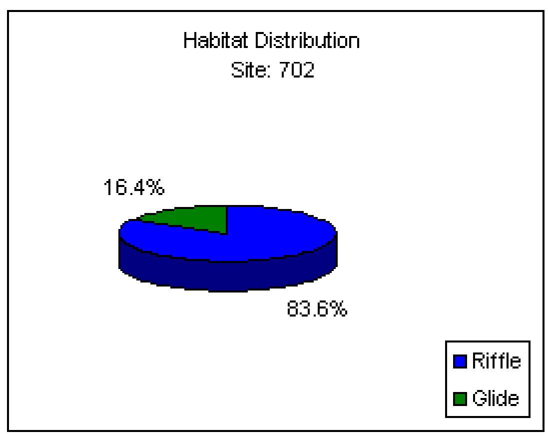

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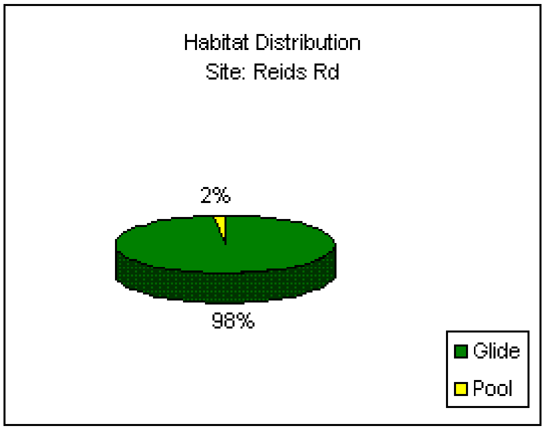

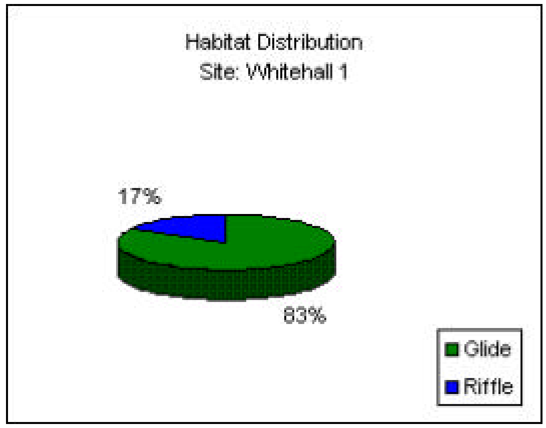

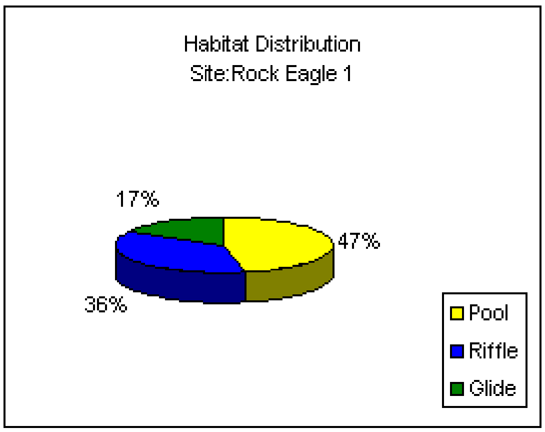

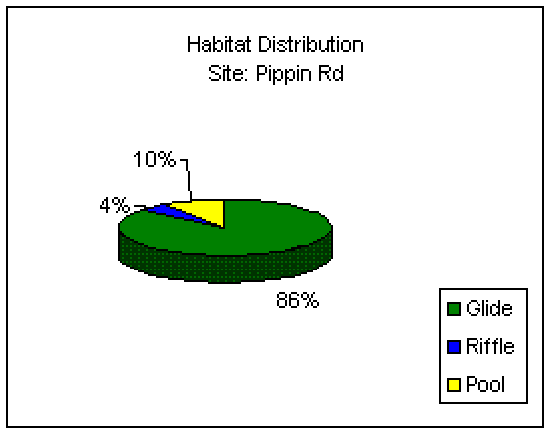

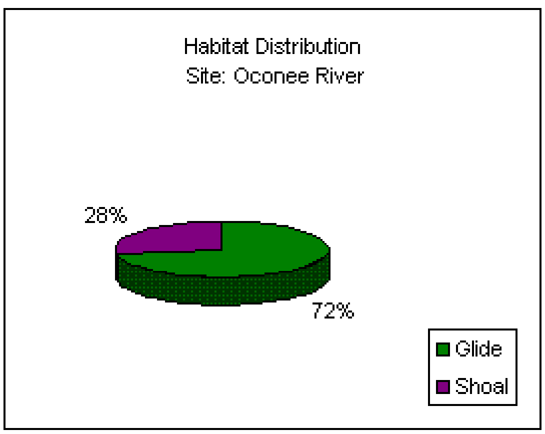

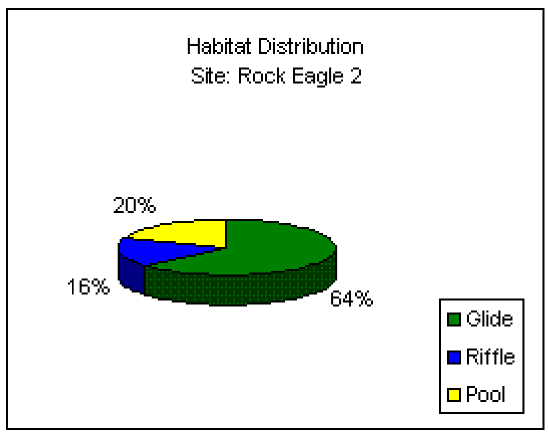

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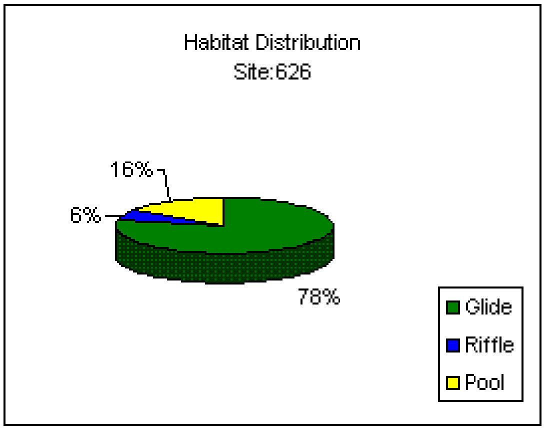
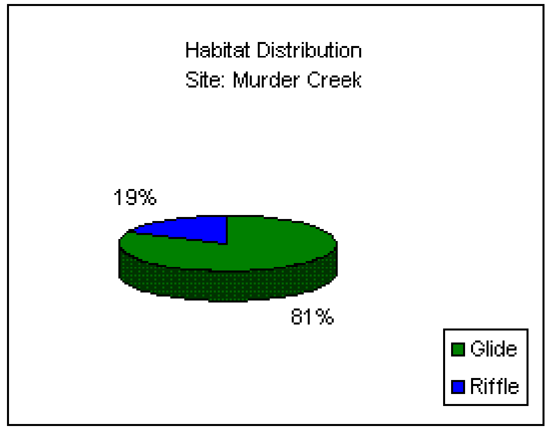




APPENDIX B. These results were determined using a Wolman pebble count. Each site is listed with a size class distribution, the number of particles within that size class and the percent of particles that were found in a finer class. Bedrock, woody debris, fine organic matter and clay particles were also noted.

	1234B Forest			1234B Marsh			1266			626	
Size Class (mm)	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**
>256	0	100	>256	0	100	>256	0	100	>256	0	100
128-256	0	100	128-256	0	100	128-256	0	100	128-256	0	100
90-128	0	100	90-128	0	100	90-128	0	100	90-128	0	100
64-90	0	100	64-90	0	100	64-90	0	100	64-90	0	100
48-64	0	100	48-64	0	100	48-64	0	100	48-64	0	100
32-48	0	100	32-48	0	100	32-48	0	100	32-48	0	100
22-32	0	100	22-32	0	100	22-32	0	100	22-32	0	100
16-22	4	98.35	16-22	0	100	16-22	0	100	16-22	140	52.7
11-16	8	95.06	11-16	0	100	11-16	28	81.57	11-16	0	52.7
8-11	5	93	8-11	0	100	8-11	0	81.57	8-11	0	52.7
4-8	4	91.35	4-8	0	100	4-8	0	81.57	4-8	0	52.7
2-4	2	90.53	2-4	0	100	2-4	0	81.57	2-4	0	52.7
<2	220	0	<2	177	0	<2	124	0	<2	156	0
Sum	243		**Sum**	177		**Sum**	152		**Sum**	296	
D50	<2 mm		**D50**	<2		**D50**	<2		**D50**	<2	
Bedrock			**Bedrock**			**Bedrock**			**Bedrock**	16	
Sm. Wood			**Sm. Wood**			**Sm. Wood**			**Sm. Wood**		
Lg. Wood			**Lg. Wood**			**Lg. Wood**	14		**Lg. Wood**		
FOD			**FOD**			**FOD**			**FOD**		
Clay			**Clay**			**Clay**	110		**Clay**		

APPENDIX B Continued.

	625			1231D			684A			702	
Size Class (mm)	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**
>256	0	100	>256	0	100	>256	0	100	>256	0	100
128-256	0	100	128-256	0	100	128-256	8	96.15	128-256	0	100
90-128	0	100	90-128	0	100	90-128	13	89.9	90-128	0	100
64-90	0	100	64-90	0	100	64-90	31	75	64-90	0	100
48-64	0	100	48-64	0	100	48-64	31	60.09	48-64	0	100
32-48	0	100	32-48	2	99.01	32-48	19	50.96	32-48	0	100
22-32	0	100	22-32	3	97.54	22-32	21	40.86	22-32	2	98.83
16-22	107	61.09	16-22	3	96.07	16-22	6	37.98	16-22	4	96.49
11-16	0	61.09	11-16	6	93.13	11-16	5	35.57	11-16	7	92.39
8-11	0	61.09	8-11	12	87.25	8-11	8	31.73	8-11	8	87.71
4-8	0	61.09	4-8	5	84.8	4-8	3	30.28	4-8	7	83.62
2-4	168	0	2-4	4	82.84	2-4	0	30.28	2-4	4	81.28
<2	0	0	<2	169	0	<2	63	0	<2	139	0
Sum	275		**Sum**	204		**Sum**	208		**Sum**	171	
D50	2-4mm		**D50**	<2		**D50**	22-32		**D50**	<2	
Bedrock			**Bedrock**	0		**Bedrock**	10		**Bedrock**	4	
Sm. Wood	30		**Sm. Wood**	6		**Sm. Wood**	10		**Sm. Wood**	10	
Lg. Wood			**Lg. Wood**	6		**Lg. Wood**	1		**Lg. Wood**		
FOD			**FOD**	34		**FOD**	28		**FOD**		
Clay			**Clay**	2		**Clay**	4		**Clay**	20	

APPENDIX B Continued.

	707A			758A			787			BFG Pine	
Size Class (mm)	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**
>256	0	100	>256	0	100	>256	0	100	>256	0	100
128-256	0	100	128-256	1	99.55	128-256	0	100	128-256	0	100
90-128	0	100	90-128	0	99.55	90-128	0	100	90-128	0	100
64-90	0	100	64-90	1	99.11	64-90	0	100	64-90	0	100
48-64	0	100	48-64	0	99.11	48-64	1	99.21	48-64	91	68.18
32-48	0	100	32-48	2	98.23	32-48	3	96.85	32-48	0	68.18
22-32	0	100	22-32	2	97.34	22-32	5	92.91	22-32	91	36.36
16-22	0	100	16-22	5	95.13	16-22	3	90.55	16-22	0	36.36
11-16	0	100	11-16	5	92.92	11-16	8	84.25	11-16	0	36.36
8-11	0	100	8-11	4	91.15	8-11	9	77.16	8-11	0	36.36
4-8	0	100	4-8	8	87.61	4-8	20	61.41	4-8	0	36.36
2-4	0	100	2-4	11	82.74	2-4	8	55.11	2-4	104	0
<2	283	0	<2	187	0	<2	70	0	<2	0	0
Sum	283		**Sum**	226		**Sum**	127		**Sum**	286	
D50	<2		**D50**	<2		**D50**	<2		**D50**	22-32	
Bedrock			**Bedrock**			**Bedrock**			**Bedrock**		
Sm. Wood			**Sm. Wood**			**Sm. Wood**			**Sm. Wood**		
Lg. Wood			**Lg. Wood**			**Lg. Wood**			**Lg. Wood**		
FOD	31		**FOD**	12		**FOD**			**FOD**		
Clay			**Clay**			**Clay**			**Clay**		

APPENDIX B Continued.

	BFG Forest			Cedar Creek			Fishing Creek			Falling Creek	
Size Class (mm)	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**
>256	0	100	>256	0	100	>256	0	100	>256	0	100
128-256	0	100	128-256	0	100	128-256	0	100	128-256	0	100
90-128	0	100	90-128	0	100	90-128	0	100	90-128	0	100
64-90	0	100	64-90	0	100	64-90	0	100	64-90	0	100
48-64	1	99.59	48-64	0	100	48-64	0	100	48-64	0	100
32-48	5	97.58	32-48	0	100	32-48	0	100	32-48	0	100
22-32	10	93.54	22-32	0	100	22-32	0	100	22-32	0	100
16-22	21	85.08	16-22	0	100	16-22	0	100	16-22	28	87.93
11-16	17	78.22	11-16	0	100	11-16	0	100	11-16	0	87.93
8-11	32	65.32	8-11	12	94.64	8-11	0	100	8-11	0	87.93
4-8	36	50.8	4-8	0	94.64	4-8	0	100	4-8	0	87.93
2-4	10	46.74	2-4	0	94.64	2-4	0	100	2-4	0	87.93
<2	116	0	<2	212	0	<2	248	0	<2	204	0
Sum	248		**Sum**	224		**Sum**	248		**Sum**	232	
D50	2-4mm		**D50**	<2		**D50**	<2		**D50**	<2	
Bedrock	2		**Bedrock**			**Bedrock**			**Bedrock**		
Sm. Wood	10		**Sm. Wood**			**Sm. Wood**			**Sm. Wood**		
Lg. Wood	4		**Lg. Wood**	13		**Lg. Wood**	19		**Lg. Wood**		
FOD	6		**FOD**			**FOD**	34		**FOD**		
Clay			**Clay**			**Clay**			**Clay**		

APPENDIX B Continued.

	Glades			Murder Creek			Hadaway W			Little Glady	
Size Class (mm)	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**
>256	0	100	>256	0	100	>256	0	100	>256	0	100
128-256	0	100	128-256	0	100	128-256	0	100	128-256	2	1.19
90-128	0	100	90-128	0	100	90-128	0	100	90-128	6	4.79
64-90	3	98.32	64-90	0	100	64-90	0	100	64-90	8	9.58
48-64	3	96.64	48-64	0	100	48-64	0	100	48-64	3	11.37
32-48	4	94.41	32-48	0	100	32-48	0	100	32-48	9	16.76
22-32	12	87.7	22-32	0	100	22-32	0	100	22-32	18	27.54
16-22	14	79.88	16-22	0	100	16-22	0	100	16-22	19	38.92
11-16	13	72.62	11-16	0	100	11-16	0	100	11-16	8	43.71
8-11	13	65.36	8-11	0	100	8-11	0	100	8-11	5	46.7
4-8	9	60.33	4-8	0	100	4-8	0	100	4-8	5	49.7
2-4	3	58.65	2-4	264	88.89	2-4	0	100	2-4	5	52.69
<2	105	0	<2	33	0	<2	252	0	<2	79	0
Sum	179		**Sum**	297		**Sum**	252		**Sum**	167	
D50	<2		**D50**	2-4mm		**D50**	<2mm		**D50**	2-4	
Bedrock	11		**Bedrock**	42		**Bedrock**			**Bedrock**	17	
Sm. Wood	2		**Sm. Wood**			**Sm. Wood**	33		**Sm. Wood**	8	
Lg. Wood	34		**Lg. Wood**			**Lg. Wood**			**Lg. Wood**	7	
FOD			**FOD**			**FOD**	30		**FOD**	6	
Clay	20		**Clay**			**Clay**			**Clay**	20	

APPENDIX B Continued.

	Little River			Old Penfield			OD Moore 1			OD Moore 2	
Size Class (mm)	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**
>256	0	100	>256	0	100	>256	0	100	>256	0	100
128-256	0	100	128-256	0	100	128-256	0	100	128-256	0	100
90-128	0	100	90-128	0	100	90-128	0	100	90-128	0	100
64-90	54	17.64	64-90	0	100	64-90	28	18.67	64-90	0	100
48-64	0	17.64	48-64	0	100	48-64	22	33.33	48-64	69	49.64
32-48	0	17.64	32-48	0	100	32-48	0	33.33	32-48	0	49.64
22-32	0	17.64	22-32	0	100	22-32	0	33.33	22-32	0	49.64
16-22	0	17.64	16-22	0	100	16-22	0	33.33	16-22	21	64.75
11-16	0	17.64	11-16	0	100	11-16	0	33.33	11-16	0	64.75
8-11	0	17.64	8-11	0	100	8-11	75	83.33	8-11	0	64.75
4-8	0	17.64	4-8	0	100	4-8	0	83.33	4-8	26	83.45
2-4	187	78.75	2-4	0	100	2-4	25	0	2-4	23	0
<2	65	0	<2	125	0	<2	0	0	<2	0	0
Sum	306		Sum	125		Sum	150		Sum	139	
D50	2-4 mm		D50	<2mm		D50	8-11mm		D50	16-22mm	
Bedrock			Bedrock			Bedrock	75		Bedrock	92	
Sm. Wood	21		Sm. Wood	43		Sm. Wood	13		Sm. Wood		
Lg. Wood	14		Lg. Wood			Lg. Wood	15		Lg. Wood		
FOD			FOD	97		FOD			FOD		
Clay			Clay	44		Clay			Clay		

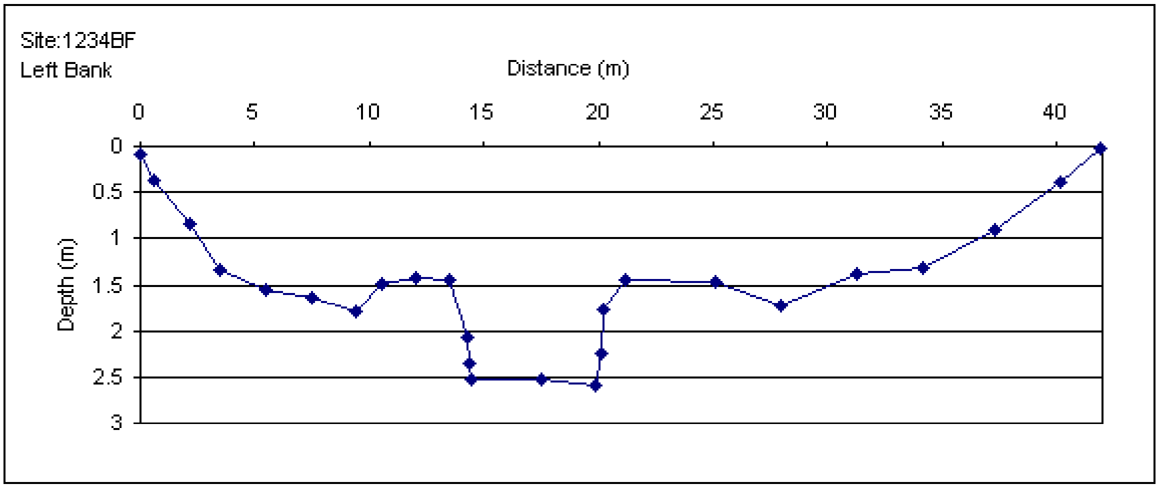
APPENDIX B Continued.

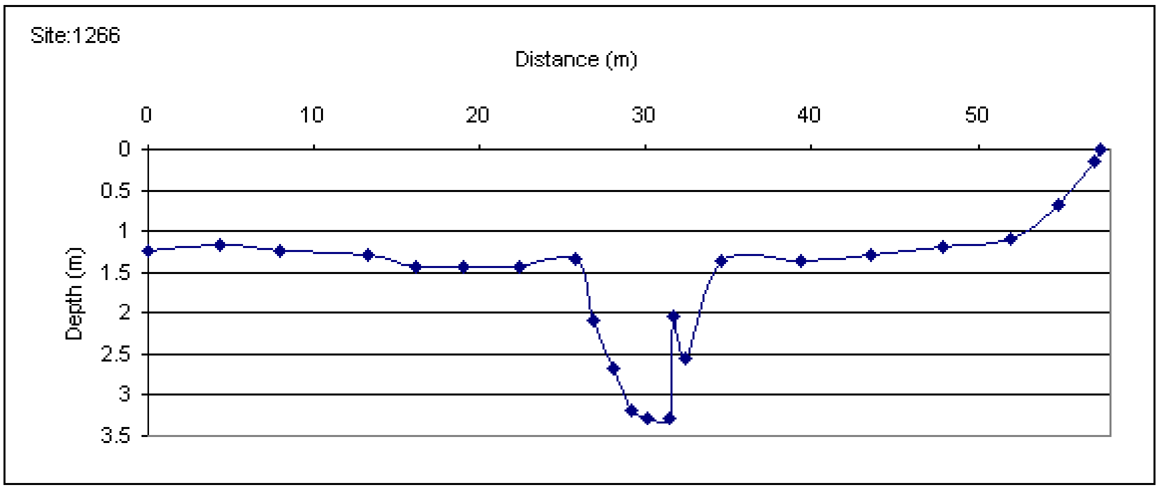
	Oconee River			Rock Eagle1			Rock Eagle 2			Pippin Rd	
Size Class (mm)	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**
>256	0	100	>256	1	0.53	>256	1	0.44	>256	0	100
128-256	0	100	128-256	3	2.15	128-256	1	0.88	128-256	0	100
90-128	0	100	90-128	7	5.91	90-128	0	0.88	90-128	0	100
64-90	0	100	64-90	18	18.81	64-90	0	0.88	64-90	0	100
48-64	0	100	48-64	22	30.64	48-64	6	3.52	48-64	0	100
32-48	0	100	32-48	19	37.63	32-48	11	8.37	32-48	0	100
22-32	0	100	22-32	22	49.46	22-32	12	13.65	22-32	46	20
16-22	12	5.66	16-22	16	58.06	16-22	7	16.74	16-22	0	20
11-16	10	10.37	11-16	12	64.51	11-16	4	18.5	11-16	0	20
8-11	0	10.37	8-11	7	68.27	8-11	11	23.34	8-11	0	20
4-8	0	10.37	4-8	8	72.58	4-8	3	24.66	4-8	0	20
2-4	0	10.37	2-4	3	74.19	2-4	0	24.66	2-4	0	20
<2	190	0	<2	48	0	<2	171	0	<2	184	0
Sum	212		**Sum**	186		**Sum**	227		**Sum**	230	
D50	<2mm		**D50**	16-22mm		**D50**	<2mm		**D50**	<2mm	
Bedrock	8		**Bedrock**	5		**Bedrock**			**Bedrock**		
Sm. Wood			**Sm. Wood**	9		**Sm. Wood**	18		**Sm. Wood**		
Lg. Wood			**Lg. Wood**	1		**Lg. Wood**	21		**Lg. Wood**		
FOD			**FOD**	39		**FOD**	27		**FOD**		
Clay			**Clay**	2		**Clay**	36		**Clay**		

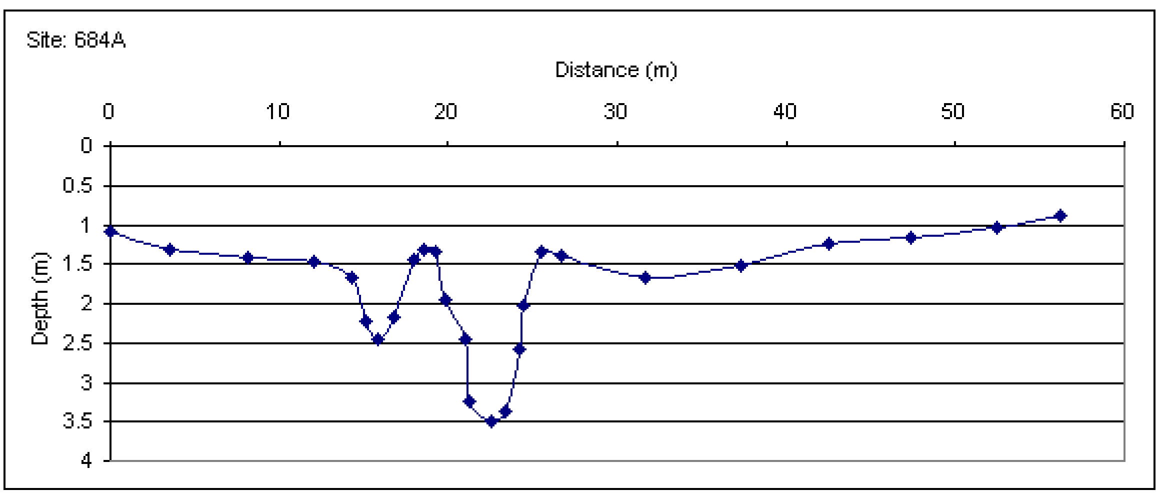
APPENDIX B Continued.

	Whitehall 1			Whitehall 2	
Size Class (mm)	**#**	**% Finer**	**Size Class (mm)**	**#**	**% Finer**
>256	0	100	>256	0	100
128-256	0	100	128-256	0	100
90-128	0	100	90-128	0	100
64-90	0	100	64-90	0	100
48-64	0	100	48-64	0	100
32-48	0	100	32-48	0	100
22-32	0	100	22-32	0	100
16-22	0	100	16-22	0	100
11-16	90	40	11-16	0	100
8-11	0	40	8-11	0	100
4-8	0	40	4-8	0	100
2-4	0	40	2-4	0	100
<2	135	0	<2	292	0
Sum	225		**Sum**	292	
D50	<2		**D50**	<2mm	
Bedrock			**Bedrock**		
Sm. Wood			**Sm. Wood**		
Lg. Wood			**Lg. Wood**		
FOD			**FOD**	53	
Clay			**Clay**		

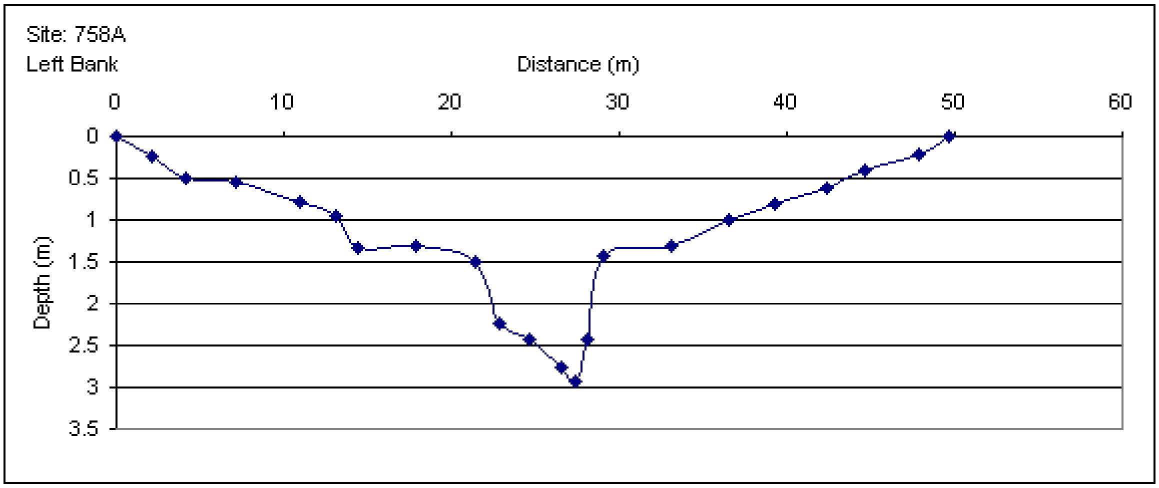
APPENDIX C. Cross sections completed during 2000-2001 for each site within a six county area in the Piedmont of Georgia.

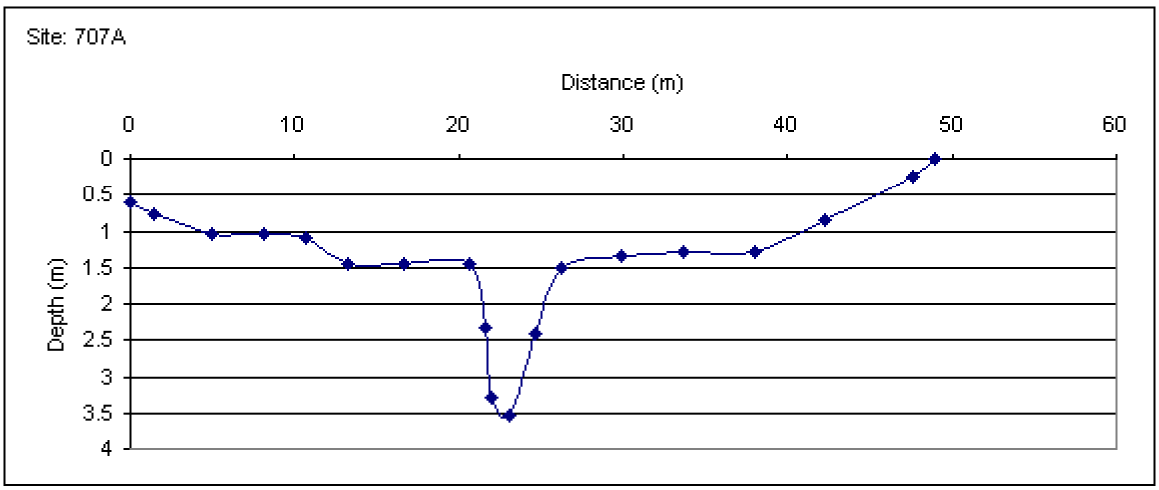


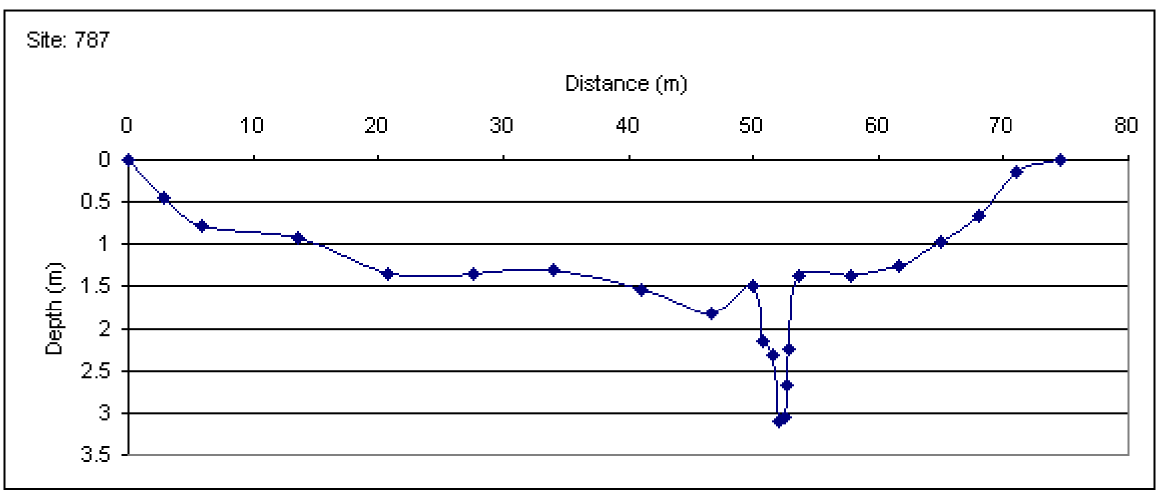




APPENDIX C Continued.







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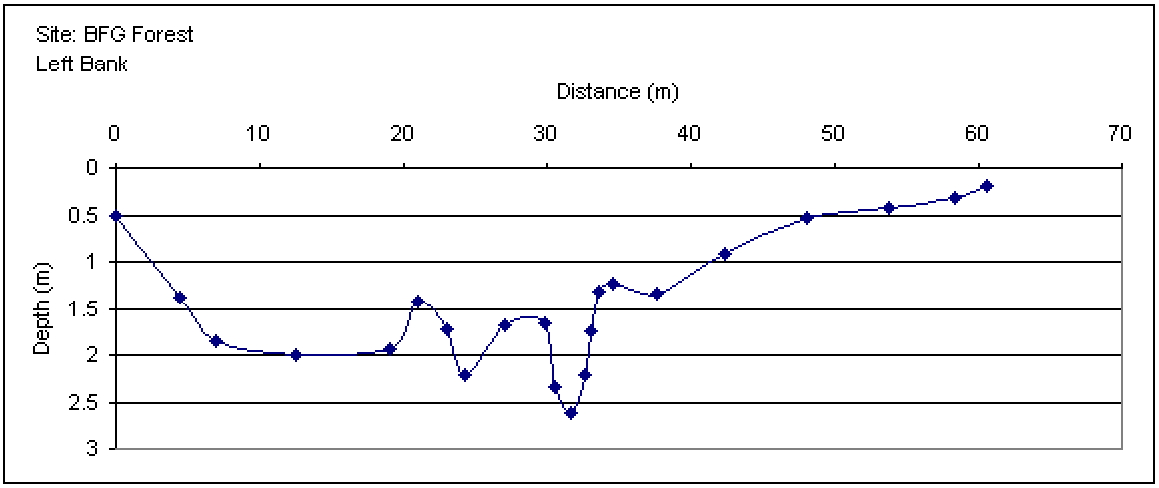

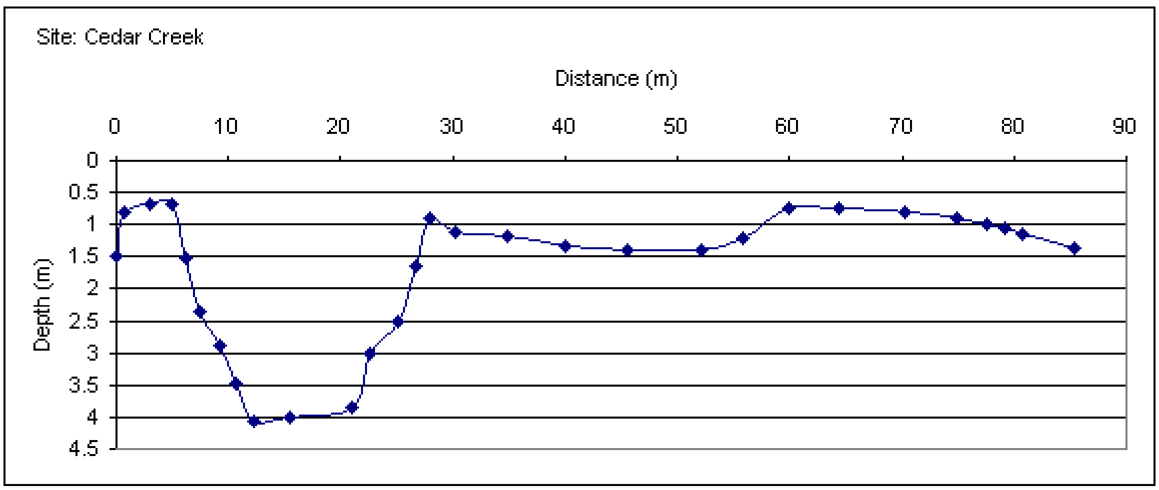

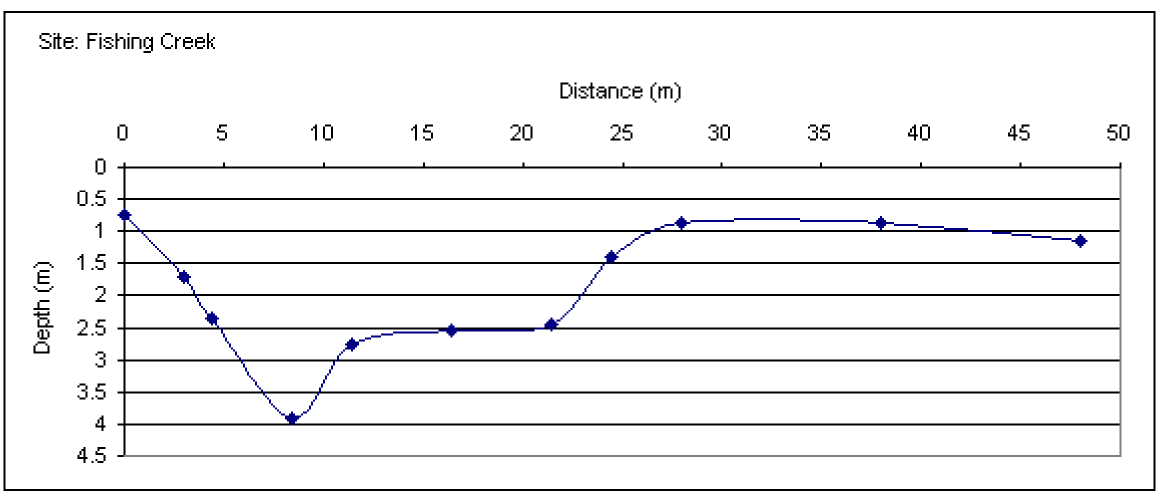

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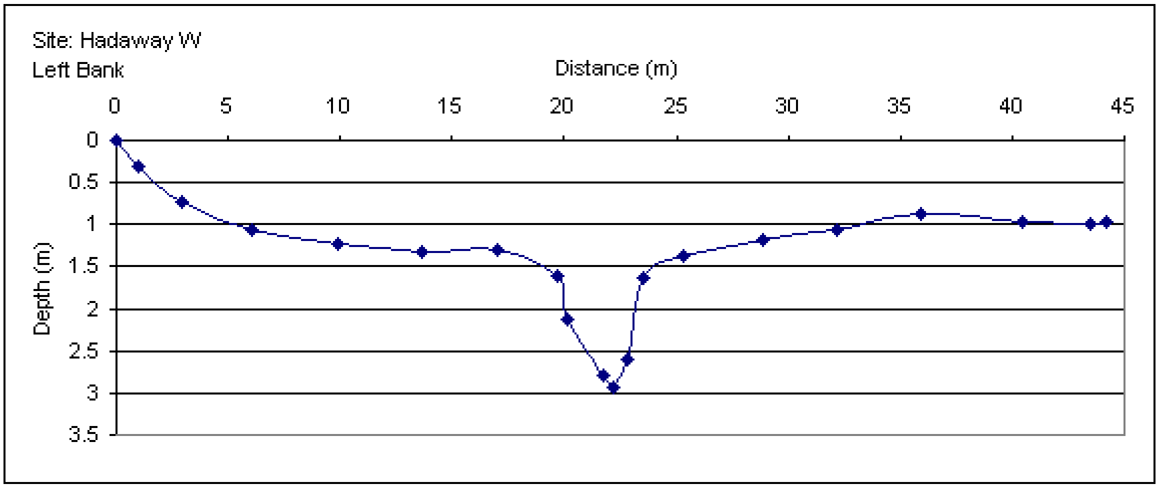

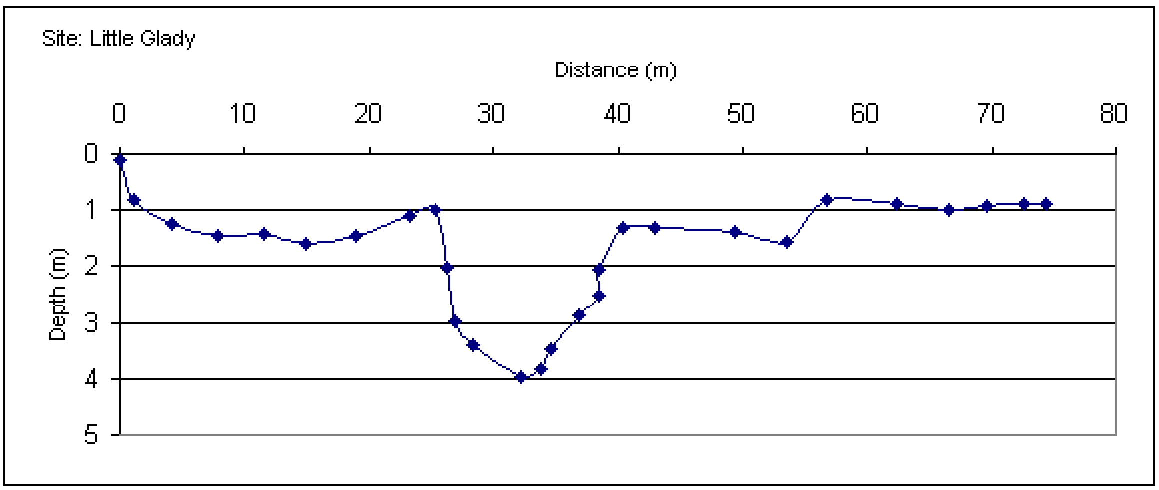

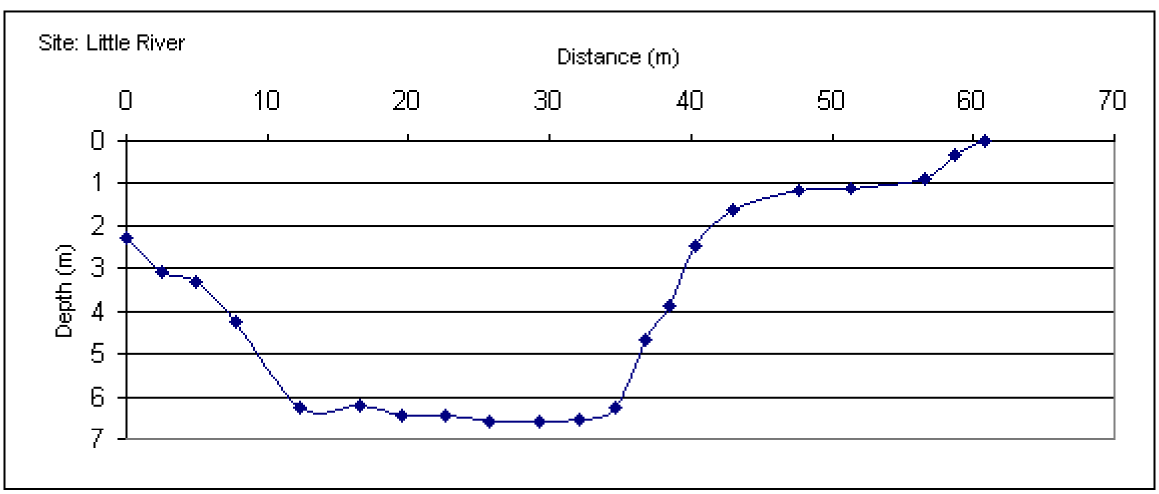

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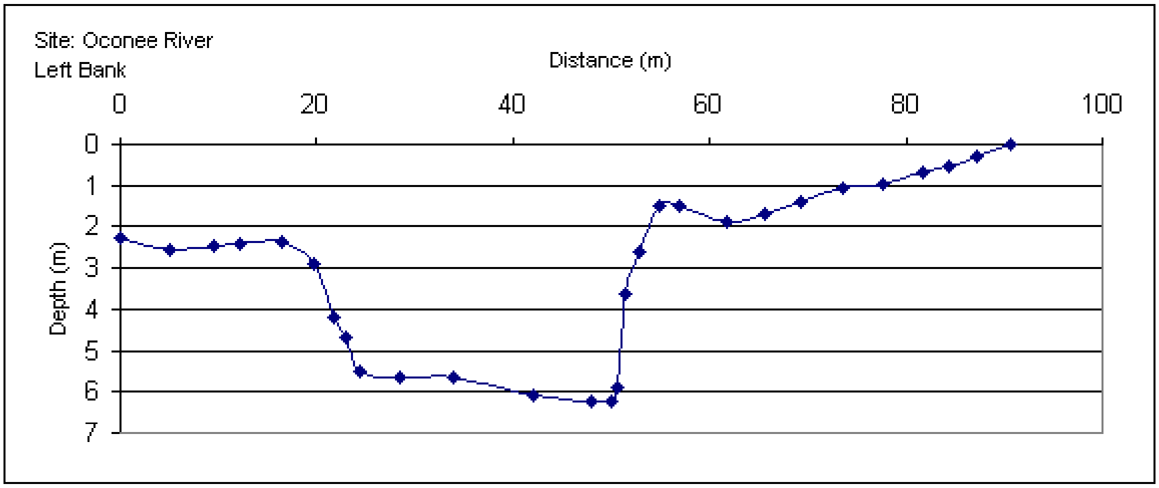

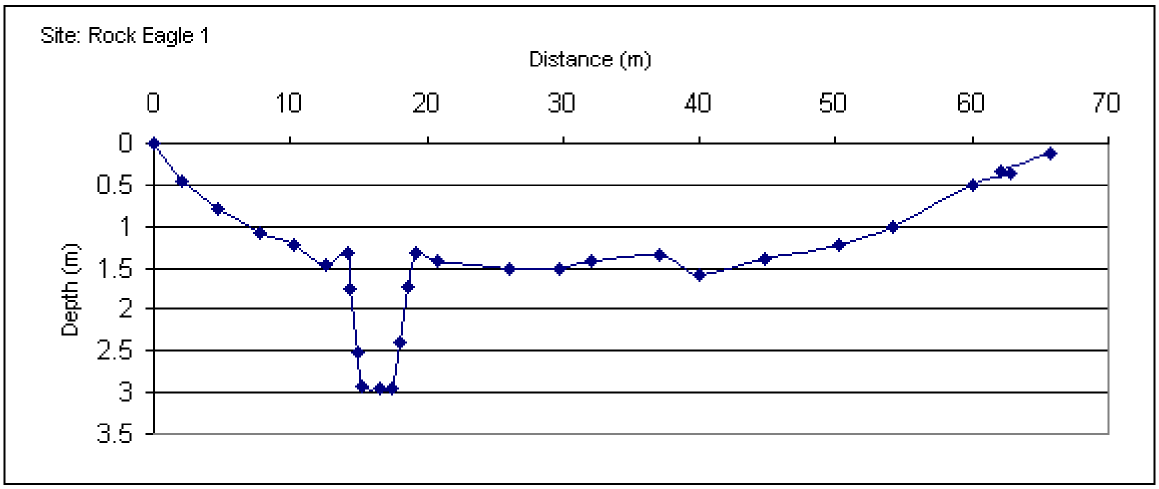

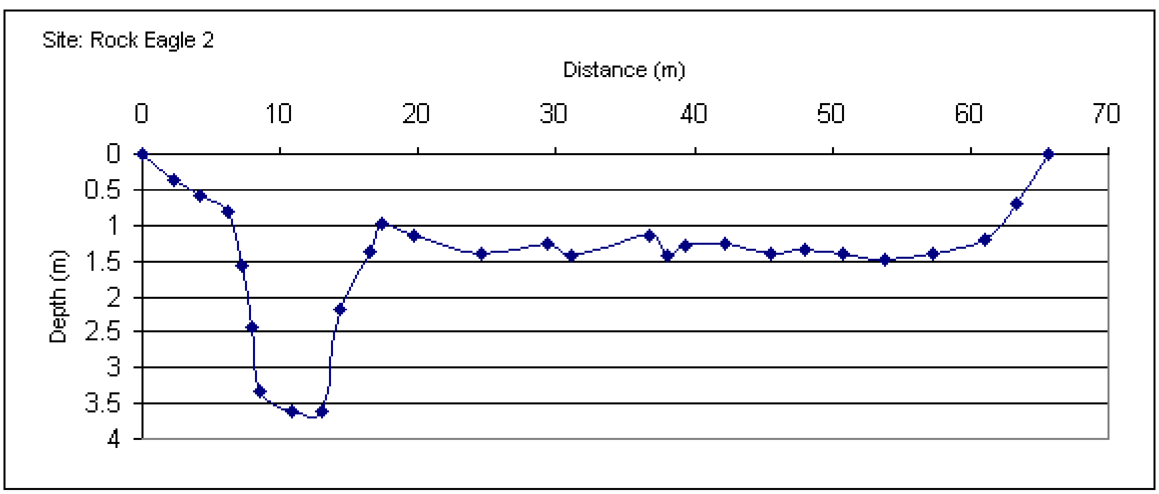

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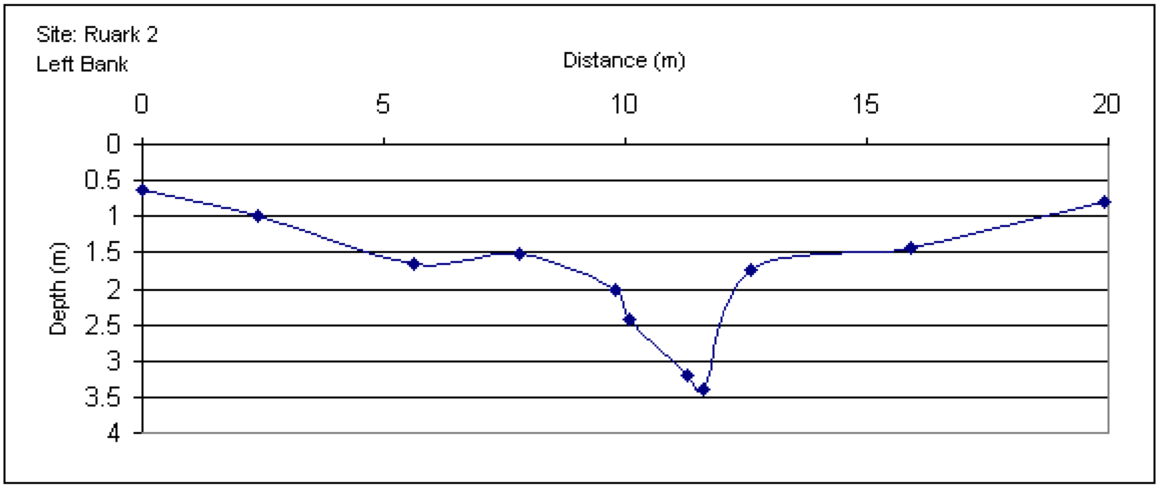

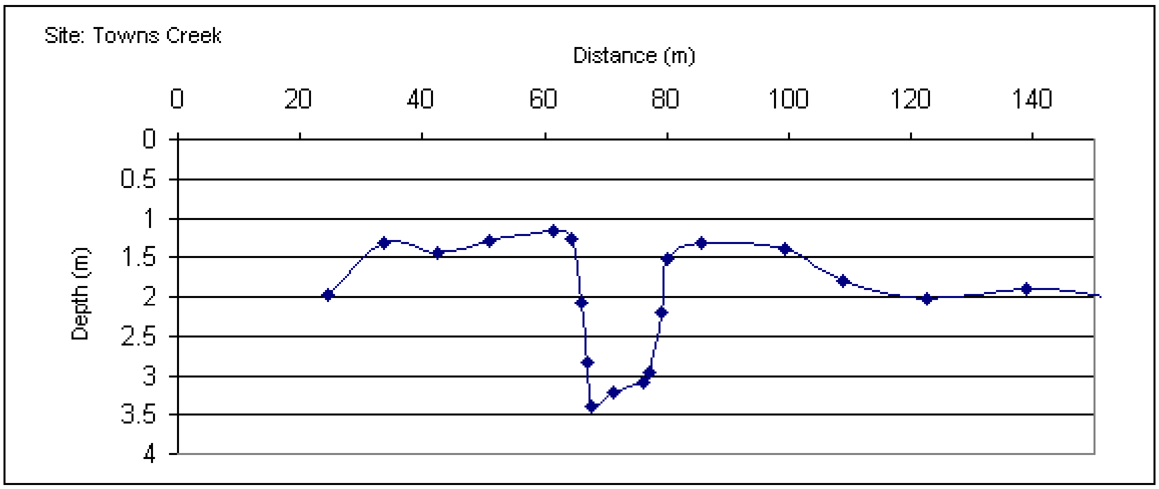

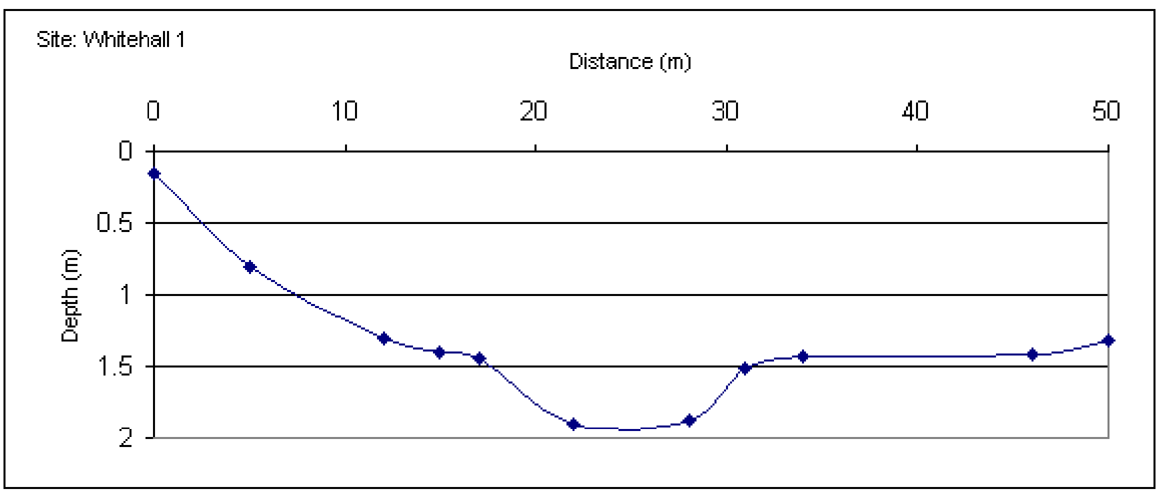

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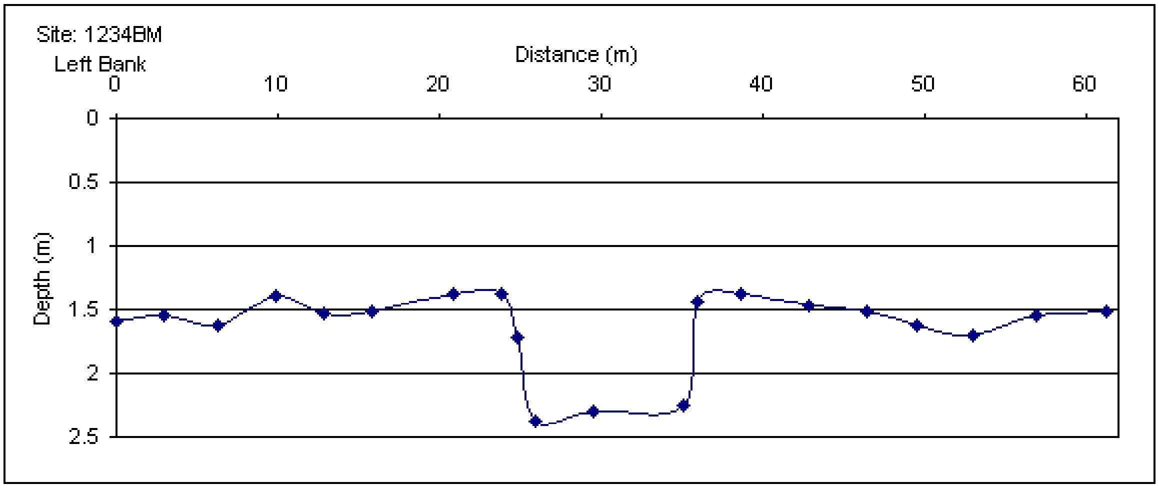

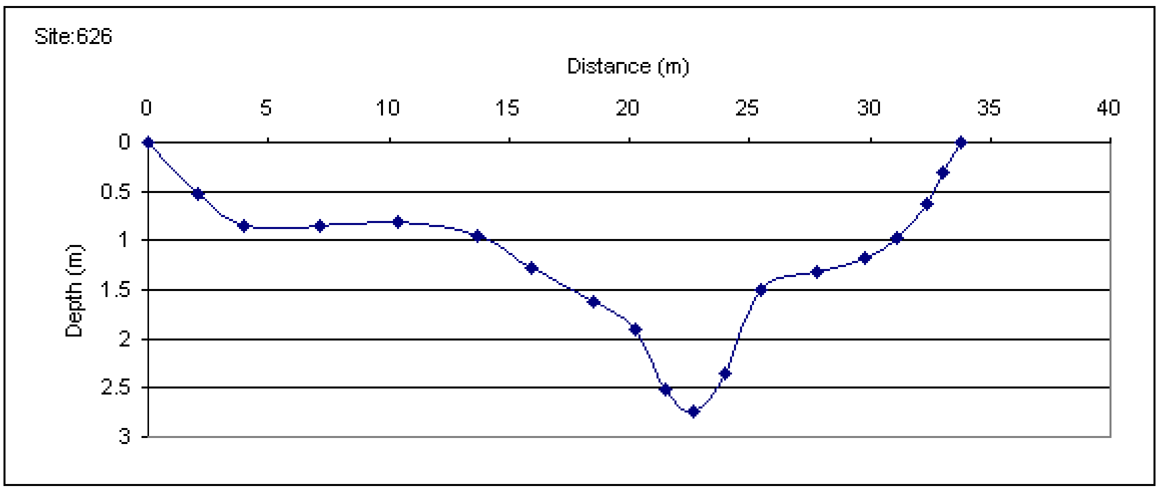

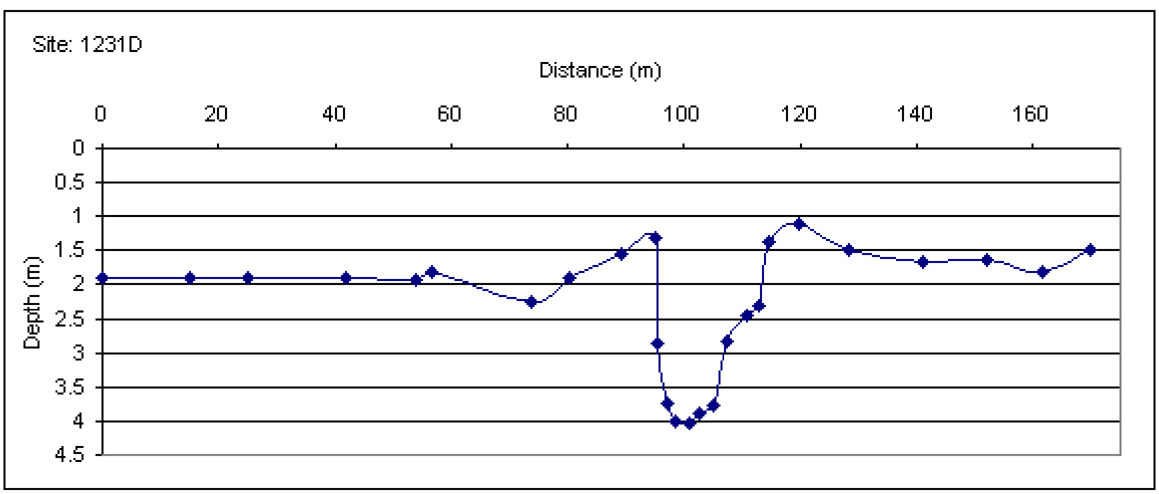

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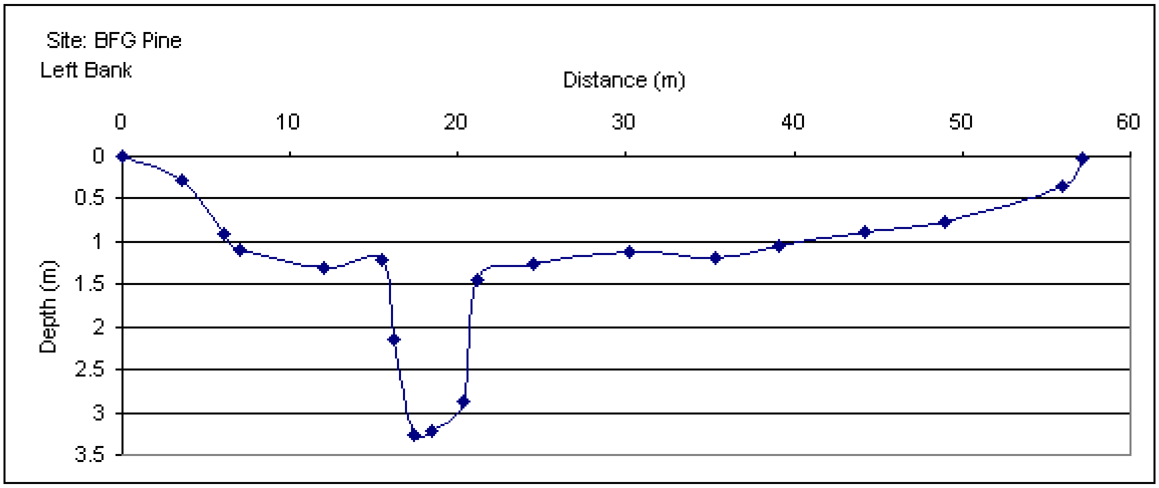

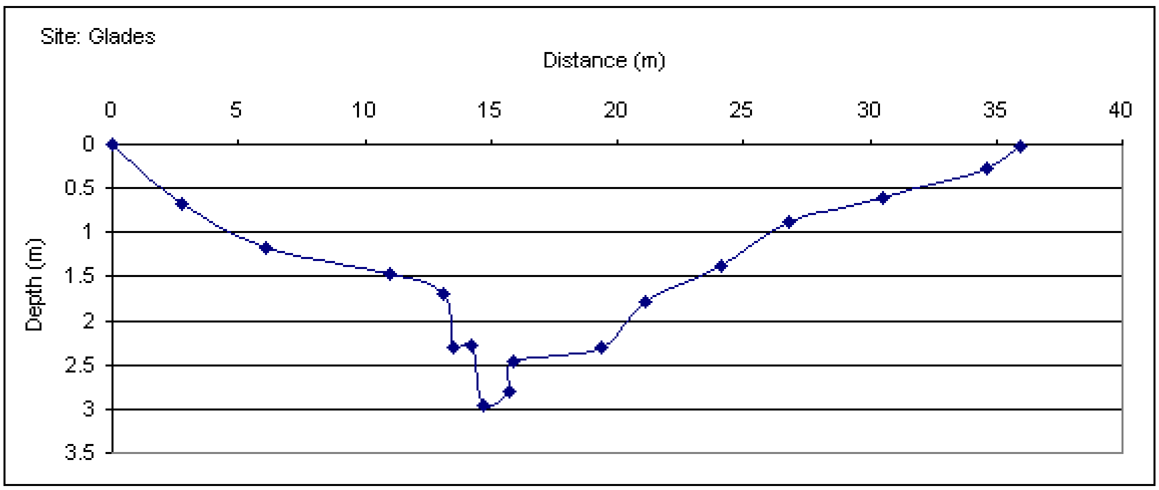

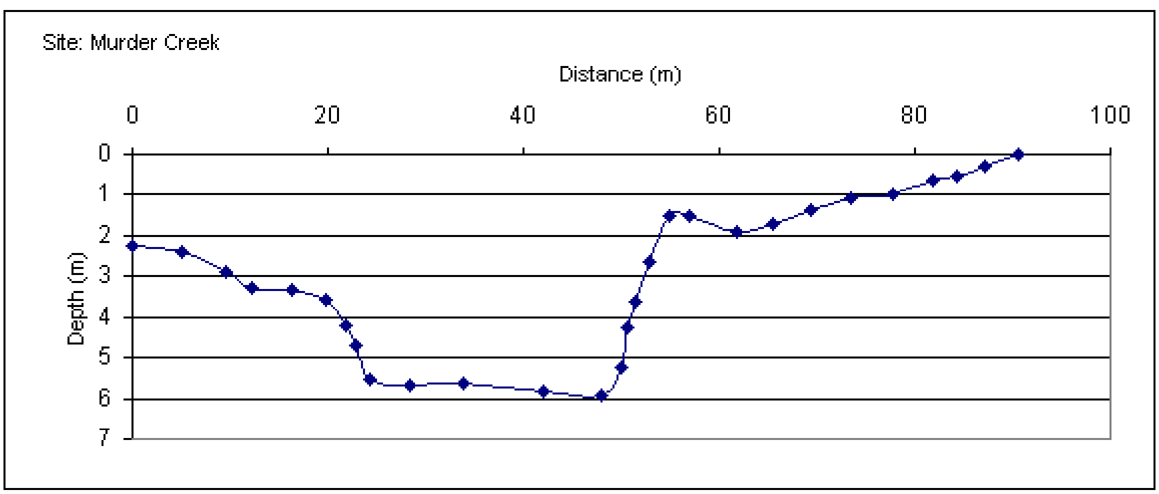

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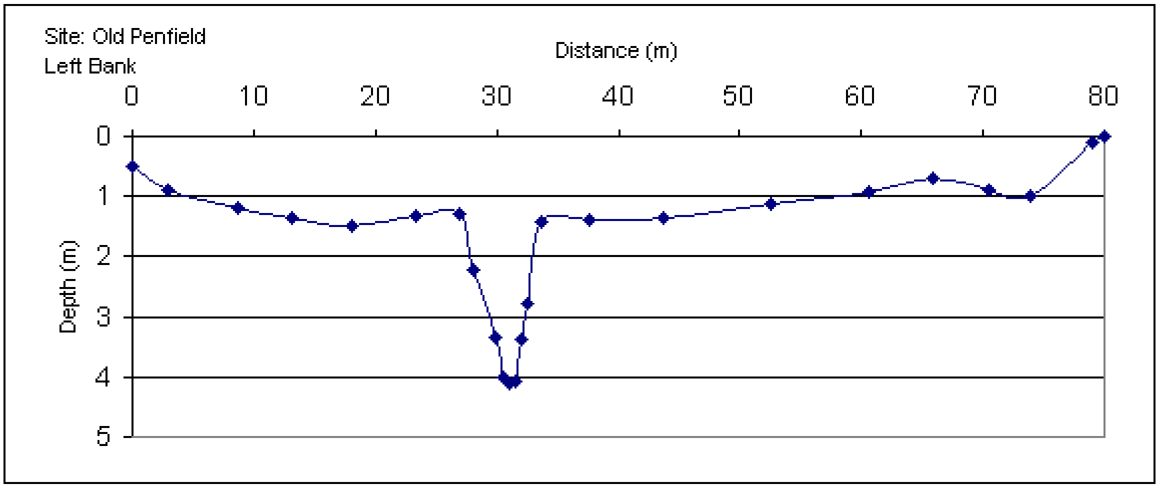

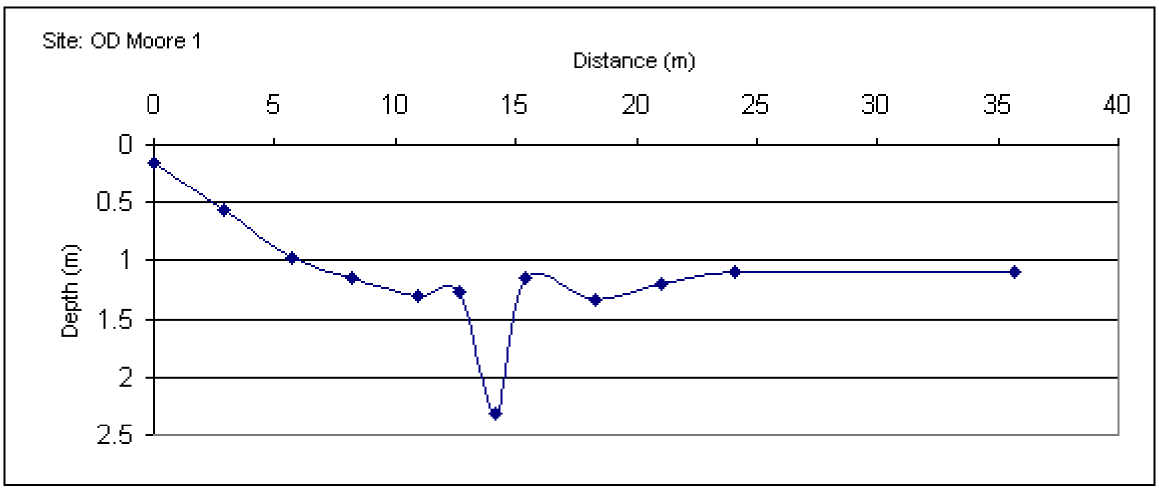

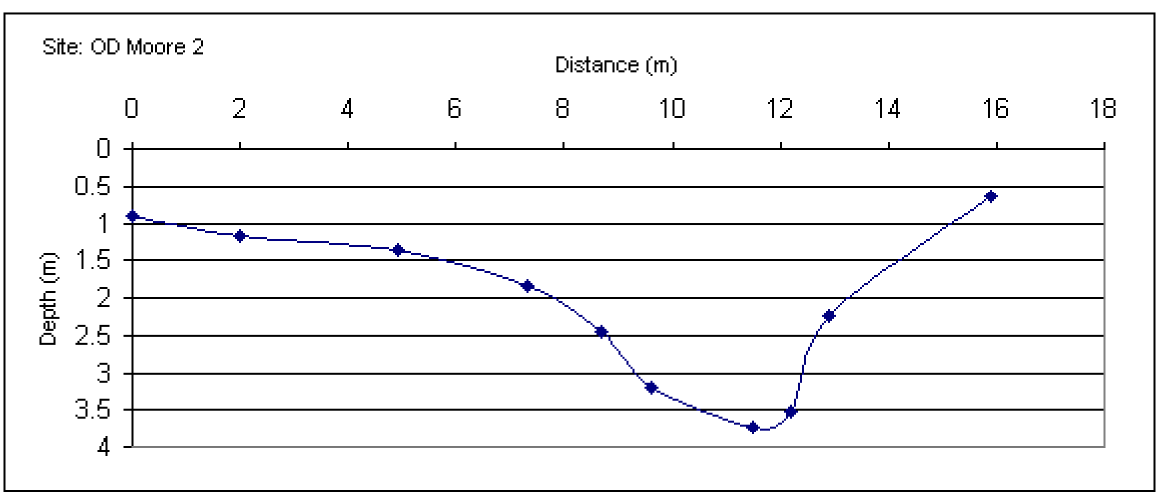

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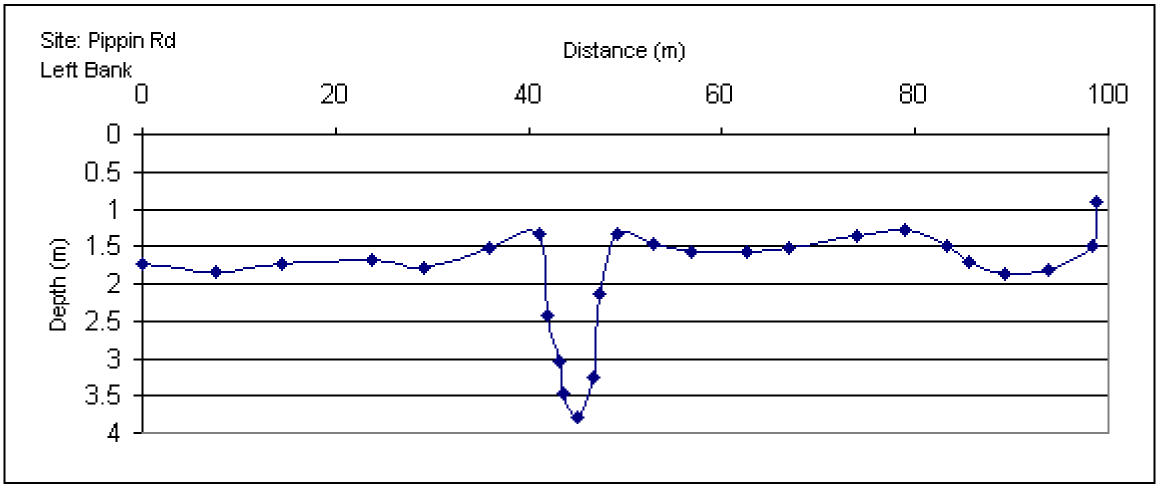

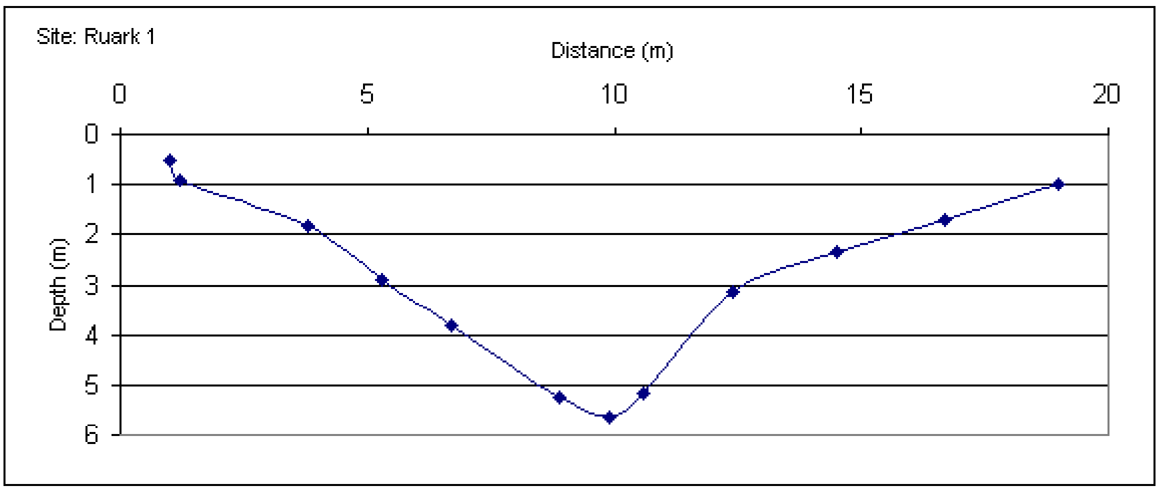

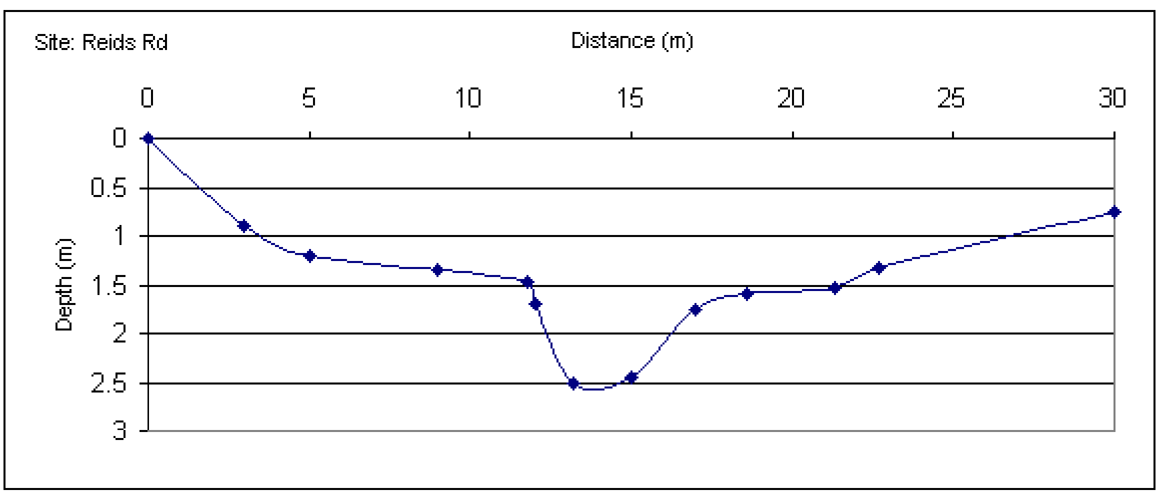

APPENDIX C Continued.

APPENDIX D. Tree and shrub species from 2000-2001 transect surveys, [a]species codes and [b]corresponding wetland indicator status.

Common Name	Scientific Name	Species Code	Indicator
American Elm	*Ulmus americana*	ULAM	FACW
American Holly	*Ilex opaca*	ILOP	FAC-
Ash	*Fraxinus americana*	FRAM	FACU
Autumn Olive	*Eleagnus umbellate*	ELUM	FAC
Azalea	*Rhododendron canescens*	RHCA	FACW-
Basswood	*Tilia americana*	TILI	NI
Beautyberry	*Callicarpa americana*	CAAM	FACU-
Bitternut Hickory	*Carya cordiformis*	CARY	FAC
Blackberry	*Rubus argutus*	RUBU	FACU+
Black Cherry	*Prunus serotina*	PRSE	FACU
Black Locust	*Robinia pseudoacacia*	ROBI	UPL
Black Walnut	*Juglans nigra*	JUNI	FACU
Black Willow	*Salix nigra*	SANI	OBL
Blackgum	*Nyssa sylvatica*	NYSY	FAC
Blueberry	*Vaccinium elliottii*	VAEL	FAC+
Box Elder	*Acer negundo*	ACNE	FACW
Buckeye	*Aesculus pavia*	AEPA	FAC
Catalpa	*Catalpa bignonoides*	CABG	FAC-
Chestnut Oak	*Quercus prinus*	QUPR	UPL
Chinquapin Oak	*Quercus muehlenbergii*	QUMU	NI
Cottonwood	*Populus deltoids*	PODE	FAC+
Cucumbertree	*Magnolia acuminata*	MAAC	NI
Dogwood	*Cornus florida*	COFL	FACU
E. Red Cedar	*Juniperus virginiana*	JUVI	FACU-
Elderberry	*Sambucus canadensis*	SACA	FACW-
Hawthorn	*Crataegus flava*	CRFL	NI
Hazel Alder	*Alnus serrulata*	ALSE	FACW+
Hornbeam	*Ostrya virginiana*	OSVI	FACU-

APPENDIX D Continued.

Ironwood	*Carpinus caroliniana*	CARC	FAC
Laurel Oak	*Quercus laurifolia*	QULA	FACW
Loblolly	*Pinus taeda*	PITA	FAC
Mimosa	*Mimosa pigra*	MIPI	NI
Mockernut Hickory	*Carya tomentosa*	CARY	UPL
Mountain Laurel	*Kalmia latifolia*	KALA	FACU
Mulberry	*Morus rubra*	MORU	FAC
Pawpaw	*Asimina parviflora*	ASPA	FACU
Persimmon	*Diospyros virginiana*	DIVI	FAC
Post Oak	*Quercus stellata*	QUST	UPL
Privet	*Ligustrum sinense*	LISI	FAC
Red Maple	*Acer rubrum*	ACRU	OBL
Red Oak	*Quercus rubra*	QURU	FACU
Redbud	*Cercis canadensis*	CECA	FACU
River Birch	*Betula nigra*	BENI	FACW
Sassafras	*Sassafras albidum*	SAAL	FACU
Scarlet Oak	*Quercus coccinea*	QUCO	UPL
Shagbark Hickory	*Carya ovata*	CARY	FACU
Slash Pine	*Pinus elliottii*	PIEL	FACW
Sourwood	*Oxydendrom arboreum*	OXAR	NI
Sugar Maple	*Acer saccharum*	ACSA	FACU-
Sweetgum	*Liquidambar styraciflua*	LIST	FAC+
Switchcane	*Platanus occidentalis*	PLOC	FACW
Water Oak	*Quercus nigra*	QUNI	FAC
White Oak	*Quercus alba*	QUAL	FACU+
Winged Elm	*Ulmus alata*	ULAL	FACU+
Witch Hazel	*Hamamelis virginiana*	HAVI	FACU
Yellow Poplar	*Liriodendron tulipifera*	LITU	FAC

[a,b]**From US Fish and Wildlife Service Biological Report 88(24).**

APPENDIX E. Bird species listed in text and/or encountered during 2000-2001 transect counts, species code[a], and migratory status[b]. NTMB=Neotropical Migratory Bird, SDM=Short Distance Migrant, RES=Resident. Nomenclature follows American Ornithologists' Union (1983). **Target species in bold** Species not detected during our surveys are indicated by *.

Common Name	Scientific Name	[a]Code	[b]Status
Acadian Flycatcher	*Empidonax virescens*	ACFL	NTMB
American Crow	*Corvus brachyrhynchos*	AMCR	RES
Barred Owl	*Strix varia*	BAOW	RES
Bay-breasted Warbler*	*Dendroica castanea*	BBWA	NTMB
Belted Kingfisher	*Ceryle alcyon*	BEKI	RES
Blackburnian Warbler*	*Dendroica fusca*	BLBW	NTMB
Black-and-White Warbler	*Mniotilta varia*	BAWW	NTMB
Black-Throated Green Warbler*	*Dendroica virens*	BTNW	NTMB
Blue Jay	*Cyanocitta cristata*	BLJA	RES
Blue-Gray Gnatcatcher	*Polioptila caerulea*	BGGN	NTMB
Brown-Headed Cowbird	*Molothrus ater*	BHCO	SDM
Cape May Warbler*	*Dendroica tigrina*	CMWA	NTMB
Carolina Chickadee	*Parus carolinensis*	CACH	RES
Carolina Wren	*Thryothorus ludovicianus*	CARW	RES
Chestnut-Sided Warbler*	*Dendroica pensylvanica*	CSWA	NTMB
Common Yellowthroat	*Geothlypis trichas*	COYE	SDM
Downy Woodpecker	*Picoides pubescens*	DOWO	RES
Eastern Phoebe	*Sayornis phoebe*	EAPH	SDM
Eastern Wood Pewee	*Contopus virens*	EAWP	NTMB
Golden-Crowned Kinglet	*Regulus satrapa*	GCKI	SDM
Great-Crested Flycatcher	*Myiarchus crinitus*	GCFL	NTMB
Hairy Woodpecker	*Picoides villosus*	HAWO	RES
Hooded Warbler	*Wilsonia citrina*	HOWA	NTMB
Indigo Bunting	*Passerina cyanea*	INBU	NTMB
Kentucky Warbler	*Oporornis formosus*	KEWA	NTMB
Louisiana Waterthrush	*Seiurus motacilla*	LOWA	NTMB
Mourning Dove	*Zenaida macroura*	MODO	RES
Northern Bobwhite	*Colinus virginianus*	NOBO	RES
Northern Cardinal	*Cardinalis cardinalis*	NOCA	RES
Northern Parula	*Parula americana*	NOPA	NTMB
Ovenbird*	*Seiurus aurocapillus*	OVEN	NTMB
Pileated Woodpecker	*Dryocopus pileatus*	PIWO	RES
Pine Warbler	*Dendroica pinus*	PIWA	SDM
Prairie Warbler	*Dendroica discolor*	PRAW	NTMB
Red-Bellied Woodpecker	*Melanerpes carolinus*	RBWO	RES
Red-Eyed Vireo	*Vireo olivaceous*	REVI	NTMB
Red-Headed Woodpecker	*Melanerpes erythrocephalus*	RHWO	RES
Scarlet Tanager	*Piranga olivacea*	SCTA	NTMB
Summer Tanager	*Piranga rubra*	SUTA	NTMB
Tufted Titmouse	*Parus bicolor*	TUTI	RES
White-Eyed Vireo	*Vireo griseus*	WEVI	SDM
White-throated Sparrow*	*Zonotrichia albicolis*	WTSP	SDM
Wood Duck	*Aix sponsa*	WODU	SDM
Wood Thrush	*Hylocichla mustelina*	WOTH	NTMB
Yellow-Throated Warbler	*Dendroica dominica*	YTWA	NTMB

[a] Species codes for birds as found in the North American Bird Banding Manual (Gustafson et al. 1997). [b]Migratory status based on Whitcomb et al. (1981), and Scott (1987).