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USING AVIFAUNA FOR ECOLOGICAL ASSESSMENT IN STREAMSIDE MANAGEMENT ZONES IMPLEMENTED BY FORESTRY BEST MANAGEMENT PRACTICES

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USING AVIFAUNA FOR ECOLOGICAL ASSESSMENT IN STREAMSIDE MANAGEMENT ZONES IMPLEMENTED BY FORESTRY BEST MANAGEMENT PRACTICES

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment of the Requirements for the Degree
Master of Science
Forest Resources

by
Keenan Jerome Adams
August 2007

Accepted by:
Dr. Joseph Drew Lanham, Committee Chair
Dr. Ben Wigley
Dr. David Guynn
ABSTRACT

Riparian ecosystems provide many ecological functions critical to both aquatic and terrestrial vertebrates. Anecdotal field observations indicate that upland forest harvesting may affect riparian ecosystem functions, yet the relationship has not been well documented, especially for wildlife. As part of the collaborative Dry Creek watershed study at International Paper’s Southlands Forest in Decatur County, Georgia, I evaluated the effects of Best Management Practices (BMP) timber harvesting on avian communities occupying riparian corridors/streamside management zones (SMZs) in headwater streams of the Gulf Coastal Plain of Georgia. Using repeated visits to established line transects, data were collected during the breeding seasons from 2003 to 2006 to assess the relative conservation value of treated and reference watersheds and the spatial distribution of select riparian zone avifauna. The activity patterns (as defined by records of occurrence from transect surveys) of Louisiana Waterthrush (*Seiurus motacilla*), Acadian Flycatchers (*Empidonax virescens*) and Northern Parula Warblers (*Parula americana*) were analyzed using a Geographic Information System (GIS) and modifications of home range kernel estimates. Activity cluster results for Louisiana Waterthrush indicated differences in cluster dispersion within the riparian zones. Results also showed that Conservation Values for riparian zone avifauna were higher in the SMZ of the unharvested watersheds. Methods such as activity clusters and conservation value scoring may provide a viable method for assessing faunal communities in riparian zones.
ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Best Management Practices (BMPs)

In Georgia, best management practices (BMPs) were originally developed by a Forestry Nonpoint Source Pollution Technical Task Force (as required by the Federal Water Pollution Control Act -Georgia Forestry Commission 1999). The purpose of the Federal Water Pollution Control Amendments of 1972 (currently known as the Clean Water Act), was to “restore and maintain the chemical, physical, and biological integrity of the Nation’s waters.”

Streamside management zones (SMZs) are one of the most important components of BMP guidelines (Governo 2004). SMZ’s are defined by the Georgia Forestry Commission (1999) as “buffer strips” adjacent to a perennial or intermittent streams or other bodies of water that should be managed with special considerations in order to protect water quality (Figure 1, Table 1). The proper management of SMZs may protect many ecological functions of riparian forest including the reduction of water temperatures, filtration of sediments and pollutants (nutrients and pesticides), supply of aquatic ecosystems with woody debris, dissipation of overland flow and provision of wildlife habitat (Georgia Forestry Commission 1999). Although the function of riparian zones in maintaining aquatic communities has been well documented, there have been relatively few studies relating SMZs to wildlife communities. How well wildlife
communities are supported should also be taken into consideration for SMZ effectiveness.

Riparian Area Importance

Lowrance et al. (1985) defined a riparian ecosystem as “… a complex assemblage of plants and other organisms in an environment adjacent to and near flowing water. Without definitive boundaries, riparian areas may include streambanks, floodplains, and wetlands, as well as sub-irrigated sites forming a transitional zone between upland and aquatic areas. Mainly linear in shape and extent, riparian areas are characterized by lateral flowing water that rises and falls at least once within a growing season. This riparian ecosystem provides important ecological functions with its connection to the soil, hydrology, and biotic communities.”

Riparian importance to water quality

Riparian forest hydrology has received an abundance of legislative and research attention (Wegner 1999). A critical function of riparian forest is the protection of water quality by reducing the amount of sediment, nutrients and other pollutants that enter streams, lakes and other surface waters. This filtration occurs as contaminants are buried in sediments, taken up by riparian vegetation, and adsorbed by clay and organic particles. Contaminants are then immobilized or denitrified by soil microorganisms, or other processes (Klapproth 1999). Protection of water quality is important to humans and wildlife communities.
Figure 1. Georgia Best Management Practices slope guidelines (Georgia Forestry Commission 1999).
Table 1. Streamside Management Zone width by slope class and stream type (Georgia Forestry Commission 1999).

<table>
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<td>Perennial (feet)</td>
<td>Intermittent (feet)</td>
<td>Trout (Feet)</td>
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<td>20</td>
<td>100</td>
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<td>Moderate (21-40%)</td>
<td>70</td>
<td>35</td>
<td>100</td>
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<tr>
<td>Steep (&gt;40%)</td>
<td>100</td>
<td>50</td>
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Riparian importance to Wildlife

Unharvested trees often represent a loss of revenue in timber harvesting operations. Because valuable stands of timber often exist in bottomlands and along water courses, riparian areas may not always be reserved from timber harvest. With the increasing losses of riparian areas, the value of SMZs for wildlife is critical in many landscapes. Rich soils, nutrient input, and water availability contribute to high productivity and diversity of vegetation within riparian areas. The diversity and productivity of the riparian plant community and its proximity to water make these areas especially attractive for many species of wildlife, including: mammals, herpetofauna, and avifauna (Klapproth 1999). For mature forest species, wider riparian zones likely are important.

Bioindicators

At times, wildlife related metrics have served as indicators for health of biological systems or bioindicators for riparian zone conditions. A bioindicator is a species used to assess the health of an environment or ecosystem health. Ecosystem health often refers to a systems’ structural and functional intactness. An ideal bioindicator should: “1) be taxonomically well-known and stable, 2) have an understood biology and general life history, 3) have populations that are readily surveyed and manipulated, 4) consist of groups and related species that should occupy a breadth of habitats and a broad geographical range, and 5) contain patterns observed in the indicator taxon that are reflected in other related and unrelated taxa” (D. Pearson 2007, personal communication).
Comprehensive, multimetric indices to evaluate stream biotic integrity were first developed for fishes (Karr 1981), and more recently for invertebrates (Lenat 1988), (Kerans and Karr 1991). The index of biological integrity (IBI) was developed for fish communities (Karr et al, 1986). This index measures the health of a stream based on a variety of resident fish attributes. After fish, benthic macroinvertebrates were used for assessing stream integrity. “Benthic macroinvertebrates are now the most widely used indicators of stream water quality because they are ubiquitous [and] have sufficiently long life cycles to integrate the effects of disturbance” (Rosenberg and Resh 1993,). A method of using taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) was established by Lenat (1988). This method focused specifically on these taxa groups to assess stream integrity, where a decline in taxa richness indicated a decline in biological integrity.

While the IBI and EPT are frequently used tools for understanding aquatic and riparian integrity, some investigators have suggested that multi-taxon/multi-species and regional/communities bioindicators may be useful for riparian communities (Brooks et al. 1998). They state that “Measures of ecological indicators and habitat conditions will vary between reference standards sites and reference sites that are impacted, and that these measures can be applied consistently across a regional gradient in the form of a Regional Index of Biological Integrity (RIBI).” For forest riparian ecosystems in the Mid-Atlantic States, they illustrated “how four integrative bioindicators can be combined to develop a RIBI.” The integrative bioindicators contained: 1) macroinvertebrate communities, 2) amphibian communities, 3) avian communities, and 4) avian
productivity, primarily for the Louisiana Waterthrush (*Sirius motacilla*). Studies of riparian wildlife that serve as bioindicators can provide insights to riparian zone condition as well as riparian ecology.

Research of wildlife associated with these riparian areas has increased the understanding of riparian ecology. Large mammal studies have added to the understanding of riparian ecology, but many of these have focused on single species and have not addressed SMZ width effectiveness. Typically larger mammals have large territorial requirements. Klapproth (1999) suggested that riparian areas must have sufficient space or connection to other large tracts of contiguous forest in order for the riparian areas to be useful for animals with larger territorial requirements. Smaller SMZs may be utilized by mammals that use riparian areas for only part of their needs or other animals with smaller area requirements. There have been conflicting results for studies of SMZ width effectiveness in maintaining populations of small mammals. Dickson and Williamson (1998) assessed the use of hardwood SMZs by small mammals in forest clearcuts and found that there were significantly more species present in narrow (≤24.99 meters) than in wider SMZs. Tappe et al. (1994) however, found that the width of hardwood SMZs had little effect on small mammal abundance, richness, or diversity in managed pine stands. Other investigators (Klapproth 1999) found that the structure of adjacent forest stands was the primary factor that determined the presence of small mammals. Studies of small mammals suggest they may not be viable bioindicators because they are not easily monitored.
Reptiles and amphibians vary in their dependence upon riparian areas, and some herpetofauna may be better bioindicators of SMZ effectiveness than small mammals. Many amphibians spend their entire lives within the stream and riparian zone while other species use it for breeding (Brode and Bury 1984, Wenger 1999). However, research addressing SMZ width effectiveness and herpetofauna in riparian areas is minimal. Rudolph and Dickson (1990) performed a study on SMZ width and the effects on herpetofauna. Focusing on communities of reptiles and amphibians in SMZs of various widths in eastern Texas, they found that the reptile and amphibian abundances were greater in the widest SMZs (> 29.87m) and lower in SMZs less than 24.99m wide.

Birds use riparian areas for a number of purposes (breeding, foraging, travel, etc.). Marquis and Whelan (1994) indicated that understanding bird-habitat relationships is important both locally and on the landscape scale because forest health may depend on the presence of breeding birds. Forest-dwelling birds have been shown to control the numbers of insects feeding on tree foliage (Hodges and Kremetz 1996).

Meiklejohn and Hughes (1999) explored the extent to which bird communities in riparian buffer strips downslope of large clear-cuts resembled communities in riparian zones with intact upslope forest by using main stem rivers, tributary streams, and reference streams as the study units. The main stem rivers buffer widths averaged 76m, while the tributary streams averaged 32m in buffer width. They found that species richness, evenness, diversity, and density varied little among riparian site types, but composition of the bird communities differed considerably. While information gained from traditional use of species diversity indices are useful, differences in species
communities composition were not defined. Therefore interpretation of conservation value relative to the presence of high priority or high conservation value species may not be evident. The advantage of using traditional metrics of diversity, in addition to novel measures (e.g. Partners In Flight scoring conservation value) may be important management or conservation context (Panjabi et al. 2005). Meiklejohn and Hughes (1999) concluded that narrow tributary buffer strips associated with small streams apparently provided little suitable habitat for forest interior species. This finding supports the contention that narrow or linear habitats may contain limited diversities and abundances of area of “area-sensitive” or forest interior species.

*Studies of SMZ Width and Birds*

SMZ width studies related to avifauna are limited. Current BMP standards for SMZ width in Georgia are generally less than those suggested in other studies citing recommendations for avifauna. Even-aged silvicultural practices remove the majority of standing timber and create early successional habitats for birds. Strelke and Dickson (1980) found that edge habitats created by clearcuts may have greater bird species abundance and diversity than the adjoining mature forest. Uncut forest retained along streams (forested streamside zones), within pine plantations, can provide valuable habitat for birds that breed in mature forest. Early successional forest species may use forested streamside zones for breeding or song perches (Conner et al. 2004).

Conner et al. (2004) evaluated bird communities in forested streamside zones in Eastern Texas to determine threshold widths (i.e., where occurrences no longer increases
and remains stable) of riparian forests. The study found that most mature forest species had an association with wider SMZs while shrub-scrub breeding birds were more closely associated with narrower SMZs. Conner et al. (2004) found that the total abundance of birds detected increased significantly as the width of forested streamside zones increased. This trend increased until the riparian zone width reached 60 m. They also found that although species richness was not statistically related to streamside zone width, it was marginally higher at widths of 20 to 40 m (Conner et al. 2004). The occurrence of many species of neotropical migrants at widths less than 100m suggested that narrow forested streamside zones (less than 100m) do have conservation value. These observations lead to the conclusion that a threshold of 60m might help forest managers balance the habitat requirements of both early-successional and mature-forest-breeding birds in southern pine forests.

Trinquet et al. (1990) examined songbird diversity in clearcuts with and without a riparian buffer strip. There were three types of units assessed in this study; unharvested controls, an area harvested according to Kentucky BMPs (15-23 m), and a logger’s choice area where BMP criteria were ignored and no riparian buffer strip was left. After clearcut harvesting bird abundance increased 23% on the logger’s choice unit and 21% on the BMP unit. Overall bird abundance declined, however, in the control area (Trinquet et al. 1990). The investigators hypothesized that differences in abundance among the sites were attributable to adjacent clearcuts and brood parasitism by Brown headed cowbirds (Molothrus ater). This study did find the Acadian Flycatcher (Empidonax virescens), a mature-forest species, present before treatment but absent after
harvest on the BMP and logger’s choice unit. Similarly, the Louisiana Waterthrush, another mature forest obligate, was present on all units before harvest but did not occur on the logger’s choice site. Simpson’s diversity index was highest on the BMP clearcut and the control units, but lowest on the logger’s choice unit. Trinquet et al. (1990) suggested that BMP harvesting provided habitat that encouraged a high diversity of breeding birds. This diversity appeared to be high because and influx of early successional species. Additionally, they suggested that forest managers should be aware that mature-forest bird species may not use riparian buffer strips if adjacent units are harvested and that the abundance of some of these species could also decrease in mature stands adjacent to clearcuts.

Thurmond et al. (1995) evaluated the effect of streamside management zone width on bird communities in the Georgia Piedmont. In their analysis of 2 years of bird community data in SMZs of 15.24 m (50 ft), 30.48 m (100 ft), and 49.99 m (164 ft), they found the densities and abundances of forest interior species were greatest in the uncut areas. Lower densities and abundances of mature forest birds in the widest of the three SMZ sizes, suggested that the wider of the SMZs (49.99 m) did not provide the same amount of habitat for most forest interior species as the controls did. Interestingly, edge species were equally abundant in all SMZ widths, and lowest in mature forest. These edge species were more than likely using the SMZ as well as the adjacent early successional habitat. Relative to SMZ width, it appeared that breeding bird abundance did not dramatically increase as SMZs width increased up to 49.99 m maximum. Densities decreased as widths increased. The densities in medium (30.48 m) and wide (49.99 m)
SMZs were similar to control areas. The investigators stated that forest interior birds were much more restricted in their habitat utilization, being more abundant in mature forest controls than in SMZs or pine plantations. Thurmond et al. (1995) suggested that “…SMZs less than 49.9 m in width were important for maintaining abundance and diversity of avian species in landscapes dominated by young pine plantations”. Two limitations of this study were that it did not incorporate the recommended SMZ width for avifauna (100 m), and there was not sufficient area that potentially could be used by forest-interior species. The study also used abundance and diversity for its assessment, a possible misleading method. Studies showed that SMZ width has an effect on avifauna communities (Triquet al 1990). Many of these studies has accredited these differences to habitat fragmentation

Riparian corridors may facilitate or dispersal of some species among habitats for some species (Beier and Noss 1998, Machtans et al. 1996). Rodriguez et al (2001) and Lima (1998) found that fragmented areas may have minimal cover, increasing the risk of predation or other negative effects. Streamside management zones may function as corridors. But other SMZ functions are vital for birds as well. The study of SMZ functions as habitat and corridors are imperative. A bioindicator is essential to effectively assess the functionality of these SMZs. A single bird or a combination of birds that meet the bioindicator requisites set by (Pearson 2007, Personal Communication) may provide insight into the corridor role of riparian areas.
Riparian Obligates

This study investigated the effectiveness of current Georgia (USA) BMPs on three species of neotropical migrants that are proposed as bioindicators of riparian condition. The Louisiana Waterthrush, Northern Parula (*Parula americana*) and the Acadian Flycatcher were chosen as focal species because all three are typically associated with riparian forests (Robinson 1995, Whitehead and Taylor 2002, Moldenhauer and Regelski 1996). Murray and Stauffer (1995) found that the Louisiana Waterthrush and Acadian Flycatcher were more closely associated with streams than other avian species in Appalachian riparian forests. Mattsson (2006) suggested that using stream-obligate avifauna as bioindicators for degradation of stream biotic integrity could improve the efficiency of watershed monitoring programs. The Louisiana Waterthrush is a ground nesting species, the Acadian Flycatcher is a mid-story nesting species, and the Northern Parula is a canopy nesting species. Thus, combination of these species’ ecology encompasses the entire forest strata and may offer insight how management practices affect the entire bird community.

*Louisiana Waterthrush*

The Louisiana Waterthrush (LOWA) is a neotropical migratory warbler that breeds along gravel-bottomed streams that often flow through hilly, deciduous forests (Mengel 1965, Graber et al. 1983, Robinson 1995). During the breeding season, the Louisiana Waterthrush typically occurs near streams. At one upland-forest site in southern Illinois, the Louisiana Waterthrush foraged exclusively within the boundaries of
the stream channel. Prey was taken from shallow water (≤ 2 cm deep), air, leaves, and stems of herbaceous plants, leaf litter, soil, rocks, and moss. The use of different microhabitats varied as the breeding season progressed (Robinson 1990).

Louisiana Waterthrush territories along streams are typically linear ranging from 188m to 1200m in length (Robinson 1995). Preferred nest sites include small hollows or cavities located within the roots of upturned trees, banks of streams, or under fallen logs where the entire nest is protected from disturbance (Bent 1953, Easton 1958, Robinson 1995). Some nests are built in partially covered ground cavities and under overhanging vegetation (Robinson 1995).

Mulvihill et al. (1999) used the Louisiana Waterthrush as a bioindicator for forested headwater streams in Pennsylvania. They proposed that the Louisiana Waterthrush could be a “…cost-effective indicator of instream biotic integrity” (Mattsson and Cooper 2006). Mattson (2006) also found Louisiana Waterthrush occupancy was useful for predicting relative abundance of macrobenthic taxa, while the Environmental Protection Agency (EPA) Visual Habitat Assessment (VHA) was best for predicting EPT richness.
Acadian Flycatcher

The Acadian Flycatcher is the most abundant breeding Empidonax flycatcher in the southeastern United States. Found most commonly in bottomland hardwood forests habitats along small and large streams, it nests in large tracts (<100 ha) (Guilfoyle et al. 2002, Whitehead and Taylor, 2002 and Woolfenden et al.) Acadian Flycatchers usually forage on insects and other arthropods, particularly on the undersurfaces of leaves. They utilize gleaning and sally-hovering while foraging, but also capture insects in the air and occasionally on the ground (Whitehead and Taylor 2002). The Acadian Flycatcher has the potential to serve as a viable indicator species, because of its abundance, nest type (typically open-cup which is susceptible to predation) and sensitivity to habitat fragmentation (Whitehead and Taylor 2002 and Vargas and Robinson 2006).

Studying spatial related dynamics of the Acadian Flycatcher may provide insight relative to the species suitability as a bio-indicator (Woolfenden et al. 2002). Although breeding territories were usually associated with streams and were not uniformly distributed within the forest plot, Woolfenden et al. (2002) observed different territorial behaviors when Acadian Flycatcher population densities were high, such as the establishment of territories not associated with streams. They found that centers of adjacent territories were typically separated by 75-100m with the nest located near the centers of territories. Conner et al. (2004) found Acadian Flycatchers appeared to require a 60 to 70 m threshold width of forest. With this threshold behavior existing, some type of response to disturbance in Acadian Flycatcher activity might be expected if any silvicultural practices might impact the 60 to 70m threshold.
Northern Parula

The Northern Parula is an active warbler occupying the mid and upper tree canopy levels of riparian areas. (Moldenhauer and Regelski 1996). In the southern parts of the Northern Parula’s breeding range, the nest is often located where Spanish moss occurs. In Texas, the Northern Parula preferred floodplain hardwood forest where water oak (*Quercus nigra*), willow oak (*Q. phellos*), swamp chestnut oak (*Q. michauxii*), and black gum (*Nyssa sylvatica*) were common. Population densities in Arkansas were positively correlated with number of tree species per unit area, percent canopy cover, number of small trees per unit area, and canopy height. (James 1971, Moldenhauer and Regelski 1996).

During the breeding season, the Northern Parula forages primarily on insects and spiders in the mid to upper forest canopy. Morgan (1984) found the mean territory size for Northern Parula to be 0.32 ha (range 0.08-0.65 ha). These territory locations had a positive relationship to the amount of American beech (*Fagus grandifolia*) and stand size.

Nests generally range between 1.6m to 6.1m in height. Cowbird parasitism occurs, but probably is an uncommon occurrence due to the closed structure of a Northern Parula nest. This area-sensitive species is uncommon in small forests (Freemark and Collins 1992). Robbins et al. (1989) rarely encountered this species in areas < 100 ha, they found that the highest probability of occurrence was in forested areas >3000 ha, while 50% probability occurred in areas of approximately 520 ha.

Moldenhauer and Regelski (1996) stated in their management recommendations that
efforts in the U.S. should concentrate on maintaining large tracts of undisturbed breeding
habitat or allow disturbed habitat to mature to the point where the habitat might support
the species. They also recommended that disturbances to drainages, bogs, swamps and
other bottomland areas be minimized.

The Louisiana Waterthrush, Acadian Flycatcher, and Northern Parula are all
abundant, widely distributed, area sensitive, forest interior, and riparian obligate species.
All are active, easily recognizable by their songs, readily detectable and arrive at similar
times on their breeding grounds. Because of these attributes, employing characteristics
(e.g. spatial activity, abundance) of these species, individually or combined as
bioindicators of riparian zone condition may be appropriate.

Previous Dry Creek Avian Study

The first phase of this study (Grooms 2005) compared 1 year pre-harvest and 1
year post-harvest data to assess short-term changes in abundance and diversity of
foraging, nesting and disturbance guilds (as defined by Hamel 1992 and Canterbury et al.
2000). Because of the ambiguous and potentially misleading nature of some diversity
indices (Gotmark et al. 1986), Grooms (2005) employed a bird-community index (BCI;
Canterbury et al. 2000) and a measure of avian conservation significance (ACS; Twedt’s
2005) to assess avian responses to clearcut harvesting and SMZ thinning in headwater
catchments.

This study found no differences in bird-community index between watershed
pairs before harvest. For post-harvest sites the bird-community index was greater in the
reference watersheds than in treatment watersheds. In pre-harvest sites, there was no
difference in the avian conservation significance index between watershed pairs, but post-
harvest the reference watershed pairs were higher in the avian conservation significance
index as compared to treatment pairs. Although this research concentrated on pre-harvest
and immediate post-harvest responses of avian communities and vegetation structure in
streamside management zones, the analysis did not separate communities inside or
outside the SMZ. Grooms (2005) focused on areas thinned and un-thinned in the
treatment watersheds and successfully utilized alternative methods of evaluating
ecological conditions of bird communities.

Abundance may not fully characterize responses to changes in habitat suitability
(Van Horne 1983). For example, in the study by Grooms (2005) traditional methods
(abundance per hectare and richness) did not show responses to harvest, but alternative
methods (BCI) and (ACS) did. Twedt (2005) proposed a new standard measure based on
regional conservation priority of each species, and used the method to compare avian
conservation significance of forested habitats before and after selective timber harvest.
For Twedt’s (2005) study, unharvested areas had higher ACS value scores, due to more
priority bird species and not due to abundance. The ACS equation uses two measures, 1)
observed avian densities and 2) Partners in Flight (PIF) scores (Carter et al. 2000). The
PIF species with lower scores have fewer or less immediate threats and these species are
likely to be more abundant and widespread, and not declining. Because evaluating these
species for conservation in a linear relationship may potentially dilute conservation
importance of higher ranking species. Instead of valuing species linearly, Twedt (2005)
suggest that the relationship among PIF concern scores when analyzed to conservation of habitats should be exponential. In Twedt’s (2005) ACS equation, the PIF scores are transformed exponentially using a logarithm of the gamma function \[\Gamma(x),\text{ SAS Institute Inc. 2001}\]. Within this transformed function relationship, each increase in unit of concern generates an increasingly greater “concern rating.” Low concern scores have corresponding “concern ratings” that are close in value, whereas high concern scores have corresponding “concern ratings” that are widely disparate.

*Partners in Flight (PIF)*

Partners in Flight (PIF) is a cooperative venture of federal, state, provincial, territorial agencies, industry, non-governmental organizations, researchers, and many others whose common goal is the conservation of North American birds (Panjabi et al. 2005). PIF has developed a species assessment process which creates a global score based on six factors: Population Size, Breeding Distribution, Non-breeding distribution, Threats to Breeding, Threats to Non-breeding, and Population Trend (Panjabi et al. 2005). PIF uses the Bird Conservation Regions (BCRs) as the standard conservation planning unit (http://www.nabci-us.org/bcrs.html).
Objectives

The goals of this study were to assess responses of riparian bird communities to forest management practices in SMZs and adjacent uplands associated with small headwater streams in the lower Coastal Plain of Georgia, and to assess the potential for using songbirds as bioindicators of riparian zone condition. Specific objectives of this study were to:

1. Document changes in the occurrence and location of activity clusters for bird species in a riparian obligate guild (Louisiana Waterthrush, *Seiurus motacilla*; Acadian Flycatchers *Empidonax virescens*; and Northern Parula, *Parula americana*) on Southwest Georgia Streams in response to SMZ thinning and clearcut harvest in adjacent uplands.
2. Characterize relationships between vegetation variables and riparian obligate species occurrence, and
3. Evaluate the avian communities’ conservation value inside and outside the SMZ.

Alternate hypotheses (Hₐ) of this study are as follows:

1. Louisiana Waterthrush activity clusters will be more dispersed in reference watersheds that in treatment watersheds because of disturbance.
2. Acadian Flycatcher activity clusters will be more dispersed in reference watersheds that in treatment watersheds because of disturbance.
3. Northern Parula activity clusters will be more dispersed in reference watersheds that in treatment watersheds because of disturbance.

4. CV and ACS values will be greater in the reference watersheds than in treatment watersheds because of habitat loss for high-priority forest-interior species.

5. ACS Value will be greater in the riparian area that in the uplands for the treatment and references.
CHAPTER II

METHODS

Study Area

The study area is located at 30.8 N, 84.6 W, in a commercial forest in the southwestern corner of Georgia approximately 16 km south of Bainbridge (Figure 4). This area is positioned on steeply sloping Pelham Escarpment, resting between the Tifton upland and the Dougherty plain (Figure 5). Streams originating from the Pelham Escarpment are characterized by perennial headwaters that become intermittent streams or drain directly into the Flint River (Entrekin et al. 1999 as cited in Winn 2005).

The study site is located in the Dry Creek Watershed, which discharges to the Flint River. The soils in upland portions of this watershed are predominately Utisols, while the soils in the riparian area are composed of Esto and Chiefland Series. These soils are classified as well drained fine sands over clay loams (International Paper 1980, Grooms 2005). Summer (2005) reported that forest stands on all of the watersheds were of similar plant species composition. The headwaters that drain into Dry Creek include the four streams in this study, labeled A, B, C, and D (Figure 4.). Streams were first order, groundwater-influenced, low to medium gradient, and sand-dominated substrate (Summer et al. 2003).
Vegetation

Vegetation in riparian zones and on adjacent slopes was characterized using plots spaced 30.5 m apart (Watershed A n=34, Watershed B n=35, Watershed C n=50, and Watershed D n=62) (Figure 4). Overstory vegetation, which included any plant with a diameter breast height (dbh) > 10 cm, was measured in 0.040 ha circular plots during July-August of 2005 and June of 2006. Using a dbh tape and a clinometer the overstory variables were measured. Overstory variables measured included overstory stem density, overstory stem dbh, and the height of the 3 dominant trees. Diameter breast height, proximity to plot center and height were the factors in determining tree dominance. Within the 0.040 ha plot, the number of snags, snag height and diameter were measured. Midstory stem density, any plant species with a dbh < 10 cm and height > 1.36m, was recorded within a 0.04 ha circular plot (Grooms 2005, Summer 2005). The understory vegetation was measured using four randomly selected 1m$^2$ plots (within 0.040ha overstory plot). The understory vegetation was classified into the following vegetation categories: grasses, forbs, vines, deciduous tree and shrub seedlings, evergreen tree and shrub seedlings, total ground cover, mineral soil, fine organic litter, and other. Within 1m$^2$ plots, litter depth was measured in four quadrants, giving a total of 16 measurements per vegetation point. Descriptive statistics were performed using SAS (SAS Institute Inc. 2001, Proc means).

To evaluate canopy openness, canopy pictures were taken in 2006 at the vegetation points on each transect using a digital camera fitted with an 180°
hemispherical fisheye lens (Grooms 2005). (Fig. 7) Pictures were taken in the morning before sun intensity increased or during an overcast event.

**Study Design**

The Dry Creek Watershed study was a paired watershed study primarily designed to test the effectiveness of Georgia Forestry BMPs for the protection of water quality. Paired watershed studies use separate time periods of calibration and treatment. During the calibration period, two watersheds that are similar (i.e. size and location) are compared with a regression to determine similarities. No land changes occur to any watersheds during this calibration phase. The treatment phase occurs after the calibration phase has ended. Then land use changes are permitted and the response of the watershed is measured (Clausen and Spooner 1993).

Watersheds A and D served as references, while watersheds B and C were clearcut harvested during the months of September through November 2003. All cutting was conducted according to Georgia BMPs for forestry, therefore the SMZs were from 12-21 meters wide in watersheds B and C. Watersheds B and C were also separated into upper and lower reaches. In the lower reach (downstream), the SMZ was thinned to 11.6 m²/ha (Figure 5). Because of topography and similarities in microhabitat and of vegetation, the treatments and references were not combined in the analyses. Watersheds A and B were considered one pair while watersheds C and D were considered another pair.
Figure 2. Location of vegetation plot transects in the four watersheds (southwestern Georgia, USA).
**Data Collection**

Grooms (2005) conducted bird surveys on Dry Creek watersheds in 2003 and 2004. Bird surveys for 2005 and 2006 followed the same methodology as Grooms (2005). In the pre-treatment season, (2003), Grooms performed six surveys from June 2 - July 1. In the post-treatment season, (2004), Grooms performed ten surveys from June 2 – July 3. In the second year post-treatment (2005), there were eight surveys from May 7 – July 1. Preliminary analysis of data for 2005 showed a small sample size for registrations within the kernel analysis for the Louisiana Waterthrush (Watershed C; n=11, Watershed D; n=9). This preliminary analysis also revealed that during the 2005 season bird activity declined notably after mid June. Therefore, a shorter but more intense survey season was implemented for the 2006 season (10 surveys from May 16–June 6.

Breeding bird communities within each watershed were surveyed using a single variable-distance transect running parallel to the stream within SMZs (Figure 3). The first two years of data were used for preliminary analysis. For the third year of post-treatment, there were 10 surveys from May 16 – June 6. Transects ranged from 300-675 meters in length. This variation was due to the variable lengths of the watersheds. Each transect was divided into 25 meter segments. Bird communities were surveyed by walking each transect at a slow, steady pace and recording the distance perpendicular to the transect at which each bird was heard or observed. All watersheds were surveyed between 0600 and 0900 Eastern Standard Time (EST). To decrease time bias, sampling was alternately initiated at the upstream or downstream end of a transect (Grooms 2005).
**Avian Clustering**

Repeated point count samples were used to establish patterns of occurrence and activity along treated and untreated riparian zones in the Dry Creek watershed. This repeated sampling resulted in the identification of aggregations of occurrences hereafter described as activity clusters. Clusters were used to define zones of activity along SMZs and they were measured to indicate how Louisiana Waterthrush, Northern Parula, or Acadian Flycatcher occurrence and activity might vary relative to changes in SMZ width, silvicultural disturbance within SMZs and adjacent forest stand treatment.

All survey transect points, vegetation survey plots, and watershed boundaries were located using global position system (GPS) technology. Discrete locations of all Louisiana Waterthrush, Northern Parula and Acadian Flycatcher registrations were entered into a shapefile with ArcGIS 9.1 (ESRI 2004). The shapefiles were combined by species, year, and watershed. A kernel analysis was performed using Home Range Extension (Rodgers and Carr. 1998; parameters tested: Standardization style=unit variance, Smoothing Factor Automation = h_bcv2, Smoothing Application = Adaptive, Type of contour= Density, and Raster Resolution=70).

The area of the kernel polygons was calculated in hectares using the extension Xtools Pro 3.1.1, (www.esri.com). The area of each polygon was then divided by the number of registrations within it, yielding a density estimate. For some polygons, the Louisiana Waterthrush had only one registration and therefore was not considered for analysis. Where robust density estimates were not obtainable (due to the lower sample size), a “distance from the center point,” method was used. A center point of the kernel
polygon was created and the distance of each registration was then measured. Using SAS 9.1 (ESRI 2004), a t-test was performed to assess if the means are different between the treatments and references, \( \alpha=.10 \). After evaluating a schematic box plot (proc boxplot), outliers were identified. To eliminate outliers, an eighty-percent kernel analysis was performed and the same methods were used to calculate distance from center. Another t-test was performed using the eighty-percent kernel analysis to compare means of reference 2 and treatment 2. Reference 1 and treatment 1 were not evaluated for Louisiana Waterthrush because their linear territory exceeded the entire length of reference 1 and treatment 1. Reference 1 totaled 300 m in length and Treatment 1 totaled in 350 m in length. The Louisiana Waterthrush’s territory averages 400 m in length (Robinson 1995). Both reference 1, treatment 1, and reference 2 and treatment 2 were evaluated for the Acadian Flycatcher and Northern Parula. For activity clusters analysis, the experimental units were the activity clusters.

**Vegetation Structure and Activity Clustering**

All vegetation measurement plots that were inside activity clusters (separated for each species) were considered “inside vegetation plots,” and all vegetation measurement plots outside the activity cluster were considered “outside vegetation plots.” Vegetation structure variables for inside and outside plots were compared for each watershed using an ANOVA, Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc. 2001; \( \alpha=.10 \)).
To evaluate conservation value (CV) of the riparian area, registrations were combined for the three riparian obligate species (Louisiana Waterthrush, Acadian Flycatcher, and Northern Parula). Unit densities (abundance per hectare) were calculated for each individual species. To standardize riparian area samples, only species found inside SMZs were selected for analysis. The Partners In Flight (PIF) scores were used as a weighting factor (Nuttle et al. 2003) based on the following equation.

\[
CV = \sum aiwi \tag{Equation 1}
\]

for species \(i=1\) to \(n\)

where:

\(ai\) = abundance per hectare

\(wi\) = weighting factor of conservation priority of a species

Partners In Flight (PIF) as \(wi\)

Using the Avian Conservation Significance (ACS) equation and the Partners in Flight (PIF) scores for the CRi value, a value (abundance per hectare was calculated):

\[
ACS = \sum_{i=1}^{n} ((CRi * Ai) / 10) \tag{Equation 2}
\]

for species \(i=1\) to \(n\)

where:

\(Ai\) = Abundance per hectare of the \(i\)th species

\(CRi\) = LOG GAMMA (PIF composite concern score of the \(i\)th species)\(^2\).
Inside/Outside SMZ

For the 2005 and 2006 seasons, each bird registration was recorded on a data sheet, with the transect line present (Figure 5). To establish consistency in linear distance estimation, a Bushnell Yardage Pro® rangefinder was used for gauging distance estimates prior to the surveys. Using ArcGis 9.1 (ESRI 2004), the SMZ distance from the transect was measured and each avian registration was measured from the transect and classified as either inside or outside the SMZ.

Grooms (2005) included bird registrations from the entire watershed area in the calculation of abundance per hectare. In this study a 100m buffer from the stream was used because no registrations were recorded 100m from the SMZ.
Figure 3. Dry Creek Watershed topography delineation and study site location.
Figure 4. Transect points for Dry Creek Watershed bird surveys.
Figure 5. Example of Survey Sheet.
CHAPTER III

RESULTS

Bird Surveys

A total of forty species was recorded in the second year post-harvest (2005) and a total of thirty-nine species was recorded in the third year post-harvest (2006) (See Appendix A and B). Differences by year was not tested because of the differences in sampling frequency and intensity between (2005) and (2006).

Riparian bird activity clusters

In 2006, a t-test revealed that there was a statistical difference in activity cluster dispersion between reference 2 and treatment 2 for the Louisiana Waterthrush (n=18) using the eighty percent kernel analysis (p=.0041, Figure 6 α=.10) (treatment 2, n=2; and reference 2, n=3). The average distance from center was greater in reference 2 watershed compared to treatment 2. Two outliers were identified for Louisiana Waterthrush registrations by using a schematic box plot SAS 9.1 (ESRI 2004) PROC BOXPLOT. Outliers were in the ninety-five percent kernel polygon. After this finding, a kernel analysis at eighty percent was used instead of the original Kernel analysis at ninety-five percent to remove outliers that could provide misleading statistics. The analysis (t-test) of Acadian Flycatcher activity clusters showed no statistical difference between treatments and references (α=.10). The t-test revealed no statistical difference in clustering of Acadian Flycatchers between Reference 1 and Treatment 1 (A vs. B, p=.6211), Reference 2 and Treatment 2 (D vs. C, p=.3520).
The Northern Parula activity cluster showed no statistical difference between treatments and references. The t-test revealed no statistical difference in clustering of Northern Parula between Reference 1 (n=2) and Treatment 1 (n=2) (A vs. B, p=.6474), Reference 2 (n=3) and Treatment 2 (n=3) (D vs. C, p=.3154) (Figure 8).
Figure 6. 2006 Cluster dispersion using 80 percent Kernel for the Louisiana Waterthrush (*Seiurus motacilla*) in southwestern Georgia, USA streams. Differences between reference 2 (n=3) and treatment 2 (n=2) lowercase letters on bars indicates statistical significance (p = .0041, α=.10,). (T-Test procedure (PROC MEANS; SAS Institute Inc. 2001).
Figure 7. 2006 Clustering of Acadian Flycatchers (*Empidonax virescens*) using 80 Percent Kernel Analysis in southwestern Georgia, USA streams. Comparison of Treatment 1 (n=2) and Reference 1 (n=2) (p=.6211, α=.10), and of Treatment 2 (n=4) and Reference 2 (n=9) (p=.3520, α=.10). (PROC MEANS; SAS Institute Inc. 2001). Comparison of Treatment 1 and Reference 1 (p=.6211, α=.10), and of Treatment 2 and Reference 2 (p=.3520, α=.10). T-Test procedure (PROC MEANS; SAS Institute Inc. 2001).
Figure 8. 2006 Clustering of Northern Parula (*Parula americana*) using 80 Percent Kernel Analysis in southwestern Georgia, USA streams. Comparison of Treatment 1 (n=2) and Reference 1(n=2). T-Test procedure (p=.6474, α=.10), and of Treatment 2 (n=3) and Reference 2 (n=3). T-Test procedure (p=.3154, α=.10). (PROC MEANS; SAS Institute Inc. 2001).
Figure 9. 2006 Louisiana Waterthrush (LOWA) Kernel Analysis Polygons and registrations. Comparison of Treatment 2 and Reference 2.
Figure 10. 2006 Acadian Flycatcher Kernel Analysis Polygons and Registrations for Treatment 1 and Reference 1.
Figure 11. 2006 Acadian Flycatcher Kernel Analysis Polygons and Registrations for Treatment 2 and Reference 2.
Figure 12. 2006 Northern Parula Kernel Analysis Polygons and Registrations for Treatment 1 and Reference 1.
Figure 13. 2006 Northern Parula Kernel Analysis Polygons and Registrations for Treatment 2 and Reference 2.
Vegetation Structure relationships to Louisiana Waterthrush Activity Clustering

Louisiana Waterthrush clustering showed a statistical relationship to vegetation structure. Comparing inside clusters versus outside clusters for treatment 2 (inside n=10; outside n=12) and reference 2 (inside n=9; outside n=12), differences occurred for percent vines (treatment 2 greater than reference 2) ($p = 0.0349$, $\alpha = .10$; Figure 14), deciduous shrubs (treatment 2 greater than reference 2) ($p = 0.0005$), total ground cover (reference 2 greater than treatment 2) ($p = 0.0220$, $\alpha = .10$; Figure 14), and percent exposed mineral soil (reference 2 greater than treatment 2) ($p = .0508$, $\alpha = .10$). For Reference 2 there were differences in percent moss ($p = .0094$, $\alpha = .10$ Figure 15), evergreen tree ($p = 0.0881$; Figure 16), and evergreen shrub ($p = 0.05$, $\alpha = .10$; Figure 16). There were no statistical differences in canopy openness, mid-story basal area, overstory basal area, percent grasses, percent forbes, percent deciduous tree, percent evergreen tree, percent evergreen shrub, or organic litter depth.
Figure 14. Percent vines, deciduous shrubs, and exposed soil comparison of the Louisiana Waterthrush activity cluster within treatment 2 (n=22) (watershed C) in 2006. Differences among lowercase letters on bars indicate statistical significance (α=.10) in index values between inside versus outside the activity clusters using Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc. 2001).
Figure 15. Percent total ground cover comparison inside versus outside of the Louisiana Waterthrush activity cluster within treatment 2 (n=22) (Watershed C) in 2006. Differences between letters on bars indicate statistical significance (p=0.0220; α=.10) in index values between inside versus outside the activity clusters using Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc. 2001).
Figure 16. Percent evergreen tree seedlings, evergreen shrubs, and moss comparison inside versus outside of the Louisiana Waterthrush activity cluster within reference 2 (n=21) (Watershed D) in 2006. Differences among letters on bars indicate statistical significance (α=.10) in index values between inside versus outside the activity clusters using Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc. 2001).
Acadian Flycatcher clustering showed some statistical relationships to vegetative structure (i.e. vegetation structure inside a cluster compared to outside a cluster). Sample sizes for the experimental unit (activity clusters) were the following: reference 1 (n=10), treatment 1 (n=11), reference 2 (n=18) and treatment 2 (n=21). For treatment 1, canopy openness (Gap Fraction percentage) was higher outside activity clusters (p=0.005, α=.10; Figure 17). Overstory basal area was higher inside activity clusters for Treatment 1 (p=0.067, α=.10; Figure 18) and Treatment 2 (p=0.0074, α=.10; Figure 18) was larger inside activity clusters. Midstory basal area for Treatment 2 was higher outside of the activity clusters for Treatment 1 (p=.0276, α=.10; Figure 19). For the comparison of inside versus outside of activity cluster of percent vines, there were statistical differences in Treatment 1 (p=0.0028, α=.10) and Treatment 2 (p=0.0737 α=.10,). There were statistical differences for percent forbs for Treatment 2 (p=0.0431, α=.10). There were no differences between inside and outside clusters for percent grasses, percent deciduous tree, percent deciduous shrub, percent total ground cover, percent exposed mineral soil, percent moss, and percent organic litter.
Figure 17. Gap fraction percentage comparison of inside versus outside of Acadian Flycatcher activity cluster within Treatment 1 (n=11) (Watershed B) in 2006. Differences between letters on bars indicate statistical significance (p=0.005, α=.10) in index values between inside versus outside the activity clusters using Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc. 2001).
Figure 18. Overstory basal area comparison of inside versus outside the Acadian Flycatcher activity cluster within Treatment 1 (n=11) (p=.067, α=.10) (Watershed B) and Treatment 2 (p=.0074, α=.10) (Watershed C) in 2006. Difference among letters on bars indicates statistical significance in index values between inside versus outside the activity clusters using Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc. 2001).
Figure 19. Midstory Basal area comparison of inside versus outside Acadian Flycatcher activity cluster within Treatment 1 (n=11) (Watershed B) in 2006. Differences between letters on bars indicate statistical significance (p=0.0276 $\alpha=.10$) in index values between inside versus outside the activity clusters using Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc. 2001).
There were no differences in vegetation structure for comparisons inside and outside of the clusters. Sample sizes for the experimental unit (activity clusters) were the following: reference 1 (n=10), treatment 1 (n=10), reference 2 (n=20) and treatment 2 (n=18).

**Avian Conservation Value**

In 2005, CV was statistically higher in reference watersheds (Reference 1 and 2) (p=0.0205) compared to treatments (Treatment 1 and 2) (p=0.0208). For 2006, Reference 1 did not differ from treatment 2, (p=.2231), but Treatment 2 was statistically greater than reference 2 (p=0.0051). The sample sizes (number of registrations) for the experimental units (activity clusters) were the following: (2005) Reference 1(n=16), Treatment 1 (n=7), reference 2 (n=19) and Treatment 2 (n=19), (2006) Reference 1(n=17), Treatment 1 (n=19), Reference 2 (n=21) and Treatment 2 (n=24).

**Avian Conservation Significance: Inside and Outside SMZ Comparisons**

For treatment year two (2005) and three (2006), the ACS score per hectare (every bird registration) was compared for each watershed inside and outside of the SMZ (See Table 2). In 2005, ACS was higher inside the SMZ when compared to outside the SMZ: Reference 1 (p=≤0.0001), Reference 2(p=≤0.0001), Treatment 1 (p=≤0.0001), and Treatment 2  (p=≤0.0001). Comparisons between Reference 1 and Treatment 1 (inside) (p=.3372) and comparisons between Reference 2 and Treatment 2 comparisons (p=.3820) did not yield significant results (See Figure 22). The 2006, ACS was higher inside than
outside the SMZ watersheds, Reference 1 (p≤0.0001), Reference 2(p≤0.0001), Treatment 1 (p≤0.0001), and Treatment 2 (p≤0.0001). ACS inside Reference 1 and Treatment 1 was not different (p=.4267), but did differ between Reference 2 and Treatment 2 (p≤0.0001) (See Figure 23).
Figure 20. 2005 Conservation Value (CV) per hectare for the three riparian obligate species: Louisiana Waterthrush (*Seiurus motacilla*), Acadian Flycatcher (*Empidonax virescens*) and Northern Parula (*Parula americana*) for Reference 1 and 2 (p=0.0205, \(\alpha=10\)), and Treatment 1 and 2 (p=0.0208, \(\alpha=10\)). Differences between lowercase letters on bars indicates statistical significance. Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc, 2001) was used to make the means comparisons.
Figure 21. 2006 Conservation Value (CV) per hectare for the three riparian obligate species: Louisiana Waterthrush (*Seiurus motacilla*), Acadian Flycatcher (*Empidonax virescens*) and Northern Parula (*Parula americana*) for Reference 1 and 2, and Treatment 1 and 2 (p=0.051 α=.10). Differences in letters between bars indicates statistical significance. Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc, 2001) was used to make the means comparisons.
Table 2. ACS per hectare for Reference 1 and 2, and Treatment 1 and 2 for the years 2005 and 2006. Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc, 2001) was used to make the means comparisons ($p=\leq0.0001; \alpha=.10$).

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<td>Reference 1</td>
<td>402.23a</td>
<td>79.67b</td>
</tr>
<tr>
<td>Treatment 1</td>
<td>393.21a</td>
<td>114.63b</td>
</tr>
<tr>
<td>Reference 2</td>
<td>341.50a</td>
<td>51.13b</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>443.83a</td>
<td>100.51b</td>
</tr>
</tbody>
</table>
Figure 22. 2006 Results of comparison of ACS value inside the SMZ of (A) Reference 1 and Treatment 1 and (B) Reference 2 and Treatment 2 in southwestern Georgia, USA. Using Least-Squares Means (α=.10) (LSMEANS, PROC GLM; SAS Institute Inc. 2001).
Figure 23. 2006 Results of comparison of ACS value inside the SMZ of (A) Reference 1 and Treatment 1 and (B) Reference 2 and Treatment 2 in southwestern Georgia, USA. Using Least-Squares Means (α=.10) (LSMEANS, PROC GLM; SAS Institute Inc. 2001).
Figure 24. Results of comparison of ACS value inside the SMZ of (A) 2005 Reference 1 and 2 and Treatment 1 and 2 and in southwestern Georgia, USA. Differences among lowercase letters on bars indicates statistical significance ($p \leq 0.001, \alpha=.10$). Using Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc. 2001).
Figure 25. Results of comparison of ACS value inside the SMZ of (A) 2005 Reference 1 and 2 ($p \leq 0.0001$, $\alpha = .10$) and Treatment 1 and 2 ($p \leq 0.0001$, $\alpha = .10$) and in southwestern Georgia, USA. Differences between lowercase letters on bars indicates statistical significance using Least-Squares Means (LSMEANS, PROC GLM; SAS Institute Inc. 2001).
CHAPTER IV
DISCUSSION

Kernel Analysis and Parameters

Density estimates may provide limited insight concerning conservation strategies for birds because they are potentially misleading indicators of habitat quality (Peak and Thompson 2006, Van Horne 1983, Vickery et al. 1992). Diversity indices provide additional information and are typically computed from the assortment of species present (richness), and the relative abundance of each of those species (evenness) (Magurran 1988). Activity-related spatial patterns may provide further insight for conservation strategies and complement data related to densities, richness, abundance, and diversity. Behavioral information, especially concerning territory characteristics, may be valuable in determining the conservation potential of riparian buffer strips (Lambert and Hannon 2000). Newer technologies such as GIS give an alternative method for measuring habitat quality. One GIS function, a kernel analysis, is a nonparametric statistical method used for estimating probability densities from a set of points. In the context of home range analysis, a kernel analysis describes the probability of finding an animal in any one place (Rodgers et al. 1998). With the combination of distance from center methods and probability densities one can evaluate activity clusters (a territory related function).
Riparian Zone Avian Bioindicators

*Louisiana Waterthrush*

There were statistical differences in average distances from kernel center points of Louisiana Waterthrush activity clusters. Louisiana Waterthrush registrations were closer to the center points of the cluster in a treatment watershed (C) and were more dispersed in a reference watershed (D). These differences in dispersion may reflect some functional response to differences in watershed habitat or condition. “Compression, distortion, or adjustments in territory position could reduce the fitness of territory-holders in a variety of ways, including depletion of food, increased cost of territory maintenance, heightened interspecific competition, and mating failure” (Lambert and Hannon 2000).

The lengths of the activity clusters were less than the average length of territories for the Louisiana Waterthrush (400m) reported by Robinson (1995). These clusters represent concentrations of activity within one or more of the Louisiana Waterthrushes’ territories. Mulvihill (2002) found that Louisiana Waterthrush males return to the same territory annually. Female Louisiana Waterthrushes show high levels of territory fidelity, with up to 50% of returning individuals reoccupying their territories from the previous year. Eliason (1986) hypothesized that female Louisiana Waterthrushes returning to formerly held territories already occupied by mates have advantages associated with early nest initiation and territory familiarity. Any type of disturbances can affect reproduction. Therefore, measuring territorial variables for indications of disturbance may prove to be an effective means of determining the viability of the species as a stream condition indicator.
Vegetation inside Louisiana Waterthrush activity clusters appeared to have more of a relationship to overstory vegetation structure. There were fewer vines, more exposed soil and less ground cover inside the activity clusters than outside of them. This finding of Louisiana Waterthrushes using “less cluttered” areas may be related to the species reported preferences for more open habitats. The height of the stream bank changes often (along the course of the stream), causing areas that are lower and flatter to have more exposure to fluctuating water. The water could wash away forest floor material (e.g. leaves and coarse woody debris) exposing the mineral soil. The Dry Creek streams typically have shallow waters (personal observation), which are preferred foraging areas for the Louisiana Waterthrush (Robinson 1990), possibly explaining why there was a relationship between clusters and areas of higher exposed mineral soil.

In this study, most of the Louisiana Waterthrush activity clusters registrations occurred within five meters of the stream. Therefore, focusing analysis on vegetation structure near the stream was appropriate. Unfortunately, the bank height and stream depth were not measured in this study. There is a need for further research investigating the relationship between stream structure/classification and Louisiana Waterthrush occurrence.

_Acadian Flycatcher_

Conner et al. (2004) found that Acadian Flycatchers required a 60 to 70m forest threshold width in riparian zones. Based in part in this study and the Acadian Flycatcher reported area sensitivity, a difference was expected in Acadian Flycatcher activity
between the treatment and reference watersheds because 21.2 m was the largest width of the SMZ in the Dry Creek Study. However, analyses showed no statistical difference in Acadian Flycatcher activity clustering between reference and treatment watersheds. A “distance from center” method was also used for Acadian Flycatcher to spatially evaluate activity cluster. This alternative method may not reflect tolerance or susceptibility to SMZ disturbance for this species. Using audio/visual types of measurements that reflects territory may be misleading due to the extra-limital territorial travel exhibited by the Acadian Flycatcher. Woolfenden et al. (2002) found that male Acadian Flycatchers made frequent off-territory forays to neighboring territories up to 1500m away. This study’s method registered activity clusters, but the possibility exists that more than one activity cluster may have existed in a territory for one individual and that registrations recorded in this study could have been far removed from any concentrated activity area. The Acadian Flycatcher is prone to leave its territory if another male intruder is detected due to its acute song recognition. Flycatchers can recognize neighbors by slight differences in songs. (Westcott 1997, Lovell and Lein 2004b and Wiley 2005). The results for activity clusters as they relate to territory spacing in this study were consistent with the findings of Woolfenden et al. (2002), where the centers of the adjacent territories were typically separated by 75-100m. Because of the frequent and relatively lengthy dispersal of the Acadian Flycatcher, a telemetry study may prove to be more effective if spatial activity is of interest.

Vegetation structure, chiefly overstory structure, was related to Acadian Flycatcher activity cluster placement in treatment 1. Inside the activity cluster for
treatment 1, Acadian Flycatcher activity occurred in areas with less canopy gap fraction (gap fraction is the amount of sunlight penetrating through the canopy that reaches the forest floor), higher overstory basal area, and lower mid-story basal area. The same trends were not found in treatment 2 where the overstory basal area was higher inside the clusters. No statistically significant difference in ground vegetation structure inside the cluster occurred for the Acadian Flycatcher. Unlike the understory active Louisiana Waterthrush, the Acadian Flycatcher spends the majority of its time in the midstory and canopy. The observation of higher basal area in most activity clusters was not surprising. The results suggest that this species might have a preference for areas with more canopy cover. The larger basal area would indicate greater canopy cover, therefore it is not clear if this species selects areas based on gap fraction or basal area. The Acadian Flycatcher’s behavior relative to mid-story basal area has the potential to be a viable indicator of activity and perhaps its reaction to SMZ disturbance. A number of investigators have found that availability of suitable perches may be a limiting resource for loggerhead shrikes, affecting habitat occupancy and territory size, (Bohall-Wood 1987, Yosef 1993, Yosef and Grubb 1994, and Guilfoyle et al, 2002). In addition to foraging use, many woodland, open-country, and grassland birds select conspicuous perches for singing/calling to attract mates and advertise territory to neighbors (Guilfoyle 2002, Castrale 1983, Collins 1981, Harrison 1977, and Kowalski 1983). Guilfoyle (2002) found that Acadian Flycatchers preferred branches that provided a relatively unobstructed view for foraging and displaying. They typically use a “sit-and-wait” foraging strategy to prey upon small flying insects or locate prey from a stationary perch.
to sally-glean from foliage. This behavior may explain why the Acadian Flycatcher’s more concentrated activity clusters had lower mid-story basal area compared to outside the cluster. Areas with more basal area would generally have less gap fraction, and areas with less gap fraction would generally have less mid-story vegetation. It is unclear whether the Acadian Flycatcher activity clusters recorded were related to one or several of the indicator variables measured in this study. However, in the treatment 2 inside/outside activity cluster comparison there were no significant differences in gap fraction or midstory basal area. The only difference in overstory vegetation's structure occurred in overstory basal area. Interestingly, Guilfoyle (2002) suggested that Acadian Flycatcher prefers exposed perches and further proposed that this behavior combined with cryptic coloration could contribute to the flycatcher’s foraging success in southern bottomland hardwood forest.

**Northern Parula**

Spatial dispersion (distance from center) did not differ for any of the comparisons involving Northern Parula activity clusters. In contrast to the other two riparian obligate species, Northern Parula registrations were dispersed throughout the watersheds and did not exhibit the same degree of aggregation. Identifying activity clusters by singing may not be the best approach for the Northern Parula. Foraging motions or movements during advertisement have little effect on song rate when compared to individuals that sing while stationary. Some individuals may even be capable of singing while carrying food (Bay
A telemetry study where the individual’s activity could be monitored more thoroughly may be more appropriate.

There were no significant differences when comparing vegetation structure inside versus outside activity clusters.

**Conservation Value**

Conservation value provided another measure of avian diversity and subsequently the impacts that forest management may have upon it. In this study, three of the four conservation value comparisons for reference versus treatment watersheds followed the trend of having a higher score in the reference than in the treatment. My approach to conservation value used a combination of Louisiana Waterthrush, Northern Parula, and Acadian Flycatcher, all of which are classified as insectivorous birds. The Acadian Flycatcher’s and Northern Parula’s primary food sources are flying insects, while the Louisiana Waterthrush relies on aquatic insects. Insect abundances respond to habitat changes resulting from forest management (Chen et al 1995). Insects, particularly flying ones, are sensitive to many microclimate variables, most of which are altered both in deforested areas and for hundreds of meters into adjacent residual forest following clearcut harvesting (Chen et al. 1995, Whitaker et al 2000). Whitaker et al (2000) speculated that retention of riparian buffer strips during clear-cut harvesting has the potential to dramatically influence the spatial distribution and activity level of flying insects and may have some impact on the conditions of riparian zones as foraging habitat for some insectivorous forest birds.
After observing high numbers of flying insects and insectivorous birds in riparian buffer strips, Whitaker et al. (2000) stated that riparian buffer strips provide shelter from strong winds and act as collecting sites for insects blown in from exposed clearcuts and lakes. This could possibly explain the higher conservation value scores in the reference watersheds that were not clearcut. There may have been more food resources analyses for two of the three riparian obligate species used in the conservation value equation.

Other research has shown similar responses to forest disturbance by one or more of the riparian obligate species. In most riparian zone studies, Acadian Flycatchers were not documented in “narrower” riparian zones (Whitcomb et al. 1981, Chapa 1996, 2001). Even though the term “narrow” is classified differently among various studies, it has always been greater than 12.2 m or the 21.3 m in this study. Even though the Acadian Flycatcher was not commonly seen in treatments in previous research, it should be noted that Grooms (2005) did find this species in the narrower buffer strips. This trend is not cited in any other studies.

In a Georgia piedmont study by McIntyre (1995), the Louisiana Waterthrush and Northern Parula decreased in abundance or were extirpated as forest management activities fragmented habitat. This same trend of vulnerability to habitat fragmentation was found in eastern Texas (Robbins et al. 1979) for the Louisiana Waterthrush and Acadian Flycatcher. The results from this study followed the same relationships of the aforementioned studies pertaining to a decrease in abundance of fragment/disturbed habitats.
In 2006, Treatment 2 had a higher CV score than reference 2. When observing data spatially, recorded observations of Acadian Flycatcher and Northern Parula were greater in reference watersheds. Many registrations were only two or three meters outside the SMZ. Only registrations within the confines of the SMZ were counted when estimating CV. Thus potential registrations may have been affected by a measuring error as either SMZ width or inaccuracies in determining the position of birds accounted for records.

Inside vs. Inside SMZ

Non-traditional methods were used in the beginning stages of this study to evaluate other ecological values for avifauna. Traditional biodiversity measures (species richness, abundance, and diversity) may not fully characterize avian response to clearcut harvesting (Grooms 2005). She found a decrease in high-priority species in treatment watersheds using Twedt’s (2005) modified conservation value index (Avian Conservation Significance or ACS).

For the inside versus inside comparison in 2005, ACS estimates were not significantly different between the treatments and references. There were no differences in 2006 for inside verses inside comparisons.

ACS in reference 2 and treatment 2 did not differ (p=.1074 and α=.10). Largely due to the appearance of the Northern Bobwhite Quail (NOBO) and the Yellow-Breasted Chat (YBCH). Both of these species had few registration either inside (NOBO = 0, YBCH = 0) and outside (NOBO=3 YBCH =1) the SMZ in 2005. The abundances
increased dramatically in 2006 inside (NOBO=4, YBCH=11) and outside (NOBO=13, YBCH=4) in both treatments. The Northern Bobwhite and Yellow-breasted chat both have relatively high PIF scores (NOBO; PIF=16) and (YBCH; PIF=13). The third year of plant succession probably provided more suitable habitat for these species. The apparent increased abundances of these highly ranked early-successional species likely caused the ACS scores to increase.

During the first year of post harvest, Grooms (2005) found that tree basal area was strongly related to differences for several bird guilds. Stem density, dbh of dominants, and height of dominants were positively correlated with the ACS index. Stem density, dbh of dominants, and height of dominants were generally higher in reference watersheds because no thinning occurred within those SMZs. These vegetation structure variables also may be related to differences in ACS inside the SMZ.

Data for this project were not analyzed collectively due to sampling and scoring differences. A difference in sampling frequency occurred where only two dates overlapped for 2005 and 2006. As such the sample size was not sufficient for any statistical comparison. Data were analyzed as separate years, 2005 and 2006. Since Grooms (2005) study, PIF scores have changed to incorporate global factors in addition to regional ones. The rank numbers are generally lower and the range has decreased. Thus, comparing ACS values would be inappropriate. Currently there are efforts underway to analyze all the Dry Creek avian data using the new PIF scores.

*Inside vs. Outside SMZ*
ACS value was significantly higher inside than outside the SMZ for all watersheds in both years (2005, 2006). These results imply that SMZ interiors have a higher value for some avifauna (those designated as riparian zone obligates) compared to those occurring outside the SMZ in this study. For the treatments, the SMZ was the only mature habitat area remaining for forest-interior avifauna. The results indicate that the value of riparian valuable habitats for avian conservation.

There was a difference between the treatment and reference for the riparian obligate species. The results from the inside versus inside SMZs showed that the treatments were still functioning habitat for mature forest or riparian zone obligates species in general. Furthermore, high conservation priority early successional species used the upland clearcuts. Relative to conservation scoring, the entrance of these early successional species did not result in higher scores for the harvested uplands. The outside versus outside comparison yielded no difference between treatment and reference watersheds.

An abundance of literature supports the contention that riparian zones exhibit different biological structure/function than adjacent uplands. In all watersheds observed in this study, the ACS value per hectare was greater inside than outside the SMZ. In references, riparian area ecological function likely extended further than the management-delimited SMZ. The overstory vegetation in the treatments limits the riparian area to the SMZ boundaries.

Timber harvesting and large- and small-scale natural disturbances may dramatically affect the species composition of bird communities. In the Southeast,
species are not eliminated from the forest landscape, but rather are temporally replaced by others as stand age is affected by forest management and natural succession (Conner et al. 1979, Dickson et al. 1993a, 1993b, Conner and Dickson 1997). With the first stages of succession shrub-nesting species such as Field Sparrows (*Spizella pusilla*) and Blue Grosbeaks (*Guiraca caerulea*) begin to appear. As shrub vegetation develops, additional species such as the Prairie Warbler (*Dendroica discolor*), Indigo Bunting, (*Passerina cyanea*), White-eyed Vireo (*Vireo griseus*) and Yellow-breasted Chat (*Icteria virens*) become very abundant (Dickson et al. 1993b, Conner and Dickson 1997). After 10 to 12 years Blue Grosbeaks, Prairie Warblers, and Field Sparrows have reached maximum density and virtually disappear with canopy closure. In 14 to 16 years, Indigo Buntings, Yellow-Breasted Chats and White-eyed Vireos will follow the same trend. In this study, the initial trends of colonization occurred within the first 3 years of succession as all of the species listed above occurred in the regenerating upland clearcuts (except the field sparrow. See Appendix B)

*Habitat Fragmentation*

Although mature forest neotropical migrants have generated a great deal of special management concern, many early-successional species such as the Eastern Kingbird (*Tyrannus tyrannus*), Indigo Bunting, and Prairie Warbler have relatively high conservation priorities and should therefore be considered in management activities. These early successional species increase in abundance with the creation of edge and even-aged management (Thompson et al. 1992). Conner et al. (2004) found that for birds
such as the Eastern Kingbird, Blue Grosbeak, Painted Bunting, and Prairie Warbler that after 20m of SMZ, these species started to decrease in numbers and disappear entirely at 70m of SMZ. In Conner’s study, the species were using song perches in tall trees and snags on SMZ edges. In the Dry Creek study, Indigo Bunting, Blue Grosbeak and Eastern Kingbird registrations were higher in treatments than in references. Two of these species carry a relatively high conservation value score (Eastern Kingbird = 15, Indigo Bunting = 14), while the Blue Grosbeak has a moderate score (12).

Linear cuts create large edge/area ratios, thereby increasing edge habitat. Leaving riparian corridors and decreasing the core habitat of adjacent stand may exacerbate the effects of habitat fragmentation for some migrant species (Trinquet et al. 1990, Robbins 1979). Further investigation is needed to gain insight on the potential effects of creating this linear edge (particularly with, ecological traps, and populations sinks). In particular, data related to reproductive success would be helpful.

SMZs are typically linear strips connecting patches of older forest. Conner et al. (2004) stated that the presence of bird species within SMZ does not equate with actual breeding or breeding success. It is possible then that the species observed in the SMZs in this study or any other using similar census methods might not be breeding in the SMZs but rather using them for other purposes.
Thinned vs. Unthinned SMZs

Neither Louisiana Waterthrushes nor Acadian Flycatchers were registered in the thinned portion of the SMZs. These areas experienced a high number of wind-throws, decreased canopy cover, and increased of mid-story growth which may have negatively altered habitat suitability for the forest-interior Louisiana Waterthrush. Forest-interior birds may avoid narrow SMZ, because of low nest site availability, low food availability, or lack of size sufficient for area-sensitive species. These decreases result from increased wind and sunlight penetration that destroys leaf litter and other habitat for invertebrates (Conner et al. 2004).
CHAPTER V
CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Management Recommendations

Some researchers have recommended 100m buffer widths on each side of the stream and no SMZ thinning to benefit bird communities. Peak and Thompson (2000) found that wide forested-riparian areas provided breeding habitat for more birds than narrow forested-riparian areas. The results of this study suggest that the narrower buffers may provide minimal value if the management objectives include mature forest bird conservation. SMZ thinning should be carefully considered in areas that are highly susceptible to strong wind events. Such events have the potential to further decrease basal area, canopy coverage and suitability of remaining mature forest for interior species. Traditionally, only SMZ width has been a focus for assessing functionality of a SMZ. It is recommended that basal area and overall stand structure also be considered.

This study suggest that some birds may offer promise as bioindicators of SMZ condition. However, they may do so at different spatial scales. The Louisiana Waterthrush is considered more of a water quality/riparian bioindicator and therefore represents conditions within or in close proximity to the stream itself. Due to their more expansive area requirements, the Acadian Flycatcher and Northern Parula may serve more as conservative choices for bioindicators of SMZ condition. These two species might be considered more facultative than obligate species for defining riparian zone condition. The combination of all three species as a riparian zone guild has the potential
to serve as a comprehensive indicator of riparian zone condition, that encompasses not only management-defined SMZ’s but also ecologically defined zones (vegetation, topography, soils, etc.) that in most cases are more expansive.

After two years post treatment (2005), the ACS scores in the uplands increased due to the occurrence of the Common Yellow-Throat (*Geothlypis trichas*) and increased further in the third year post-treatment (2006) with occurrence of the Northern Bobwhite Quail and Yellow-Breasted Chat. In the fourth year post treatment (2007), the Prairie Warbler was recorded. These species utilized upland habitat and the edges of the SMZ as well, thereby increasing the conservation value of the riparian area. Considering the overall bird community, the BMP guidelines (particularly width and reduced BA) were sufficient in terms of conservation value for the watershed area. However, if consideration for the mature forest riparian guild is of primary importance, then narrow BMP requirements may yield lower CV scores within the SMZ than the wider recommendations. It would not be appropriate to conclude from this study that this lower value indicated a negative impact on riparian guild reproductive success, as reproductive success was not a variable in this study. Rather, this study should serve as a baseline for further investigation using this riparian guild as a bioindicator of riparian zone condition. This research should include studies of reproductive success, territory size, resource abundance, and post-fledging habitat use among others.
APPENDICES
Appendix A

A-1. Species detected in four headwater streams in the Dry Creek Watershed on Georgia Gulf Coastal Plain inside and outside of the streamside management zone in 2005.

<table>
<thead>
<tr>
<th>Species</th>
<th>PIF Priority Score</th>
<th>Reference 1 2005</th>
<th>Treatment 1 2005</th>
<th>Reference 2 2005</th>
<th>Treatment 2 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Southeastern Coastal Plain BCR</td>
<td>Inside</td>
<td>Outside</td>
<td>Inside</td>
<td>Outside</td>
</tr>
<tr>
<td><strong>Acadian Flycatcher</strong> <em>Empidonax virescens</em></td>
<td>15</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
<td><strong>American Crow</strong> <em>Corvus brachyrhynchos</em></td>
<td>11</td>
<td>0</td>
<td>X</td>
<td>0</td>
<td>X</td>
</tr>
<tr>
<td><strong>Blue Grosbeak</strong> <em>Guiraca caerulea</em></td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td><strong>Blue Jay</strong> <em>Cyanocitta cristata</em></td>
<td>14</td>
<td>0</td>
<td>X</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
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<td>X</td>
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<tr>
<td><strong>Brown-headed Cowbird</strong> <em>Molothrus ater</em></td>
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<td>0</td>
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<td>X</td>
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<td>X</td>
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<td>X</td>
</tr>
<tr>
<td><strong>Eastern Kingbird</strong> <em>Tyrannus tyrannus</em></td>
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<td>0</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td><strong>Eastern Towhee</strong> <em>Pipilo erythrophthalmus</em></td>
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<td>0</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td><strong>Fish Crow</strong> <em>Corvus ossifragus</em></td>
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<td>0</td>
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Appendix B

B-1. Species detected in four headwater streams in the Dry Creek Watershed on Georgia Gulf Coastal Plain inside and outside of the streamside management zone in 2006.

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<th>Species</th>
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LITERATURE CITED


Chapa, L. 1996. Effects of corridor width and edge type on the abundance and nesting success of Acadian Flycatchers (Empidonax virescens) in the Cache River Biosphere Reserve, Illinois, Thesis, University of Illinois, Urbana-Champaign, USA.


ESRI. 2004. ArcGIS 9.1, Environmental Systems Research Institute, Redlands, California, U.S.A.


