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Winter bird use of the Chinese tallow tree in Louisiana

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WINTER BIRD USE OF THE CHINESE TALLOW TREE IN LOUISIANA

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

In

The School of Renewable Natural Resources

by
Michael John Baldwin
B.S., University of Wyoming, 1997
May 2005

DEDICATION

To my wife. Your patience, support, and encouragement were invaluable.

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TABLE OF CONTENTS

DEDICATION.....	ii
ACKNOWLEDGMENTS.....	iii
LIST OF TABLES.....	vi
LIST OF FIGURES.....	vii
ABSTRACT.....	viii
CHAPTER 1. INTRODUCTION.....	1
CHAPTER 2. COMPARISON OF WINTER BIRD COMMUNITIES UTILIZING CHINESE TALLOW-TREE DOMINATED WOODLANDS AND BOTTOMLAND HARDWOOD FORESTS.....	5
STUDY AREA AND METHODS.....	6
RESULTS.....	17
DISCUSSION.....	30
CHAPTER 3. ENERGY ASSIMILATION OF TALLOW FRUIT BY YELLOW-RUMPED WARBLERS, NORTHERN CARDINALS AND AMERICAN ROBINS.....	34
METHODS.....	36
RESULTS.....	43
DISCUSSION.....	47
SUMMARY AND CONCLUSIONS.....	50
LITERATURE CITED.....	51
APPENDIX	
A. SPECIES DETECTIONS IN BOTTOMLAND HARDWOODS.....	61
B. SPECIES DETECTIONS IN CHINESE TALLOW WOODLANDS.....	63
C. INFORMATION-THEORY MODEL SELECTION RESULTS.....	65
D. NITROGEN CORRECTED METABOLIZABLE ENERGY OF DIFFERENT FRUITS BY INDIVIDUAL.....	76
VITA.....	78

LIST OF TABLES

1.1	Fatty acid composition of Chinese tallow fruit (pulp only).....	4
2.1	Results from the species richness data analysis.....	19
2.2	Relative abundance of the most common species by woodland type, both years combined. Habitat comparisons were performed using the Friedmann's test....	20
2.3	Model selection results by species for models with a $\Delta AIC_c \leq 4$	21
2.4	Mean (standard error) for landscape variables by habitat type.....	25
2.5	Model-averaged parameter estimates, unconditional standard errors, and relative Akaike weights ($3 w_i$) for each explanatory variable by species and winter.....	27
3.1	Nutritional qualities of fruits used in this study using a random sample of fruits (N=30).....	44
3.2	Summary of AME results by bird and plant species.....	44
3.3	Nitrogen budget and weight loss during AME trials.....	44
3.4	Food requirements to satisfy daily energy needs (EM_{avg}) based on AME results. Calculations are based on pulp only.....	47

LIST OF FIGURES

2.1	Locations of point count stations, Mermentau River Basin, Louisiana.....	7
2.2	Species richness (mean number of species detected per point \pm standard error) according to habitat type, year, and month.....	18
3.1	AME of Chinese tallow pulp by Yellow-rumped Warblers (YRWA), Northern Cardinal (NOCA), and American Robin (AMRO).....	45
3.2	Yellow-rumped Warbler AME for Chinese tallow, wax myrtle, and poison ivy fruit.....	46
3.3	Northern Cardinal AME for Chinese tallow, deciduous holly, and hackberry fruit.....	46

ABSTRACT

Chinese tallow (*Triadica sebifera*) is a non-native invasive tree that is of particular concern in the Southeastern United States. It has become naturalized in a variety of habitats and can be found in monospecific stands. The use of tallow woodlands by overwintering birds is poorly documented. I compared use of tallow woodlands to use of bottomland hardwood forests by birds in the Mermentau River Basin, Louisiana. Species richness and evenness were greater in the bottomland hardwood sites. Three species were more abundant in tallow woodlands, six species were more common in bottomland hardwoods, and six species exhibited no difference between habitats. Information-theory methodology was used to determine the relative importance of woodland type and certain landscape variables to species richness and bird abundance. Model-averaged parameter estimates and relative Akaike weights were calculated. In most cases, woodland type was a better predictor of species richness and abundance than percent forest cover, distance to nearest forest patch, or the number of forest patches within 1 km. Energy assimilation of tallow fruit by captive birds was measured to determine if apparent metabolizable energy differed between bird species and plant species. Assimilation of tallow fruit pulp differed significantly between birds. Yellow-rumped Warblers (*Dendroica coronata*) exhibited the highest assimilation of tallow, followed by American Robins (*Turdus migratorius*) and then Northern Cardinals (*Cardinalis cardinalis*). Yellow-rumped Warblers, which were more common in the tallow woodlands, were able to metabolize tallow fruit more effectively than wax myrtle (*Morella cerifera*) and poison ivy (*Toxicodendron radicans*) fruit. Metabolization of wax myrtle and poison ivy fruit did not differ significantly. Cardinals metabolized deciduous

holly fruit (*Ilex decidua*) more efficiently than either hackberry (*Celtis laevigata*) or tallow. Overall, bottomland hardwoods supported more bird species and exhibited a higher measure of species evenness. Tallow may provide an alternate food source for some species and could potentially influence the local winter distribution of Yellow-rumped Warblers.

CHAPTER 1: INTRODUCTION

Invasive species pose a serious threat to native ecosystems by altering community structure and composition and ecosystem function (Stein and Flack 1996, Schmitz et al. 1997, Wall and Darwin 1999, Mack et al. 2000, Wittenberg and Cock 2001, National Research Council 2002). More than 40% of the species on the U. S. Threatened or Endangered Species List are in decline due in part to exotic species (Stein and Flack 1996). The United Nations Secretariat of the Convention on Biological Diversity (2001) declared invasive alien species to be one of the four leading factors causing declines in biodiversity. Economic losses from non-native organisms to agricultural crops, pastures and forests range from \$78 billion to \$137 billion per year in the United States (Invasive Species Program 2000, Pimentel et al. 2001). Non-native plants alone cause \$33.9 billion in losses per year. In extreme cases, native habitats can be overrun by exotic plants and converted into single-species dominated systems, causing declines in native fauna and flora (Westbrooks 1998). Examples of this have occurred with the Australian paperbark tree (*Melaleuca quinquenervia*) in Florida (Schmitz et al. 1997, Westbrooks 1998), *Mimosa pigra* in Australia (Braithwaite et al. 1989), *Acacia mearnsii* in South Africa (de Witt et al. 2001), leafy spurge (*Euphorbia esula*) in the northern United States and southern Canada (Westbrooks 1998) and salt cedar (*Tamarix* spp.) along riparian zones of the Southwest (Wittenberg and Cock 2001). Similarly, the Chinese tallow tree (*Triadica sebifera*) is invading habitats in the southeastern United States, often forming near monospecific woodlands.

Chinese tallow is a member of the Euphorbiaceae (spurge family). The tree sap is toxic and the leaves are poor forage for cattle, causing diarrhea and even death

(Russell et al. 1969). Common names for tallow include chicken tree, popcorn tree, Florida aspen, and it has been placed in the genera *Sapium sebiferum*, *Croton sebifera*, and *Stillingia sebifera* (Jubinsky 1994, Jubinsky and Anderson 1996, Rogers et al. 2000). Tallow is capable of growing in a variety of habitats including bottomland hardwood forests, coastal prairie, abandoned agricultural fields, cheniers, levees and spoil banks (Duke 1983, Jones and McLeod 1989, Bruce et al. 1995, Neyland and Meyer 1997, Wall and Darwin 1999, Cameron et al. 2000). It is considered a threat to coastal prairie in Texas and Louisiana (Bruce et al. 1995, Grace 1998, Barrilleaux and Grace 2000). Expansion of tallow into more northerly regions of the United States may be limited by temperature (Charron et al. 2000). Like other invasive plants, tallow possesses several competitive advantages over native flora, including: low insect herbivory and pathogen load; rapid seedling growth equal to or greater than native species; early maturation; high fecundity; ability to grow in full sun or low light; and tolerance of poor soils, flooding, drought, and low salt levels (Tsing et al. 1956, Jones and McLeod 1989, Jones and Sharitz 1990, Houran and Pengxin 1991, Conner and Askew 1993, Bruce et al. 1997, Grace 1998, Wall and Darwin 1999).

Chinese tallow is native to southeast Asia where it is grown as an agricultural crop, primarily for its seed oil (stilingia oil) (Singh et al. 1993, Sharma et al. 1996, Bruce et al. 1997). Products manufactured using tallow include soap, dyes, fuel, paint and varnish, candles, honey and wood pulp (Scheld and Cowles 1981, Duke 1983, Xu et al. 1991, Cameron et al. 2000). Tallow was first introduced into the United States in Georgia by Benjamin Franklin circa 1772 (Bruce et al. 1997) and in Texas and Louisiana by the Bureau of Plant Industry (U. S. Department of Agriculture) in the early

1900's in the hopes of establishing tallow as a seed crop (Cameron and Spencer 1989, Jubinsky 1994, Barrow, pers. comm.). Earlier plantings may have occurred in the Gulf Coast, since a herbarium sample was collected in the late 1800's from Louisiana (Barrow, pers. comm.). Later introductions in the 1900's occurred due to horticultural plantings because of its fast growth and showy red colors as the leaves change color in the fall.

The effects of tallow on avifauna are not fully understood and are likely dependent on the species of interest and time of year. Tallow produces an abundant late-fall fruit crop, which persists through winter and is primarily bird-dispersed (Jones and McLeod 1989). Conway et al. (2002) documented foraging on tallow fruit by fall migrants in coastal Texas and recorded use by 24 species. Barrow and Fontenot (unpubl. data) have observed 64 species feeding on tallow fruit. Renne et al. (2000) stated that about 40% of the tallow fruit crop is consumed by birds. This is an indication that certain species may benefit from tallow fruit, mid-fall through early spring. In contrast, previous research on spring Neotropical migrants suggests that tallow trees do not provide sufficient food resources for certain insectivorous trans-Gulf migrants because of a lack of foliage-eating insects (Barrow and Renne 2001). Consequently, tallow woodlands may provide poor stop-over habitat; worse yet, tallow may serve as an ecological trap for these migrants.

Few birds may be able to efficiently assimilate the energy in tallow. The pulp (aril) layer of tallow fruit is high in fatty acids, primarily palmitic acid and oleic acid (Table 1.1) (Khan et al. 1973, Raie et al. 1983, Xu et al. 1991). Palmitic acid, the most abundant fatty acid in tallow pulp, is a saturated fatty acid with a high melting point.

Most animals have poor assimilation of similar fatty acids with high melting points (Place and Stiles 1992). Scott et al. (1976) reported the percent absorption of palmitic acid and stearic acid in chickens was only 12 and 4%, respectively. Consequently, tallow may provide poor quality food to most birds even though it has caloric rich fruit (33.5 kJ/g, range of other plant species = 14.91-30.23 kJ/g, Barrow and Jeske, unpubl. data) and attracts many bird species.

Table 1.1. Fatty acid composition of Chinese tallow fruit (pulp only).

Type of Fatty Acid	Fatty Acid	Shorthand Designation ^a	Melting Point (°C)	% Composition ^b	% Composition ^c	% Composition ^d
Saturated	Lauric	C12:0	44.2	.	.	0.21
Saturated	Myristic	C14:0	53.9	3.1	trace	0.38
Saturated	Palmitic	C16:0	63.1	70.0	64.5	34.08
Saturated	Stearic	C18:0	69.6	2.0	1.4	6.82
Saturated	Arachidic	C20:0	75.3	.	.	1.02
Mono-unsaturated	Oleic	C18:1	16.2	26.25	28.1	31.00
Polyunsaturated	Linoleic	C18:2	-5.0	.	1.8	21.47
Polyunsaturated	Linolenic	C18:3	-11.0	.	4.2	3.94

^a = Shorthand designation for carbon structure.

^b = Khan et al. 1973

^c = Raie et al. 1983

^d = Xu et al. 1991

This study was initiated to determine whether bird species richness and abundance differed between tallow-dominated woodlands and bottomland hardwood forests in southwest Louisiana. I was also interested in whether energy assimilation of tallow fruit was similar between bird species and to other fruiting plants commonly visited by those species.

CHAPTER 2: COMPARISON OF WINTER BIRD COMMUNITIES UTILIZING CHINESE TALLOW-TREE DOMINATED WOODLANDS AND BOTTOMLAND HARDWOOD FORESTS

Non-native, invasive species are a major concern to the conservation of fauna and flora in the United States. Exotics are the primary cause for declines in 18% of the species listed on the U. S. Threatened and Endangered Species List and are a contributing factor for declines for an additional 24% (Stein and Flack 1996). No ecosystem in the U. S. has been left unaffected by this problem (Invasive Species Program 2000). Particularly severe invasions by non-native organisms have converted diverse ecosystems into single-species dominated systems (Westbrooks 1998, Mack et al. 2000).

In the Southeast, an invasive plant of particular concern is the Chinese tallow tree. Tallow is native to southeast Asia and was introduced into the United States in the late 1700's as a potential agriculture crop for its seed oil (Singh et al. 1993, Sharma et al. 1996, Bruce et al. 1997). It is now spread throughout the northern Gulf Coast and south Atlantic states and can be found in near monospecific stands (Scheld and Cowles 1981, Harcombe et al. 1993, Renne et al. 2000). Little is known about the use of this new woodland type by birds during the winter months. Many birds consume tallow fruit and are the primary dispersal agent of the seeds (Jones and McLeod 1989, Barrow and Fontenot, unpubl. data). However, plant diversity within tallow woodlands tends to be low (pers. obs.) and may not provide suitable habitat for most woodland birds. With current declines in Neotropical migratory birds (DeGraaf and Rappole 1995), it is important to document bird use of tallow woodlands to indicate potential effects that tallow will have on these populations.

The objectives of this study were to compare species richness and relative abundance of species between tallow-dominated woodlands and nearby stands of hardwoods during winter in southwest Louisiana. I also examined the relative importance of specific landscape variables and woodland type to avian abundance and species richness. Results from this study may provide insight into the role Chinese tallow in shaping winter bird assemblages.

STUDY AREA AND METHODS

Sites were located in the Mermentau River Basin of southwest Louisiana. This basin was historically dominated by tallgrass prairie and riparian gallery forests, most of which has been converted into agricultural fields. Remaining riparian woodlands occur along natural water drainages and man-made canals. In the fall of 2001, 50 sites were selected in bottomland hardwood forests with some mixed pine (n=25) and tallow-dominated (n=25) woodlands on private (n=48) and public land (n=2) (Figure 2.1). Tallow-dominated stands were characterized as having an estimated $\geq 70\%$ tallow in the canopy. The majority of these stands occurred on fallow agriculture fields. Most hardwood stands had some tallow present. Only hardwood sites with less than 10% tallow in the canopy were used. All woodland stands were greater than 0.5 ha in area. Independence between sites was achieved by selecting sites at least 1 km apart for sites of a particular woodland type. This criterion was relaxed for minimum distances between tallow and bottomland sites, where sites were at least 0.8 km apart.

Birds were surveyed using 50-m fixed-radius point counts based on methods established by Hamel et al. (1996). Sites were sampled once per month over a 7 – 10 day period in mid-December, mid-January, and mid-February in the winters of 2001-02

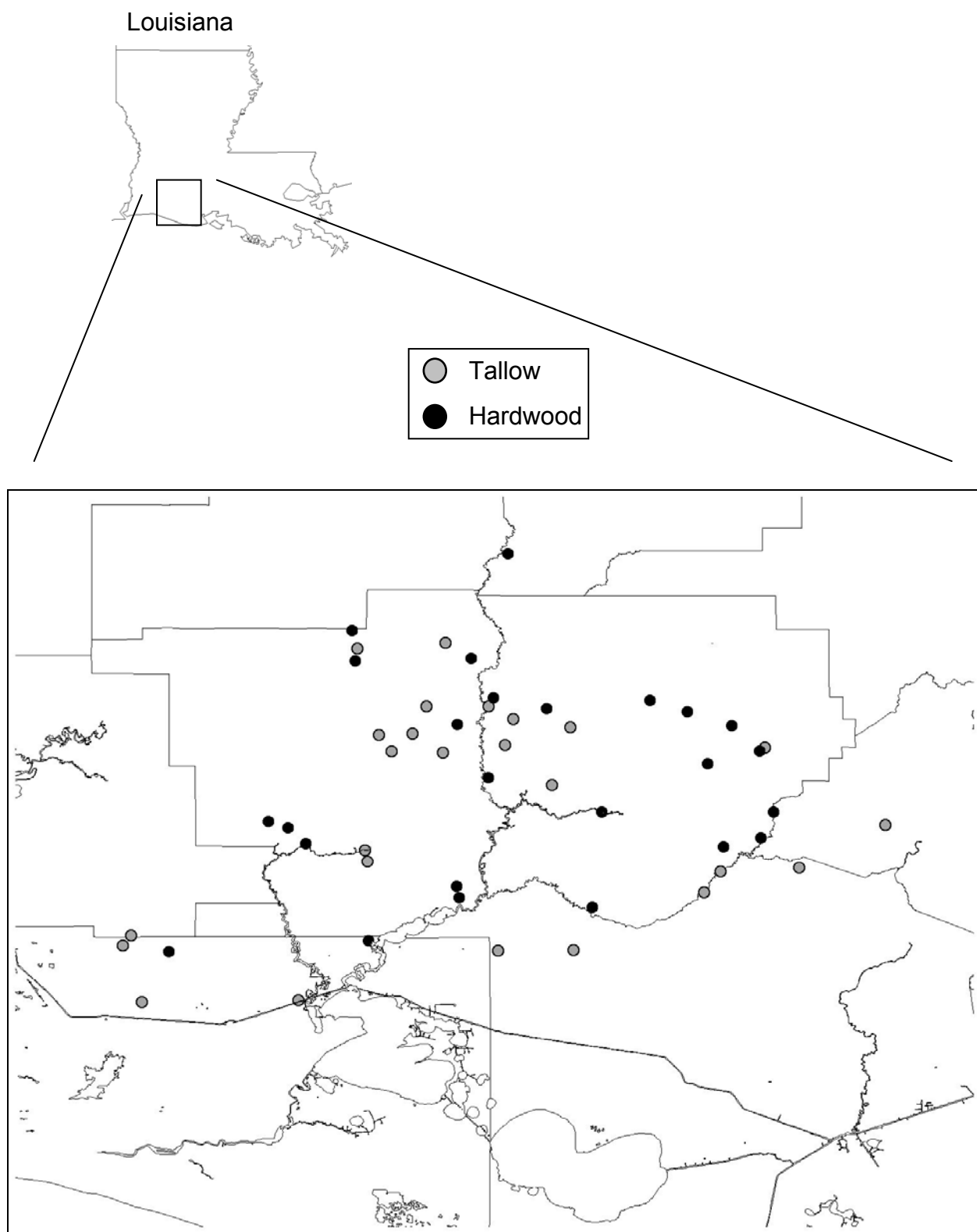


Figure 2.1. Locations of point count stations, Mermentau River Basin, Louisiana.

and 2002-03. Surveys were conducted from 07:00 to 13:45, which is longer than the interval used for breeding surveys, but has been shown to be valid for winter point count studies in other geographic locations (Rollfinke and Yahner 1990, Gutzwiller 1991). Counts were conducted in pairs of one tallow site and one bottomland hardwood site, with three or four pairs were randomly sampled per day. All birds detected visually or aurally within a 10-min period were recorded on a data sheet according to their azimuth and distance from observer. If any bird was flushed within the point count circle while walking to the site, the initial location of the bird was recorded. Flyovers and birds detected outside 50 meters were recorded, but not included in analyses because of uncertainties on whether the birds were occupying the stand or adjacent habitats. The 10-min period was divided into 3 time intervals (0-3 min, 3-5 min, and 5-10 min), and bird observations were recorded according to the interval of detection. Estimated position of a bird was recorded on the data sheet. All observations fell into two distance bands: 0-25 m and >25-50 m. I conducted all counts and wore neutral-colored clothing during counts (Gutzwiller and Marcum 1997). Surveys were not conducted if winds were greater than 20 km/h, at temperatures less than 0°C, or during rain or snow.

Detection Probability

Recently, researchers have suggested that point counts uncorrected for detectability may produce biased or imprecise measurements of bird abundance (Barker and Sauer 1995, Boulinier et al. 1998, Bart and Earnst 2002, Farnsworth et al. 2002, MacKenzie and Kendall 2002, Rosenstock et al. 2002). Their assertion is that detection probabilities differ between species and individuals and can be influenced by a variety of factors (e.g., season, weather conditions, time of day, habitat). Three types

of factors that influence species detection rates have been described: 1) observer abilities, skills, and behavior; 2) environmental variables; and 3) physical and behavioral characteristics of birds (Rosenstock et al. 2002). For these reasons, it has been argued that accurate estimates of bird abundance cannot be determined without accounting for these effects.

One technique that deals with this issue is the removal model (Farnsworth et al. 2002). This method determines detection probabilities of birds based on the first interval of detection out of three or more periods. This method is useful for counts where most detections are aural, a characteristic of this study. However the model is not appropriate in this study because it requires an assumption of a closed population within the count radius during the survey period. Since surveys were conducted in the winter and contained many non-territorial birds and also mixed species flocks, this assumption cannot be satisfied (John Sauer, pers. comm.). Neither does this model work well for wide-ranging species such as Pileated Woodpecker (*Dryocopus pileatus*) or American Crow (*Corvus brachyrhynchos*) (Farnsworth et al. 2002). Shortening counts to 5 minutes was suggested as a way to improve the likelihood of meeting this assumption; however, even at this shorter length, the presence of primarily non-territorial birds, mixed foraging flocks, and wide-ranging species still precludes the use of this technique. Also, shortening counts results in fewer detections of uncommon species. For example, in this study, species richness in tallow woodlands would decline by 7 (15.9%) and by 5 species (10.4%) in the bottomland hardwoods.

Distance sampling (Buckland et al. 1993) is another method that has been used to estimate bird densities and species detection rates. Distances to birds are recorded

in radial distances or in 3 or more distance bands. Bird densities are determined from these distances using program DISTANCE (Thomas et al. 2004). Minimal sample size is 60 to 80, but 100 or more is recommended (Buckland et al. 1993). For this study, seven species had 100 observations (2 in Year 1, 5 in Year 2); however, because one objective of this study was to examine relationships between species abundance and landscape variables, none of the species satisfied this requirement on a site-by-site basis. Also, detections were recorded into two distance bands using perpendicular distances from the observer to the birds. This is according to standard point count procedure (Paul Hamel, pers. comm.). Radial distances (i.e., angle and perpendicular distance), as required by DISTANCE, were not recorded and may not be equivalent to perpendicular distances (Buckland, pers. comm.). Also, because detections were lumped into two distance bands, the data are restricted to a single-parameter detection function and model fit cannot be adequately tested (Buckland et al. 1993). In addition to these problems, serious concerns have been raised as to whether avian point count data meet model assumptions for DISTANCE (Hutto and Young 2003). The issues raised by the authors' are discussed in length and are not trivial. Their most critical statement is that three of the four model assumptions are probably always violated when applied to avian point counts in forest settings.

MacKenzie et al. (2002) proposed a method to estimate detection probabilities based on species occupancy rates. This method was not considered because it requires a closed population, which, as mentioned previously, is not reasonable for winter point count data. For the same reason, the methods presented by MacKenzie and Kendall (2002) for estimating detection probabilities (i.e., hypothesis testing,

equivalence testing, and model averaging) were not used due to the closed population assumption.

Other field methods have been suggested as an alternative to standard point count procedures. Double sampling (Cochran 1977, Bart and Earnst 2002) involves a larger sample of incomplete counts (estimated densities) and a random sample of thorough, complete counts (actual densities). The latter is used to adjust the results from the incomplete counts. It has been used for shorebird surveys (Handel and Gill 1992, Bart and Earnst 2002) and deer pellet surveys (Eberhardt and Simmons 1987), but may have problems when applied to avian point counts in forested settings (Thompson 2002) since it is not reasonable to assume that all individuals will be recorded in the complete counts. In addition, fewer sites can be surveyed with this technique in the same amount of time, so more personnel are required or fewer data are collected.

Another count method is the double-observer approach (Nichols et al. 2000). This method employs two observers, a primary and a secondary observer. The secondary observer records all bird detections from the primary observer and also any other bird sightings that the primary missed. Detection probabilities are derived from each observer's counts. Problems with this method include lack of independence between observer sightings and reduced detections by the secondary observer in high bird density areas due to his/her dual role as recorder and observer. Nichols et al. (2000) suggest ways to deal with this including adding a third person as a recorder. The problem with this approach is that the authors do not adequately consider the effect a second or third person has on bird behavior. Observer effects on bird behavior are

well documented (McShea and Rappole 1997, Bye et al. 2001) and adding observers can only compound the problem. In addition, the method does not work well for species and/or individuals with low detection probabilities. Finally, the requirement of a second observer precludes the use of this method in many avian studies due to higher costs, including this one.

As mentioned above, three factors have been described that influence species detection rates (Rosenstock et al. 2002). The first of these deals with observer skills and ability. Since all of my counts were made by the same person and neutral colored clothing was worn during counts, this should not be a major concern. The second factor consists of environmental variables that may influence species detectability. In this study, counts were not conducted with winds greater than 20 km/h, at temperatures less than 0°C, or during rain or snow. Topography was not an issue as site elevations were near level. Vegetation characteristics can influence detectability of birds. In this study, I argue that habitat comparisons made without accounting for species detectability are acceptable, since the majority of bird detections in southeastern forests are auditory, often greater than 90 percent (Hamel et al. 1996, 87% in northern Rockies - Hutto and Young 2003), and auditory detection thresholds in forests were found to be 70 meters and beyond in earlier studies (Emlen and DeJong 1981, Wolf et al. 1995). In addition, stem density (i.e., all woody plants at breast height or greater) and shrub density (i.e., shrubs at breast height or greater) at my study sites did not differ significantly between woodland type (stem density: $P = 0.729$; shrub density: $P = 0.555$). Therefore, differences in vegetation density between habitats should not be a significant concern. Also, the goal of this study is to compare relative abundance of species between

woodland types, not estimate bird densities. Finally, the third factor discussed is concerned with “...physical and behavioral attributes of birds that make them more or less conspicuous...” (e.g., body size, color, vocalization characteristics, flight behavior). Again, I am not concerned with estimating densities and most detections are aural. In addition, I am only comparing species ‘X’ in tallow woodlands to species ‘X’ in native woodlands, not species ‘X’ to ‘Y’. Therefore, due to the aforementioned reasons, this study does not include detection probabilities, nor are the data adjusted for this factor. However, I do test for differences in detection rates between distance bands to determine if bird detectability differs between woodland type (see below).

Landscape Metrics

Landscape variables were measured to determine their relationship to species richness and abundance. These metrics were chosen under the presumption that they were important factors affecting species richness and abundance. Variables measured included forest patch size (ha) (PatchSize), distance to nearest forest patch (km) (DistPatch), distance to nearest road (km) (DistRoad), percent forest cover within 1 km radius (ForCover), forest perimeter within 1 km radius (km) (ForPerim), and number of distinct forest patches within 1 km of the site (NumPatch). Landscape variables were measured using Digital Ortho Quarter Quads in ArcView[®] 3.3 Geographic Information Systems (Environmental Services Research Institute 2002). Some of the 1 km radius survey areas overlapped with nearby sites; therefore, one of the overlapping sites was randomly removed from the analysis. Four sites were removed leaving 23 tallow sites and 23 bottomland hardwood sites. Forest patches were defined as woodlands ≥ 25 m wide. Any linear patch of trees (e.g., treeline along a fence) would not be included

unless it met these width requirements. Patch boundaries were defined as woodlands isolated from other woodlands by either watercourses or forest clearings greater than 25 m wide or separated by roadways. DistPatch was measured as the straight-line distance from the edge of the patch containing the point count to the nearest forest patch. DistRoad was measured as the distance from the point count center to the nearest road.

In October 2002, Hurricane Lili hit Louisiana, causing damage to many of the plots. Damage ranged from none to several trees blown down in one plot. Because this damage could affect avian use of the woodlands, a hurricane damage index was created. Each site was visually ranked from 1 to 5 based on extent of damage according to the following criteria:

1. Little or no damage.
2. Moderate limb damage, few if any topped trees.
3. Major limb damage, topped trees, a few felled trees, small canopy gaps.
4. Several felled trees, large canopy gaps.
5. Major blowdown, most trees lost with little canopy remaining.

Statistical Analysis

For species comparisons, only species with at least 30 detections and a frequency of occurrence of 0.20 across all sites in both years combined were included in the analysis. Species richness comparisons included all species. To determine if species detection rates were similar between habitats, 2x2 contingency tables were created using distance from plot center (i.e., 0-25 m or 25-50 m) and habitat type. These tables were analyzed using log-linear analysis (Proc CATMOD, SAS Institute Inc.

1999). Three species exhibited significant habitat/distance interactions: American Goldfinch (*Carduelis tristis*), American Robin (*Turdus migratorius*), and Downy Woodpecker (*Picoides pubescens*), while the other 14 species did not. For these three species, detections recorded beyond 25 meters were excluded. Consequently, Goldfinches and Downy Woodpeckers were dropped from further analyses, due to fewer than 30 observations remaining.

Habitat comparisons of species abundance were made using Freidmann's nonparametric test (Conover 1980), controlling for year and month (Proc FREQ, SAS Institute Inc. 1999). Because multiple species comparisons were made, a more conservative alpha of 0.01 was used. Species richness data met parametric assumptions and were analyzed as repeated measures analysis of variance, with year and month repeated (Proc MIXED, SAS Institute Inc. 1999). Pielou's J' (Pielou 1969) was calculated to measure species evenness between habitats. Evenness data were logit transformed and analyzed as repeated measures analysis of variance, with year and month repeated (Proc MIXED).

An information-theoretic approach (Burnham and Anderson 2002) was used to examine the relative importance of landscape variables (i.e., PatchSize, DistPatch, ForCover, ForPerim, and NumPatch), habitat/woodland type (Hab), and hurricane damage (Damage) to species richness (SppRich) and abundance. Correlations were calculated for each pair of explanatory variables to remove highly correlated variables ($r > 0.80$). PatchSize was positively correlated to ForCover ($r = 0.858$), so the former was excluded from the analysis. Preliminary regression analyses indicated multicollinearity problems when including ForPerim in the global model, so this variable was also

excluded. Additionally, little support was found for including DistRoad in the analysis, so it was also excluded. Damage from Hurricane Lili occurred between field seasons; therefore, each year was analyzed separately. All linear combinations of the remaining variables were used in the analyses.

Second order Akaike's Information Criterion (AIC_c) for small sample size (Sugiura 1978) was used to rank model importance, with a lower AIC_c meaning a better model fit. Use of AIC_c is recommended over AIC when the number of explanatory variables is less than 40 times the number of observations (Anderson et al. 2001). Models were ranked and differences calculated (ΔAIC_c) based on the best model (model with the minimum AIC_c) so that the highest ranked model had a ΔAIC_c equal to 0. Models with $\Delta AIC_c \leq 2$ are considered to have substantial support, models with ΔAIC_c between 4 and 7 have considerably less support, and those with $\Delta AIC_c \geq 10$ have essentially no support (Burnham and Anderson 2002). Standardized Akaike model weights (w_i) were calculated to rank model importance, such that the sum of w_i across models is 1. Each w_i is a measure of the strength of evidence or a probability that a particular model is the true model. The greater the w_i , the more likely that that model is the true model. If support for a single best model is lacking (i.e., $w_i \leq 0.90$), it is useful to examine the relative importance of each variable. This may be done by examining w_i across models known as multimodel inference (Burnham and Anderson 2002). This technique was used to examine the relative importance of the explanatory variables by summing w_i ($\sum w_i$) for each model in the set that contains the variable of interest. The larger $\sum w_i$, the more important that variable is relative to the other variables. Model-averaged

parameter estimates and unconditional standard errors were calculated for each species.

Proc MIXED (SAS Institute, Inc. 1999) was used to calculate model fit statistics using log+1-transformed data for SppRich and the more abundant species (Northern Cardinal, Ruby-crowned Kinglet-Year 2 only, and Yellow-rumped Warbler-Year 2 only). Proc REG (SAS Institute, Inc. 1999) was used to calculate parameter estimates and standard errors. Less common species were analyzed with logistic regression as presence/absence data (Proc LOGISTIC, SAS Institute, Inc. 1999). A goodness-of-fit test (Hosmer and Lemeshow 1989) was performed to test the fit of the global model for each species and data were checked for potential problems of overdispersion (Proc GENMOD was used for SppRich and common species, while Proc LOGISTIC was used for the less common species, SAS Institute, Inc. 1999). All possible subsets of the explanatory variables were modeled. Model-averaged parameter estimates for Hab are either positive for species tending to respond favorably to native sites or negative for those responding more favorably to tallow.

RESULTS

A total of 54 species were observed in this study; 48 species were detected in the hardwood sites and 44 species were detected in tallow (See Appendices A and B for complete species list). Species richness was lower in tallow woodlands with 4.8 (SE = 0.19) species detected per point versus 6.0 (SE = 0.27) species per point in bottomland hardwood sites (Table 2.1). Species richness also varied between years and months (Figure 2.2), but no interactions were detected between habitat, year and/or

month. Species evenness (J') was significantly higher in the bottomland hardwood sites ($J' = 0.94$, $SE = 0.006$) than the tallow sites ($J' = 0.87$, $SE = 0.010$) ($P < 0.001$).

Fifteen species met the minimum requirements for analysis of at least 30 individuals detected and a frequency of occurrence of 0.20 or greater. Of these, three species were more common in tallow woodlands; American Robin, Gray Catbird (*Dumetella carolinensis*), and Yellow-rumped Warbler (*Dendroica coronata*); six species were more common in bottomland hardwood stands Red-bellied Woodpecker (*Melanerpes carolinus*), Tufted Titmouse (*Baeolophus bicolor*), Carolina Chickadee (*Poecile carolinensis*), Carolina Wren (*Thryothorus ludovicianus*), Ruby-crowned Kinglet

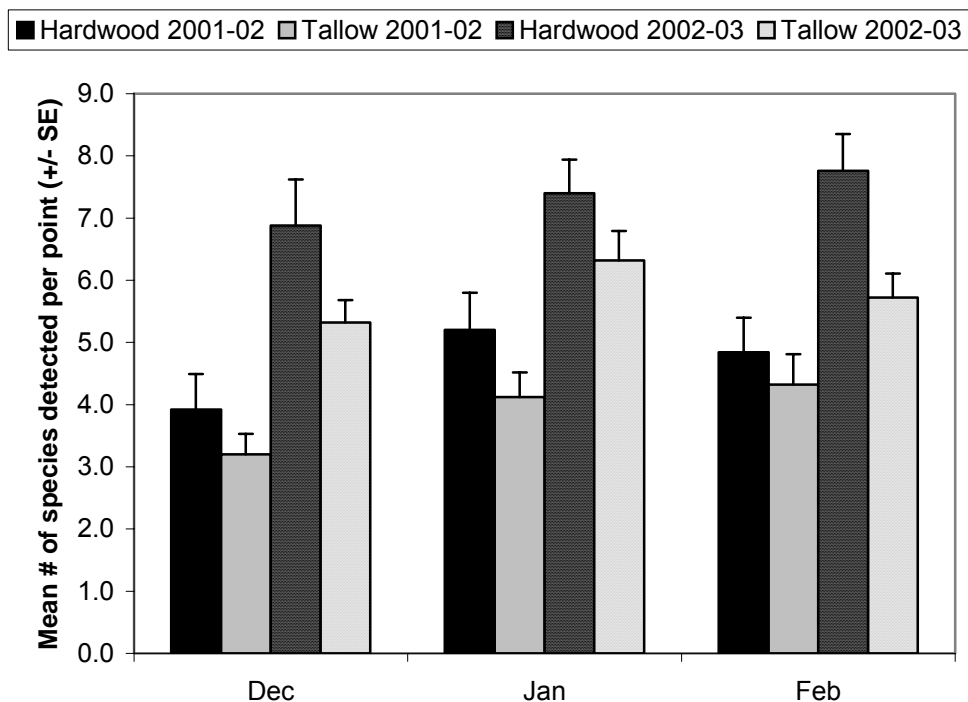


Figure 2.2. Species richness (mean number of species detected per point \pm standard error) according to habitat type, year, and month.

(*Regulus calendula*), and Pine Warbler (*Dendroica pinus*); and six species exhibited no statistical difference between habitats Mourning Dove (*Zenaida macroura*), Eastern Phoebe (*Sayornis phoebe*), Blue Jay (*Cyanocitta cristata*), Blue-gray Gnatcatcher (*Polioptila caerulea*), White-throated Sparrow (*Zonotrichia albicollis*), and Northern Cardinal (*Cardinalis cardinalis*) (Table 2.2).

Results from the information-theoretic models containing ΔAIC_c values of 4 or less, are listed in Table 2.3 (Full model results are listed in Appendix C). For first winter data (Year 1), SppRich and eight bird species (Blue Jay, Carolina Chickadee, Carolina Wren, Eastern Phoebe, Northern Cardinal, Red-bellied Woodpecker, Ruby-crowned

Table 2.1. Results from the species richness data analysis.

Effect	Numerator DF	Denominator DF	F value	P value
Habitat	1	86.4	14.42	< 0.001*
Year	1	76.8	48.41	< 0.001*
Year*Habitat	1	76.8	1.42	0.238
Month	2	110	4.50	0.013*
Month*Habitat	2	110	0.05	0.954
Year*Month	2	119	0.16	0.854
Year*Month*Habitat	2	119	0.58	0.564

* Significant at alpha = 0.05.

Kinglet, and Yellow-rumped Warbler) met minimum requirements for analysis and were examined using four explanatory variables (Hab, DistPatch, ForCover, and NumPatch). In the second winter (Year 2), SppRich and 10 species (American Robin, Blue Jay, Carolina Chickadee, Carolina Wren, Northern Cardinal, Red-bellied Woodpecker, Ruby-crowned Kinglet, Tufted Titmouse, White-throated Sparrow, and Yellow-rumped Warbler) were analyzed using the same four explanatory variables and Damage. Measurements of DistPatch and NumPatch were similar between habitats (Table 2.4).

ForCover was greater in the 1-km radius surrounding the bottomland hardwood sites. These sites also experienced greater hurricane damage.

The best predictor for SppRich was model Hab NumPatch in Year 1 and Hab ForCover Damage in Year 2 (Table 2.3). No other model had substantial support in either year. Relative Akaike weights ($\sum w_i$) of the explanatory variables mimicked these results (Table 2.5). NumPatch and Hab were considered the most important variables in Year 1 with SppRich declining in tallow woodlands and decreasing as the number of forest patches increased (Table 2.5). In Year 2, Hab, ForCover, and Damage exhibited the largest weight; however, the model-averaged slope estimate for ForCover was weak (-0.0014). SppRich in Year 2 is predicted to be higher in bottomland hardwoods and in

Table 2.2. Relative abundance of the most common species by woodland type, both years combined. Habitat comparisons were performed using the Friedmann's test.

Species	Native		Tallow		P-value
	N	Mean (SE)	N	Mean (SE)	
Mourning Dove	10	0.07 (0.03)	36	0.24 (0.06)	0.016
Red-bellied Woodpecker	79	0.53 (0.06)	21	0.14 (0.03)	< 0.001*
Eastern Phoebe	31	0.21 (0.04)	37	0.25 (0.04)	0.507
Blue Jay	28	0.19 (0.04)	42	0.28 (0.05)	0.131
Tufted Titmouse	52	0.35 (0.05)	6	0.04 (0.02)	< 0.001*
Carolina Chickadee	136	0.91 (0.10)	50	0.33 (0.05)	0.003*
Carolina Wren	88	0.59 (0.06)	30	0.20 (0.04)	< 0.001*
Ruby-crowned Kinglet	133	0.89 (0.06)	70	0.47 (0.05)	< 0.001*
Blue-gray Gnatcatcher	34	0.23 (0.04)	16	0.11 (0.03)	0.020
American Robin ^a	25	0.17 (0.04)	104	0.69 (0.13)	< 0.001*
Gray Catbird	4	0.03 (0.01)	33	0.22 (0.04)	< 0.001*
Yellow-rumped Warbler	165	1.10 (0.12)	539	3.59 (0.26)	< 0.001*
Pine Warbler	26	0.17 (0.04)	6	0.04 (0.02)	0.001*
White-throated Sparrow	42	0.28 (0.07)	39	0.26 (0.05)	0.643
Northern Cardinal	182	1.21 (0.11)	154	1.03 (0.11)	0.065

^a American Robin data only includes observations between 0 and 25 meters.

* Significant at alpha = 0.01.

Table 2.3. Model selection results by species for models with a $\Delta AIC_c \leq 4$. Log(L) is the maximized log-likelihood, k is the number of model parameters, AIC_c equals Akaike's Information Criterion for small sample size, ΔAIC_c is the AIC_c difference between each model and the best model, and w_i is the Akaike weight.

Species	Winter	Model	k	log(L)	AIC_c	ΔAIC_c	w_i
SppRich	2001-02	Hab NumPatch	4	-7.8	24.6	0.0	0.333
		Hab	3	-10.2	27.0	2.4	0.100
		NumPatch	3	-10.3	27.1	2.5	0.096
		Hab DistPatch NumPatch	5	-7.8	27.1	2.5	0.096
		Hab ForCover NumPatch	5	-7.8	27.1	2.5	0.096
		ForCover NumPatch	4	-9.4	27.7	3.1	0.071
		Hab ForCover	4	-9.8	28.6	4.0	0.045
SppRich	2002-03	Hab ForCover Damage	5	8.1	-4.7	0.0	0.371
		Hab DistPatch ForCover Damage	6	8.3	-2.4	2.3	0.117
		Hab ForCover	4	5.7	-2.3	2.4	0.112
		Hab ForCover NumPatch Damage	6	8.1	-2.0	2.7	0.096
American Robin	2002-03	ForCover Damage	3	-20.3	47.3	0.0	0.239
		DistPatch ForCover Damage	4	-19.5	48.0	0.7	0.168
		ForCover NumPatch Damage	4	-20.3	49.5	2.3	0.077
		Hab ForCover Damage	4	-20.3	49.6	2.4	0.073
		DistPatch ForCover NumPatch Damage	5	-19.2	49.9	2.6	0.065
		ForCover	2	-22.9	50.1	2.8	0.059
		DistPatch ForCover	3	-21.9	50.4	3.1	0.051
		Hab DistPatch ForCover Damage	5	-19.5	50.5	3.2	0.048
Blue Jay	2001-02	ForCover	2	-27.5	59.2	0.0	0.163
		ForCover NumPatch	3	-26.3	59.2	0.0	0.163
		NumPatch	2	-27.9	60.1	0.9	0.104
		DistPatch ForCover	3	-26.8	60.2	1.0	0.102
		DistPatch	2	-28.3	60.9	1.7	0.071
		Hab ForCover	3	-27.3	61.2	2.0	0.060
		DistPatch NumPatch	3	-27.3	61.3	2.0	0.059
		DistPatch ForCover NumPatch	4	-26.2	61.3	2.1	0.058
		Hab NumPatch	3	-27.5	61.5	2.3	0.051
		Hab ForCover NumPatch	4	-26.3	61.6	2.4	0.050
		Hab DistPatch ForCover	4	-26.8	62.5	3.3	0.032
		Hab DistPatch	3	-28.0	62.6	3.4	0.030
		Hab DistPatch NumPatch	4	-27.0	62.9	3.7	0.026
Blue Jay	2002-03	NumPatch	2	-28.7	61.7	0.0	0.227
		NumPatch Damage	3	-28.3	63.2	1.5	0.109
		ForCover NumPatch	3	-28.5	63.5	1.7	0.096
		DistPatch NumPatch	3	-28.7	64.0	2.3	0.073
		Hab NumPatch	3	-28.7	64.0	2.3	0.072
		ForCover NumPatch Damage	4	-27.9	64.7	3.0	0.052
		Hab NumPatch Damage	4	-28.3	65.5	3.8	0.035
		Hab ForCover NumPatch	4	-28.3	65.5	3.8	0.034
		DistPatch NumPatch Damage	4	-28.3	65.6	3.9	0.033

Table 2.3 (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Carolina	2001-02	ForCover	2	-28.9	62.0	0.0	0.156
Chickadee		DistPatch ForCover NumPatch	4	-26.6	62.1	0.2	0.144
		ForCover NumPatch	3	-27.8	62.2	0.2	0.142
		DistPatch ForCover	3	-28.4	63.4	1.5	0.076
		Hab DistPatch	3	-28.6	63.7	1.7	0.066
		Hab ForCover	3	-28.7	63.9	1.9	0.059
		Hab	2	-29.9	64.0	2.1	0.056
		Hab DistPatch NumPatch	4	-27.6	64.2	2.2	0.051
		DistPatch	2	-30.0	64.3	2.3	0.050
		DistPatch NumPatch	3	-28.9	64.3	2.3	0.048
		Hab ForCover NumPatch	4	-27.8	64.5	2.5	0.044
		Hab DistPatch ForCover NumPatch	5	-26.5	64.5	2.6	0.043
		Hab DistPatch ForCover	4	-28.1	65.2	3.2	0.031
Carolina	2002-03	ForCover	2	-19.5	43.3	0.0	0.201
Chickadee		ForCover NumPatch	3	-18.9	44.3	1.0	0.122
		DistPatch ForCover	3	-18.9	44.3	1.0	0.120
		ForCover Damage	3	-19.2	44.9	1.6	0.090
		Hab ForCover	3	-19.3	45.1	1.8	0.082
		ForCover NumPatch Damage	4	-18.4	45.8	2.5	0.058
		DistPatch ForCover NumPatch	4	-18.6	46.2	2.9	0.046
		DistPatch ForCover Damage	4	-18.7	46.3	3.0	0.045
		Hab ForCover Damage	4	-18.7	46.5	3.1	0.042
		Hab ForCover NumPatch	4	-18.8	46.5	3.2	0.041
		Hab DistPatch ForCover	4	-18.8	46.5	3.2	0.040
Carolina Wren	2001-02	Hab	2	-27.3	58.9	0.0	0.339
		Hab ForCover	3	-27.0	60.6	1.7	0.146
		Hab DistPatch	3	-27.1	60.8	1.9	0.133
		Hab NumPatch	3	-27.2	61.0	2.1	0.121
		ForCover	2	-29.1	62.5	3.5	0.059
		Hab DistPatch ForCover	4	-27.0	62.9	4.0	0.047
Carolina Wren	2002-03	Hab	2	-26.5	57.4	0.0	0.156
		Hab DistPatch	3	-25.7	57.9	0.5	0.120
		Hab Damage	3	-25.9	58.4	1.1	0.091
		Hab DistPatch NumPatch	4	-25.1	59.1	1.7	0.065
		Hab NumPatch	3	-26.5	59.5	2.1	0.054
		Hab DistPatch Damage	4	-25.3	59.6	2.2	0.052
		Hab ForCover	3	-26.5	59.6	2.2	0.051
		Hab DistPatch ForCover	4	-25.6	60.1	2.7	0.040
		Damage	2	-28.0	60.3	3.0	0.035
		Hab NumPatch Damage	4	-25.8	60.6	3.3	0.030
		Hab ForCover Damage	4	-25.9	60.8	3.5	0.028
		Hab DistPatch NumPatch Damage	5	-24.8	61.0	3.6	0.025
		ForCover	2	-28.4	61.0	3.7	0.025
		ForCover Damage	3	-27.2	61.1	3.7	0.025

Table 2.3 (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Eastern Phoebe	2001-02	DistPatch	2	-27.7	59.7	0.0	0.382
		DistPatch ForCover	3	-27.6	61.8	2.1	0.134
		Hab DistPatch	3	-27.7	62.0	2.2	0.126
		DistPatch NumPatch	3	-27.7	62.0	2.2	0.126
Northern Cardinal	2001-02	Hab ForCover	4	-13.3	35.5	0.0	0.191
		DistPatch	3	-15.0	36.6	1.1	0.110
		NumPatch	3	-15.1	36.7	1.2	0.105
		ForCover	3	-15.5	37.5	2.0	0.070
		Hab	3	-15.5	37.5	2.0	0.070
		Hab DistPatch ForCover	5	-13.0	37.5	2.0	0.070
		Hab ForCover NumPatch	5	-13.1	37.6	2.1	0.067
		Hab DistPatch	4	-14.4	37.7	2.2	0.064
		Hab NumPatch	4	-14.5	38.0	2.5	0.055
		DistPatch NumPatch	4	-14.6	38.1	2.6	0.052
		DistPatch ForCover	4	-14.8	38.6	3.1	0.041
		ForCover NumPatch	4	-14.9	38.6	3.1	0.041
		Hab DistPatch NumPatch	5	-14.0	39.4	3.9	0.027
Northern Cardinal	2002-03	Hab ForCover	4	-14.8	38.6	0.0	0.203
		Hab DistPatch ForCover	5	-14.1	39.6	1.0	0.123
		Hab ForCover Damage	5	-14.5	40.4	1.8	0.083
		Hab	3	-17.2	40.9	2.3	0.064
		Hab ForCover NumPatch	5	-14.8	41.0	2.4	0.061
		Hab DistPatch ForCover NumPatch	6	-13.8	41.8	3.2	0.041
		Hab NumPatch	4	-16.6	42.0	3.4	0.037
		Hab DistPatch ForCover Damage	6	-13.9	42.0	3.4	0.037
		Damage	3	-17.8	42.1	3.5	0.035
		NumPatch	3	-17.8	42.1	3.5	0.035
Red-bellied Woodpecker	2001-02	Hab	2	-28.0	60.2	0.0	0.231
		Hab DistPatch	3	-27.3	61.1	0.9	0.145
		Hab NumPatch	3	-27.6	61.7	1.5	0.110
		ForCover	2	-28.8	61.9	1.7	0.098
		Hab ForCover	3	-27.8	62.1	1.9	0.087
		DistPatch	2	-29.4	63.1	2.9	0.054
		Hab DistPatch NumPatch	4	-27.2	63.3	3.1	0.049
		Hab DistPatch ForCover	4	-27.3	63.5	3.3	0.044
		DistPatch ForCover	3	-28.5	63.7	3.5	0.041
		Hab ForCover NumPatch	4	-27.5	64.0	3.8	0.034
		ForCover NumPatch	3	-28.8	64.1	3.9	0.032
Red-bellied Woodpecker	2002-03	Hab DistPatch	3	-16.6	39.8	0.0	0.204
		Hab	2	-18.2	40.8	1.0	0.123
		Hab ForCover	3	-17.2	41.0	1.2	0.109
		Hab DistPatch Damage	4	-16.3	41.5	1.8	0.084
		Hab DistPatch ForCover	4	-16.4	41.7	1.9	0.078

Table 2.3 (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Red-bellied	2002-03	Hab Damage	3	-17.6	41.9	2.1	0.072
Woodpecker		Hab DistPatch NumPatch	4	-16.6	42.2	2.4	0.062
- continued		Hab ForCover Damage	4	-16.7	42.4	2.6	0.055
		Hab NumPatch	3	-18.1	42.7	2.9	0.047
		Hab ForCover NumPatch	4	-17.2	43.4	3.6	0.033
		Hab DistPatch ForCover Damage	5	-16.0	43.6	3.8	0.030
Ruby-crowned	2001-02	NumPatch	2	-22.9	50.0	0.0	0.151
Kinglet		Hab NumPatch	3	-21.9	50.3	0.3	0.131
		Hab	2	-23.0	50.4	0.4	0.126
		Hab ForCover	3	-22.1	50.8	0.8	0.103
		DistPatch NumPatch	3	-22.4	51.4	1.4	0.074
		Hab DistPatch NumPatch	4	-21.4	51.8	1.8	0.061
		Hab ForCover NumPatch	4	-21.5	52.0	2.0	0.056
		ForCover NumPatch	3	-22.8	52.2	2.2	0.051
		DistPatch	2	-24.1	52.4	2.4	0.046
		ForCover	2	-24.1	52.4	2.4	0.045
		Hab DistPatch ForCover	4	-21.7	52.5	2.5	0.044
		Hab DistPatch	3	-23.0	52.6	2.6	0.041
		Hab DistPatch ForCover NumPatch	5	-20.8	53.0	3.0	0.034
		DistPatch ForCover NumPatch	4	-22.4	53.8	3.8	0.023
Ruby-crowned	2002-03	Hab Damage	4	12.8	-16.5	0.0	0.208
Kinglet		Hab DistPatch Damage	5	13.6	-15.7	0.8	0.139
		Hab DistPatch	4	12.2	-15.4	1.1	0.120
		Hab	3	10.8	-15.1	1.4	0.103
		Hab NumPatch Damage	5	13.1	-14.6	1.9	0.080
		Hab ForCover Damage	5	12.9	-14.3	2.2	0.069
		Hab NumPatch	4	11.2	-13.4	3.1	0.044
		Hab DistPatch ForCover Damage	6	13.6	-13.1	3.4	0.038
		Hab DistPatch NumPatch Damage	6	13.7	-13.1	3.4	0.038
		Hab ForCover	4	11.0	-13.0	3.5	0.036
		Hab DistPatch ForCover	5	12.2	-12.9	3.6	0.034
		Hab DistPatch NumPatch	5	12.2	-12.9	3.6	0.034
Tufted Titmouse	2002-03	Hab ForCover Damage	4	-12.9	34.8	0.0	0.180
		Hab ForCover NumPatch Damage	5	-11.9	35.2	0.4	0.146
		Hab NumPatch Damage	4	-13.2	35.3	0.5	0.140
		Hab ForCover	3	-15.2	36.9	2.1	0.063
		Hab DistPatch ForCover Damage	5	-12.7	36.9	2.1	0.062
		Hab ForCover NumPatch	4	-14.1	37.2	2.4	0.054
		Hab DistPatch NumPatch Damage	5	-13.0	37.4	2.6	0.049
		Hab NumPatch	3	-15.6	37.7	2.9	0.042
		Hab DistPatch ForCover NumPatch Damage	6	-11.8	37.8	3.0	0.040
		Hab DistPatch ForCover	4	-14.5	38.0	3.2	0.036
		Hab DistPatch Damage	4	-14.6	38.1	3.3	0.034
		Hab DistPatch	3	-15.9	38.4	3.6	0.029

Table 2.3 (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Tufted Titmouse - continued	2002-03	Hab DistPatch NumPatch	4	-14.8	38.6	3.8	0.027
		Hab Damage	3	-16.1	38.7	3.9	0.026
White-throated Sparrow	2002-03	Hab DistPatch ForCover NumPatch Damage	6	-22.2	58.6	0.0	0.148
		Hab DistPatch ForCover Damage	5	-23.6	58.6	0.1	0.143
		Hab DistPatch ForCover	4	-24.9	58.7	0.2	0.137
		Hab DistPatch ForCover NumPatch	5	-23.6	58.8	0.2	0.133
		Hab ForCover NumPatch Damage	5	-23.9	59.2	0.6	0.107
		DistPatch ForCover Damage	4	-25.7	60.5	1.9	0.057
		ForCover NumPatch Damage	4	-25.9	60.7	2.1	0.051
		Hab ForCover NumPatch	4	-26.0	60.9	2.4	0.045
		ForCover Damage	3	-27.4	61.3	2.7	0.038
		DistPatch ForCover NumPatch Damage	5	-25.1	61.8	3.2	0.030
		Hab ForCover Damage	4	-26.4	61.8	3.2	0.030
Yellow-rumped Warbler	2001-02	Hab	2	-22.7	49.7	0.0	0.322
		Hab DistPatch	3	-22.2	50.9	1.2	0.175
		Hab NumPatch	3	-22.2	50.9	1.2	0.174
		Hab ForCover	3	-22.6	51.8	2.1	0.111
		Hab DistPatch NumPatch	4	-21.9	52.9	3.2	0.066
		Hab DistPatch ForCover	4	-22.2	53.3	3.6	0.053
		Hab ForCover NumPatch	4	-22.2	53.3	3.6	0.052
Yellow-rumped Warbler	2002-03	Hab DistPatch	4	-29.4	67.6	0.0	0.180
		Hab	3	-30.9	68.4	0.8	0.121
		Hab DistPatch NumPatch	5	-28.5	68.5	0.9	0.115
		Hab ForCover	4	-29.9	68.7	1.1	0.104
		Hab DistPatch ForCover	5	-29.0	69.5	1.9	0.070
		Hab DistPatch ForCover NumPatch	6	-27.8	69.6	2.0	0.066
		Hab DistPatch Damage	5	-29.3	70.0	2.4	0.054
		Hab Damage	4	-30.6	70.1	2.5	0.052
		Hab ForCover NumPatch	5	-29.3	70.1	2.5	0.052
		Hab NumPatch	4	-30.8	70.6	3.0	0.040
		Hab ForCover Damage	5	-29.6	70.7	3.1	0.038
		Hab DistPatch NumPatch Damage	6	-28.4	71.0	3.4	0.033

Table 2.4. Mean (standard error) for landscape variables by habitat type.

Landscape Metric	Native	Tallow	Total
DistPatch (km)	0.3 (0.19)	0.4 (0.12)	0.3 (0.11)
ForCover (%)	38.1 (4.94)	11.6 (2.63)	24.9 (3.40)
NumPatch	3.5 (0.39)	3.6 (0.48)	3.6 (0.31)
Damage	2.1 (0.23)	1.4 (0.17)	1.7 (0.15)

areas with increasing Damage. For American Robins, ForCover Damage was the best model. ForCover was noticeably present in all eight models with ΔAIC_c under 4. Model-averaged results also indicate that ForCover was the most important predictor for Robin abundance and that the relationship was negative (-0.0538). Models ForCover and ForCover NumPatch were the best predictors of Blue Jay abundance in Year 1, although ForCover was the more parsimonious model. Both of these were the strongest variables and each had a negative influence on Blue Jays. NumPatch best predicted abundance of Blue Jays in Year 2. This variable was present in all 9 models with a ΔAIC_c less than 4. The ω_i of NumPatch was larger than the other explanatory variables. Blue Jays were predicted to decline as NumPatch increased. In both years, Carolina Chickadee abundance was best predicted by model ForCover. Evidence also suggests ForCover was the most informative predictor of their abundance relative to the other variables in the set (Table 2.5). The response to ForCover was positive in each year.

Hab was the best or second-best model for Carolina Wrens, Red-bellied Woodpeckers, and Yellow-rumped Warblers in both years (Table 2.3). Hab also carried the greatest ω_i for these species (Table 2.5). Overall, the relative weight of Hab was the best predictor of bird abundance for five of the eight species in Year 1 and six of the ten species examined in Year 2. Of the species found to show significant differences between habitat types in the habitat comparison analysis, all but American Robin and Carolina Chickadee exhibited strong evidence that Hab was the best predictor for these species. The direction of those relationships was also consistent with previous results (Table 2.5).

Table 2.5. Model-averaged parameter estimates, unconditional standard errors, and relative Akaike weights ($3 w_i$) of each explanatory variable by species and winter.

Species	Winter	Variable	Estimate	St. Error	$3 w_i$
SppRich ^a	2001-02	Hab	0.1983	0.0955	0.753
		DistPatch	0.0000	0.0001	0.248
		ForCover	0.0002	0.0009	0.289
		NumPatch	-0.0480	0.0222	0.767
SppRich ^a	2002-03	Hab	0.2542	0.0907	0.940
		DistPatch	0.0000	0.0001	0.277
		ForCover	-0.0014	0.0006	0.820
		NumPatch	-0.0037	0.0184	0.227
		Damage	0.0739	0.0342	0.771
American Robin ^b	2002-03	Hab	-0.4968	1.0435	0.272
		DistPatch	0.0037	0.0036	0.465
		ForCover	-0.0538	0.0212	0.926
		NumPatch	0.1169	0.2270	0.259
		Damage	-0.7768	0.3757	0.762
Blue Jay ^b	2001-02	Hab	-0.0962	0.8579	0.281
		DistPatch	0.0006	0.0007	0.395
		ForCover	-0.0323	0.0190	0.644
		NumPatch	-0.3069	0.2167	0.527
Blue Jay ^b	2002-03	Hab	0.1517	0.7778	0.259
		DistPatch	0.0000	0.0005	0.257
		ForCover	-0.0168	0.0171	0.357
		NumPatch	-0.4087	0.2013	0.837
		Damage	0.3056	0.3211	0.340
Carolina Chickadee ^b	2001-02	Hab	0.7319	0.7906	0.371
		DistPatch	-0.0009	0.0007	0.509
		ForCover	0.0346	0.0193	0.696
		NumPatch	-0.2741	0.1975	0.506
Carolina Chickadee ^b	2002-03	Hab	-0.5400	1.0217	0.276
		DistPatch	-0.0006	0.0007	0.329
		ForCover	0.0851	0.0384	0.962
		NumPatch	0.2566	0.2646	0.348
		Damage	0.4006	0.4769	0.311
Carolina Wren ^b	2001-02	Hab	1.7823	0.7084	0.886
		DistPatch	-0.0002	0.0004	0.265
		ForCover	0.0187	0.0198	0.355
		NumPatch	0.0440	0.1728	0.252

^a Abundance data analyzed with linear regression. For every unit increase in the explanatory variable, the change in the species abundance is the parameter estimate (Perkins et al. 2003).

^b Abundance data analyzed with logistic regression. For every unit increase in the explanatory variable, the odds of presence increase/decrease by $\exp(\text{Estimate})$ (Perkins et al. 2003).

Table 2.5 (continued).

Species	Winter	Variable	Estimate	St. Error	$3 w_i$
Carolina Wren ^b	2002-03	Hab	1.5979	0.7705	0.779
		DistPatch	-0.0006	0.0005	0.297
		ForCover	0.0083	0.0231	0.432
		NumPatch	-0.1425	0.1816	0.308
		Damage	0.4411	0.4021	0.386
Eastern Phoebe ^b	2001-02	Hab	0.2708	0.7342	0.258
		DistPatch	0.0028	0.0017	0.912
		ForCover	-0.0110	0.0172	0.291
		NumPatch	-0.0742	0.1864	0.269
Northern Cardinal ^a	2001-02	Hab	0.1908	0.1333	0.566
		DistPatch	0.0001	0.0001	0.401
		ForCover	-0.0013	0.0010	0.517
		NumPatch	-0.0264	0.0271	0.383
Northern Cardinal ^a	2002-03	Hab	0.2838	0.1438	0.765
		DistPatch	-0.0001	0.0001	0.331
		ForCover	-0.0018	0.0010	0.673
		NumPatch	-0.0229	0.0291	0.313
		Damage	0.0458	0.0551	0.316
Red-bellied Woodpecker ^b	2001-02	Hab	1.3271	0.7023	0.714
		DistPatch	-0.0006	0.0007	0.376
		ForCover	0.0141	0.0178	0.363
		NumPatch	0.1039	0.1684	0.300
Red-bellied Woodpecker ^b	2002-03	Hab	3.9755	1.4256	0.997
		DistPatch	-0.0009	0.0006	0.515
		ForCover	0.0346	0.0335	0.357
		NumPatch	0.0127	0.2264	0.242
		Damage	0.4586	0.4937	0.318
Ruby-crowned Kinglet ^b	2001-02	Hab	1.4454	1.0419	0.595
		DistPatch	-0.0004	0.0005	0.337
		ForCover	-0.0186	0.0270	0.369
		NumPatch	-0.2724	0.1785	0.580
Ruby-crowned Kinglet ^a	2002-03	Hab	0.28784	0.06471	0.999
		DistPatch	0.00005	0.00004	0.424
		ForCover	-0.00013	0.00054	0.232
		NumPatch	-0.00794	0.01502	0.251
		Damage	-0.05244	0.02936	0.605

^a Abundance data analyzed with linear regression. For every unit increase in the explanatory variable, the change in the species abundance is the parameter estimate (Perkins et al. 2003).

^b Abundance data analyzed with logistic regression. For every unit increase in the explanatory variable, the odds of presence increase/decrease by $\exp(\text{Estimate})$ (Perkins et al. 2003).

Table 2.5 (continued).

Species	Winter	Variable	Estimate	St. Error	$3 w_i$
Tufted Titmouse ^b	2002-03	Hab	3.8900	1.7217	0.958
		DistPatch	-0.0013	0.0022	0.308
		ForCover	0.0493	0.0280	0.643
		NumPatch	0.5168	0.3444	0.528
		Damage	1.0411	0.5693	0.715
White-throated Sparrow ^b	2002-03	Hab	2.2927	1.1824	0.764
		DistPatch	-0.0012	0.0008	0.684
		ForCover	-0.0723	0.0323	0.964
		NumPatch	0.3297	0.2109	0.539
		Damage	0.7097	0.4073	0.629
Yellow-rumped Warbler ^b	2001-02	Hab	-2.4466	0.8955	0.971
		DistPatch	0.0005	0.0007	0.323
		ForCover	-0.0051	0.0197	0.258
		NumPatch	-0.1740	0.1960	0.320
Yellow-rumped Warbler ^a	2002-03	Hab	-0.7589	0.1706	0.998
		DistPatch	0.0002	0.0001	0.557
		ForCover	-0.0016	0.0014	0.389
		NumPatch	0.0431	0.0399	0.361
		Damage	-0.0438	0.0753	0.251

^a Abundance data analyzed with linear regression. For every unit increase in the explanatory variable, the change in the species abundance is the parameter estimate (Perkins et al. 2003).

^b Abundance data analyzed with logistic regression. For every unit increase in the explanatory variable, the odds of presence increase/decrease by $\exp(\text{Estimate})$ (Perkins et al. 2003).

Eastern Phoebe was the only species that strongly associated with DistPatch. Model DistPatch was the only predictor of Phoebe abundance with substantial support. The model-averaged estimate for DistPatch indicates that Phoebe abundance will increase as the distance between forest patches increases, but this slope was small (0.0028). Model Hab ForCover was the best predictor of Northern Cardinal abundance in both years. These two variables carried the greatest weight as well. Parameter estimates predict that Cardinals will be more abundant in bottomland hardwoods, but become less common as percent forest cover increases. However, the slope for

ForCover in both years was near zero (Year 1 = -0.0013; Year 2 = -0.0018), an indication that ForCover may not be important. Predictors of Ruby-crowned Kinglet abundance were models NumPatch in Year 1 and Hab Damage in Year 2. In both years, parameter estimates indicate that Kinglets are less abundant in tallow woodlands. Besides Hab in Year 1, NumPatch was also important to Kinglets, as they tended to decrease in abundance as NumPatch increased. Hab and Damage were the most important variables to Kinglets in Year 2. Damage was predicted to decrease Kinglet abundance. The best model for fitting Tufted Titmice abundance was Hab ForCover Damage. These variables also had the largest weight, with Hab being the greatest ($\sum w_i = 0.958$). Of note, Hab was present in each of the 14 models with a ΔAIC_c less than 4. The global model was the best predictor for White-throated Sparrows; however, the third best model, Hab DistPatch ForCover, is likely the better choice because of two fewer parameters and a ΔAIC_c of only 0.2. ForCover had the largest $\sum w_i$ (0.964) and was a strong predictor of White-throated Sparrow abundance suggesting that they decline as ForCover increased.

DISCUSSION

Species richness and evenness were lower in the tallow woodlands. This is an indication that winter bird communities in tallow woodlands are less diverse and tend to be dominated by fewer, but more abundant species. Differences were observed in the relative abundance of the certain species between woodland types. Six species (Red-bellied Woodpecker, Tufted Titmouse, Carolina Chickadee, Carolina Wren, Ruby-crowned Kinglet, and Pine Warbler) exhibited higher detections in the bottomland hardwoods than the tallow woodlands. However, three species (American Robin, Gray

Catbird, Yellow-rumped Warbler) were more common in tallow and six species (Mourning Dove, Eastern Phoebe, Blue Jay, Blue-gray Gnatcatcher, White-throated Sparrow, and Northern Cardinal) showed no difference in abundance between habitats. Eight of these aforementioned species are commonly associated with edge habitat (Cimprich and Moore 1995, Falls and Kopachena 1994, Halkin and Linville 1999, Hunt and Flaspohler 1998, Mirarchi and Baskett 1994, Salabanks and James 1999, Tarvin and Woolfenden 1999, Weeks 1994), which was a common characteristic of the tallow stands.

Differences in species richness between years may be linked to weather-related differences between years. The first field season was preceded by a drought that began in the late 1990's that did not subside until 2001 (National Weather Service 2004). In addition, the winter of 2001-02 was relatively warm in the northern United States, but in 2002-03 a more typical winter occurred to our north. The large increase in American Robins on my sites from Year 1 to Year 2 may be a product of these weather conditions. Christmas Bird Count data from the same period in Louisiana also shows a similar pattern between winters (2001-02 = 11.8/party hour, 2002-03 = 21.7/party hour) (National Audubon Society 2005). Robins tend to be variable in their migration patterns and their distribution has been linked to weather patterns (Sallabanks and James 1999).

While the landscape variables DistPatch, ForCover, NumPatch, and Damage were sometimes important predictors of species abundance; overall, Hab was the best predictor. This is not unanticipated since 11 of the 15 most abundant species differed significantly between woodland types. Model-averaged results closely resembled those from the habitat comparison analyses. The model-predicted importance of Damage to

the abundance of Robins, Ruby-crowned Kinglets, and Tufted Titmice and SppRich in Year 2 may be an artifact of the less severe hurricane damage that tallow sites received compared to bottomland hardwood sites. Eastern Phoebe was the only species that responded to DistPatch. DistPatch was expected to have a greater influence on the other species studied, since DistPatch is a measure of patch isolation. The lack of effect of DistPatch may be related to the timing of this study. Non-breeding birds may be less affected by patch isolation than during the breeding season, but this is dependent on other factors such as patch size and forest/edge ratio. NumPatch was relatively important to SppRich (Year 1), Blue Jays, (Year 2), and Ruby-crowned Kinglets (both years). In each case, as the number of forest patches increased within 1 km of the point count, abundance declined. As with DistPatch, I would expect the importance of NumPatch to increase during the breeding season, since landscape forest patchiness likely affects nesting success. Following Hab, ForCover was observed more frequently as a strong predictor of bird abundance. For species that responded to ForCover, all but Carolina Chickadees exhibited a negative response. Species predicted to decline in abundance as percentage forest cover increased, were all species common in forest-edge habitats.

Including additional landscape/habitat variables may have been informative in the information theory analyses; however, I was constrained by an already saturated model. Had more data been available, it would have been useful to include more variables such as canopy height, stand age, and snag density, because these variables likely affect bird abundance. A possible alternative to the approach used in this study would be to analyze models consisting of groups of related variables instead of an all subsets

approach (see Weyrauch and Grubb 2004). This technique might be useful for comparing the relative importance of landscape variables versus habitat variables (e.g., stem density, shrub density, canopy height).

In summary, bottomland hardwoods supported more bird species than tallow woodlands. Tallow woodlands may provide adequate habitat for certain species, but those individuals tend to be edge-associated species. I found information-theory modeling to be a useful tool for examining the relative importance of habitat type versus specific landscape metrics.

CHAPTER 3: ENERGY ASSIMILATION OF TALLOW FRUIT BY YELLOW-RUMPED WARBLERS, NORTHERN CARDINALS AND AMERICAN ROBINS

Chinese tallow is an invasive non-native tree from southeast Asia. It was introduced into the United States in the late 1700's (Bruce et al. 1997). It is now common in many habitats along the northern Gulf Coast and south Atlantic (Scheld and Cowles 1981, Harcombe et al. 1993, Renne et al. 2000). Tallow is primarily a bird-dispersed plant producing an abundant fruit crop in the fall that can persist until early spring. At least 64 species of birds feed on tallow fruit (Barrow and Fontenot, unpubl. data), more than any other fruiting plant species in Louisiana. Of the tallow consumers, 43 are considered seed dispersers, while the rest are known only to scrape or peck off portions of the pulp with their bill.

Tallow pulp consists of a waxy coating that has more energy (33.5 kJ/g) than any known fruit in Louisiana (Barrow and Jeske, unpubl. data). Saturated fatty acids comprise a significant proportion of tallow pulp (Khan et al. 1973, Raie et al. 1983, Xu et al. 1991). Many animals exhibit poor assimilation of high melting point fatty acids, especially palmitic and stearic acids (Scott et al. 1976, Place and Stiles 1992). Therefore, birds consuming tallow may not effectively assimilate the available energy in the pulp. One species that may be an exception is the Yellow-rumped Warbler (*Dendroica coronata*). Yellow-rumped Warblers are known to possess a specialized digestive system enabling them to assimilate waxy foods such as bayberry (*Morella* spp.) and wax myrtle fruit (*M. cerifera*) (Place and Stiles 1992), which are important winter food sources for this species (Wilz and Giampa 1978). These digestive system traits include "...reflux of intestinal contents to the gizzard, elevated gall-bladder and intestinal bile-salt concentration, and a slow gastrointestinal transit of dietary lipids."

Yellow-rumped Warblers show a facultative migration that is dependent on food abundance and climate conditions (Terrill and Ohmart 1984). Wax myrtle fruit abundance has been positively correlated with Yellow-rumped Warbler abundance in South Carolina (Kwit et al. 2004) and Florida (Borgmann et al. 2004). Like tallow fruit, wax myrtle produces abundant fruit that is high in saturated fatty acids (Place and Stiles 1992, Conway et al. 2000). Yellow-rumped Warblers were the most common tallow consumers on the upper coastal prairie region of Texas (Conway 1997). Consequently, Chinese tallow has the potential of influencing their winter distribution. Such a pattern has been documented with the Northern Mockingbird (*Mimus polyglottos*) and the introduced multiflora rose (*Rosa multiflora*) in the Northeast (Stiles 1982). Mockingbirds have expanded their winter range northward in concert with the spread of this non-native plant. Stiles suggests that Northern Mockingbirds would not be able to maintain a positive daily energy balance in the winter in their northern range without multiflora rose fruit.

The first step at understanding the association of Yellow-rumped Warblers to tallow is to determine how much of the available energy in tallow fruit can they assimilate. Although Yellow-rumped Warblers can assimilate high-melting point fatty acids, they prefer unsaturated fatty acids to saturated fatty acids (McWilliams et al. 2002). Therefore, it is important to quantify metabolizable energy of tallow fruit in relation to other diets, specifically other fruiting plants with overlapping fruiting phenology. Of interest are wax myrtle and poison ivy (*Toxicodendron radicans*) fruit, both are waxy, lipid-rich fruit (White 1989) commonly eaten by Yellow-rumped Warblers.

The ability of other avifauna to metabolize tallow fruit is also of interest. American Robins (*Turdus migratorius*) and Northern Cardinals (*Cardinalis cardinalis*) are two species that frequently consume tallow fruit (Renne et al. 2000, 2002). In choice trials, Robins preferred sugar-rich fruits to lipid-rich fruits and metabolized a greater amount of the sugar-rich fruit (Lepczyk et al. 2000). Robins prefer foods containing unsaturated lipids over those containing saturated lipids, even though assimilation rates did not vary for three test diets differing only in lipid concentration (Zurovchak 1997). Zurovchak hypothesized that this was due to changes in gut retention time, with passage time increasing as lipid levels increased. Cardinals' seed preferences have received some study (Willson and Harmeson 1973), but no information is available on fruit preferences based on lipid content.

In this study, I compared apparent metabolizable energy (AME) of tallow fruit by Yellow-rumped Warblers, Northern Cardinals and American Robins. For Yellow-rumped Warblers, tallow assimilation was compared to that of wax myrtle and poison ivy. For Cardinals, tallow was compared to hackberry (*Celtis laevigata*) and deciduous holly (*Ilex decidua*). These fruits were chosen for comparison because they are relatively common during the winter, have overlapping fruiting phenology with tallow, and are known food items for the bird species examined.

METHODS

Capture and Care of Birds

In the winters of 2001-02 and 2002-03, Yellow-rumped Warblers, Northern Cardinals and American Robins were captured with mist-nets near Lafayette, Louisiana. For each bird, I recorded weight, wing chord, culmen, bill depth, bill width, tarsus, tail

length and sex if known. Birds were transported to an environmental chamber at the National Wetlands Research Center where they were kept in under controlled temperatures (20°C) and photoperiod (10.5 hr light:13.5 hr dark) for the duration of the feeding trials (IACUC Permit No. 2001-8717-037). Each bird was held individually in 30 x 36 x 36 cm metal cages. Water and maintenance diet were provided *ad libitum* in plastic cups. For Yellow-rumped Warblers, this diet consisted of Avian-Fare and /or Softbilled-Fare (Reliable Protein Products[®], commercial diets designed for omnivorous birds), fruit from wax myrtle, poison ivy, and tallow, and mealworms. Robins and Cardinals were fed Softbilled-Fare, fruit from hackberry, deciduous holly, and tallow, and mealworms. Cardinals were also provided a mixture of commercially available birdseed including black oil sunflower, striped sunflower, and safflower. Fruit was collected in the field, placed in Ziploc bags, and stored in a refrigerator. The cage bottoms were lined with absorbent laboratory bench paper with polyethylene backing and were changed regularly. Small sticks were placed in each cage to allow birds to perch. Previously used cages were cleaned with a wire brush, rinsed, soaked in a mild bleach solution, rinsed again, and air-dried prior to reuse.

Birds were allowed to acclimate to captivity and their test diets for 7 to 10 days prior to onset of AME trials. During this acclimation period, three Yellow-rumped Warblers were released due to poor adjustment to captivity and one Warbler and one Robin died. During the AME trials, 27 Yellow-rumped Warblers, 27 Cardinals and 5 Robins were studied. Nine Warblers were placed each on diets of wax myrtle (February 2002), poison ivy (n=3, February 2002; n=6, December 2002), and tallow (n=9, February 2002). Ten Cardinals were placed each on deciduous holly (February 2003)

and tallow (n=7, December 2002; n=3, February 2003), and seven on hackberry (n=6, February 2003; n=1, March 2003). All five Robins were given tallow (n=2, December 2002; n=3, January 2003).

AME was determined via the total collection method (Haufler and Servello 1994). Each individual was placed on a diet of one fruit species for the duration of the trial (2-5 days). Whole fruit (seed included) were fed to Northern Cardinals and American Robins, while Yellow-rumped Warblers were presented with whole wax myrtle and poison ivy fruit (seed included), and tallow (pulp only). Yellow-rumped Warblers are not able to swallow tallow fruit because of their size. Instead, they feed on tallow by pecking or scraping off the outer-waxy layer. Warblers might not be able to efficiently handle and feed on whole tallow fruit not attached to the plant, so only the pulp was offered. Pulp was removed from tallow fruit using either a dissecting needle or by rubbing them over a 2-mm sieve.

Fruit was placed into a plastic food cup and weighed prior to feeding. The first day of the AME trial was used to 'clean' the digestive tract of non-experimental foods; therefore, no fecal material was collected. After day 1, food was removed daily and weighed, and then fresh food was provided and reweighed. Food and fecal samples were collected into scintillation vials, vacuum-dried in a lyophilizer and stored in an ultra-cold freezer at -80°C .

Gross energy in food and fecal samples was measured using a Parr 1261 Isoperibol Bomb Calorimeter. Benzoic acid was used as the standard (6.318 kcal/g) and mineral oil (11.002 kcal/g, SD=0.018) was used as a combustion aid to compensate

for low sample weights. Samples were ground with a mortar and pestle. Three sub-samples were analyzed for each species.

AME values may be influenced by nitrogen loss/gain flux during feeding trials due to protein tissue growth/catabolism (Scott et al. 1976). This would affect endogenous urinary nitrogen levels in individual's feces, so zero nitrogen balance AME calculations were needed. Percent total nitrogen in food and fecal samples was measured with a Thermo Finnigan® FlashEA 1112 Elemental Analyzer. Previous studies have used the Kjeldahl technique to measure nitrogen composition (Scott et al. 1976, Carl and Brown 1985, Harder and Kirkpatrick 1994, Haufler and Servello 1994). The method used by the elemental analyzer, dry combustion or Dumas method, was chosen because it is as accurate as the Kjeldahl method, allows for smaller sample size, and requires less preparation and run time (Matejovic 1995). Aspartic acid (N: 10.52 % ± 0.009) was used as a nitrogen standard while peach leaves (N: 2.94% ± 0.12) and domestic sludge (N: 4.78% ± 0.11) were used as reference checks. All samples were run in duplicates. Percent crude protein in the fruits was calculated by multiplying percent nitrogen by 6.25 (Scott et al. 1976). Nitrogen corrected AME values were calculated using the following equation:

$$1) \quad \text{AME (kcal/g)} = [(F * \text{FE}) - (X * \text{XE} + 8.22 * N)] / F,$$

where F and X equal the dry weights (g) of food ingested and excrement, FE and XE equal the energy (kcal/g) of food ingested and excrement, 8.22 is the energy constant (kcal/g) of nitrogen in uric acid, and N equals the grams of nitrogen retained/lost per dry gram of diet (Scott et al. 1976). AME may also be expressed in kiloJoules according to the following equation:

$$2) \quad \text{AME (kJ/g)} = \text{AME (kcal/g)} * 4.1841.$$

AME calculations for whole fruits are influenced by energy in seeds as well as the pulp. For fruit-eating birds that do not digest the seeds, AME calculations will underestimate the true metabolizability of fruit pulp. For these frugivorous birds, the seed holds no nutritional value. Yellow-rumped Warblers consumed the entire fruit of poison ivy and wax myrtle and defecated the whole seed; therefore the average mass per fruit used in the calculations included the seed and pulp. Rarely did Cardinals swallow whole tallow fruit and were not observed consuming whole fruit of hackberry or deciduous holly. Most frequently, they worked the fruit in their bill to scrape off portions of the pulp. A few instances occurred when tallow was ingested, but the seed was regurgitated each time. Robins frequently ingested whole tallow fruit, but regurgitated the seed. No instance of a bird defecating a tallow seed was observed Robins or Cardinals. Regurgitated seeds showed no signs of damage to the seed coat. Therefore, seed mass and energy for all fruit were excluded in the AME calculations for both Cardinals and Robins. To compare metabolizable energy of tallow by Yellow-rumped Warblers to wax myrtle and poison ivy, seed energy in the food and feces was excluded from AME calculations.

The usefulness of metabolizable energy values is limited without information on average fruit mass or daily energy requirements of the birds. Therefore, AME estimates were used to calculate the mass of food (g) each bird needed to consume per day to meet its daily metabolic needs. Energy demands are often reported as basal metabolic rate (BMR), however BMR is only relevant for a nonactive, awake, unexcited, healthy, nonreproductive adult at thermoneutral conditions (Peters 1983). Existence metabolism

(EM, kcal/bird-day) is a more appropriate measure since it also includes energy required for locomotion and other daily activities (Kendeigh 1969, 1970). EM calculations are typically for birds at either 30°C or 0°C (i.e., at or below thermoneutral temperature) (Kendeigh 1969, 1970). In southwest Louisiana, mean daily temperatures during the months of December, January, and February range from 10.0 to 14.4°C (National Weather Service 2004). To approximate conditions in southwest Louisiana, an average EM was determined using the two calculations. Kendeigh's (1969, 1970) equation for EM (kcal/bird-day) for passerines at 30°C is:

$$3. \quad \log (EM_{30}) = 0.1965 + 0.6210 * \log (B_g),$$

and at 0°C is:

$$4) \quad \log (EM_0) = 0.6372 + 0.5300 * \log (B_g),$$

where B_g equals bird mass (g) at the start of the trials. The average EM_{avg} was computed and converted to kilojoules as follows:

$$5) \quad EM_{avg} = 4.1841 * [\log (EM_{30}) + \log (EM_0)] / 2.$$

Mass of food M_f needed per day to satisfy EM_{avg} can be calculated for each plant species by:

$$6) \quad M_f (g/day) = EM_{avg} * AME (kJ/g).$$

To calculate the number of fruit that would have to be consumed per day to satisfy EM_{avg} :

$$7) \quad \text{Number of fruit} = M_f (g/day) / M_b (g/fruit),$$

where M_b is the average pulp mass for each plant species.

As mentioned previously, Yellow-rumped Warblers do not ingest whole tallow fruit and Cardinals rarely did. To quantify the amount of pulp flaked off per scrape/peck,

I video recorded captive birds feeding on fruit. Each bird was deprived of food for one hour and then given a weighed amount of fruit. Whole tallow fruit were provided to six Yellow-rumped Warblers and three Cardinals. For the Warblers, a small tallow branch with several clusters of tallow fruit was supplied. Cardinals were fed tallow fruit that had been removed from the branch and placed into a feeding cup. Two additional Cardinals were given deciduous holly and four were given hackberry. Feeding was recorded for two hours on videotape and then the food was reweighed. The video was reviewed and each feeding activity was counted. An average weight of food ingested per scrape/peck was determined and used to calculate the number of scrapes/pecks required to satisfy EM_{avg} .

Statistical Analysis

Nitrogen corrected AME values (kJ/g) for tallow pulp were compared between Northern Cardinals, Yellow-rumped Warblers and American Robins. Additional comparisons were made between tallow fruit and native plant species fed to Northern Cardinals and Yellow-rumped Warblers. The data did not satisfy normality assumptions and data transformations did not ameliorate the problem. Therefore data were analyzed using the Kruskal-Wallis nonparametric test (Conover 1980) in SAS (Proc NPAR1WAY, SAS Institute Inc. 1999). When the null hypothesis of no difference between groups was rejected, contrasts were performed on the ranks using Tukey's pairwise comparisons (Proc MIXED, SAS Institute Inc. 1999). Log-linear analysis was used to test for differences between death rates in Cardinals according to sex (Proc CATMOD, SAS Institute Inc. 1999).

RESULTS

Gross energy content in the test fruits was highest in tallow pulp (34.43 ± 0.118 kJ/g) and lowest in hackberry pulp (16.52 ± 0.202 kJ/g) (Table 3.1). Protein composition of the fruits was low for all species, ranging from 2.00 % to 6.81 %.

AME of tallow pulp differed significantly between bird species ($\chi^2 = 17.73$, $P < 0.001$) (Figure 3.1). AME was highest in Yellow-rumped Warblers, followed by Robins and Cardinals (Table 3.2). Although variability among Cardinals was high, ranging from 11.34 to 28.77 kJ/g (see Appendix D for individual results), the ability of Cardinals to metabolize tallow pulp was still significantly lower than Yellow-rumped Warblers or Robins. Yellow-rumped Warblers did not exhibit similar AME values between fruit species ($\chi^2 = 16.52$, $P < 0.001$) (Figure 3.2). These birds metabolized tallow more efficiently than either wax myrtle ($P < 0.001$) or poison ivy pulp ($P < 0.001$), which did not have different AME values ($P = 0.560$). Energy metabolism by Cardinals differed by plant species ($\chi^2 = 6.62$, $P = 0.037$) (Figure 3.3), with tallow AME significantly lower than deciduous holly, but not different from hackberry. Cardinals fed hackberry did not show significantly different assimilation rates than those birds given deciduous holly.

All birds lost body mass and exhibited negative nitrogen budgets during the trials (Table 3.3). Two Yellow-rumped Warblers, one of the Warblers was fed wax myrtle and the other poison ivy. Thirteen Cardinals died, four on tallow, four on hackberry, and five on deciduous holly. The number of Cardinals that died did not differ according to sex with 4 of 11 (36.4%) females dying and 9 of 16 (56.3%) males dying ($\chi^2 = 1.02$, $P = 0.313$).

Table 3.1. Nutritional qualities of fruits used in this study using a random sample of fruits (N=30).

Plant Species	Wet fruit mass (g) ^a	% Pulp (wet)	# seeds / fruit	Gross energy (kJ/g) ^b	% Crude protein ^b
Tallow	0.199	36.9	1	34.43 ± 0.118	2.00 ± 0.025
Wax myrtle	0.015	51.0	1	28.89 ± 0.353	5.69 ± 0.469
Poison ivy	0.012	37.3	1	23.42 ± 0.549	3.88 ± 0.106
Deciduous holly	0.125	75.0	4	19.61 ± 0.210	3.56 ± 0.219
Hackberry	0.100	30.8	1	16.52 ± 0.202	6.81 ± 0.169

^a Average of 30.

^b Pulp only.

Table 3.2. Summary of AME results by bird and plant species. Analysis performed with Kruskal-Wallis test and pairwise comparisons were made on the ranks using Tukey's post-hoc test. Within species contains the pairwise comparisons of AME for plant species with each bird species analyzed separately. Between species compares energy assimilation of tallow by bird species.

Bird Species	Plant Species	N	AME (kJ/g)	SE	CV ^a	Within Species ^b	Between Species ^b
Yellow-rumped Warbler	tallow – pulp	9	30.32	0.62	6.09	A	A
	wax myrtle – whole	9	8.38	0.63	22.64	.	.
	wax myrtle – pulp	9	18.31	1.70	27.93	B	.
	poison ivy – whole	9	5.84	0.61	31.55	.	.
	poison ivy – pulp	9	16.74	1.59	28.53	B	.
Northern Cardinal	tallow – pulp	10	10.08	3.47	108.86	A	C
	decid. holly – pulp	10	15.75	0.67	13.49	B	.
	hackberry – pulp	7	11.76	0.46	10.48	AB	.
American Robin	tallow – pulp	5	23.84	0.89	8.33	.	B

^a CV = coefficient of variation (%).

^b Species with same letter are not significantly different.

Table 3.3. Nitrogen budget and weight loss during AME trials.

Bird species	Plant species -pulp	Nitrogen budget (mg N lost / g N in diet)	Mean daily weight loss (%)	# died of total
Yellow-rumped Warbler	tallow	-36.4 ± 6.92	5.3 ± 20.13	0:9
	wax myrtle	-72.4 ± 7.48	5.6 ± 2.81	1:9
	poison ivy	-51.9 ± 36.55	7.3 ± 1.43	1:9
Northern Cardinal	tallow	-114.8 ± 34.01	8.5 ± 1.25	4:10
	deciduous holly	-130.7 ± 35.19	9.4 ± 0.96	5:10
	hackberry	-102.5 ± 22.93	9.1 ± 1.42	4:7
American Robin	tallow	-68.9 ± 25.63	5.5 ± 0.83	0:5

During the two-hour videotaped observation period, no Yellow-rumped Warbler fed from tallow fruit. Tallow was left in their cages for the next of couple days (with maintenance diet), but no feeding was observed. One Cardinal given hackberry and another given deciduous holly did not feed during that period. The average mass of pulp removed per scrape/peck by Cardinals was 0.004 ± 0.004 g (n=3) for tallow, 0.021 ± 0.016 g (n=3) for hackberry and 0.055 g (n=1) for deciduous holly. Based on bird weights recorded at the beginning of the experiment, EM_{avg} was determined to be 26.5 ± 1.19 kJ/bird-day for Yellow-rumped Warblers, 52.0 ± 1.58 kJ/bird-day for Cardinals and 75.4 ± 3.14 kJ/bird-day for Robins. At these rates, Cardinals would need to feed at a frequency of 1300.0 scrapes per day on tallow, 210.5 scrapes per day on

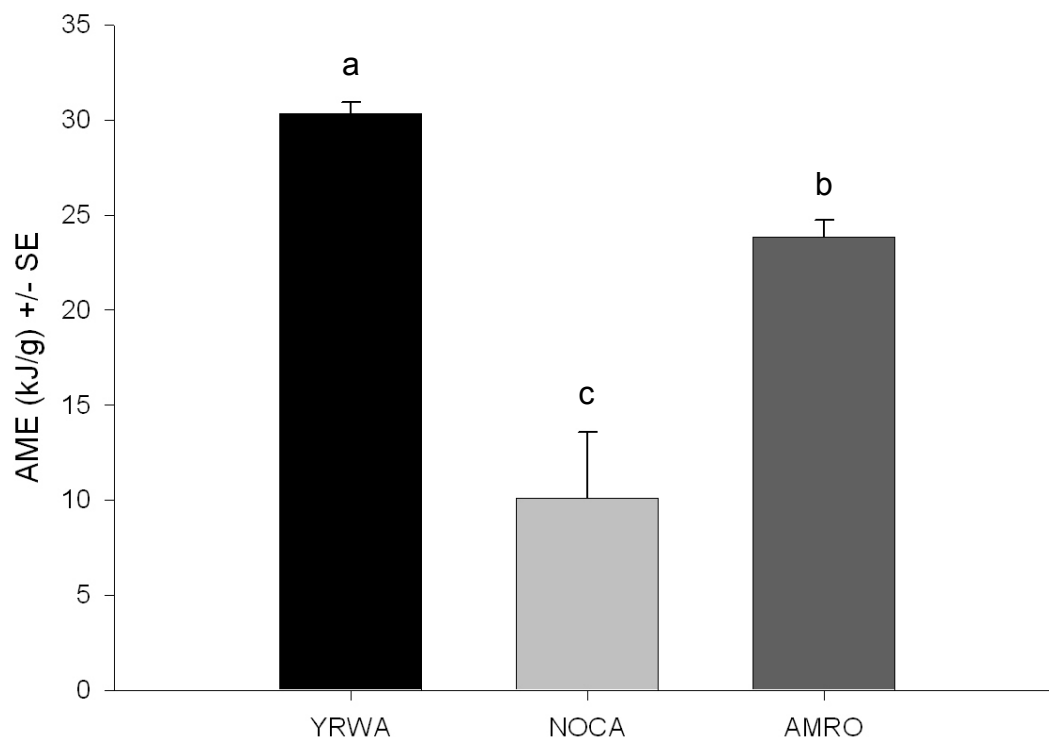


Figure 3.1. AME of Chinese tallow pulp by Yellow-rumped Warblers (YRWA), Northern Cardinals (NOCA), and American Robins (AMRO).

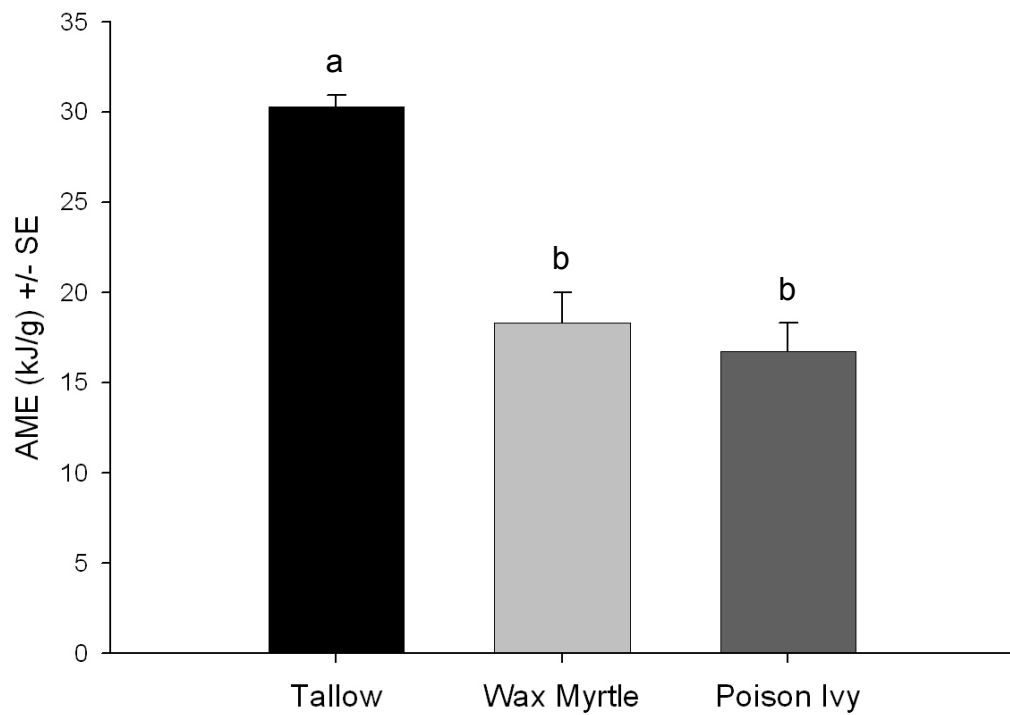


Figure 3.2. Yellow-rumped Warbler AME for Chinese tallow, wax myrtle, and poison ivy fruit.

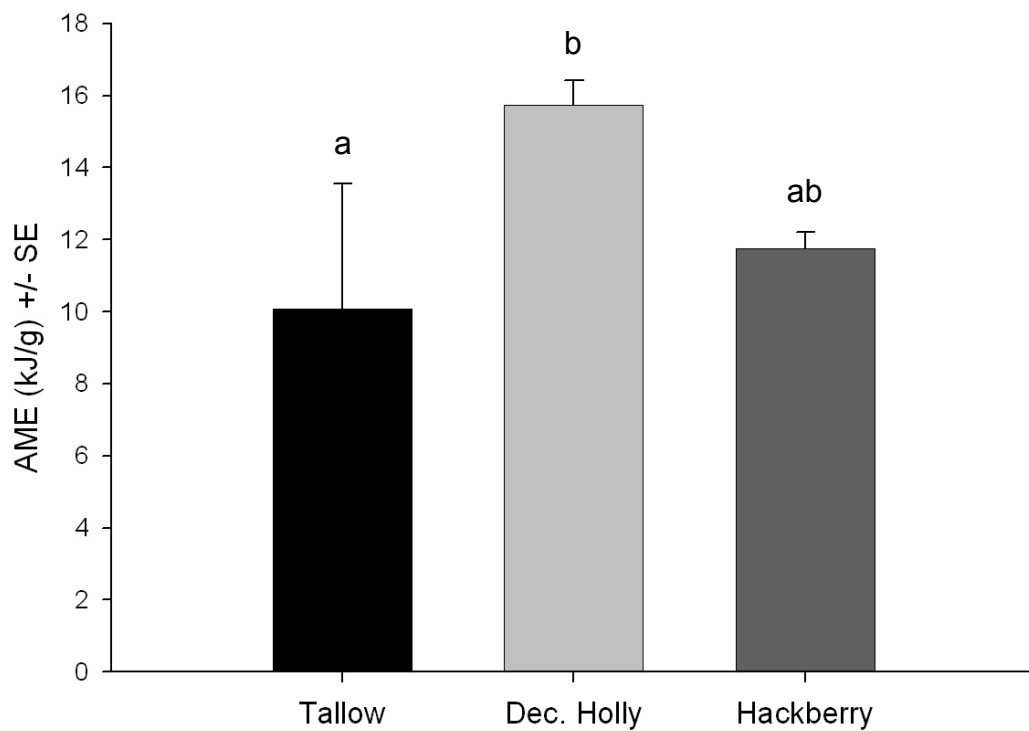


Figure 3.3. Northern Cardinal AME for Chinese tallow, deciduous holly, and hackberry fruit.

Table 3.4. Food requirements to satisfy daily energy needs (EM_{avg}) based on AME results. Calculations are based on pulp only.

Bird species	Plant species	Food mass / day (g)	Fruit / day	Scrapes / day
Yellow-rumped Warbler	tallow	0.86 ± 0.051	12.3 ± 0.73	.
	wax myrtle	1.54 ± 0.388	260.9 ± 65.81	.
	poison ivy	1.72 ± 0.515	409.7 ± 122.62	.
Northern Cardinal	tallow	5.20 ± 5.022	73.1 ± 71.34	1300.0
	deciduous holly	3.32 ± 0.487	96.5 ± 14.16	80.4
	hackberry	4.42 ± 0.476	162.1 ± 17.45	210.5
American Robin	tallow	3.18 ± 0.322	45.2 ± 4.57	.

hackberry and 80.4 scrapes per day on deciduous holly fruit to satisfy EM_{avg} (Table 3.4). Yellow-rumped Warblers would need to consume 260.9 wax myrtle fruit, 409.7 poison ivy fruit or completely remove the pulp from 12.3 tallow fruit daily to meet EM_{avg} . Robins would have to consume 45.2 tallow fruit per day to meet EM_{avg} .

DISCUSSION

The relatively high AME for Robins fed tallow suggests that tallow may be a source of energy for Robins. Yellow-rumped Warblers demonstrated the ability to metabolize tallow at a greater rate than wax myrtle and poison ivy. From the previous chapter, both Robins and Yellow-rumped Warblers were significantly more abundant in tallow woodlands. Yellow-rumped Warblers exhibit a facultative migratory behavior and their abundance is often associated with wax myrtle (Terrill and Ohmart 1984, Kwit et al. 2004, Borgmann et al. 2004). They are also known to possess specialized digestive traits that enable digestion of long-chain fatty acids (Place and Stiles 1992). Because of these factors and the nutritional similarities between tallow and wax myrtle, tallow may benefit Yellow-rumped Warblers during the winter and has the potential of influencing

their local distributions in the Southeast. I suggest that tallow is not an important food source for Cardinals.

None of the birds maintained body mass during the trials, suggesting that the nutritional qualities of the fruits examined were deficient of certain components. Fruits in general contain low amounts of protein compared to other dietary items (Snow 1971, Morton 1973), and the species in this study were no exception. Birds fed low protein diets or diets deficient in certain amino acids may be unable to maintain a positive nitrogen balance and consequently lose body mass (Parrish and Martin 1977, Witmer 1998). Izhaki and Safriel (1989) described weight loss in captive birds fed single-species fruit diets and suggested that secondary compounds in the fruit limited the birds' ability to effectively digest protein. Mack (1990) and Sedinger (1990) suggest that amino acid deficiency and not secondary compounds is the more likely cause of weight loss for birds fed fruit diets. Certain plant proteins in chicken feed are contain proteins that lower the nutritional value of the feed (Scott et al. 1976). These proteins can inhibit digestive enzymes, lower growth rate, cause enlargement of the pancreas, decrease protein and fat digestibility and can induce *in vitro* agglutination of red blood cells. Consequently, these proteins must be removed by heat treatment prior to feeding. It is not known whether the fruits used in this study contain anti-nutritional attributes.

Future AME experiments using the total collection method should be designed so that test diets contain all of the necessary daily nutritional requirements for the species of interest. Otherwise the total collection method is not recommended and alternative techniques, such as the indicator method (Scott et al. 1976, Haufler and Servello 1994), should be considered. This method uses an indigestible indicator such as radioactive

chromic chloride or chromic oxide, which is added to the test diet. The indicator is not absorbed or changed during the digestion process, so its concentration in the diet and excrement can be used to calculate energy assimilation in a shorter time span.

Therefore, eliminating the confounding effects of weight loss. I controlled for weight loss by adjusting AME calculations for zero nitrogen balance.

Cardinals that were fed tallow fruit exhibited highly variable AME values between individuals. Time of year is not a likely cause of this variability, which was observed in both December (n=7) and February (n=3). Cardinals fed hackberry or deciduous holly did not display the same degree of variability between individuals as Cardinals consuming tallow. A possible cause of variation may be poor acclimation to tallow during the pre-trial period. Cardinals tended to avoid eating tallow during this time and may not have acclimated to tallow. It is also possible that Cardinals require more time to acclimate to tallow fruit than Yellow-rumped Warblers and Robins due to the elevated concentrations of saturated fatty acids. Another cause for the large variation in tallow assimilation may be due to inherent differences of individual Cardinals in digestibility of tallow fruits. Results do not indicate that sex is a factor; however, sample size was low.

SUMMARY AND CONCLUSIONS

Winter bird communities occupying Chinese tallow woodlands differed from those found in bottomland hardwood stands in the Mermentau River Basin, Louisiana. Species richness was lower in tallow stands. Information-theoretic modeling allowed me to make inferences about the relative importance of habitat type and specific landscape variables to species richness and bird abundance. Habitat type was a better predictor of species abundance than landscape variables for 5 of 8 species in Year 1 and 6 of 10 species in Year 2.

Energy assimilation of tallow fruit differed between bird species. Yellow-rumped Warblers were able to metabolize tallow fruit pulp more effectively than either wax myrtle or poison ivy. Northern Cardinals were not able to metabolize tallow pulp as well as deciduous holly fruit. Yellow-rumped Warblers likely performed better in these trials due to their specialized digestive system.

Chinese tallow woodlands may provide adequate habitat for certain species, but those tend to be edge-associated species whose population numbers are either stable or not declining significantly. In general, bottomland hardwoods sites supported more species and possessed a higher measure of species evenness. Tallow woodlands may influence the local winter distribution of Yellow-rumped Warblers because of that species' ability to effectively metabolize tallow fruit pulp and because they were very abundant in tallow-dominated woodlands. Future research should consider food availability in tallow woodlands and the choices birds make when offered tallow fruit versus fruits from native plants.

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APPENDIX A. SPECIES DETECTIONS IN BOTTOMLAND HARDWOODS

Species detected within 50 meters at the bottomland hardwood sites during the winters of 2001-02 and 2002-03. Flyovers were not included. Species organized according to American Ornithologists' Union (1998).

Bird Species	Total Observations	Mean / Point	St. Dev.	St. Error	Freq. of Occurrence
Wood Duck (<i>Aix sponsa</i>)	5	0.03	0.24	0.02	0.12
Sharp-shinned Hawk (<i>Accipiter striatus</i>)	2	0.01	0.12	0.01	0.08
Cooper's Hawk (<i>Accipiter cooperii</i>)	1	0.01	0.08	0.01	0.04
Red-shouldered Hawk (<i>Buteo lineatus</i>)	6	0.04	0.23	0.02	0.20
American Woodcock (<i>Scolopax minor</i>)	2	0.01	0.12	0.01	0.08
Mourning Dove (<i>Zenaida macroura</i>)	10	0.07	0.36	0.03	0.24
Barn Owl (<i>Tyto alba</i>)	1	0.01	0.08	0.01	0.04
Eastern Screech-Owl (<i>Otus asio</i>)	1	0.01	0.08	0.01	0.04
Barred Owl (<i>Stix varia</i>)	1	0.01	0.08	0.01	0.04
Red-bellied Woodpecker (<i>Melanerpes carolinus</i>)	79	0.53	0.69	0.06	0.92
Yellow-bellied Sapsucker (<i>Sphyrapicus varius</i>)	23	0.15	0.41	0.03	0.60
Downy Woodpecker (<i>Picoides pubescens</i>)	32	0.21	0.41	0.03	0.76
Hairy Woodpecker (<i>Picoides villosus</i>)	2	0.01	0.12	0.01	0.08
Northern Flicker (<i>Colaptes auratus</i>)	9	0.06	0.26	0.02	0.24
Pileated Woodpecker (<i>Dryocopus pileatus</i>)	9	0.06	0.26	0.02	0.24
Eastern Phoebe (<i>Sayornis phoebe</i>)	31	0.21	0.45	0.04	0.72
Ash-throated Flycatcher (<i>Myiarchus cinerascens</i>)	1	0.01	0.08	0.01	0.04
White-eyed Vireo (<i>Vireo griseus</i>)	18	0.12	0.36	0.03	0.44
Blue-headed Vireo (<i>Vireo solitarius</i>)	13	0.09	0.31	0.02	0.44
Blue Jay (<i>Cyanocitta cristata</i>)	28	0.19	0.48	0.04	0.60
American Crow (<i>Corvus brachyrhynchos</i>)	15	0.10	0.40	0.03	0.28
Carolina Chickadee (<i>Poecile carolinensis</i>)	136	0.91	1.24	0.10	0.92
Tufted Titmouse (<i>Baeolophus bicolor</i>)	52	0.35	0.56	0.05	0.80

Appendix A (continued).

Bird Species	Total Observations	Mean / Point	St. Dev.	St Error	Freq. of Occurrence
Brown Creeper (<i>Certhia americana</i>)	3	0.02	0.18	0.01	0.08
Carolina Wren (<i>Thryothorus ludovicianus</i>)	88	0.59	0.79	0.06	0.92
House Wren (<i>Troglodytes aedon</i>)	2	0.01	0.12	0.01	0.08
Winter Wren (<i>Troglodytes troglodytes</i>)	1	0.01	0.08	0.01	0.04
Golden-crowned Kinglet (<i>Regulus satrapa</i>)	10	0.07	0.28	0.02	0.24
Ruby-crowned Kinglet (<i>Regulus calendula</i>)	133	0.89	0.71	0.06	1.00
Blue-gray Gnatcatcher (<i>Polioptila caerulea</i>)	34	0.23	0.52	0.04	0.68
Hermit Thrush (<i>Catharus guttatus</i>)	13	0.09	0.28	0.02	0.40
American Robin (<i>Turdus migratorius</i>)	118	0.79	1.61	0.13	0.84
Gray Catbird (<i>Dumetella carolinensis</i>)	4	0.03	0.16	0.01	0.12
Northern Mockingbird (<i>Mimus polyglottos</i>)	4	0.03	0.16	0.01	0.16
Brown Thrasher (<i>Toxostoma rufum</i>)	11	0.07	0.35	0.03	0.24
Cedar Waxwing (<i>Bombycilla cedrorum</i>)	47	0.31	3.84	0.31	0.04
Orange-crowned Warbler (<i>Vermivora celata</i>)	6	0.04	0.23	0.02	0.20
Yellow-rumped Warbler (<i>Dendroica coronata</i>)	165	1.10	1.53	0.12	0.96
Pine Warbler (<i>Dendroica pinus</i>)	26	0.17	0.50	0.04	0.56
Common Yellowthroat (<i>Geothlypis trichas</i>)	1	0.01	0.08	0.01	0.04
Eastern Towhee (<i>Pipilo erythrophthalmus</i>)	1	0.01	0.08	0.01	0.04
White-throated Sparrow (<i>Zonotrichia albicollis</i>)	42	0.28	0.81	0.07	0.56
Northern Cardinal (<i>Cardinalis cardinalis</i>)	182	1.21	1.29	0.11	0.96
Red-winged Blackbird (<i>Agelaius phoeniceus</i>)	27	0.18	1.69	0.14	0.08
Common Grackle (<i>Quiscalus quiscula</i>)	7	0.05	0.44	0.04	0.08
Brown-headed Cowbird (<i>Molothrus ater</i>)	2	0.01	0.12	0.01	0.04
House Finch (<i>Carpodacus mexicanus</i>)	6	0.04	0.49	0.04	0.04
American Goldfinch (<i>Carduelis tristis</i>)	50	0.33	1.28	0.10	0.56

APPENDIX B. SPECIES DETECTIONS IN CHINESE TALLOW WOODLANDS

Species detected within 50 meters in the Chinese tallow sites during the winters of 2001-02 and 2002-03. Flyovers were not included. Species organized according to American Ornithologists' Union (1998).

Bird Species	Total Observations	Mean / Point	St. Dev.	St Error	Freq. of Occurrence
Wood Duck (<i>Aix sponsa</i>)	1	0.01	0.08	0.01	0.04
Red-shouldered Hawk (<i>Buteo lineatus</i>)	2	0.01	0.12	0.01	0.08
Red-tailed Hawk (<i>Buteo jamaicensis</i>)	3	0.02	0.14	0.01	0.12
American Woodcock (<i>Scolopax minor</i>)	2	0.01	0.12	0.01	0.08
Mourning Dove (<i>Zenaida macroura</i>)	36	0.24	0.77	0.06	0.48
White-winged Dove (<i>Zenaida asiatica</i>)	3	0.02	0.24	0.02	0.04
Barn Owl (<i>Tyto alba</i>)	2	0.01	0.12	0.01	0.04
Barred Owl (<i>Stix varia</i>)	2	0.01	0.16	0.01	0.04
Red-bellied Woodpecker (<i>Melanerpes carolinus</i>)	21	0.14	0.37	0.03	0.36
Yellow-bellied Sapsucker (<i>Sphyrapicus varius</i>)	2	0.01	0.12	0.01	0.08
Downy Woodpecker (<i>Picoides pubescens</i>)	43	0.29	0.54	0.04	0.60
Hairy Woodpecker (<i>Picoides villosus</i>)	2	0.01	0.12	0.01	0.08
Northern Flicker (<i>Colaptes auratus</i>)	9	0.06	0.26	0.02	0.20
Eastern Phoebe (<i>Sayornis phoebe</i>)	37	0.25	0.50	0.04	0.72
White-eyed Vireo (<i>Vireo griseus</i>)	4	0.03	0.16	0.01	0.12
Blue Jay (<i>Cyanocitta cristata</i>)	42	0.28	0.58	0.05	0.56
American Crow (<i>Corvus brachyrhynchos</i>)	1	0.01	0.08	0.01	0.04
Carolina Chickadee (<i>Poecile carolinensis</i>)	50	0.33	0.63	0.05	0.84
Tufted Titmouse (<i>Baeolophus bicolor</i>)	6	0.04	0.23	0.02	0.12
Carolina Wren (<i>Thryothorus ludovicianus</i>)	30	0.20	0.45	0.04	0.60
House Wren (<i>Troglodytes aedon</i>)	11	0.07	0.26	0.02	0.28
Golden-crowned Kinglet (<i>Regulus satrapa</i>)	2	0.01	0.12	0.01	0.04
Ruby-crowned Kinglet (<i>Regulus calendula</i>)	70	0.47	0.55	0.05	1.00

Appendix B (continued).

Bird Species	Total Observations	Mean / Point	St. Dev.	St Error	Freq. of Occurrence
Blue-gray Gnatcatcher (<i>Polioptila caerulea</i>)	16	0.11	0.35	0.03	0.36
Hermit Thrush (<i>Catharus guttatus</i>)	13	0.09	0.31	0.02	0.44
American Robin (<i>Turdus migratorius</i>)	266	1.77	3.72	0.30	1.00
Gray Catbird (<i>Dumetella carolinensis</i>)	33	0.22	0.53	0.04	0.48
Northern Mockingbird (<i>Mimus polyglottos</i>)	4	0.03	0.20	0.02	0.12
Brown Thrasher (<i>Toxostoma rufum</i>)	15	0.10	0.36	0.03	0.32
European Starling (<i>Sturnus vulgaris</i>)	39	0.26	2.19	0.18	0.16
Cedar Waxwing (<i>Bombycilla cedrorum</i>)	104	0.69	6.05	0.49	0.12
Orange-crowned Warbler (<i>Vermivora celata</i>)	3	0.02	0.18	0.01	0.08
Yellow-rumped Warbler (<i>Dendroica coronata</i>)	539	3.59	3.18	0.26	1.00
Pine Warbler (<i>Dendroica pinus</i>)	6	0.04	0.26	0.02	0.16
Common Yellowthroat (<i>Geothlypis trichas</i>)	7	0.05	0.27	0.02	0.16
Lincoln's Sparrow (<i>Melospiza lincolnii</i>)	1	0.01	0.08	0.01	0.04
Swamp Sparrow (<i>Melospiza georgiana</i>)	12	0.08	0.41	0.03	0.16
White-throated Sparrow (<i>Zonotrichia albicollis</i>)	39	0.26	0.67	0.05	0.52
Northern Cardinal (<i>Cardinalis cardinalis</i>)	154	1.03	1.31	0.11	0.96
Red-winged Blackbird (<i>Agelaius phoeniceus</i>)	34	0.23	2.47	0.20	0.08
Common Grackle (<i>Quiscalus quiscula</i>)	23	0.15	1.29	0.11	0.20
Brown-headed Cowbird (<i>Molothrus ater</i>)	1	0.01	0.08	0.01	0.04
American Goldfinch (<i>Carduelis tristis</i>)	17	0.11	0.85	0.07	0.28
House Sparrow (<i>Passer domesticus</i>)	1	0.01	0.08	0.01	0.04

APPENDIX C. INFORMATION-THEORY MODEL SELECTION RESULTS

Full model selection results by species and year. Log(L) is the maximized log-likelihood, k is the number of model parameters, AIC_c equals Akaike's Information Criterion for small sample size, ΔAIC_c is the AIC_c difference between each model and the best model, and w_i is the Akaike model weight.

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
SppRich	2001-02	Hab NumPatch	4	-7.8	24.6	0.0	0.333
		Hab	3	-10.2	27.0	2.4	0.100
		NumPatch	3	-10.3	27.1	2.5	0.096
		Hab DistPatch NumPatch	5	-7.8	27.1	2.5	0.096
		Hab ForCover NumPatch	5	-7.8	27.1	2.5	0.096
		ForCover NumPatch	4	-9.4	27.7	3.1	0.071
		Hab ForCover	4	-9.8	28.6	4.0	0.045
		Hab DistPatch	4	-9.9	28.7	4.1	0.043
		DistPatch NumPatch	4	-10.3	29.4	4.8	0.030
		Hab DistPatch ForCover NumPatch	6	-7.8	29.7	5.1	0.026
		DistPatch ForCover NumPatch	5	-9.4	30.2	5.6	0.020
		Hab DistPatch ForCover	5	-9.7	30.9	6.3	0.014
		DistPatch	3	-12.3	31.1	6.5	0.013
		ForCover	3	-12.4	31.3	6.7	0.012
		DistPatch ForCover	4	-11.9	32.8	8.2	0.006
		Hab DistPatch	4	-9.9	28.7	4.1	0.043
		DistPatch NumPatch	4	-10.3	29.4	4.8	0.030
SppRich	2002-03	Hab ForCover Damage	5	8.1	-4.7	0.0	0.371
		Hab DistPatch ForCover Damage	6	8.3	-2.4	2.3	0.117
		Hab ForCover	4	5.7	-2.3	2.4	0.112
		Hab ForCover NumPatch Damage	6	8.1	-2.0	2.7	0.096
		Hab Damage	4	4.4	0.0	4.7	0.035
		Hab DistPatch Damage	5	5.7	0.0	4.7	0.035
		Hab DistPatch ForCover	5	5.7	0.1	4.8	0.034
		Hab ForCover NumPatch	5	5.7	0.1	4.8	0.034
		Hab DistPatch ForCover NumPatch Damage	7	8.3	0.3	5.0	0.030
		Hab	3	2.5	1.4	6.1	0.018
		Hab NumPatch Damage	5	5.0	1.4	6.1	0.018
		DistPatch Damage	4	3.6	1.7	6.4	0.015
		Damage	3	2.3	1.9	6.6	0.014
		Hab DistPatch NumPatch Damage	6	5.9	2.4	7.1	0.011
		Hab DistPatch	4	3.1	2.7	7.4	0.009
		Hab DistPatch ForCover NumPatch	6	5.7	2.7	7.4	0.009
		Hab NumPatch	4	3.0	2.9	7.6	0.008
		NumPatch Damage	4	3.0	3.0	7.7	0.008
		ForCover Damage	4	2.8	3.3	8.0	0.007
		DistPatch ForCover Damage	5	3.8	3.9	8.6	0.005
		DistPatch NumPatch Damage	5	3.8	3.9	8.6	0.005
		Hab DistPatch NumPatch	5	3.3	4.9	9.6	0.003
		ForCover NumPatch Damage	5	3.2	5.1	9.8	0.003
		DistPatch ForCover NumPatch Damage	6	3.8	6.4	11.1	0.001
		NumPatch	3	-0.7	7.9	12.6	0.001

Appendix C. (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
SppRich - continued	2002-03	DistPatch	3	-0.7	8.0	12.7	0.001
		ForCover	3	-1.1	8.7	13.4	0.000
		DistPatch NumPatch	4	-0.5	10.0	14.7	0.000
		ForCover NumPatch	4	-0.7	10.3	15.0	0.000
		DistPatch ForCover	4	-0.7	10.4	15.1	0.000
		DistPatch ForCover NumPatch	5	-0.5	12.5	17.2	0.000
American Robin	2002-03	ForCover Damage	3	-20.3	47.3	0.0	0.239
		DistPatch ForCover Damage	4	-19.5	48.0	0.7	0.168
		ForCover NumPatch Damage	4	-20.3	49.5	2.3	0.077
		Hab ForCover Damage	4	-20.3	49.6	2.4	0.073
		DistPatch ForCover NumPatch Damage	5	-19.2	49.9	2.6	0.065
		ForCover	2	-22.9	50.1	2.8	0.059
		DistPatch ForCover	3	-21.9	50.4	3.1	0.051
		Hab DistPatch ForCover Damage	5	-19.5	50.5	3.2	0.048
		Hab ForCover	3	-22.6	51.8	4.5	0.025
		DistPatch ForCover NumPatch	4	-21.5	51.9	4.6	0.024
		Hab DistPatch ForCover	4	-21.5	52.0	4.8	0.022
		Hab ForCover NumPatch Damage	5	-20.3	52.1	4.8	0.022
		ForCover NumPatch	3	-22.8	52.2	4.9	0.021
		Hab DistPatch Damage	4	-21.7	52.5	5.2	0.018
		Hab DistPatch ForCover NumPatch Damage	6	-19.2	52.5	5.3	0.017
		DistPatch Damage	3	-23.1	52.8	5.5	0.015
		Hab DistPatch	3	-23.3	53.2	6.0	0.012
		Hab DistPatch ForCover NumPatch	5	-21.3	54.0	6.8	0.008
		Hab ForCover NumPatch	4	-22.6	54.1	6.9	0.008
		Hab Damage	3	-24.2	55.0	7.7	0.005
		Hab DistPatch NumPatch Damage	5	-21.7	55.0	7.7	0.005
		DistPatch NumPatch Damage	4	-23.1	55.1	7.8	0.005
		Hab DistPatch NumPatch	4	-23.3	55.6	8.3	0.004
		Hab NumPatch Damage	4	-23.8	56.5	9.2	0.002
		DistPatch	2	-26.1	56.6	9.3	0.002
		Hab	2	-26.4	57.0	9.8	0.002
		Damage	2	-26.4	57.0	9.8	0.002
		Hab NumPatch	3	-25.9	58.4	11.1	0.001
		DistPatch NumPatch	3	-26.0	58.6	11.3	0.001
		NumPatch Damage	3	-26.1	58.8	11.5	0.001
		NumPatch	2	-30.0	64.2	17.0	0.000
Blue Jay	2001-02	ForCover	2	-27.5	59.2	0.0	0.163
		ForCover NumPatch	3	-26.3	59.2	0.0	0.163
		NumPatch	2	-27.9	60.1	0.9	0.104
		DistPatch ForCover	3	-26.8	60.2	1.0	0.102
		DistPatch	2	-28.3	60.9	1.7	0.071
		Hab ForCover	3	-27.3	61.2	2.0	0.060
		DistPatch NumPatch	3	-27.3	61.3	2.0	0.059
		DistPatch ForCover NumPatch	4	-26.2	61.3	2.1	0.058
		Hab NumPatch	3	-27.5	61.5	2.3	0.051
		Hab ForCover NumPatch	4	-26.3	61.6	2.4	0.050

Appendix C. (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Blue Jay - continued	2001-02	Hab DistPatch ForCover	4	-26.8	62.5	3.3	0.032
		Hab DistPatch	3	-28.0	62.6	3.4	0.030
		Hab DistPatch NumPatch	4	-27.0	62.9	3.7	0.026
		Hab DistPatch ForCover NumPatch	5	-26.2	63.8	4.6	0.017
		Hab	2	-29.9	64.0	4.8	0.015
Blue Jay	2002-03	NumPatch	2	-28.7	61.7	0.0	0.227
		NumPatch Damage	3	-28.3	63.2	1.5	0.109
		ForCover NumPatch	3	-28.5	63.5	1.7	0.096
		DistPatch NumPatch	3	-28.7	64.0	2.3	0.073
		Hab NumPatch	3	-28.7	64.0	2.3	0.072
		ForCover NumPatch Damage	4	-27.9	64.7	3.0	0.052
		Hab NumPatch Damage	4	-28.3	65.5	3.8	0.035
		Hab ForCover NumPatch	4	-28.3	65.5	3.8	0.034
		DistPatch NumPatch Damage	4	-28.3	65.6	3.9	0.033
		Hab DistPatch NumPatch	4	-28.7	66.4	4.7	0.022
		ForCover Damage	3	-30.1	66.7	4.9	0.019
		Hab ForCover	3	-30.2	66.9	5.2	0.017
		DistPatch	2	-31.3	66.9	5.2	0.017
		Hab ForCover NumPatch Damage	5	-27.8	67.1	5.4	0.015
		DistPatch ForCover NumPatch Damage	5	-27.9	67.2	5.5	0.015
		Damage	2	-31.5	67.3	5.6	0.014
		DistPatch ForCover	3	-30.6	67.8	6.1	0.011
		Hab DistPatch ForCover NumPatch	5	-28.2	67.9	6.1	0.011
		Hab	2	-31.8	68.0	6.2	0.010
		Hab DistPatch NumPatch Damage	5	-28.3	68.0	6.3	0.010
		DistPatch Damage	3	-30.8	68.2	6.4	0.009
		Hab ForCover Damage	4	-29.7	68.5	6.7	0.008
		DistPatch ForCover Damage	4	-29.8	68.6	6.9	0.007
		Hab DistPatch	3	-31.3	69.2	7.5	0.005
		Hab DistPatch ForCover	4	-30.1	69.2	7.5	0.005
		Hab Damage	3	-31.5	69.6	7.8	0.005
		Hab DistPatch ForCover NumPatch Damage	6	-27.8	69.8	8.0	0.004
		Hab DistPatch Damage	4	-30.7	70.5	8.7	0.003
		Hab DistPatch ForCover Damage	5	-29.6	70.8	9.0	0.003
Carolina Chickadee	2001-02	ForCover	2	-28.9	62.0	0.0	0.156
		DistPatch ForCover NumPatch	4	-26.6	62.1	0.2	0.144
		ForCover NumPatch	3	-27.8	62.2	0.2	0.142
		DistPatch ForCover	3	-28.4	63.4	1.5	0.076
		Hab DistPatch	3	-28.6	63.7	1.7	0.066
		Hab ForCover	3	-28.7	63.9	1.9	0.059
		Hab	2	-29.9	64.0	2.1	0.056
		Hab DistPatch NumPatch	4	-27.6	64.2	2.2	0.051
		DistPatch	2	-30.0	64.3	2.3	0.050
		DistPatch NumPatch	3	-28.9	64.3	2.3	0.048
		Hab ForCover NumPatch	4	-27.8	64.5	2.5	0.044
		Hab DistPatch ForCover NumPatch	5	-26.5	64.5	2.6	0.043

Appendix C. (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Carolina	2001-02	Hab DistPatch ForCover	4	-28.1	65.2	3.2	0.031
Chickadee		Hab NumPatch	3	-29.7	66.1	4.1	0.020
- continued		NumPatch	2	-31.3	67.0	5.0	0.013
Carolina	2002-03	ForCover	2	-19.5	43.3	0.0	0.201
Chickadee		ForCover NumPatch	3	-18.9	44.3	1.0	0.122
		DistPatch ForCover	3	-18.9	44.3	1.0	0.120
		ForCover Damage	3	-19.2	44.9	1.6	0.090
		Hab ForCover	3	-19.3	45.1	1.8	0.082
		ForCover NumPatch Damage	4	-18.4	45.8	2.5	0.058
		DistPatch ForCover NumPatch	4	-18.6	46.2	2.9	0.046
		DistPatch ForCover Damage	4	-18.7	46.3	3.0	0.045
		Hab ForCover Damage	4	-18.7	46.5	3.1	0.042
		Hab ForCover NumPatch	4	-18.8	46.5	3.2	0.041
		Hab DistPatch ForCover	4	-18.8	46.5	3.2	0.040
		Hab ForCover NumPatch Damage	5	-18.2	47.8	4.5	0.021
		DistPatch ForCover NumPatch Damage	5	-18.3	48.1	4.8	0.018
		Hab DistPatch ForCover Damage	5	-18.4	48.4	5.1	0.016
		Hab DistPatch ForCover NumPatch	5	-18.6	48.6	5.3	0.014
		Hab DistPatch ForCover NumPatch Damage	6	-18.1	50.4	7.1	0.006
		DistPatch	2	-23.1	50.4	7.1	0.006
		NumPatch Damage	3	-22.3	51.1	7.8	0.004
		Hab DistPatch	3	-22.4	51.3	8.0	0.004
		DistPatch NumPatch	3	-22.4	51.3	8.0	0.004
		NumPatch	2	-23.6	51.5	8.2	0.003
		DistPatch Damage	3	-22.5	51.5	8.2	0.003
		Hab NumPatch	3	-22.7	51.9	8.6	0.003
		Hab DistPatch NumPatch	4	-21.6	52.1	8.8	0.003
		DistPatch NumPatch Damage	4	-21.6	52.2	8.9	0.002
		Hab NumPatch Damage	4	-21.8	52.7	9.3	0.002
		Hab DistPatch Damage	4	-22.0	53.1	9.7	0.002
		Hab DistPatch NumPatch Damage	5	-21.1	53.8	10.4	0.001
		Damage	2	-25.0	54.2	10.9	0.001
		Hab	2	-25.5	55.3	11.9	0.001
		Hab Damage	3	-24.6	55.8	12.5	0.000
Carolina Wren	2001-02	Hab	2	-27.3	58.9	0.0	0.339
		Hab ForCover	3	-27.0	60.6	1.7	0.146
		Hab DistPatch	3	-27.1	60.8	1.9	0.133
		Hab NumPatch	3	-27.2	61.0	2.1	0.121
		ForCover	2	-29.1	62.5	3.5	0.059
		Hab DistPatch ForCover	4	-27.0	62.9	4.0	0.047
		Hab ForCover NumPatch	4	-27.0	63.0	4.1	0.045
		Hab DistPatch NumPatch	4	-27.1	63.2	4.2	0.041
		ForCover NumPatch	3	-29.0	64.6	5.6	0.020
		DistPatch ForCover	3	-29.1	64.7	5.8	0.019
		Hab DistPatch ForCover NumPatch	5	-27.0	65.4	6.5	0.013
		DistPatch ForCover NumPatch	4	-29.0	67.0	8.0	0.006
		DistPatch	2	-31.6	67.4	8.5	0.005

Appendix C. (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Carolina Wren - continued	2001-02	NumPatch	2	-31.8	67.8	8.9	0.004
		DistPatch NumPatch	3	-31.6	69.7	10.8	0.002
Carolina Wren	2002-03	Hab	2	-26.5	57.4	0.0	0.156
		Hab DistPatch	3	-25.7	57.9	0.5	0.120
		Hab Damage	3	-25.9	58.4	1.1	0.091
		Hab DistPatch NumPatch	4	-25.1	59.1	1.7	0.065
		Hab NumPatch	3	-26.5	59.5	2.1	0.054
		Hab DistPatch Damage	4	-25.3	59.6	2.2	0.052
		Hab ForCover	3	-26.5	59.6	2.2	0.051
		Hab DistPatch ForCover	4	-25.6	60.1	2.7	0.040
		Damage	2	-28.0	60.3	3.0	0.035
		Hab NumPatch Damage	4	-25.8	60.6	3.3	0.030
		Hab ForCover Damage	4	-25.9	60.8	3.5	0.028
		Hab DistPatch NumPatch Damage	5	-24.8	61.0	3.6	0.025
		ForCover	2	-28.4	61.0	3.7	0.025
		ForCover Damage	3	-27.2	61.1	3.7	0.025
		Hab DistPatch ForCover NumPatch	5	-25.1	61.6	4.3	0.019
		DistPatch Damage	3	-27.6	61.7	4.3	0.018
		Hab ForCover NumPatch	4	-26.4	61.7	4.4	0.018
		DistPatch	2	-28.8	61.9	4.5	0.016
		Hab DistPatch ForCover Damage	5	-25.2	61.9	4.6	0.016
		ForCover NumPatch	3	-27.8	62.2	4.8	0.014
		NumPatch Damage	3	-27.9	62.3	5.0	0.013
		ForCover NumPatch Damage	4	-26.7	62.4	5.1	0.012
		DistPatch ForCover	3	-28.1	62.7	5.3	0.011
		DistPatch NumPatch	3	-28.2	62.9	5.5	0.010
		DistPatch NumPatch Damage	4	-27.0	62.9	5.5	0.010
		DistPatch ForCover NumPatch	4	-27.0	63.0	5.6	0.009
		Hab ForCover NumPatch Damage	5	-25.8	63.0	5.7	0.009
		DistPatch ForCover Damage	4	-27.1	63.1	5.8	0.009
		NumPatch	2	-29.6	63.5	6.1	0.007
		Hab DistPatch ForCover NumPatch Damage	6	-24.8	63.7	6.3	0.007
		DistPatch ForCover NumPatch Damage	5	-26.2	63.8	6.5	0.006
Eastern Phoebe	2001-02	DistPatch	2	-27.7	59.7	0.0	0.382
		DistPatch ForCover	3	-27.6	61.8	2.1	0.134
		Hab DistPatch	3	-27.7	62.0	2.2	0.126
		DistPatch NumPatch	3	-27.7	62.0	2.2	0.126
		Hab DistPatch ForCover	4	-27.4	63.8	4.1	0.050
		DistPatch ForCover NumPatch	4	-27.6	64.2	4.5	0.041
		Hab DistPatch NumPatch	4	-27.7	64.3	4.6	0.039
		ForCover	2	-30.6	65.4	5.7	0.023
		NumPatch	2	-30.6	65.4	5.7	0.022
		ForCover NumPatch	3	-29.9	66.3	6.6	0.014
		Hab DistPatch ForCover NumPatch	5	-27.4	66.3	6.6	0.014
		Hab ForCover	3	-30.2	67.0	7.3	0.010
		Hab NumPatch	3	-30.5	67.6	7.9	0.007

Appendix C. (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Eastern Phoebe - continued	2001-02	Hab	2	-31.8	68.0	8.2	0.006
		Hab ForCover NumPatch	4	-29.7	68.4	8.7	0.005
Northern Cardinal	2001-02	Hab ForCover	4	-13.3	35.5	0.0	0.191
		DistPatch	3	-15.0	36.6	1.1	0.110
		NumPatch	3	-15.1	36.7	1.2	0.105
		ForCover	3	-15.5	37.5	2.0	0.070
		Hab	3	-15.5	37.5	2.0	0.070
		Hab DistPatch ForCover	5	-13.0	37.5	2.0	0.070
		Hab ForCover NumPatch	5	-13.1	37.6	2.1	0.067
		Hab DistPatch	4	-14.4	37.7	2.2	0.064
		Hab NumPatch	4	-14.5	38.0	2.5	0.055
		DistPatch NumPatch	4	-14.6	38.1	2.6	0.052
		DistPatch ForCover	4	-14.8	38.6	3.1	0.041
		ForCover NumPatch	4	-14.9	38.6	3.1	0.041
		Hab DistPatch NumPatch	5	-14.0	39.4	3.9	0.027
		Hab DistPatch ForCover NumPatch	6	-12.9	39.9	4.4	0.021
		DistPatch ForCover NumPatch	5	-14.5	40.5	5.0	0.016
Northern Cardinal	2002-03	Hab ForCover	4	-14.8	38.6	0.0	0.203
		Hab DistPatch ForCover	5	-14.1	39.6	1.0	0.123
		Hab ForCover Damage	5	-14.5	40.4	1.8	0.083
		Hab	3	-17.2	40.9	2.3	0.064
		Hab ForCover NumPatch	5	-14.8	41.0	2.4	0.061
		Hab DistPatch ForCover NumPatch	6	-13.8	41.8	3.2	0.041
		Hab NumPatch	4	-16.6	42.0	3.4	0.037
		Hab DistPatch ForCover Damage	6	-13.9	42.0	3.4	0.037
		Damage	3	-17.8	42.1	3.5	0.035
		NumPatch	3	-17.8	42.1	3.5	0.035
		ForCover	3	-18.1	42.7	4.1	0.026
		Hab Damage	4	-17.0	42.9	4.3	0.024
		NumPatch Damage	4	-17.0	43.0	4.4	0.023
		Hab ForCover NumPatch Damage	6	-14.4	43.0	4.4	0.023
		ForCover Damage	4	-17.2	43.2	4.6	0.020
		DistPatch	3	-18.4	43.3	4.7	0.019
		Hab DistPatch	4	-17.2	43.3	4.7	0.019
		DistPatch NumPatch	4	-17.5	43.9	5.3	0.014
		Hab NumPatch Damage	5	-16.3	44.0	5.4	0.014
		Hab DistPatch NumPatch	5	-16.3	44.1	5.5	0.013
		ForCover NumPatch	4	-17.7	44.2	5.6	0.012
		Hab DistPatch ForCover NumPatch Damage	7	-13.7	44.3	5.7	0.012
		DistPatch Damage	4	-17.8	44.5	5.9	0.011
		DistPatch ForCover	4	-18.0	44.8	6.2	0.009
		ForCover NumPatch Damage	5	-16.7	44.9	6.3	0.009
		DistPatch NumPatch Damage	5	-16.9	45.3	6.7	0.007
		Hab DistPatch Damage	5	-17.0	45.4	6.8	0.007
		DistPatch ForCover Damage	5	-17.1	45.7	7.1	0.006

Appendix C. (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Northern	2002-03	DistPatch ForCover NumPatch	5	-17.2	45.9	7.3	0.005
Cardinal		Hab DistPatch NumPatch Damage	6	-16.1	46.4	7.8	0.004
- continued		DistPatch ForCover NumPatch Damage	6	-16.5	47.1	8.5	0.003
Red-bellied	2001-02	Hab	2	-28.0	60.2	0.0	0.231
Woodpecker		Hab DistPatch	3	-27.3	61.1	0.9	0.145
		Hab NumPatch	3	-27.6	61.7	1.5	0.110
		ForCover	2	-28.8	61.9	1.7	0.098
		Hab ForCover	3	-27.8	62.1	1.9	0.087
		DistPatch	2	-29.4	63.1	2.9	0.054
		Hab DistPatch NumPatch	4	-27.2	63.3	3.1	0.049
		Hab DistPatch ForCover	4	-27.3	63.5	3.3	0.044
		DistPatch ForCover	3	-28.5	63.7	3.5	0.041
		Hab ForCover NumPatch	4	-27.5	64.0	3.8	0.034
		ForCover NumPatch	3	-28.8	64.1	3.9	0.032
		DistPatch NumPatch	3	-29.4	65.3	5.1	0.018
		Hab DistPatch ForCover NumPatch	5	-27.2	65.8	5.6	0.014
		DistPatch ForCover NumPatch	4	-28.5	66.1	5.9	0.012
Red-bellied	2002-03	Hab DistPatch	3	-16.6	39.8	0.0	0.204
Woodpecker		Hab	2	-18.2	40.8	1.0	0.123
		Hab ForCover	3	-17.2	41.0	1.2	0.109
		Hab DistPatch Damage	4	-16.3	41.5	1.8	0.084
		Hab DistPatch ForCover	4	-16.4	41.7	1.9	0.078
		Hab Damage	3	-17.6	41.9	2.1	0.072
		Hab DistPatch NumPatch	4	-16.6	42.2	2.4	0.062
		Hab ForCover Damage	4	-16.7	42.4	2.6	0.055
		Hab NumPatch	3	-18.1	42.7	2.9	0.047
		Hab ForCover NumPatch	4	-17.2	43.4	3.6	0.033
		Hab DistPatch ForCover Damage	5	-16.0	43.6	3.8	0.030
		Hab NumPatch Damage	4	-17.4	43.8	4.1	0.027
		Hab DistPatch ForCover NumPatch	5	-16.3	44.0	4.3	0.024
		Hab DistPatch NumPatch Damage	5	-16.3	44.1	4.3	0.024
		Hab ForCover NumPatch Damage	5	-16.7	44.9	5.1	0.016
		Hab DistPatch ForCover NumPatch Damage	6	-16.0	46.1	6.4	0.008
		ForCover Damage	3	-22.0	50.5	10.7	0.001
		ForCover	2	-23.3	51.0	11.2	0.001
		ForCover NumPatch Damage	4	-21.5	52.0	12.2	0.000
		ForCover NumPatch	3	-22.8	52.1	12.4	0.000
		DistPatch ForCover Damage	4	-21.9	52.8	13.1	0.000
		DistPatch ForCover	3	-23.3	53.2	13.5	0.000
		DistPatch ForCover NumPatch	4	-22.6	54.3	14.5	0.000
		DistPatch ForCover NumPatch Damage	5	-21.5	54.5	14.7	0.000
		Damage	2	-27.4	59.1	19.4	0.000
		DistPatch Damage	3	-26.9	60.5	20.7	0.000
		NumPatch Damage	3	-27.4	61.4	21.6	0.000
		DistPatch	2	-29.2	62.7	22.9	0.000

Appendix C. (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Red-bellied	2002-03	DistPatch NumPatch Damage	4	-26.9	62.8	23.1	0.000
Woodpecker		NumPatch	2	-30.2	64.7	25.0	0.000
- continued		DistPatch NumPatch	3	-29.1	64.9	25.1	0.000
Ruby-crowned	2001-02	NumPatch	2	-22.9	50.0	0.0	0.151
Kinglet		Hab NumPatch	3	-21.9	50.3	0.3	0.131
		Hab	2	-23.0	50.4	0.4	0.126
		Hab ForCover	3	-22.1	50.8	0.8	0.103
		DistPatch NumPatch	3	-22.4	51.4	1.4	0.074
		Hab DistPatch NumPatch	4	-21.4	51.8	1.8	0.061
		Hab ForCover NumPatch	4	-21.5	52.0	2.0	0.056
		ForCover NumPatch	3	-22.8	52.2	2.2	0.051
		DistPatch	2	-24.1	52.4	2.4	0.046
		ForCover	2	-24.1	52.4	2.4	0.045
		Hab DistPatch ForCover	4	-21.7	52.5	2.5	0.044
		Hab DistPatch	3	-23.0	52.6	2.6	0.041
		Hab DistPatch ForCover NumPatch	5	-20.8	53.0	3.0	0.034
		DistPatch ForCover NumPatch	4	-22.4	53.8	3.8	0.023
		DistPatch ForCover	3	-24.0	54.6	4.6	0.015
Ruby-crowned	2002-03	Hab Damage	4	12.8	-16.5	0.0	0.208
Kinglet		Hab DistPatch Damage	5	13.6	-15.7	0.8	0.139
		Hab DistPatch	4	12.2	-15.4	1.1	0.120
		Hab	3	10.8	-15.1	1.4	0.103
		Hab NumPatch Damage	5	13.1	-14.6	1.9	0.080
		Hab ForCover Damage	5	12.9	-14.3	2.2	0.069
		Hab NumPatch	4	11.2	-13.4	3.1	0.044
		Hab DistPatch ForCover Damage	6	13.6	-13.1	3.4	0.038
		Hab DistPatch NumPatch Damage	6	13.7	-13.1	3.4	0.038
		Hab ForCover	4	11.0	-13.0	3.5	0.036
		Hab DistPatch ForCover	5	12.2	-12.9	3.6	0.034
		Hab DistPatch NumPatch	5	12.2	-12.9	3.6	0.034
		Hab ForCover NumPatch Damage	6	13.1	-12.0	4.5	0.022
		Hab ForCover NumPatch	5	11.2	-10.9	5.6	0.013
		Hab DistPatch ForCover NumPatch	6	12.3	-10.3	6.2	0.009
		Hab DistPatch ForCover NumPatch Damage	7	13.7	-10.3	6.2	0.009
		DistPatch ForCover	4	5.9	-2.8	13.7	0.000
		DistPatch ForCover NumPatch	5	6.3	-1.1	15.4	0.000
		ForCover	3	3.7	-0.8	15.7	0.000
		ForCover NumPatch	4	4.8	-0.6	15.9	0.000
		DistPatch ForCover Damage	5	6.0	-0.4	16.1	0.000
		DistPatch	3	2.7	1.1	17.6	0.000
		ForCover Damage	4	3.9	1.1	17.6	0.000
		ForCover NumPatch Damage	5	5.1	1.3	17.8	0.000
		DistPatch ForCover NumPatch Damage	6	6.4	1.3	17.8	0.000
		NumPatch	3	2.3	2.0	18.5	0.000
		Damage	3	2.0	2.5	19.0	0.000
		DistPatch NumPatch	4	2.8	3.4	19.9	0.000

Appendix C. (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Ruby-crowned Kinglet - continued	2002-03	DistPatch Damage	4	2.7	3.5	20.0	0.000
		NumPatch Damage	4	2.3	4.3	20.8	0.000
		DistPatch NumPatch Damage	5	2.8	5.9	22.4	0.000
Tufted Titmouse	2002-03	Hab ForCover Damage	4	-12.9	34.8	0.0	0.180
		Hab ForCover NumPatch Damage	5	-11.9	35.2	0.4	0.146
		Hab NumPatch Damage	4	-13.2	35.3	0.5	0.140
		Hab ForCover	3	-15.2	36.9	2.1	0.063
		Hab DistPatch ForCover Damage	5	-12.7	36.9	2.1	0.062
		Hab ForCover NumPatch	4	-14.1	37.2	2.4	0.054
		Hab DistPatch NumPatch Damage	5	-13.0	37.4	2.6	0.049
		Hab NumPatch	3	-15.6	37.7	2.9	0.042
		Hab DistPatch ForCover NumPatch Damage	6	-11.8	37.8	3.0	0.040
		Hab DistPatch ForCover	4	-14.5	38.0	3.2	0.036
		Hab DistPatch Damage	4	-14.6	38.1	3.3	0.034
		Hab DistPatch	3	-15.9	38.4	3.6	0.029
		Hab DistPatch NumPatch	4	-14.8	38.6	3.8	0.027
		Hab Damage	3	-16.1	38.7	3.9	0.026
		ForCover Damage	3	-16.2	39.0	4.3	0.021
		Hab DistPatch ForCover NumPatch	5	-13.9	39.2	4.4	0.020
		Hab	2	-18.2	40.8	6.0	0.009
		DistPatch ForCover Damage	4	-16.1	41.1	6.3	0.008
		ForCover NumPatch Damage	4	-16.2	41.3	6.5	0.007
		ForCover	2	-19.7	43.6	8.8	0.002
		DistPatch ForCover NumPatch Damage	5	-16.1	43.6	8.8	0.002
		DistPatch ForCover	3	-19.4	45.3	10.5	0.001
		ForCover NumPatch	3	-19.7	45.9	11.1	0.001
		DistPatch ForCover NumPatch	4	-19.4	47.7	12.9	0.000
		DistPatch Damage	3	-23.0	52.7	17.9	0.000
		DistPatch NumPatch Damage	4	-22.9	54.7	19.9	0.000
		Damage	2	-25.5	55.2	20.4	0.000
		NumPatch Damage	3	-24.5	55.5	20.7	0.000
		DistPatch	2	-26.8	57.9	23.1	0.000
		DistPatch NumPatch	3	-26.8	60.1	25.4	0.000
		NumPatch	2	-29.3	63.0	28.2	0.000
White-throated Sparrow	2002-03	Hab DistPatch ForCover NumPatch Damage	6	-22.2	58.6	0.0	0.148
		Hab DistPatch ForCover Damage	5	-23.6	58.6	0.1	0.143
		Hab DistPatch ForCover	4	-24.9	58.7	0.2	0.137
		Hab DistPatch ForCover NumPatch	5	-23.6	58.8	0.2	0.133
		Hab ForCover NumPatch Damage	5	-23.9	59.2	0.6	0.107
		DistPatch ForCover Damage	4	-25.7	60.5	1.9	0.057
		ForCover NumPatch Damage	4	-25.9	60.7	2.1	0.051
		Hab ForCover NumPatch	4	-26.0	60.9	2.4	0.045
		ForCover Damage	3	-27.4	61.3	2.7	0.038
		DistPatch ForCover NumPatch Damage	5	-25.1	61.8	3.2	0.030
		Hab ForCover Damage	4	-26.4	61.8	3.2	0.030
		DistPatch ForCover	3	-28.2	63.1	4.5	0.016
		Hab ForCover	3	-28.5	63.6	5.1	0.012

Appendix C. (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
White-throated Sparrow - continued	2002-03	Damage	2	-29.9	64.1	5.6	0.009
		DistPatch ForCover NumPatch	4	-27.9	64.7	6.1	0.007
		ForCover NumPatch	3	-29.2	65.0	6.4	0.006
		ForCover	2	-30.5	65.3	6.7	0.005
		NumPatch Damage	3	-29.5	65.6	7.0	0.004
		DistPatch Damage	3	-29.5	65.6	7.0	0.004
		DistPatch	2	-31.0	66.3	7.7	0.003
		Hab Damage	3	-29.9	66.4	7.8	0.003
		NumPatch	2	-31.4	67.1	8.5	0.002
		Hab	2	-31.7	67.6	9.0	0.002
		DistPatch NumPatch Damage	4	-29.4	67.7	9.1	0.002
		Hab NumPatch Damage	4	-29.5	68.0	9.4	0.001
		Hab DistPatch Damage	4	-29.5	68.0	9.4	0.001
		Hab DistPatch	3	-30.9	68.3	9.7	0.001
		DistPatch NumPatch	3	-30.9	68.4	9.8	0.001
		Hab NumPatch	3	-31.2	69.0	10.4	0.001
		Hab DistPatch NumPatch Damage	5	-29.4	70.2	11.6	0.000
		Hab DistPatch NumPatch	4	-30.8	70.5	11.9	0.000
Yellow-rumped Warbler	2001-02	Hab	2	-22.7	49.7	0.0	0.322
		Hab DistPatch	3	-22.2	50.9	1.2	0.175
		Hab NumPatch	3	-22.2	50.9	1.2	0.174
		Hab ForCover	3	-22.6	51.8	2.1	0.111
		Hab DistPatch NumPatch	4	-21.9	52.9	3.2	0.066
		Hab DistPatch ForCover	4	-22.2	53.3	3.6	0.053
		Hab ForCover NumPatch	4	-22.2	53.3	3.6	0.052
		Hab DistPatch ForCover NumPatch	5	-21.9	55.3	5.6	0.019
		ForCover	2	-25.9	56.1	6.4	0.013
		DistPatch ForCover	3	-25.8	58.2	8.5	0.005
		ForCover NumPatch	3	-25.9	58.4	8.7	0.004
		DistPatch	2	-27.4	59.2	9.5	0.003
		NumPatch	2	-28.0	60.2	10.5	0.002
		DistPatch ForCover NumPatch	4	-25.8	60.6	10.9	0.001
		DistPatch NumPatch	3	-27.4	61.4	11.7	0.001
Yellow-rumped Warbler	2002-03	Hab DistPatch	4	-29.4	67.6	0.0	0.180
		Hab	3	-30.9	68.4	0.8	0.121
		Hab DistPatch NumPatch	5	-28.5	68.5	0.9	0.115
		Hab ForCover	4	-29.9	68.7	1.1	0.104
		Hab DistPatch ForCover	5	-29.0	69.5	1.9	0.070
		Hab DistPatch ForCover NumPatch	6	-27.8	69.6	2.0	0.066
		Hab DistPatch Damage	5	-29.3	70.0	2.4	0.054
		Hab Damage	4	-30.6	70.1	2.5	0.052
		Hab ForCover NumPatch	5	-29.3	70.1	2.5	0.052
		Hab NumPatch	4	-30.8	70.6	3.0	0.040
		Hab ForCover Damage	5	-29.6	70.7	3.1	0.038
		Hab DistPatch NumPatch Damage	6	-28.4	71.0	3.4	0.033
		Hab DistPatch ForCover Damage	6	-28.9	72.0	4.4	0.020
		Hab ForCover NumPatch Damage	6	-29.0	72.1	4.5	0.019

Appendix C. (continued).

Species	Winter	Model	k	log(L)	AIC _c	ΔAIC _c	w _i
Yellow-rumped Warbler	2002-03	Hab DistPatch ForCover NumPatch Damage	7	-27.7	72.2	4.6	0.018
- continued		Hab NumPatch Damage	5	-30.5	72.4	4.8	0.016
		ForCover NumPatch	4	-35.3	79.5	11.9	0.000
		ForCover NumPatch Damage	5	-34.1	79.6	12.0	0.000
		ForCover	3	-37.0	80.5	12.9	0.000
		ForCover Damage	4	-35.8	80.5	12.9	0.000
		DistPatch ForCover NumPatch	5	-34.8	81.0	13.4	0.000
		DistPatch ForCover NumPatch Damage	6	-33.8	81.6	14.0	0.000
		DistPatch ForCover	4	-37.0	82.8	15.2	0.000
		DistPatch ForCover Damage	5	-35.8	83.0	15.4	0.000
		Damage	3	-41.7	89.8	22.2	0.000
		DistPatch Damage	4	-41.0	91.0	23.4	0.000
		NumPatch Damage	4	-41.5	92.0	24.4	0.000
		DistPatch	3	-42.8	92.1	24.5	0.000
		DistPatch NumPatch Damage	5	-40.4	92.3	24.7	0.000
		DistPatch NumPatch	4	-42.1	93.2	25.6	0.000
		NumPatch	3	-43.8	94.2	26.6	0.000

APPENDIX D. NITROGEN CORRECTED METABOLIZABLE ENERGY OF DIFFERENT FRUITS BY INDIVIDUAL

Bird species	Plant species	ID	Sex	Fruit pulp ^a		Whole fruit	
				AME (kcal/g)	AME (kJ/g)	AME (kcal/g)	AME (kJ/g)
Yellow-rumped Warbler	Tallow	1	U	7.25	30.32	.	.
		2	U	7.43	31.07	.	.
		3	U	7.40	30.97	.	.
		4	U	7.38	30.89	.	.
		5	U	7.67	32.07	.	.
		6	U	7.03	29.43	.	.
		7	U	7.62	31.90	.	.
		8	U	7.25	30.35	.	.
		9	U	6.19	25.89	.	.
	Wax Myrtle	10	U	4.28	17.90	1.99	8.34
		11	U	7.09	29.65	2.92	12.23
		12	U	3.11	13.03	1.49	6.23
		13	U	2.77	11.60	1.34	5.60
		14	U	4.56	19.08	2.12	8.86
		15	U	4.69	19.61	2.17	9.07
		16	U	3.96	16.57	1.86	7.77
		17	U	4.24	17.72	1.97	8.24
		18	U	4.69	19.63	2.17	9.07
	Poison Ivy	19	U	4.20	17.57	1.73	7.24
		20	U	4.36	18.25	1.81	7.57
		21	U	4.81	20.11	1.95	8.16
		22	U	3.63	15.17	1.19	4.98
		23	U	6.25	26.16	1.78	7.45
		24	U	3.94	16.48	1.28	5.34
		25	U	3.77	15.76	1.23	5.15
		26	U	2.61	10.91	0.82	3.43
		27	U	2.45	10.27	0.77	3.21
Northern Cardinal	Tallow	1	M	4.71	19.72	.	.
		2	M	1.81	7.56	.	.
		3	M	1.18	4.93	.	.
		4	F	1.99	8.31	.	.
		5	M	6.88	28.77	.	.
		6	M	0.90	3.77	.	.
		7	M	4.86	20.32	.	.
		8	F	-2.71	-11.34	.	.
		9	M	2.08	8.72	.	.
		10	F	2.40	10.04	.	.
	Deciduous holly	1	M	3.91	16.37	.	.
		2	F	3.06	12.79	.	.
		3	F	3.57	14.95	.	.
		4	M	3.89	16.27	.	.
		5	F	3.52	14.74	.	.
		6	M	2.86	11.97	.	.
		7	M	4.19	17.52	.	.
		8	F	3.99	16.69	.	.
		9	F	4.29	17.93	.	.
		10	F	4.37	18.29	.	.

Appendix D (continued).

Bird species	Plant species	ID	Sex	Fruit pulp		Whole fruit	
				AME (kcal/g)	AME (kJ/g)	AME (kcal/g)	AME (kJ/g)
Northern Cardinal	Hackberry	1	F	2.80	11.72	.	.
		2	M	2.48	10.36	.	.
		3	M	3.07	12.84	.	.
		4	M	2.49	10.43	.	.
		5	M	2.82	11.82	.	.
		6	M	2.72	11.36	.	.
		7	F	3.29	13.78	.	.
American Robin	Tallow	1	U	6.12	25.59	.	.
		2	U	6.25	26.14	.	.
		3	U	5.33	22.31	.	.
		4	U	5.16	21.59	.	.
		5	U	5.64	23.58	.	.

^a not directly measured for Yellow-rumped Warblers

VITA

Michael Baldwin was born in Rapid City, South Dakota, to parents Colleen and John. He developed an interest in wildlife and the outdoors at an early age. Most of his childhood was spent in and around the Black Hills area where many days were spent hiking, camping and exploring the pine forests and granite outcroppings. He graduated from Belle Fourche High School, in Belle Fourche, South Dakota, in May 1991. He attended the University of Nebraska for two years, before transferring to the University of Wyoming where he received a Bachelor of Science degree with a double major in wildlife biology and management and in biology in May 1997. In July of that year, he accepted a position as an ecologist with the United States Geological Survey, National Wetlands Research Center in Lafayette, Louisiana, where he is still employed. In 2001, he entered graduate school at Louisiana State University. He is happily married to wife Heather. Michael is a candidate for a Master of Science degree in wildlife.