NEST DISTRIBUTION OF BIRDS IN CHRISTMAS TREE PLANTATIONS OF *ABIES FRASERI* AND *PINUS STROBUS* IN WATAUGA COUNTY, NORTH CAROLINA

A Thesis

by

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ABSTRACT

NEST DISTRIBUTION OF BIRDS IN CHRISTMAS TREE PLANTATIONS OF *ABIES FRASERI* and *PINUS STROBUS* IN WATAUGA COUNTY, NORTH CAROLINA. (May 1985)

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Christmas tree plantations are unusual artificial avian habitats because of their regular tree spacing, single tree species composition (monoculture), relatively uniform tree height, reduced undergrowth, and trimming maintenance. Avian nesting behavior was studied in five White Pine (*Pinus strobus)*, and four Fraser Fir (*Abies fraseri*) Christmas tree plantations in Watauga County, North Carolina. This study was conducted from April to November, 1984.

Bird species nesting in the plantations included Song Sparrow, *Melospiza melodia* Wilson, Chipping Sparrow, *Spizella passerina* Bechstein, Field Sparrow, Spizella pusilla *Wilson*, American Robin, *Turdus migratorius* Linnaeus, Rufous-Sided Towhee, *Pipilo erythrophthalmus* Linnaeus, and Northern Cardinal, *Cardinalis cardinalis* Linnaeus.

Several nesting bird species showed a preference between Fraser Fir and White Pine. Elevation and aspect of the Christmas tree plantation had no effect on avian nesting behavior. Nest height selection was within the range recorded for other habitats, and tree height selection varied among bird species. The nesting diversity was lower than reported for natural forests. Avian reproductive success was higher in Fraser Fir plantations than in White Pine.

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CHAPTER I

INTRODUCTION

Christmas tree plantations are artificial habitats for many plants and animals. The plantation is constructed in such a manner that it resembles an orchard in appearance, with the trees planted in uniform rows, and any undergrowth is kept to a minimum. Since the trees are trimmed to a uniform height, there is no vertical stratification. Because of the uniform tree height and spacing, as well as reduced undergrowth, the Christmas tree plantation is an unusual avian habitat.

There have been studies of birds in artificial coniferous habitats, but these were made only of a single tree species and no comparisons could be made. Buech (1982) studied bird populations in an artificial habitat of Scotch Pine trees, and Messersmith (1963) studied birds in Red Pine trees.

To get a better understanding of avian nesting behavior in these types of artificial habitats, it would be advantageous to study similar artificial plantations composed of more than one tree species. The trees selected for this study were Fraser Fir, *Abies fraseri* (Pursh), and Eastern White Pine, *Pinus strobus* Linnaeus. Watauga County, located in northwestern North

Carolina, is a major Christmas tree producing area and was chosen as the site for this study.

Commercial Christmas tree plantations are relatively new additions to the landscape of western North Carolina. The first Christmas tree plantation in Watauga County was started in 1947 by Herbert Aldridge when he planted five hundred Fraser Fir trees and began harvesting in 1954. Today, the area of Christmas tree plantations in Watauga County exceeds four hundred hectares, with approximately five hundred Christmas tree plantations, ranging in size from three hundred thousand trees in the largest plantation, to some as small as one hundred trees.

When man first arrived in western North Carolina, the landscape was predominantly a hardwood forest. Agricultural development followed with the creation of fields of tobacco and corn. Today, with Christmas trees becoming more profitable ($3,700,000 alone in Watauga County), more of the land is being converted into Christmas tree fields; thus creating a new kind of artificial habitat.

The most common types of trees planted as Christmas trees in this area are Fraser Fir and White Pine, with other tree species of lesser importance including

Scotch Pine, *Pinus sylvestris*, Blue Spruce, *Picea pungens*, and White Spruce, *Picea glauca*.

The objectives of this study were:

(1) To identify all avian species found in the study areas and record their observed activities.

(2) To determine the number of nesting bird species present in the study areas.

(3) To determine if birds that nest in Christmas trees show a preference between Fraser Fir and White Pine when choosing a nesting site.

(4) To determine the effect of Christmas tree habitats on the nest height of birds.

(5) To determine the effects of aspect and elevation of Christmas tree plantations on the density and diversity of bird nests.

(6) To obtain some measure of reproductive success of birds that nest in Christmas tree plantations and make a comparison of this success between Fraser Fir and White Pine Christmas trees.

CHAPTER II

REVIEW OF THE LITERATURE

Habitat alterations, such as the fragmentation of forests, can greatly affect bird species diversity as well as species composition (Whitcomb, 1977). Stauffer and Best (1980) classified several birds as to their tolerance of habitat alteration. Among the birds classified as tolerant were the Northern Cardinal, *Cardinalis cardinalis* Linnaeus, Song Sparrow, *Melospiza melodia* Wilson, and Brown Thrasher, *Toxostoma rufum* Linnaeus. The Rufous-Sided Towhee, *Pipilo erythrophthalmus* Linnaeus, was classified as a bird that was intolerant to any habitat alteration. The American Robin, *Turdus migratorius* Linnaeus, was said to be of moderate tolerance and the Field Sparrow, *Spizella pusilla* Wilson, was to be of low tolerance. These categories were based on the species' flexibility of nesting habitats or their distribution among different habitat types. The conclusions of Stauffer and Best (1980) do not agree with Brackbill (1947). He found that the American Robin could tolerate man and he reports nests built on window ledges and in vines on a trellis.

Because of habitat alteration, many of the permanent resident species may be increasing in numbers,

while many of the neotropical migratory species are disappearing (Whitcomb, 1977). In his study of woodland clearings, Lay (1938) found that the margins of a forest had ninety-five percent more birds and forty-one percent more species than were found in the interior woodland. The Northern Cardinal, a permanent resident species, was reported to be twice as numerous at the margins of clearings as in the interior woodland.

There have been many studies concerning the causes of avian species diversity. Morrison and Meslow (1983) state that the plant species may determine avian diversity. Others contend that diversity is determined by vertical stratification, or the number of vertical layers present (MacArthur, 1964). In support of MacArthur's theory, Webb *et al.* (1977) found that logging in a forest increased the avian species diversity because of the new vertical layers created. MacArthur (1964) states that a two layered habitat has about four more species than a one layered habitat. Karr and Roth (1971) have shown that foliage height diversity and percent vegetation cover can be related to avian species diversity. In 1976, Roth states that data from a quantitative model he has developed indicated that a habitat uniform in structure, such as an orchard, would

have few bird species present because of the difficulty of spatially partitioning the habitat.

The most common method of measuring species diversity is the Shannon index (Shannon and Weaver, 1949). Willson (1974) states that if too much emphasis is placed on any diversity index in the description of an area, the description may become inaccurate. Peet (1975) argues that most diversity indices cannot be strictly compared unless the sample sizes are identical. In a study of several areas to test the Shannon index, Tramer (1969) found that while diversity varied between different areas, the relative abundance remained similar.

Previously, it was stated that a relationship existed between species diversity and the ability of species to partition the habitat (Roth, 1976). Allaire and Fisher (1975) studied how the Field Sparrow and Chipping Sparrow were able to partition their habitat in relation to foraging behavior. They found that while both fed predominantly on grass seeds, the Chipping Sparrow, *Spizella passerina* Bechstein, usually foraged at a greater height. While the Chipping Sparrows have been shown to be ecologically dominant to Field Sparrows, Evans (1978) concludes that competition is reduced

between these birds by partitioning the nest site at different heights.

Partitioning of nest sites is accomplished by many birds when they select different types of vegetation. Savard and Falls (1981) report that the American Robin will nest in almost any type of tree. In their study within an urban environment, they observed robin nests in thirty different species of tree or shrub. The American Robin was also observed nesting in man-made structures. In a study of the Chipping Sparrow in Michigan, Walkinshaw (1944) reports that the conifer is the most preferred nesting site. Snyder (1950) conducted a study of birds in the coniferous biome and found that the Ruby Crowned Kinglet, *Regulus calendula* normally nested in a Lodgepole Pine in a certain area. However, in plots of Lodgepole Pine at a different elevation, the Ruby Crowned Kinglet was not found. From this and other data, Snyder concluded that some aspect of the bird's niche was missing and it could not nest there. The reverse of the above study was reported by Stewart and Aldrich (1949). They state that in the spruce zone of the Cheat Mountains in West Virginia, the predominant bird species are characteristic of birds from the northern boreal forest. All of these mountains are over

four thousand feet in elevation, and many of the birds are not found in the surrounding areas. The spruce zone is supporting different avian species than would be predicted from that latitude.

Much of the descriptive work done concerning the nest site attributes was completed in the early to middle 1900's. In 1942 Pearson found and described many birds of North Carolina. He reported that the Northern Cardinal nest height ranged from two to twelve feet, but averaged two to four feet. There were other reports about nest site attributes of birds; Chapman (1932), Preston (1946), Preston and Norris (1947), and Bent (1968). Walkinshaw studied the Field Sparrow (1936), and Chipping Sparrow (1944) nesting behavior in Michigan. Laskey (1944) reported on the life history of the Northern Cardinal in Tennessee. Best (1976) studied the nesting ecology of the Field Sparrow. The American Robin nesting behavior has been studied in Maryland by Brackbill (1947) and in urban areas by Savard and Falls (1981).

In order for a bird to nest in a habitat of limited size, it may have to decrease its territory. It has been shown that the Song Sparrow is able to nest in an area that is one-tenth the minimum size usually

defended (Beer *et al.* 1956). Schoener (1968) states that a Chipping Sparrow needs nearly three hectares for its feeding territory. The Northern Cardinal and Song Sparrow were shown to require less than one-half of a hectare. In a different study, Laudenslayer and Balda (1978) report three hectares of territory for the Chipping Sparrow. Ewert (1982) studied avian populations in isolated bogs in Michigan. He states that the small size of the bogs may be limiting the number of species present because the bog may be smaller than their territories. He found the Song Sparrow territory to be less than one-half of a hectare. Morse (1977) reports the same size for a Song Sparrow territory but when they were found nesting on islands the territory was almost five times smaller. Morse did not find any American Robin nests on the islands possibly because their territory usually exceed four hectares. Another similar study was conducted by Rusterholz and Howe (1979). They found Song and Chipping Sparrows nesting on very small islands, but were usually represented by a single pair.

The threat of predators is another factor that influences bird nest site selection (Collias and Collias, 1984). The American Robin is known to shift nest height

and foliage preference as the nesting season progresses (Savard and Falls, 1981). Best (1981) found that the nest height of the Field Sparrow increases during the nesting season. This increase in nest height may be a response to the increase in undergrowth during the summer (Collias and Collias, 1984).

There has been only one study of avian nesting behavior in a Christmas tree plantation. Buech (1982) studied the reproductive success of birds in a Scotch Pine plantation in Minnesota. He found that Clay-Colored Sparrows, *Spizella pallida* Swainson, Chipping and Field Sparrows dominated the plantation in terms of the number of nests. Messersmith (1963), in a similar study of a Red Pine plantation in Michigan, found the habitat to be most suitable to Cedar Waxwings, *Bombycilla cedrorum*, and Chipping Sparrows. These trees were not planted to be used as Christmas trees, and grew to heights of six meters or more. Messersmith reported a density of 7.1 birds per acre (2.9 per hectare) and states that the uniformity of the tree growth and the fact that the areas surrounding the plantation had suitable nesting sites for birds may have lowered the density in the plantation from what might be predicted.

Shelterbelts built in the mid-west to decrease wind around certain areas have been used for bird nest studies. Yahner (1984) believes that avian nesting success and nest site selection may be different in the relatively new shelterbelts than in older, more established habitats. In his study of the American Robin and Mourning Dove, *Zenaida macroura* Linnaeus nests, he found that robins that nested in higher trees (6.6 meters) had a lower reproductive success than at lower nest heights (5 meters). In an earlier study of the shelterbelt habitat, Yahner (1982) looked at avian nest densities and nest site selection. He mentions several reasons why some bird species were missing that he would expect to ordinarily nest in that region. The availability of food and the size of the shelterbelt may have kept some bird species out of the area. Yahner states that the area of the shelterbelt may be smaller than the minimum territory size of some birds. Maintenance of the shelterbelts such as the removal of snags and mowing may have destroyed the habitat for some bird species. Also the birds would have to be able to tolerate the presence of human disturbances such as motor noises, human noise, farm animals, and the presence of human pets such as cats

and dogs which would be possible nest predators. All of these factors would be important in determining the bird species composition in most man-made habitats.

CHAPTER III

MATERIALS AND METHODS

Five White Pine and four Fraser Fir plantations were used in the observation of avian nesting behavior. These plantations were chosen in different areas of Watauga County so that they have different elevations, aspects, and surrounding habitats. The plantations varied in age and ranged in area from 648 square meters to 4,200 square meters, with the height of the trees ranging from .7 meters to 2.6 meters. While all of these plantations were different, each was sampled in the same manner. The habitats surrounding the Christmas tree plantations were varied enough to receive consideration.

In order to determine the extent of avian nesting in Christmas tree plantations, and the species of birds involved, active nest searches and field observations were employed. Field observations began several weeks before the expected onset of the nesting season to become proficient at nest searching and to be certain that no early nests would go undetected. An active nest search began April 17, 1984, and ended October 27, 1984. The maximum time period between active nest searches was two weeks. Two weeks is the minimum time

period that a bird can build the nest, lay, hatch, and incubate the eggs, and fledge the young. The nest search consisted of walking between the rows of Christmas trees and bending the branches so that a tree could be examined. The search was systematic, beginning at one side of a plantation and proceeding to the other. Any active nest (i.e. any nest that contained at least one egg) was recorded as to the height of the nest and tree, its location within the plantation, the species of bird that built the nest, and the number of eggs present. Also included in the data was a description of the eggs, the behavior of the parents, and any other birds that were present in the immediate area. The fate of the nest, eggs, and young were recorded during each search until the young had left the nest. Old nests from previous years were not included in this study. Bird species were identified using the Peterson's *A Field Guide to the Birds* (Peterson, 1980), and tree identification was made using the *Manual of the Vascular Flora of the Carolinas* (Radford et al., 1968). Nest identification was made from the eggs, attentive parents, young, and the nest itself using *A Field Guide to Bird's Nests* (Harrison, 1975). All statistical tests used are described by Sokal and Rohlf (1973) unless otherwise noted.

From these data, the number and percent nesting birds by species was determined. The percent nesting birds was obtained by the formula:

$$\text{Percent Nesting Birds} = \frac{\text{Number of nests by a species}}{\text{Total number of nests}} .$$

A nesting frequency was determined for each species nesting in the plantations from the formula:

$$\text{Nesting Frequency} = \frac{\text{Number of plantations a species nested}}{\text{Total number of plantations}} .$$

A comparison was made of the number of nests to determine if birds showed a preference between Fraser Fir and White Pine fields in selecting a nesting site. A binomial was used to test for differences in choice between the two types of trees for each bird species. The nesting density was determined for White Pine and Fraser Fir plantations. This nesting density refers to the total number of nests observed during the entire nesting season in a given species per hectare. A t-test was performed to find out if any differences existed between the densities of the two plantations. The t-formula for unequal sample sizes was used because five plantations were White Pine, and four were Fraser Fir (df=9).

Tree height of each plantation was determined by randomly choosing plots within a plantation from a grid. An average tree height as well as the mean and two standard deviations of the mean tree height were calculated for each plantation. Any Christmas tree that contained a nest was measured and compared to see if a bird chose a significantly tall or short tree (Two SD above and below the mean).

Nest height was measured for each nesting bird, and was considered to be the distance from the ground to the bottom of the nest. From the measurements, a nest height average was calculated for each bird species. The nest height ranges were compared to nest heights that have been recorded in the literature for these same bird species.

To get a general idea about avian nesting species diversity, a Shannon Index was calculated for all nine plantations combined (Shannon and Weaver, 1948). A diversity index was obtained for Fraser Fir plantations combined, and for White Pine plantations combined, using the Shannon Index. These indices were compared by a t-test according to Hutcheson (1970). A diversity index was also calculated for each of the individual

plantations. This nesting species diversity represents all of the nests that were observed during the entire breeding season.

A measure of reproductive success was considered in reference to birds nesting in Fraser Fir and White Pine. A bird that was able to produce offspring that were capable of leaving the nest was said to be successful. An unsuccessful bird was defined as any bird that built a nest and laid at least one egg, but was unable to produce any fledglings that could leave the nest. Avian nesting success or percent of successful birds was determined for both Fraser Fir and White Pine plantations. This value was obtained by the formula:

$$\text{Percent Successful Nests} = \frac{\text{Number of successful nests}}{\text{Total number of nests}} .$$

The number of fledglings per successful nest was also calculated for birds in each of the tree species. The number of eggs in a nest was recorded from each nest search in regard to their progress toward development. The probability of a nest surviving was calculated from the percent of successful nests for both Fraser Fir and White Pine plantations. The probability of an individual bird surviving from an egg to fledgling was also determined for both types of plantations. This

value was obtained by the formula:

$$p(\text{individual surviving}) = \frac{\text{Number of eggs producing fledgling}}{\text{Total number of eggs laid}}.$$

These probabilities were compared in reference to the tree species by confidence intervals of percentages to test for any differences. The confidence interval of percentages was constructed at the 95% level.

In order to ascertain the impact of aspect of the Christmas tree plantation on avian nesting density and nesting species diversity, the aspect of each plantation was obtained by using a compass. In an effort to discover the possible effects of temperature on nesting preference, Christmas tree plantations were dichotomized into north and south aspects. A nesting density, representing all nests observed during the entire nesting season per hectare, was determined for both north and south aspects. The north aspect involved three Fraser Fir plantations, while the south aspect was made up of four plantations of both types. A comparison was made to discover if there was a significant difference between the avian nest density of the north and south aspects ($t=1.02, df=7, p \propto .05$). Avian nesting species diversity was measured for north and south aspects using the Shannon Index. The nesting

diversity represents the number of nests observed during the entire nesting season. For statistical purposes, all of the plantations with a north aspect were combined, as were those with a south aspect. The indices that were obtained from the two types of plantations were compared by using the t-test method according to Hutcheson (1970), in order to test for a significant difference in avian nesting diversity in relation to the aspect of the Christmas tree plantation.

The elevation of each plantation was obtained by using a topographic map of Watauga County, North Carolina. Avian nest density was calculated for plantations at three different elevations. This density represents all of the nests observed during the entire breeding season. Five plantations were located in the Foscoe area at 3000 feet, three were in the Boone area at 3400 feet, and one was in the Howard's Creek area at 4200 feet. A comparison was made to determine if the avian nest densities in the different elevations occurred by chance alone (One way ANOVA, df=1,8). A linear regression analysis was performed (for unequal sample sizes), to determine the possibility of a relation between elevation of the plantation and the avian nest density.

CHAPTER IV

EXPERIMENTAL RESULTS

Avian activity began to increase in early May within the Christmas tree plantations and the first nests of the season were built. Four bird species accounted for eighty-seven percent of the total number of bird nests built in Christmas tree plantations. Almost one-half or forty-seven percent of the total number of nests were built by Song Sparrows (Table 1).

When the frequency of nesting birds by species is compared, it is clear that Song Sparrows were the most common birds nesting in the nine Christmas tree plantations (Table 2). The Song Sparrow was found nesting in two-thirds of the plantations studied. Field Sparrows and Chipping Sparrows were less common in the plantations with both birds nesting in one-third of the nine plantations. Three less frequent nesters included the Rufous-Sided Towhee, Northern Cardinal, and Brown Thrasher.

No difference was observed in terms of the number of nests built in each of the two species, with seventeen nests built in Fraser Fir, and seventeen in White Pine (Table 3). However, if the nesting density is considered, a difference is evident. Comparisons of

Table 1. Percent Of Nesting Birds By Species

Avian Species	Percent Of Nesting Birds
Song Sparrow *Melospiza melodia*	47%
Field Sparrow *Spizella pusilla*	14%
American Robin *Turdus migratorius*	14%
Chipping Sparrow *Spizella passerina*	12%
Rufous-Sided Towhee *Pipilo erythrophthalmus*	5%
Northern Cardinal *Cardinalis cardinalis*	2%
Brown Thrasher *Toxostoma rufum*	2%

Table 2. Frequency Of Nesting Birds By Species

Avian Species	Nesting Frequency
Song Sparrow	66.6%
Field Sparrow	33.3%
Chipping Sparrow	33.3%
American Robin	22.2%
Rufous-Sided Towhee	11.1%
Northern Cardinal	11.1%
Brown Thrasher	11.1%

Table 3. Nest Density In Christmas Trees

Tree Species	Area	Number of Nests	Nest+ Density
Fraser Fir	.089ha	17	18.9/ha ∓
White Pine	.600ha	17	28.0/ha

+Nest Density was calculated as the total number of nests in a tree species during the entire nesting season per hectare.

∓ns ($t=1.40$, $df=9$, $p > .05$)

the 18.9 nests per hectare in Fraser Fir plantations, and the 28 nests per hectare in White Pine, revealed that this difference in nesting densities was not significant ($t=1.41, df=9, \alpha=.05$). Some bird species showed a tree preference, while some birds did not prefer one tree species over the other in selecting a nesting site. The American Robin built nests only in Fraser Fir trees. The Rufous-Sided Towhee, Brown Thrasher, and Northern Cardinal only built nests in White Pine. Birds showing no particular preference between the two species of trees include Song Sparrow, Field Sparrow, and Chipping Sparrow (all $p<.05$). These probabilities were calculated using a two-tailed binomial (Table 4). Certain bird species do show a preference when selecting a tree species for a nesting site, however, there is no significant difference in nesting density.

Birds do not show a preference for the taller or shorter Christmas trees in a plantation when selecting a tree for a nesting site. Ten of the trees chosen as nesting sites were two standard deviations above the mean tree height of the plantation; seven trees were of average height, and seventeen were two standard deviations below the mean tree height. Some individual bird species prefer the taller or shorter trees in a

Table 4. Nesting Preference In Christmas Trees.

Avian Species	Fraser Fir	White Pine
Song Sparrow	5(31) + ∓	11(69)
Chipping Sparrow	3(75)	1(25)
Field Sparrow	4(80)	1(20)
American Robin	5(100)	-----
Rufous-Sided Towhee	-----	2(100)
Brown Thrasher	-----	1(100)
Northern Cardinal	-----	1(100)

+ Percentages of the total nests for a species are in parentheses.

∓ ns ($p > .05$)

plantation for nesting sites (Table 5). The data indicate that in every case, the Field Sparrow chose a tree that was two standard deviations below the mean tree height of the plantation. In contrast, the American Robin chose trees that were two standard deviations above the mean tree height eighty percent of the time. The Song Sparrow, when selecting a nesting site in White Pine, preferred trees of average height up to two standard deviations above the mean tree height. However, they show no height preference when selecting among Fraser Fir trees. The Chipping Sparrow showed no significant tree height among Fraser Fir or White Pine. The Rufous-Sided Towhee prefers taller trees when nesting in White Pine. The Brown Thrasher chose average tree height, and the Northern Cardinal selected a taller tree that was two standard deviations above the mean tree height. While every group of tree heights was used by birds in selecting nesting sites, individual species may choose trees of a certain height for a nest site and avoid other Christmas trees.

Because of the artificial nature of the Christmas tree plantation, it was hypothesized that nest height selection might be different than nest heights of the

Table 5. Tree Height Selection By Nesting Birds

Avian Species (n)	Above 2SD	Average Height	Below 2SD
Song Sparrow (16)	2	4	10
Fraser Fir (5)	2	0	3
White Pine (11)	0	4	7
Chipping Sparrow (4)	2	0	2
Fraser Fir (3)	2	0	1
White Pine (1)	0	0	1
Field Sparrow (5)	0	0	5
Fraser Fir (4)	0	0	4
White Pine (1)	0	0	1
Rufous-Sided Towhee(2)	1	1	0
American Robin (5)	4	1	0
Brown Thrasher (1)	0	1	0
Northern Cardinal (1)	1	0	0
	10	7	17

same species of birds in a more natural habitat. For each bird species found nesting in the Christmas tree plantation, Table 6 shows the range of nest heights and also the preferred nest heights for more natural areas that have been recorded in the literature. From a comparison between the preferred nest heights that have been recorded in the literature and the nest heights found in this study, it is clear that the Christmas tree habitat had no effect on the nest height selection of these birds. The range of nest heights in the Christmas tree plantations fall within the range that was measured for birds of the same species in different habitats.

Avian nest diversity was calculated for the Christmas tree plantations over the entire nesting season using the Shannon Index (Shannon and Weaver, 1949). A nesting species diversity value of H' =1.53 was found for all of the Christmas tree plantations combined. A value of H' =1.36 was calculated for Fraser Fir plantations, and a value of H' =1.20 was found for White Pine. These last two indices where nest diversity was examined on the basis of tree species, are lower than the nesting species diversity of all plantations combined. While Fraser Fir had a

Table 6. Nest Height Selection

Avian Species	Nest Height(m)	Source
American Robin	0.50-1.06	Present Study
	1.53-9.15	Chapman (1932)
	0.61-9.15	Preston & Norris (1947)
	3.66-7.03	Brackbill (1950)
	0.63-2.15	Messersmith (1963)
Song Sparrow	0.63-1.37	Present Study
	0.00-2.44	Preston & Norris (1947)
	0.91-1.83	Brackbill (1950)
	ground	Messersmith (1963)
	0.00-3.70	Harrison (1975)
Chipping Sparrow	0.20-1.34	Present Study
	1.09-3.52	Walkinshaw (1944)
	0.30-0.91	Preston & Norris (1947)
	0.87-3.19	Messersmith (1963)
	0.30-7.60	Harrison (1975)
Field Sparrow	0.10-0.61	Present Study
	0.05-1.20	Walkinshaw (1944)
	0.00-1.20	Harrison (1975)
	0.00-0.90	Evans (1978)
Brown Thrasher	1.57	Present Study
	0.00-2.44	Preston & Norris (1947)
	0.00-1.24	Messersmith (1963)
	0.00-4.30	Harrison (1975)
Rufous-Sided Towhee	1.27-1.54	Present Study
	0.30-1.21	Bent (1968)
	0.00-1.50	Harrison (1975)
Northern Cardinal	1.65	Present Study
	0.60-3.70	Pearson (1946)
	0.80-3.70	Laskey (1944)
	0.90-6.10	

fewer number of nesting species than White Pine, the diversity index was greater (Table 7). The indices determined for Fraser Fir and White Pine plantations were compared with a t-test according to Hutcheson (1970), and it was concluded that there was no significant difference between the two indices ($t=.638, df=16, \alpha=.05$). It is evident that plantation number one had a much greater diversity than the other plantations (Table 8). Three different plantations had a diversity index of zero, and the remaining ones had similar indices.

Data on the fate of each individual nest indicated that while both Fraser Fir and White Pine plantations had the same number of active nests, Fraser Fir had a much higher number of nests that were able to produce viable offspring (Table 9). Any bird that was able to leave the nest was assumed to be viable. Fraser Fir had eighty-one percent of the nests to produce fledglings, and White Pine had only forty-seven percent of the nests to produce fledglings. The actual number of viable offspring varied in each tree species. Birds in Fraser Fir plantations produced forty-three fledglings and those in White Pine produced thirty-one. Nests whose fate were unknown were not included in any

Table 7. Nest Diversity In Christmas Tree Plantations

Plantation	Shannon Diversity Index H'
Fraser Fir	H' = 1.36[+]
White Pine	H' = 1.20

[+]ns ($t = .638$, $df = 16$, $p > .05$)

Table 8. Plantation Diversity Indices

Plantation	Tree Species	Diversity Index	Area
1	Fraser Fir	H' =1.055	.42ha
2	White Pine	H' =0.735	.27ha
3	White Pine	H' =0.635	.12ha
4	White Pine	H' =0.635	.06ha
5	White Pine	H' =0.000	.11ha
6	Fraser Fir	H' =0.635	.13ha
7	Fraser Fir	H' =0.000	.19ha
8	White Pine	H' =0.000	.07ha
9	Fraser Fir	H' =0.635	.16ha

Table 9. Avian Nesting Success In Christmas Trees

	Fraser Fir	White Pine	Statistical Significance
Number of eggs	51	54	$p > .05$
p(nest) surviving[a]	.81	.47	$p > .05$
p(individual) surviving[b]	.84[c]	.57	$p < .05$

[a] % successful nests

[b] the probability of an individual bird surviving from egg the fledgling

[c] 95% confidence interval of percentages

calculation. Several bird pairs nesting in White Pine produced a larger number of birds per nest than members of the same species nesting in Fraser Fir. The mean number of birds per successful nest in Fraser Fir was 3.3, while that in White Pine was 3.8. This was not a significant difference. The probability of a bird nest surviving or producing at least one fledgling in a Fraser Fir plantation was 0.81, and in White Pine was 0.47. A comparison was made of the avian nest survival probabilities using a 95% confidence interval of percentages. The probabilities of a nest surviving were determined to be not significantly different between the two tree species. The probability of an individual bird surviving from egg to fledgling in Fraser Fir and White Pine plantations was 0.84 and 0.57 respectively. A 95% confidence interval of percentages indicated that the probability of an individual bird surviving from egg to fledgling is significantly different between the two tree species.

Since aspect may be ecologically important to many organisms, avian nesting densities were measured for Christmas tree plantations of north and south aspects. Temperature is important for incubating birds, and temperature varies slightly between aspects

during different times of the day. So aspect may be a determining factor of where a bird nests. Three bird species, Brown Thrasher, Northern Cardinal, and Rufous-Sided Towhee only nested in a plantation with a south aspect. From these three species there were only a total of four nests. These nests may be accidental since there was only one nest recorded for two of these species. The total area of plantations with a north aspect was 0.741 ha. and the avian nesting density was 18.89 birds per hectare. The plantations with a south aspect had an area of 0.628 ha. and an avian nesting density of 23.8 birds per hectare. Nesting density was determined from the number of nests built in an area for the entire nesting season. North aspect plantations were composed entirely of Fraser Fir trees, while those with a south aspect include White Pine and some Fraser Fir plantations. Fourteen nests were built in plantations with a north aspect, and fifteen nests were built in those with a south aspect. A comparison showed that there was no significant difference between the density of 18.89 nests per hectare in plantations with a north aspect, and the density of 23.8 nests per hectare in those with a south aspect ($t=1.02, df=7, \alpha=.05$) (Table 10). The aspect of the plantation alone has little influence on avian nest densities.

Table 10. Aspect Of Plantation and Avian Nest Density

Aspect	Tree Species	Area	Nest + Density
North	Fraser Fir	.740ha	18.9/ha ∓
South	Both Species	.628ha	23.8/ha

+ Nest density was calculated as the number of nests built in a tree species during the entire nesting season per hectare.

∓ ns ($t=1.02$, $df=7$, $p > .05$)

Nest species diversity was examined in relation to the aspect of the plantation. The nest species diversity, calculated by the Shannon Index, represents all of the nests observed in the plantation over the entire nesting season. For plantations with a north aspect, a Shannon Index of H'=1.33 was obtained, and for south aspect plantations the index was H'=1.47. It was determined from a comparison, (described by Hutcheson, 1970), that the two indices were not significantly different ($t=.219, df=20, \alpha=.05$).

Avian nest density was analyzed in relation to elevation. The nine Christmas tree plantations were grouped into areas of three elevations (for statistical purposes) with Foscoe at 3000 feet, Boone area at 3400 feet, and Howard's Creek area at 4200 feet. While White Pine grows naturally at these elevations, Fraser Fir usually is found at slightly higher elevations. Both of these trees occur together at slightly higher elevations. Because both tree species were planted and maintained artificially in Watauga County, it was thought that avian nest density might vary according to the elevation of the plantation. It was determined that a linear regression was not present between the nest density and the elevation of the Christmas tree

plantation ($F=.698, \alpha=.05$). Elevation alone was not the main determining factor causing differences in avian nesting densities in the Christmas tree plantations.

CHAPTER V

DISCUSSION

This study provides some interesting facts about avian nesting behavior in Christmas tree plantations. Five of the seven species of birds found nesting in this study belong to the same family (Fringillidae). The fringillids have been considered by ornithologists to be among the most advanced birds in the world. The two species not members of the family Fringillidae were the American Robin (Turdidae), and Brown Thrasher (Mimidae).

The Song Sparrow had the greatest nesting frequency and the highest number of nests. In his study of a Red Pine plantation, Messersmith (1963) found nests of Song Sparrow, Chipping Sparrow, Rufous-Sided Towhee, American Robin, Brown Thrasher, and some others not found in this study. The size of the Red Pine trees varied from one meter to five meters in height. Although this was an artificially constructed plantation, the trees were not trimmed, and undergrowth was not controlled. The average tree height used for nesting in his study was three to four meters. This is much larger than the 1.9 meter average height of the Christmas trees used in this study.

In his study of Scotch Pine Christmas trees in Minnesota, Buech (1982) found nests of Chipping Sparrow, Field Sparrow, American Robin, Brown Thrasher, and two other species not found in this study. The average tree height of the Scotch Pine Christmas trees was 1.4 meters. This is approximately the same as in this study for both Fraser Fir and White Pine.

Buech (1982) had a density of five nests per hectare in the Scotch Pine Christmas trees. Messersmith (1963) had a density of nine nests per hectare in Michigan. These densities are much lower than the 18.9 nests per hectare in Fraser Fir fields and 28 nests per hectare in White Pine plantations. One possible explanation for such large differences may be the length of the breeding season. The other two studies were conducted in northern areas of the United States where many birds are only able to raise one group of young before the nesting season is over. However, it is possible for birds in southern areas to build two nests and raise two groups of young in a single season. The density was calculated as the number of nests in an area during the entire nesting season. Therefore, it would be expected that areas with a longer nesting season would produce more than one group of nestlings.

Another possible explanation for the different densities may be an edge effect (Lay, 1938). The Scotch Pine Christmas trees were all located in one single plantation that was 14.6 hectares in area. Also, the Red Pine trees were all in one single plantation that was 11.3 hectares in area. In this study, the area was .9 hectares for Fraser Fir, and .6 for White Pine. There was a total of nine plantations and therefore, much more edge present than in the large plantations. One other possible explanation for these differences might lie in the search method. Buech (1982) reports that he used some assistants because the plantation was too large.

While some other birds were observed feeding in the Christmas tree plantations during nest searches, the number was so minimal that they were not included in the Shannon Index. The nest diversity index can be compared to indices obtained elsewhere. The plantations in this study had a Shannon Index value of H'=1.53 for nesting species. This is higher than the H'=1.27 found by Webb *et. al.* (1977) of bird species diversity in a northern hardwood forest in the Adirondack Mountains of New York. Roland Roth (1976) reports values of H'=2.80 for a Delaware forest, H'=2.10 for an area of

shrubs in Illinois, and H'=2.00 in a Texas grassland. These values are avian species diversity indices in different geographic areas using the Shannon Index. While a significance test cannot be done because no variance estimates were provided by these authors, a nominal examination is possible. The nesting diversity of the Christmas tree plantations is somewhat lower than would be expected with a comparison of these other areas. However, because of the artificial properties of the plantation, such as uniform tree height and spacing, and reduced undergrowth, it may be unsuitable for many avian species. If the avian species diversity had been measured for the surrounding habitats, a value comparable to the value for the Delaware forest (H'=2.80) probably would have been found.

Before this study began, it was hypothesized that White Pine would be the tree species most preferred by birds for nesting, because it grows in the area of the plantations naturally. Fraser Fir grows well in the plantations, but is not naturally occurring. Some birds did show a preference between the two tree species. While statistically there is no difference, the Song Sparrow built the majority of its nests in White Pine trees. While the American Robin built no nests in

White Pine during the course of this study, it evidently will nest there since an old nest from previous years was discovered. Because the areas of the plantations varied, the nesting density was examined. As already mentioned, the nesting density of Fraser Fir was 18.9 nests per hectare, and in White Pine was 28 nests per hectare. One possible explanation for the differences in nest density may be the thickness of the tree. White Pine Christmas trees are much thicker after trimming than are Fraser Fir. One is able to see through a Fraser Fir tree because the needles are smaller, and do not grow in a group bound by a sheath. Instead, each needle occurs singularly on the twig. The branches are slightly closer together on young White Pine trees than on young Fraser Fir. The physical characteristics of the White Pine may provide an actual isolation from other birds, predators, and human disturbances which were usually near the plantations.

It has been shown that birds did not choose mostly taller or shorter trees in a plantation for nesting sites, with the exception of the Field Sparrow and American Robin. In most plantations, the variance from the mean tree height was very small because the trees

were usually planted at the same time, and were subject to the same type of trimming. However, the Field Sparrow chose trees that were significantly shorter than the average for a nesting site. These birds are usually found singing and nesting in open fields. The average size trees in the plantation may have been unsuitable for nesting because they were too tall. In contrast, the American Robin commonly nests in trees more than two meters tall (Preston and Norris, 1947). They selected the taller trees in the plantation, with four out of five being in trees that were two standard deviations above the mean tree height. The fifth nest was in a tree that was borderline on being tall. Average and short trees may have been unsuitable for nesting. The Rufous-Sided Towhee and Northern Cardinal, both of which usually nest in trees approximately four to six meters tall (Preston and Norris, 1947), chose taller trees in which to build their nests. There were similar results when nest height selection was examined. Birds that characteristically nest low or high, maintained that height in Christmas tree plantations. Therefore, the Christmas tree plantation habitat has no effect on the nest height selection of birds.

When avian reproductive success was examined, it was shown that an individual has a significantly greater chance of surviving from egg to fledgling in Fraser Fir fields than in White Pine. One explanation may lie in the physical characteristics of the trees themselves. The White Pine Christmas trees are thicker after trimming than Fraser Fir, and while a bird is well hidden inside a nest, a predator may also be well hidden, and is therefore able to get the eggs or young. Observations point to such predators as snakes, mice, and cats in several of the White Pine plantations. No predators were observed in any Fraser Fir field, and the unsuccessful nests were attributed to destructive winds, or abandonment by the parents. A predator would be more successful preying in a tree species where the avian nest density was 28 nests per hectare (White Pine), than in a tree species where the avian nest density was 18.9 nest per hectare (Fraser Fir). If the probability of a nest surviving and the probability of an individual bird surviving are compared within Fraser Fir and White Pine plantations (.81 and .84, .47 and .57 respectively), it can be said that an individual bird usually survives along with its siblings: several nestlings will survive.

Aspect alone did not affect avian nest density or diversity. It is possible that a combination of factors may be responsible since three bird species (Rufous-Sided Towhee, Brown Thrasher, and Northern Cardinal) nested in plantations of south aspect, in the Foscoe area, and in White Pine trees.

There was no relationship between the elevation of the plantation and the nest density. The nesting season began earlier (May 4) in Foscoe at 3000 feet elevation, and later at the Howard's Creek plantation (May 31) at 4200 feet elevation. One of the original hypotheses was that since the nesting season was shorter at the higher elevation, there would be less nesting by birds. While the nest density was lower in Boone at 3400 feet elevation than at Foscoe, it was also lower than the nest density at the Howard's Creek plantation. One of the reasons for the low density in Boone was the inclusion of a large Fraser Fir plantation where the average tree height was only .9 meters. Consequently, only one bird chose to nest there.

Christmas tree plantations are artificially constructed with many unusual features, such as a single tree species composition (monoculture), regular spacing, relatively uniform tree height, and reduced

undergrowth. In conclusion, several bird species are able to nest in Christmas tree plantations, in relatively large numbers. Because of the horizontal homogeneity and the lack of vertical stratification, only a few bird species are able to partition the Christmas tree habitat. With an increase in Christmas tree farming in Watauga County and surrounding areas, this suggests that more bird species must nest in Christmas tree plantations or be forced to other areas with more suitable habitats.

LITERATURE CITED

Allaire, P.N., and C.D. Fisher. 1975. Feeding ecology of three resident sympatric sparrows in eastern Texas. AUK 92(2) 260-269.

Beer, J.R., L.D. Franzel, and N. Hansen. 1956. Minimum space requirements of some nesting passerine birds. Wilson Bulletin 68: 200-209.

Bent, A.C. 1968. Life histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows, and allies. U.S. National Museum Bulletin 237: 1-15, 562-680, 1166-1181, 1217-1233.

Best, L.B. 1978. Field Sparrow reproductive success and nesting ecology. AUK 95(2) 9-22.

Brackbill, H. 1947. Choice of nest site in the American Robin. Wilson Bulletin 59: 116.

Buech, R.R. 1982. Nesting ecology and Cowbird parasitism of Clay-Colored, Chipping, and Field Sparrows in a Christmas tree plantation. Journal of Field Ornithology 53(4) 363-369.

Chapman, F.M. 1932. Handbook of birds of eastern North America. D. Appleton and Co., New York.

Collias, N.E., and E.C. Collias. 1984. Nest building and bird behavior. Princeton University Press, Princeton, New Jersey.

Evans, E.W. 1978. Nesting responses of Field Sparrows to plant succession on a Michigan oldfield. Condor 80: 34-40.

Ewert, D. 1982. Birds in isolated bogs in central Michigan. American Midland Naturalist 108: 41-50.

Harrison, H.H. 1975. A field guide to birds' nests. Houghton Mifflin Co., Boston, Massachusetts.

Hutcheson, K. 1970. A test for comparing diversities based on the Shannon formula. Journal of Theoretical Biology 29: 151-154.

Karr, J.R., and R.R. Roth. 1971. Vegetation structure and avian diversity in several new world areas. American Naturalist 105: 423-435.

Laskey, A.R. 1944. A study of the Cardinal in Tennessee. Wilson Bulletin 56: 27-43.

Laudenslayer, W.R., and R. P. Balda. 1976. Breeding bird use of a Pinyon-Juniper-Ponderosa Pine ecotone. AUK 93(3) 571-583.

Lay, D.W. 1938. How valuable are woodland clearings to birdlife? Wilson Bulletin 50: 254-256.

MacArthur, R.H. 1964. Environmental factors affecting bird species diversity. American Naturalist 98: 387-397.

Messersmith, D.H. 1963. Birds in a Red Pine plantation. Wilson Bulletin 74: 235-243.

Morrison, M.L., and E. C. Meslow. 1983. Bird community structure on early growth clearcuts in western Oregon. American Midland Naturalist 110: 129-137.

Morse, D.H. 1977. The occupation of small islands by passerine birds. Condor 79: 399-412.

Pearson, R.T. 1942. Birds of North Carolina. University of North Carolina Press, Chapel Hill, North Carolina.

Peet, R.K. 1975. Relative diversity indices. Ecology 56: 496-498.

Peterson, R.T. 1980. A field guide to the birds east of the Rockies. Houghton Mifflin Co., Boston, Massachusetts.

Preston, F.W. 1946. Nesting heights of birds building in shrubs. Ecology 27: 87-91.

_____ and R.T. Norris. 1947. Nest heights of breeding birds. Ecology 28: 241-273.

Radford, A., H.E. Ahles, and C.R. Bell. 1968. A manual of the vascular flora of the Carolinas. University of North Carolina Press, Chapel Hill, North Carolina.

Roth, R.R. 1976. Spatial heterogeneity and bird species diversity. Ecology 57: 773-782.

Rusterholz, K.A., and R.W. Howe. 1979. Species-area relations of birds on small islands in a Minnesota lake. Evolution 33: 468-477.

Savard, J.P.L., and J.B. Falls. 1981. Influence of habitat structure on the nesting height of birds in urban areas. Canadian Journal of Zoology 59: 924-932.

Schoener, T.W. 1968. Sizes of feeding territories among birds. Ecology 49: 123-141.

Shannon, E.C., and W. Weaver. 1949. The mathematical theory of communications. University of Illinois Press, Urbana, Illinois.

Snyder, D.P. 1950. Bird communities in the coniferous forest biome. Condor 52: 17-27.

Sokal, R.R., and F. J. Rohlf. 1973. Introduction to biostatistics. W.H. Freeman and Co., San Francisco, California.

Stauffer, D.G., and L.B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. Journal of Wildlife Management 44: 1-15.

Stewart, R.C., and J. W. Aldrich. 1949. Breeding bird populations in the spruce region of the central Appalachians. Ecology 30: 75-82.

Tramer, E.J. 1969. Bird species diversity: components of Shannon's formula. Ecology 50: 927-930.

Walkinshaw, L.H. 1936. Notes on the Field Sparrow in Michigan. Wilson Bulletin 48: 94-101.

_____. 1944. The Eastern Chipping Sparrow in Michigan. Wilson Bulletin 56: 193-205.

Webb, W.C., D.F. Behrend, and B. Saisorn. 1977. Effect of logging on songbird populations in a northern hardwood forest. Wildlife Monograms No. 55: 6-34.

Whitcomb, R.F. 1977. Island biogeography and "habitat islands" of the eastern forest. American Birds 31: 3-5.

Willson, M.F. 1974. Avian community organization and habitat structure. Ecology 55: 1017-1029.

Yahner, R.H. 1982. Avian nest densities and nest-site selection in farmstead shelterbelts. Wilson Bulletin 94: 156-175.

_____. 1984. Site related nesting success of Mourning Doves and American Robins in shelterbelts. Wilson Bulletin 95: 573-580.

APPENDIX A

Birds Found In Christmas Tree Plantations

American Goldfinch	*Spinus tristis* (Linnaeus)
Indigo Bunting	*Passerina cyanea* Linnaeus
Common Flicker	*Colaptes auratus* (Linnaeus)
American Crow	*Corvus brachyrhynchus* Brehm
Common Grackle	*Quiscalus quiscula* Ridgway
Gray Catbird	*Dumatella carolinensis* (Linnaeus)
Eastern Phoebe	*Sayornis phoebe* (Latham)
Brown-Headed Cowbird	*Molothrus ater* Boddaert
House Sparrow	*Passer domesticus* Linnaeus
Chipping Sparrow	*Spizella passerina* Bechstein
Song Sparrow	*Melospiza melodia* Wilson
Field Sparrow	*Spizella pusilla* Wilson
Rufous-Sided Towhee	*Pipilo erythrophthalmus* Linnaeus
American Robin	*Turdus migratorius* Linnaeus
Brown Thrasher	*Toxostoma rufum* Linnaeus
Northern Cardinal	*Cardinalis cardinalis* Linnaeus

APPENDIX B

Description of Plantations

Plantation 1

a. tree species - Fraser Fir
b. area - 4200m^2
c. average tree height - 1.921m
d. aspect - northeast
e. elevation - approximately 3000 feet above sea level
f. location - 9 miles south of Boone, NC on highway 105 in Foscoe, NC - owned by Cecil Aldridge

Plantation 2

a. tree species - White Pine
b. area - 2365m^2
c. average tree height - 1.702m
d. aspect - south
e. elevation - approximately 3000 feet above sea level
f. location - 9.2 miles south of Boone, NC on highway 105 in Foscoe, NC - owned by Noah Church

Plantation 3

a. tree species - White Pine
b. area - 1250m^2
c. average tree height - 1.82m
d. aspect - southeast
e. elevation - approximately 3000 feet above elevation
f. location - 9.5 miles south of Boone, NC on highway 105 in Foscoe, NC - owned by Herbert Aldridge

Plantation 4

a. tree species - White Pine
b. area - 648m^2
c. average tree height - 1.77m
d. aspect - none (flat)
e. elevation - approximately 3000 feet above sea level
f. location - 9.5 miles south of Boone, NC on highway 105 in Foscoe, NC - owned by Herbert Aldridge

Plantation 5

a. tree species - White Pine
b. area - 1105m^2
c. average tree height - 1.96m
d. aspect - south
e. elevation - approximately 3000 feet above sea level
f. location - 9.5 miles south of Boone, NC on highway 105 in Foscoe, NC - owned by Herbert Aldridge

Plantation 6

a. tree species - Fraser Fir
b. area - 1353m^2
c. average tree height - 1.71m
d. aspect - north
e. elevation - approximately 3400 feet above sea level
f. location - 6 miles northeast of Boone, NC on Harrison Road - owned by Tony Grey

Plantation 7

a. tree species - Fraser Fir
b. area - 1856m^2
c. average tree height - 0.98m
d. aspect - north
e. elevation - approximately 3400 feet above sea level
f. location - 6 miles northeast of Boone, NC on Harrison Road - owned by Tony Grey

Plantation 8

a. tree species - White Pine
b. area - 696m^2
c. average tree height - 1.43m
d. aspect - east
e. elevation - approximately 3400 feet above sea level
f. location - 6 miles northeast of Boone, NC on Harrison Road - owned by Tony Grey

Plantation 9

a. tree species - Fraser Fir
b. area - 1560m^2
c. average tree height - 1.61m
d. aspect - southwest
e. elevation - approximately 4200 feet above sea level
f. location - 7 miles north of Boone, NC near Howard's Creek Road - owned by Ned Austin

APPENDIX C

Tree Height Selection

1. Fraser Fir

Avian Species	Nest Number +	Tree Height Selected
American Robin	6	Above 2SD
Song Sparrow	8	Below 2 SD
American Robin	9	Average
American Robin	10	Above 2 SD
Song Sparrow	11	Below 2 SD
Chipping Sparrow	12	Above 2 SD
Field Sparrow	13	Below 2 SD
Chipping Sparrow	14	Below 2 SD
American Robin	15	Above 2 SD
American Robin	20	Above 2 SD
Song Sparrow	22	Below 2 SD
Song Sparrow	23	Above 2 SD
Field Sparrow	24	Below 2 SD
Song Sparrow	28	Above 2 SD
Field Sparrow	29	Below 2 SD
Chipping Sparrow	30	Above 2 SD
Field Sparrow	32a	Below 2 SD

+ Each individual nest was assigned a number for proper identification.

2. White Pine

Avian Species	Nest Number	Tree Height Selection
Song Sparrow	1	Average
Song Sparrow	1a	Below 2 SD
Brown Thrasher	2	Average
Chipping Sparrow	3	Below 2 SD
Song Sparrow	4	Below 2 SD
Rufous-Sided Towhee	5	Above 2 SD
Song Sparrow	7	Below 2 SD
Song Sparrow	16	Below 2 SD
Song Sparrow	17	Average
Song Sparrow	18	Below 2 SD
Song Sparrow	19	Below 2 SD
Song Sparrow	21	Below 2 SD
Rufous-Sided Towhee	25	Average
Song Sparrow	26	Average
Field Sparrow	27	Below 2 SD
Song Sparrow	31	Average
Northern Cardinal	32	Above 2 SD

APPENDIX D

Avian Reproductive Success in Christmas Tree Plantations

1. Fraser Fir

Avian Species	Nest Number	Success-ful	No. of Fledglings	No. of Eggs
American Robin	6	yes	3	3
Song Sparrow	8	yes	4	4
American Robin	9	no	0	2
American Robin	10	no	0	2
Song Sparrow	11	yes	4	4
Chipping Sparrow	12	yes	3	3
Field Sparrow	13	yes	3	3
Chipping Sparrow	14	yes	4	4
American Robin	15	yes	3	4
American Robin	20	no	0	2
Song Sparrow	22	yes	2	3
Song Sparrow	23	yes	4	4
Field Sparrow	24	yes	3	3
Song Sparrow	28	yes	3	3
Field Sparrow	29	yes	3	3
Chipping Sparrow	30	yes	4	4
Field Sparrow	32a	unknown	?	?

Total fledglings produce = 43
Total eggs produced = 51
No. fledglings per successful nest = 3.3

2. White Pine

Avian Species	Nest Number	Successful	No. of Fledglings	No. of Eggs
Song Sparrow	1	yes	4	4
Song Sparrow	1a	no	0	2
Brown Thrasher	2	no	0	3
Chipping Sparrow	3	yes	4	4
Song Sparrow	4	yes	5	5
Rufous-Sided Towhee	5	no	0	2
Song Sparrow	7	no	0	4
Song Sparrow	16	no	0	4
Song Sparrow	17	yes	5	5
Song Sparrow	18	no	0	1
Song Sparrow	19	yes	5	5
Song Sparrow	21	yes	2	3
Rufous-Sided Towhee	25	no	0	1
Song Sparrow	26	yes	3	3
Field Sparrow	27	yes	3	3
Song Sparrow	31	no	0	2
Northern Cardinal	32	no	0	3

Total fledglings produced = 31
Total eggs produced = 54
No. fledglings per successful nest = 3.8

APPENDIX E

Avian Nesting Diversity for Plantations

Plantation 1 (Fraser Fir)

H' = 1.055
American Robin n = 4
Song Sparrow n = 4
Chipping Sparrow n = 2

Plantation 2 (White Pine)

H' = 0.736
Song Sparrow n = 6
Field Sparrow n = 1
Northern Cardinal n = 1

Plantation 3 (White Pine)

H' = 0.636
Song Sparrow n = 2
Brown Thrasher n = 1

Plantation 4 (White Pine)

H' = 0.636
Song Sparrow n = 2
Chipping Sparrow n = 1

Plantation 5 (White Pine)

H' = 0.00
Rufous-Sided Towhee n = 2

Plantation 6 (Fraser Fir)

H' = 0.636
Field Sparrow n = 2
Song Sparrow n = 1

Plantation 7 (Fraser Fir)

H' = 0.00
Chipping Sparrow n = 1

Plantation 8 (White Pine)

H' = 0.00
Song Sparrow n = 1

Plantation 9 (Fraser Fir)

H' = 0.636
Field Sparrow n = 2
American Robin n = 1

VITA

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