

ABSTRACT

BREWSTER, JEROME PAUL. Spatial and Temporal Variation in the Singing Rates of Two Forest Songbirds, the Ovenbird and the Black-throated Blue Warbler: Implications for Aural Counts of Songbirds. (Under the direction of Theodore R. Simons, Kenneth H. Pollock, and Jaime A. Collazo).

The most common method of surveying birds is the point count. There are two approaches to analyzing count data to produce species abundance estimates and monitor abundance changes through space and time. The first method uses count data as a direct index to bird abundance. Uncorrected index counts are currently the norm in ornithological research. The second method estimates probability of detection during each count so count statistics can be corrected for spatial and temporal variation. Probability of detection can be thought of as being composed of two components: an availability component and a detection given availability component. I designed an observational field study to examine the factors affecting variation in singing rates for two species of warblers over the breeding season, the breeding cycle, and in relation to territory density. I was also interested in determining the relative importance of the availability component of probability of detection during the detection process. I conducted field work in the French Broad Ranger District of Pisgah National Forest in the southern Appalachian Mountains of North Carolina. The Ovenbird and the Black-throated Blue Warbler were my study species. Work involved identifying individual males, tracking them, and recording samples of their singing behavior. To simplify rate recording, we developed a singing rate sampling program designed to be operated on a palm size computer (pda) that we could take into the field. We sampled at points during 2004, but moved sampling to plots in 2005. We searched for nests and monitored those

found to fledging or failure, collecting singing samples for males associated with each nest. We performed variable circular plot, time-of-detection point counts on a weekly basis from the center of each plot to produce estimates of species density in 2005. We also spot mapped each plot to produce secondary territory density estimates. I was able to calculate true availabilities for both species across a range of count durations using program "R". Analysis of data indicated that average singing rates for both species declined significantly over the course of the breeding season. Ovenbird availability declined throughout the season while Black-throated Blue Warbler availability remained fairly constant. My work has confirmed the importance of considering both availability and detection given availability in any auditory sampling protocol.

Two methods of detection are available to us during a count: eyesight and hearing. We rely almost exclusively on bird vocalizations, especially songs, for detecting and identifying species during counts in forested habitats. I designed an experiment to quantify the relative importance of visual versus aural detections of birds in forested habitats and conducted it on 15 May 2006 in Umstead State Park, near Raleigh, North Carolina. The vegetation structure in the park is similar to that found at the Pisgah National Forest field sites where I collected singing rate data. Three teams of three observers each performed simultaneous 3-minute variable circular plot point counts at points along a park trail. In each team, one team member was blinded to all visual input, one was deafened to all auditory input, and the last team member had no handicap. We randomized detection methods among team members at each point. Non-handicapped observers detected 79% of the total

number of birds detected at each point. Blinded observers detected 77%, and deafened observers detected only 3.5%. The auditory and visual detection processes are quite different from each other and can often compete for an observer's attention during a count. Attempting to use both simultaneously reduces the effectiveness of each, but by separating auditory counts from visual counts we reduce count complexity and improve observer effectiveness.

**SPATIAL AND TEMPORAL VARIATION IN THE SINGING RATES OF TWO
FOREST SONGBIRDS, THE OVENBIRD AND THE BLACK-THROATED BLUE
WARBLER: IMPLICATIONS FOR AURAL COUNTS OF SONGBIRDS.**

by
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A thesis submitted to the Graduate Faculty of
North Carolina State University
In partial fulfillment of the
Requirements for the degree of
Master of Science

ZOOLOGY

Raleigh, NC

2006

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BIOGRAPHY

I was born on December 31st, 1967 in Pittsburgh, Pennsylvania. I spent the first 18 years of my life, along with my two older sisters, living in a rural area east of Pittsburgh. At a young age, I spent a lot of my free time outside, and everything about the natural world fascinated me. With no formal guidance in this area, I just dabbled here and there whenever I came upon something that caught my interest like an ant hill, a hawk, or a snake. I could sit and watch ants going about their work for hours at a time. During high school, I developed an interest in growing flowers which led me to apply to the Horticulture Department of NC State in 1987. I switched to Botany and graduated with my BS in 1992. I worked odd jobs for many years while attempting to deal with clinical depression which had become a primary focus in my life. Bird watching became a passion of mine over those years, and when I had the opportunity to take an ornithology class in 2003, I jumped at it. I met many graduate students in that class, and revived a long dead notion of continuing my education. Over the following summer, I volunteered for two weeks on the project of a master's student, Will Boyd, who was working in the North Carolina Mountains on Ovenbirds. I decided to apply in the masters program. The day I came to meet with Ted and discuss options, I was informed that Will was going to drop out of the program. His abandoned project fell right into my lap as I entered the program in January of 2004. I have met and worked with wonderful people here at N.C. State. I have expanded the way in which I think about science and approach problem solving. I have grown personally and have thoroughly enjoyed my experience here.

ACKNOWLEDGMENTS

I first want to thank my committee members: Ken Pollock, Jaime Collazo, and Ted Simons for helping me expand my thinking and knowledge, and for guiding me through all parts of the graduate experience. Special thanks go to my advisor, Ted Simons, for the support he gave me and the patience he showed when faced with my various “issues” along the way. I don’t believe Ted ever turned me away when I dropped by his office with questions or concerns on any subject. I would also like to acknowledge the input of Kay Franzreb from the US National Forest Service which provided all funding for this project. Great thanks goes to my Pisgah field assistants: Amy Hudnor, Nathan Tarr, Randy Scheiner, Adam Efird, Jeff Davidson, and Drew Simpson. They all worked very hard and helped make my field experiences enjoyable and sometimes quite interesting. Others took the time out to participate in my forest songbird detection experiment. They are Becky Hylton, Mariamar Gutierrez, Norm Budnitz, Salina Kohut, Will Fields, Ted Simons, Nathan Tarr, and Ed Laurent. With their help the experiment turned out to be a great success. I couldn’t have done it without them. I am very grateful to Mat Alldredge, Krishna Pacifici, Shiloh Schulte, Nathan Tarr, Becky Hylton, and my sister Martha. All have helped me immeasurably in getting over one hurdle or another, with brain storming, and just showing wonderful friendship. Wendy Moore has been instrumental in the handling of all administrative issues along the way. Will Boyd took me on as a volunteer for his project, starting me down the path to graduate education. Finally I will mention my good friend Michele Pagnotta who has kept my nose pointed in the

right direction no matter what reservations I had or impossible situations I imagined myself to be in.

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Chapter 1

Introduction

One of the reasons we monitor bird populations is to track changes in populations over space and time. Monitoring is often motivated by concerns that populations are declining in response to human activities. Monitoring spatial and temporal changes in abundance can indicate which species are most threatened, identify the habitats they require, and help determine the effectiveness of management practices. Numerous groups are concerned with the population status of bird species. These organizations, including state and federal governments, public land management agencies, and private entities have instituted population studies in hopes of benefiting threatened species (Bart 2005). They spend millions of dollars annually performing hundreds of thousands of counts continent wide (Simons et al. in press). Conservation priorities are set, and habitat management decisions are made, based on analyses of data from these counts.

The most common method of counting birds is the point count (Ralph et al. 1995). Point counts are popular because of their relatively low cost, and because they are the most efficient method for covering large areas. They have become the cornerstone of most bird population studies (Rosenstock et al. 2002; Diefenbach et al. 2003). The North American Breeding Bird Survey (BBS) is based on point counts (Sauer et al. 2004) and it has been operating throughout North America since 1966. Observers detect birds during counts using visual and auditory cues. Auditory

detection of birds predominates on counts conducted in heavily vegetated environments (Faanes and Bystrak 1981; Scott et al. 1981; Dejong and Emlen 1985)

I conducted the majority of my field work in the French Broad Ranger District of Pisgah National Forest in the southern Appalachian Mountains of North Carolina (Fig. 1.1). My work continues a long line of avian ecology projects in this region, including individual and collaborative work by Farnsworth (1999, 2001, 2002); Lichstein (2002, 2002); Podolsky (2003); Shriner (2001); Simons (2000, 2006); and Weeks (2001). Cooperation among these researchers and management agencies has allowed for the development of an ecosystem level approach to forest song bird management in the area. The region is important because it contains the largest remaining area of primary forests in eastern North America, with over 5 million acres of protected land. It supports a rich avian diversity and is recognized as an internationally significant sanctuary of temperate forest biodiversity. I chose the Ovenbird (*Seiurus aurocapillus*) and the Black-throated Blue Warbler (*Dendroica caerulescens*) as my focal study species. Located at the southern end of the breeding range for these species, this region provides the longest breeding season available to both species. The longer breeding season increases opportunities for double brooding. Podolsky (2002) observed up to 30% double brooding for Ovenbirds in this area, a species previously thought to be single brooded. Black-throated Blue Warblers are a known double brooding species (Holmes 1994).

The U.S. Forest Service and the National Park Service conduct point counts throughout the southern Appalachians to monitor breeding bird populations. Nevertheless, considerable disagreement exists over how to interpret these counts.

Historically, biologists believed that raw count statistics provided an unbiased index of species abundance. This belief was based on an implicit assumption that the probability of detecting birds is constant over space and time. Although most count programs, including the BBS, continue to interpret count data in this way, the assumption is often not validated and usually not justified. An alternate viewpoint that the probability of detecting birds during counts varies continuously, and that raw count data must be corrected to account for this variation, is gaining wider acceptance (Burnham 1981; Nichols et al. 2000; Farnsworth et al. 2002; Pollock et al. 2002; Rosenstock et al. 2002; Thompson 2002; Alldredge 2004). In this model, true abundance (N_i) is estimated by dividing the count statistic (C_i) by the probability of detection (p_i) where i denotes a particular time or location.

$$\hat{N}_i = C_i / \hat{p}_i$$

Changes in count statistics over time may not be due to actual changes in bird abundance, but due to changing probability of detection. Thus, the probability of detection and species abundance are often confounded, and abundance estimates based on uncorrected count data are often biased. The need to understand the factors responsible for variations in probability of detection has been recognized by the ornithological community for many years. However, in practice, uncorrected counts are still the norm in ornithological research (Rosenstock et al. 2002; Thompson 2002). As we learn more about the complexity of the detection process and the factors affecting the probability of detection during counts, it is increasingly apparent that count indices provide inadequate measures of abundance.

We can think of the probability of detection (p) as being the product of two individual components, an availability component (p_a), and a detection given availability component (p_d) (Marsh and Sinclair 1989; Farnsworth et al. 2002; Alldredge 2004).

$$\hat{p} = \hat{p}_a \hat{p}_d$$

Substituting this into the model equation gives us

$$\hat{N}_i = C_i / \hat{p}_a \hat{p}_d$$

The availability component is the probability that a bird is available to be counted. Birds are available to be counted if they are visible to an observer or if they produce sounds an observer can detect. In highly vegetated environments, the majority of birds are detected by ear alone (Scott et al. 1981; Dejong and Emlen 1985), which usually means a bird must call or sing to be available for detection. A silent bird that remains hidden in dense vegetation throughout a count interval is never available to be detected and will not be counted. The second component, detection given availability, is the probability that a bird is detected given that it is available. Detection given availability is often less than one because observers frequently fail to detect birds every time they sing. Both components of probability of detection are important and both must be considered when estimating abundance from count data.

Many factors influence the probability of detecting birds during counts. They include time of year (Best 1981; Ralph 1981; Skirvin 1981), time of day (Shields 1977; Robbins 1981a; Skirvin 1981), weather conditions (Mayfield 1981; Robbins

1981b), species (Schieck 1997), habitat type (Diehl 1981; McShea and Rappole 1997), presence of an observer (McShea and Rappole 1997), observer skill or hearing ability differences (Emlen and Dejong 1981; 1992, Kepler and Scott 1981; Sauer et al. 1994; Kendall et al. 1996; Downes et al. 2003), background noise level (Simons et al. in press), pairing status (Krebs et al. 1980; Johnson 1983; Cuthill and Hindmarsh 1985; Gibbs and Wenny 1993), and stage of nesting cycle (Wilson and Bart 1985). A change in any one of these conditions will influence the probability of detection on a particular count. Let us consider observer and habitat type differences to illustrate these issues. A veteran count observer retires after 25 years of collecting count data on a particular project route. Over the 25 years he participated, his high frequency hearing ability is likely to have decreased. A recent survey found that 45% of observers retiring from the Canadian Breeding Bird Survey cited “hearing loss” as their primary reason for leaving (Downes et al. 2003). With his ability to detect birdsong in this range having decreased over time, a bias was introduced into all the data he collected. A new observer assigned to the same route may have better hearing ability, but may not be as skilled in birdsong recognition. He is likely to produce different count statistics than the previous observer for these reasons. Vegetation structure at each point along the route will also change with time. An open field in year one may change to a young forest after 25 years of natural succession. Attenuation of sound increases as the vegetation in an area grows more dense (Richards 1981). Consequently, the maximum radius of bird detection at such a point is lowered over time, producing a decline in the total area

sampled. These are just a few examples that demonstrate how changing count statistics may be completely unrelated to species abundance.

Some efforts have been made to reduce variability during counts and to find ways to correct data for variation in probability of detection. Standardization of count procedures and conditions can reduce observed variability during counts.

Standardized protocols have been developed for this reason (Ralph et al. 1995).

Most counts are performed during the breeding season. Males are the most conspicuous to observers at this time because they sing, and their movements are restricted to defined areas as they aggressively defend breeding territories. Most counts are performed between the hours of sunrise and 10 AM, and are not performed if weather conditions include high winds or rain. Many believe that this level of standardization is enough to reduce variability in the probability of detection to levels at which it can be ignored. Others believe that the probability of detection is influenced by so many factors that no level of standardization will reduce variation to the point that it can be overlooked (Burnham 1981; Nichols et al. 2000; Thompson 2002; Novell et al. 2003).

Several approaches to adjust counts for variations in probability of detection have been developed. These methods include distance sampling (Reynolds et al. 1980, Buckland et al. 1993, 2001), double sampling (Bart and Earnst 2002), multiple observer approaches (Nichols et al. 2000; Alldredge et al. 2006), repeated counts (Royle and Nichols 2003; Royle 2004), and time of detection methods (Farnsworth et al. 2002; Alldredge et al. in press). The distance and multiple observer methods model the detection given availability component of probability of detection only.

Implicit in the use of these methods, is the assumption that all birds are available during the count. These methods do not account for variations in the availability component of detection probability. Time of detection and repeated counts methods model both components of detection probability. However, the individual components cannot be separated. None of these alternative methods have been validated. Knowledge of true species abundance is necessary to validate any method, and this is knowledge that no count observer has possessed, until just recently.

Researchers at North Carolina State University have developed a system to simulate auditory counts in the field (Simons et al. in press). They are using this system to isolate and quantify the effects of individual factors influencing the probability of detection during counts. With this system, count results can be compared directly to known species abundance in the count area. Experiments performed with the system have already demonstrated that the ability of observers to estimate distances to singing birds is poor (Alldredge et al. in review). Poor distance estimation ability has negative implications for the use of distance sampling for adjusting auditory counts. One of the key assumptions of using distance sampling is accurate estimation of the distances to singing birds by observers. In other tests, Alldredge et al. (in press) confirmed that the probability of detection in counts is significantly influenced by factors including observer skill, species of bird, distance to a singing bird, count complexity, and singing rates. Further experiments examining the influence of factors such as habitat type are in progress or planned for the future. The system can also be used to validate the effectiveness of any point count

method. Validation of the distance, multiple observer, and time of detection methods is currently in progress.

Previous researchers have concluded that 81%(Scott et al. 1981) , 94% (Dejong and Emlen 1985), and up to 95% (Faanes and Bystrak 1981) of birds counted in highly vegetated environments are detected by ear alone. Clearly, we rely almost exclusively on bird vocalizations, especially songs, for detecting and identifying species during point counts in these habitats. Factors such as song volume, rate of delivery, and song duration presumably have important influences on detection probability. Birds that sing louder, more often, or have longer songs are more likely to be detected. Those that sing with less volume, less often, or have shorter songs are less likely to be detected. Most of the factors affecting the probability of detection during counts manifest their effects through influencing singing behavior and singing rates.

Male birds sing for two primary reasons; to attract mates (Eriksson and Wallin 1986; Johnson and Searcy 1996; Collins 2004) and to defend territory boundaries from intruding males (Krebs 1976; Falls 1988). If we remove one of these two reasons for singing, we might expect a reduction in song output. This is exactly what occurs in many species after a male pairs with a female. Many species show a several fold reduction in singing rate after pair formation (Sayre et al. 1980; Lein 1981; Johnson 1983; Hayes et al. 1986; Gibbs and Wenny 1993), potentially making unpaired males much easier to detect than paired males. If pairing rates vary from site to site, singing rates may provide a false impression of the breeding density of a species. Many species change singing rates as they move through the stages of the

nesting cycle (Lein 1981; Best and Petersen 1982; Wilson and Bart 1985). Birds sing less when it is raining or dark (Mayfield 1981; Robbins 1981a, 1981b), and overall singing rates decline over the course of the breeding season (Ralph 1981; Skirvin 1981). Species density has been shown to have a positive correlation with singing rates (McShea and Rappole 1997). Likewise, the intrusion of observers into bird territories has been shown to influence singing rates of several species (McShea and Rappole 1997). Singing behavior is influenced by a complex set of ever changing factors, making it central to the auditory detection process during counts.

Interpreting bird abundance estimates is further complicated by the relationship between species abundance and habitat quality (Van Horne 1983). We often view high species density at a site as an indication of high habitat quality. Van Horne, however, pointed out that there are situations in which the “density-habitat quality relationship is likely to be decoupled” (Vickery 1992; Moorman et al. 2002). A recent study of Indigo Buntings (*Passerina cyanea*) is informative (Weldon and Haddad 2005). Indigo Buntings are an edge nesting species, however, the greater the amount of edge habitat present at a site, the greater the risk of predation. Many bird predators focus their prey search efforts specifically on edge areas. The more edge that is present, the higher the concentration of predators. Weldon and Haddad (2005) demonstrated that when given a choice, dominant male buntings were attracted to areas with more extensive edge habitat when establishing breeding territories even when less extensive edge habitat was available. Nesting success for pairs found on the extensive edge habitat was much lower than for pairs found on

less extensive habitat due to predation. However, the fittest males continue to seek these areas, a so called ecological trap (Gates and Gysel 1978; Schlaepfer et al. 2002) for breeding. In this case, the density of singing birds is a poor measure of habitat quality. Van Horne proposes to define habitat quality as the product of not only species density, but mean individual survival probability, and mean expectation of future offspring. Nesting success provides a better indication of habitat quality than an estimate of species density alone. Studying nesting success can be time consuming and expensive, making it impractical for most large scale population studies. Singing rate, however, can indicate the pairing status of many species (Lein 1981; Johnson 1983; Hayes et al. 1986; Gibbs and Wenny 1993), and pairing status may indicate habitat quality. We would expect to find a greater percentage of paired males, which sing at lower rates, on high quality sites where nesting success is high. In contrast, we would expect to find a greater percentage of unpaired males, which sing at higher rates, on low quality sites where nesting success is low. Thus, an analysis of singing behavior, especially singing rates at any one site, may inform us of both the breeding status and the density of a species.

I designed my research with several objectives in mind. First, I wanted to measure the singing behavior and singing rates of two species of warblers and examine the factors influencing singing in these species during the breeding season. I also wanted to estimate the bias introduced into species abundance estimates caused by variations in singing behavior. Second, I wanted to measure how singing rate and behavior change for each species as the males move through the stages of the nesting cycle from territory initiation to fledging of young. I wanted to determine

if I could distinguish between paired males and unpaired males by measuring their singing rates. I also wanted to assess the relationship between species territory density and singing rates. I hoped to determine whether comparisons of site specific singing rates were useful as relative measures of habitat quality. Lastly, I was interested in determining the relative importance of the availability component of probability of detection to the detection process. A fourth objective arose after I determined that visual detections of birds in heavily vegetated habitats were nearly impossible. Therefore, I designed an experiment to quantify the relative importance of visual versus aural detections of birds in forested habitats.

I chose two species of warblers, the Ovenbird (Van Horn and Donovan 1994), and the Black-throated Blue Warbler (Holmes 1994) to study because these species nest at or near the ground level making nests easy to monitor. Field work lasted for approximately 11 weeks beginning at the end of April and finishing in the middle of July both study years. The majority of work involved identifying individual males of each species, tracking them, and recording samples of their singing behavior. In 2004, we detected males and collected singing rate samples at points along roads and trails. In 2005, I changed procedures, moving all sampling of singing males to six 250 m X 250 m square plots, each equivalent to 6.25 hectares of area. In 2004, we sampled for 15 minutes, but I increased the target sample length to 30 minutes in 2005, because I had come to believe that samples of shorter length were not long enough to capture the full range of singing variability being observed for either species. I alternated species sampled from week to week, producing five separate weeks of singing data for each species over the 10-week seasons. We searched for

nests (Martin and Geupel 1993) of both species and monitored those found to fledging or failure, collecting singing samples for males associated with each nest. We calculated Mayfield (1961, 1975) nesting success from the data. In 2005, we performed variable circular plot, (Reynolds et al. 1980), multiple-observer (Nichols et al. 2000; Alldredge et al. in press)/ time-of-detection (Farnsworth et al. 2002; Alldredge et al. in press) point counts (Ralph et al. 1995) on a weekly basis from the center of each plot to produce estimates of species density. We also spot mapped each plot to produce secondary density estimates. I compared observed singing rates to these abundance estimates to determine the relationship between territory density and singing rate. I also used singing rates to estimate the availability component of probability of detection during point counts. We know little about this component, and it is often ignored in analyses of point count data. Most researchers assume availability is 1.0 and, therefore, focus solely on estimates of detection given availability.

After completing the 2004 and 2005 work and concluding that visual detections in forests were extremely rare, I formed the last objective of my research. This objective was to determine the relative importance of visual detections during point counts performed in forest habitats. I designed a detectability experiment which we conducted on 15 May 2006 in Umstead State Park (35° 51.22' N 078° 44.58' W) near Raleigh, North Carolina. The vegetation structure in the park is similar to that found at the Pisgah National Forest field sites where I collected singing rate data. Three teams of three observers each performed simultaneous 3-minute variable circular plot point counts at 30 points along a trail in the park. At

each point, one team member was blinded by wearing a cap with a face mask, one was deafened by wearing ear plugs and headphones, and the last member was not handicapped in any way. We switched detection methods among observers using a predefined randomization scheme.

I test several hypotheses in this research:

1. I predict each species to exhibit a bimodal declining pattern of song production over the nesting season. The onset of breeding activity within each species is fairly synchronized at the beginning of May, and the highest singing rates generally occur during territory initiation before any pairing has taken place. If species double brood and are successful on their first nest attempt, I predict a secondary rise in singing rates during mid season when those males begin pairing for their second nesting attempt.
2. I predict high variability in daily singing rates due to the short term influence of factors such as daily weather patterns on singing behavior. My goal was to test the common assumption that restricting sampling to the peak of the breeding season is adequate to control for seasonal variation in singing rates.
3. I expect that singing rates of Ovenbirds in the Southern Appalachians will be similar to those reported by Lein (1981) in Massachusetts and New Hampshire. Lein's work showed the highest rates for unmated birds (2.3 songs/minute), decreased by over 50% during the courtship period to 1.1 songs/minute, then increased slightly during the incubation and nestling periods to 1.4 songs/minute, and finally decreased to their lowest levels

- during the fledging period to 0.45 songs/minute. I found no previous nest stage singing data to make predictions for Black-throated Blue Warblers.
4. I predict an increase in song output with increases in species territory density for both species as reported by McShea and Rappole (1997).
 5. I expect to demonstrate for both species that the availability component of probability of detection during counts is often < 1.0 as Gibbs and Wenny (1993) found for Ovenbirds in Missouri, illustrating the importance of accounting for availability in estimating probability of detection.
 6. Finally, I expect to demonstrate that only a small proportion of detections in heavily vegetated environments are made by eyesight alone, confirming the importance of aural detections in the overall detection process.

My thesis is comprised of three chapters beginning with this introduction. Chapter two describes the field work I performed on singing rates and singing behavior in Pisgah National Forest during the spring of 2004 and 2005. This work comprises the majority of field work I performed. Chapter three describes the detectability experiment I performed in Umstead State Park, near Raleigh, North Carolina in May of 2006.

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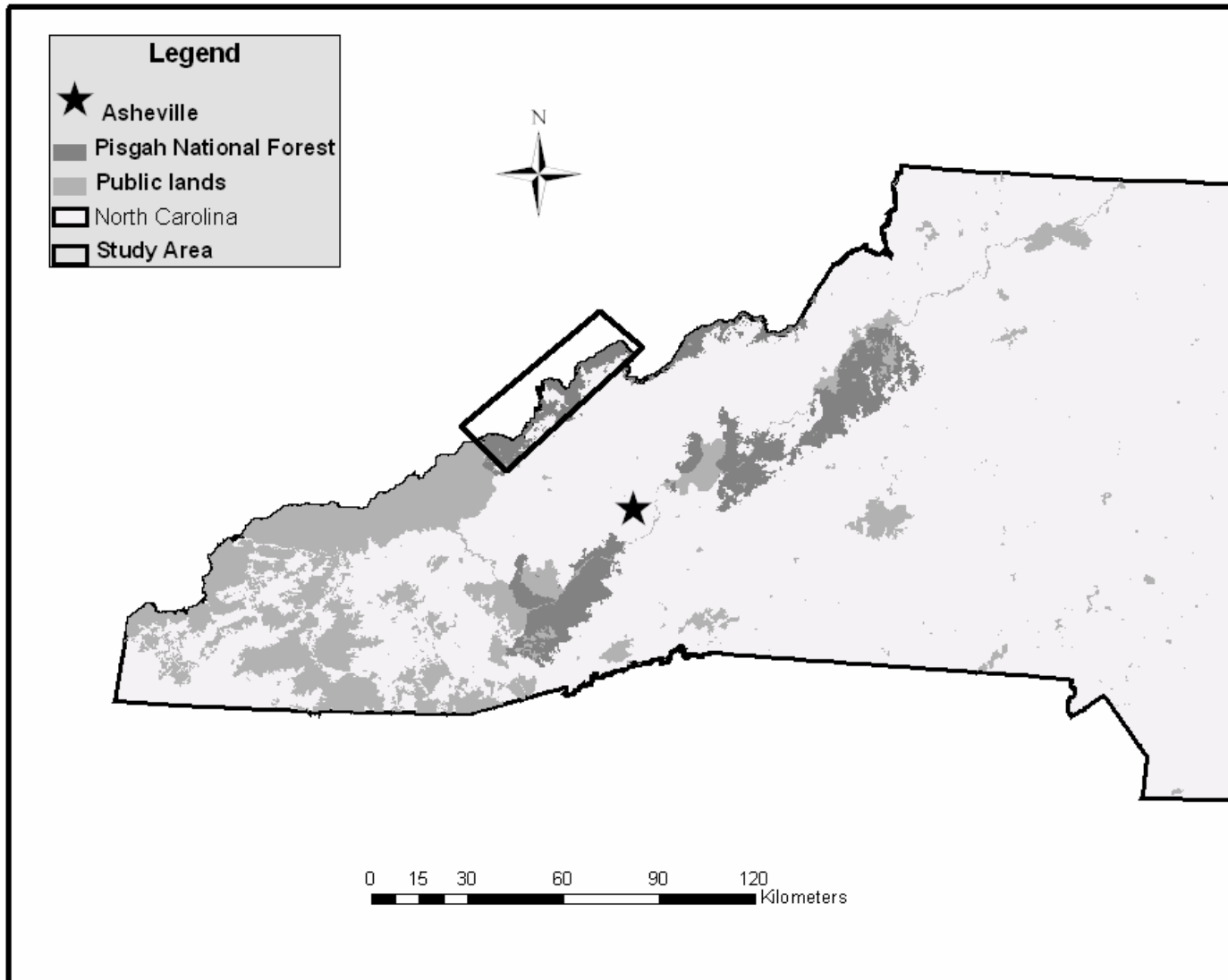


Figure 1.1 Location of Pisgah National Forest and the study area in western North Carolina

Chapter 2 Ovenbird and Black-throated Blue Warbler singing rate variation during the breeding season, the nesting cycle, and in relation to species density

Abstract

I examined spatial and temporal singing rate variation in Ovenbirds (*Seiurus aurocapillus*) and Black-throated Blue Warblers (*Dendroica caerulescens*) over the 2004 and 2005 breeding seasons in the French Broad Ranger District of Pisgah National Forest, North Carolina. I developed a new singing rate recording program that can run on hand held computers (pda's) that can be taken into the field. I collected 30 minute singing rate samples from numerous birds over the ten week study seasons. Both Ovenbirds and Black-throated Blue Warblers showed significant declines in singing rate over the season, over the nesting cycle, and across the six sampling plots used in 2005. I was able to calculate the availability component of probability of detection by randomly re-sampling my singing rate data to estimate the availability of both species over counts of one to ten minutes. Comparisons of singing rate with species density, estimated from spot maps and point counts, indicate a weak decline in singing with increasing species density. Both components of detection probability: availability and detection given availability vary significantly, making abundance estimation extremely difficult. Changing probability of detection is confounded with changes in species abundance. Considering raw count data as an index to species abundance is unwise. Detection probability must be accounted for to make inference concerning species abundance from count data.

Introduction

The most common method of surveying birds is the point count (Ralph et al. 1995). It has become the cornerstone of most bird population studies (Rosenstock et al. 2002; Diefenbach et al. 2003). During a point count, an observer attempts to identify and record all birds detected at a point during a fixed time interval. Auditory detections predominate on counts conducted in heavily vegetated environments (Faanes and Bystrack 1981; Scott et al. 1981; Dejong and Emlen 1985). Despite their widespread use, disagreement exists over the interpretation of raw point count data. Historically, biologists believed raw count statistics provided an unbiased index of species abundance. This belief was based on the implicit assumption that the probability of detecting birds is constant over space and time. This assumption is often not validated and usually not justified. An alternate viewpoint that the probability of detecting birds during counts varies continuously, and that raw count data must be corrected to account for this variation, is gaining wider acceptance (Burnham 1981; Nichols et al. 2000; Farnsworth et al. 2002; Pollock et al. 2002; Rosenstock et al. 2002; Thompson 2002; Alldredge 2004). This viewpoint acknowledges that the probability of detection and species abundance are often confounded, and abundance estimates based on uncorrected count data are often biased.

We can think of the probability of detection (p) as being the product of two individual components, an availability component (p_a), and a detectability component (p_d) (Marsh and Sinclair 1989; Farnsworth et al. 2002; Alldredge 2004). The availability component is the probability that a bird is available to be counted. Birds

are available to be counted if they are visible or if they produce sounds an observer can detect. In highly vegetated environments, this effect usually means that a bird must sing or call to be available for detection. The second component, detectability, is the probability that a bird is detected given that it is available. Detection given availability is often less than 1.0 because observers frequently fail to detect birds every time they sing or call. Both components of detection probability are important and both must be considered when estimating abundance from count data.

Many factors influence the probability of detecting birds during counts. They include time of year (Best 1981; Ralph 1981; Skirvin 1981), time of day (Shields 1977; Robbins 1981a; Skirvin 1981), weather conditions (Mayfield 1981; Robbins 1981b), species (Schieck 1997), habitat type (Diehl 1981; McShea and Rappole 1997), presence of an observer (McShea and Rappole 1997), observer skill or hearing ability differences (Emlen and Dejong 1981, 1992; Kepler and Scott 1981; Sauer et al. 1994, Kendall et al. 1996, Downes et al. 2003), background noise level (Simons et al. in press), pairing status (Krebs et al. 1980; Johnson 1983; Cuthill and Hindmarsh 1985; Gibbs and Wenny 1993), and stage of nesting cycle (Wilson and Bart 1985). Most of the factors affecting probability of detection during counts influence singing behavior and singing rates. We rely almost exclusively on bird vocalizations, especially songs, for detecting and identifying species during point counts. I wanted to examine the factors affecting variation in singing rates for two species of warblers over the breeding season, the breeding cycle, and in relation to territory density. I designed an observational field study to answer these questions by sampling the singing rates of both species over space and time.

Methods

Research was conducted on the French Broad Ranger District of Pisgah National Forest in Madison and Haywood Counties, North Carolina (Fig. 2.1). My study builds on two recent studies by Weeks (2001) and Lichstein (2002) funded by the U.S. Forest Service indicating high abundance of both species in this district. Field work was conducted at seven sites: White Oak Flats, Rich Mountain/Tanyard Gap, Garenflo Gap, Lemon Gap, Cherry Ridge, Cold Springs/Harmon Den Horse Camp, and Brown Gap. All sites are composed of mixed deciduous secondary growth forest at elevations between 805 and 1119 m. Habitats were described by Weeks (2001) and Lichstein (2002). Rich Mountain/Tanyard Gap is characterized by a xeric hardwood community dominated by a canopy mainly composed of *Quercus coccinia*, *Quercus prinus*, *Quercus alba*, and *Oxydendron arboreum*. The dominant shrub is *Kalmia latifolia*. Herbaceous vegetation is sparse. White Oak Flats, Garenflo Gap, Lemon Gap, Cherry Ridge, Cold Springs/Harmon Den Horse Camp, and Brown Gap are characterized as deciduous mesic hardwood forest. The term mesic hardwood includes Acidic Cove Hardwood and Rich Cove Hardwood forests as described by Shafale and Weakly (1990). The canopy species in descending order of importance include *Liriodendron tulipifera*, *Quercus rubra*, *Acer rubra*, *Betula lenta*, *Tsuga canadensis*, *Magnolia fraseri*, *Acer saccharum*, *Fagus grandifolia*, *Aesculus octandra*, *Tilia heterophylla*, and *Betula alleghaniensis*. On more acidic soils (Acidic Cove Hardwood), the mid-story zone includes *Oxydendron arboreum* and *Hamamelis virginiana* with the shrub layer dominated by

Rhododendron maximum and *Leucothoe axillaries*. On more circumneutral soils (Rich Cove Hardwood), *Prunus serotina*, and *Fraxinus americana* also appear in the mid-story, and a diverse herbaceous layer is present. The herbs include *Rubus sp.*, *Hydrangea arborea*, *Caulophyllum thalictroides*, *Cimicifuga racemosa*, *Laportea canadensis*, and *Astilbe biternata*. We performed work at all sites during the pilot season of 2004. I dropped the White Oak Flats, Rich Mountain/Tanyard Gap, Garenflo Gap and Cherry Ridge sites in 2005 due to relatively low numbers of nests being found and low singing rate sampling success at these sites the previous year.

We developed a singing rate sampling program designed to operate on a palm size computer (pda) that we could take into the field. The program includes a timer and an interface to record the start and end time of each song a bird produces. We used the HP iPAQ Pocket PC h1945 model pda enclosed in a waterproof case to run the "Call Rate Tracker" program (Figs. 2.2 and 2.3). The interface includes fields in which to record observer, species, call type, and the target sample length in seconds. The screen also displays eight stylus activated buttons: Start Experiment, Stop Experiment, Begin Call, End Call, Begin Song, End Song, View Results, and Save Results. An observer presses "Start Experiment" to start the program timer when they are ready to begin sampling. During sampling, the observer presses "Begin Song" every time a target bird begins a song and "End Song" when the song ends. Sampling ends when the observer presses "Stop Experiment" or the session timer runs out. The date and start and end times of each sample are automatically recorded by the program. The observer can save a sample by pressing "Save Results" and view it later by pressing "View Results". When a sample is saved, the

program creates a file name composed of the sample date, sample start time, observer identification, and location. The units held a charge for at least the four hours of use we required each day. Data were saved on SanDisk 256k flash memory cards. We downloaded all files from the pda's directory into an Excel spreadsheet on a laptop computer at the end of each day. We collected singing rate records for individual Ovenbirds and Black-throated Blue Warblers over approximately 10 weeks of the breeding season in both 2004 and 2005. We recorded one species a week, alternating weeks, to yield 5 weeks each of Ovenbird and Black-throated Blue Warbler samples. All samples were recorded between sunrise and 10AM on each sampling day. Data collected on rainy or windy days were not used in the analyses. Our protocol was consistent with the point count recommendations of Ralph et al. (1995).

We took great care to ensure the validity of each singing rate sample we collected. Birds chosen for sampling were visually identified and monitored for 10 to 15 minutes by the observer before they began to sample. An observer would learn the target male's song and familiarize himself with the target's overall movement patterns during this orientation period. Each Ovenbird sings a unique version of the "teacher" song (Lein 1981). An astute observer can quickly learn to distinguish one particular male from all other singers in the area. Black-throated Blue Warblers do not sing single songs like Ovenbirds, but observers can usually distinguish one male from others by noting song differences. Observers would also make note of neighboring singing males and their positions relative to the target male. Confusion of the target male with a neighboring male can occur if observers have not properly

oriented themselves. Target males move during sampling, and observers must carefully track their position. Observers began sampling a male only after positioning themselves to maximize visual contact with the target. Recording valid singing samples was very difficult, but by using these methods, we were able to collect many valid samples, although sometimes confusion could not be avoided. Observers who became even the least bit unsure of a target's identification were instructed to stop sampling and to truncate the sample at the point where they became uncertain of their target. An observer would spend up to 2 hours with an individual bird to collect a single valid sample. We often made numerous attempts at sampling individual birds without success. Observers were also instructed to document how they maintained target certainty in their notebooks. We would continue to sample as long as we could remain in contact with the target bird, or until the target sample length was reached. We collected continuous records of up to 1 hour in length when possible.

At the outset of this project, I believed a singing rate sample of 15 minutes in length would be adequate to provide a representative sample of species singing rates for Ovenbirds and Black-throated Blue Warblers. As we began to collect more lengthy samples, I realized that a sample of 15 minutes was often too short to capture the total range of singing behaviors. Some of our longer samples included inter-song intervals of up to 25 minutes in length. This prompted us to double the target sample length to at least 30 minutes. We attempted to ensure that all samples collected in 2005 were at least 30 minutes long.

In 2004, we marked almost 200 sampling points along roads, trails, or gated service roads throughout the study area and conducted all sampling from these points. After arrival at a point, an observer would listen for the song of a target species male. If a male was not heard at the point within 5 minutes of arrival, the observer would move to the next sampling point and repeat the procedure. If a target bird was detected, the observer would select the first male they heard. This procedure introduced a size bias (Patil and Ord 1976, Patil and Rao 1978, Alldredge 2004) into our data because males that sang more often were more likely to be included in our samples. To determine the magnitude of this bias, we attempted to collect data on birds detected by eyesight alone, assuming that the group detected by sight would not be biased as hearing was not used at all to detect these birds. By comparing the average singing rates calculated for each group, we hoped we could estimate the sampling bias and predict its influence on abundance estimates made from count data. During visual sampling, we wore radio headphones that completely covered our ears and blocked out all outside sounds. We tested visual detection procedures for a total of 25 hours over a 3 week period and managed only one visual target species detection. With such meager results, we dropped visual detection from the sampling protocol. The failure of visual detection did, however, inspire the work described in Chapter Three of my thesis.

In 2005, we moved all sampling from points along trails to six 250 m x 250 m (6.25 ha) plots. Plot size was chosen to encompass several territories of both species simultaneously. Ovenbird territories have been reported to range anywhere from 0.2 to 1.8 ha in size (Hann 1937; Stenger 1958; Zach and Falls 1975; Wenny

1989). Black-throated Blue Warbler territories have been reported to range from 1 to 4 ha (Steele 1992). Three plots were located in the Cold Springs/Harmon Den Horse Camp area (Fig. 2.4), one plot at Brown Gap, and two plots at the Lemon Gap site. I flagged six transect lines 50 meters apart across each plot using a compass and hip chain. I labeled the transect lines A through F. Observers sampled plots in pairs, one walking the A, B, C lines, and the other the D, E, F lines simultaneously performing spot mapping, singing rate sampling, and nest searching. We sampled any target males detected inside a plot. I rotated observers through all plots areas throughout the season. Occasionally, no target species males were noted singing inside plot boundaries. In those instances, observers would sample the singing rate of the closest males detected outside the plots. We sampled individual males only once during any sample week. Individual birds may have been sampled several times over the entire 5 weeks of data collection for each species however.

The singing rate data we collected suggest that the singing behavior of both species is exemplified by singing bouts separated by periods of silence. The frequency of singing bouts varies from bird to bird. Nevertheless, birds that sang most often were more likely to be detected. We examined this by looking at the distribution of singing rates for all samples over time. All samples were likely to indicate the highest singing rates at the beginning of each sample, because in order for us to find a bird and initiate sampling, the bird had to sing (Figs. 2.5 and 2.6). The analysis supports our hypothesis that the first several minutes of each sample have inflated singing rates. Therefore, we deleted the first six minutes of data from each sample to reduce the “size bias” of our data (Alldredge 2004). All further

analyses were performed on truncated data. I used the 'proc ANOVA' procedure in the statistical package SAS, release 9.1.3 (SAS institute, Cary, North Carolina) to calculate a completely randomized one way ANOVA of singing rates over the five weeks of sampling for each species with week as the treatment. All further statistical analyses used SAS 9.1.3 as well. I used a least significant difference test to determine differences between individual pairs of weeks.

I was able to calculate true availabilities for both species across a range of count durations from 1 minute to 10 minutes in length using program "R" (R Development Core Team 2006). The "R" code used in this analysis is provided in Fig. 2.7. The program randomly re-samples all of the combined weekly singing samples for a species and calculates the proportion of times the selected time interval encompass a period of silence in the data. I split the total number of samples of each data set into two sub-samples, those collected during the first half of the season and those collected during the second half to determine the change in availability for both species over the nesting season. Approximately equal numbers of samples fell on either side of the midseason demarcation date dividing the samples uniformly between groups for both species.

We began nest searching immediately after our arrival each season; April 28th in 2004, and May 1st in 2005. Many migrant Ovenbirds were already present on our sites by these dates, and more continued to arrive for several weeks. Black-throated Blue Warblers were present in much lower numbers at the beginning of our field work, and they appeared to be approximately 1.5 weeks behind the Ovenbirds in establishing their territories. We located and monitored nests as described by Martin

and Geupel (1993). This included visual searches of the vegetation and tracking females exhibiting nesting behavior.

When a nest was located, the observer marked it using flagging tape. They placed the flag approximately 10 m from the nest and labeled it with a nest identification code, compass bearing, and the distance to the nest from the flag. Observers then sketched a picture of the nest as seen from the marking flag. The sketches were helpful in locating nests quickly during later monitoring visits. We attempted to monitor active nests every third day until hatching, every second day during early brooding and every day as the predicted fledging date approached. The average incubation period for Ovenbird and Black-throated Blue Warblers is 13 days (Van Horn and Donovan 1994)(Holmes 1994). The fledging period is 8-9 days for both species. We estimated nest success based on the predicted fledging date. Any known age nest found empty prior to its predicted fledge date was considered predated. We used visual signs of fledging at an empty nest to confirm fledging. These signs included flattened nest edges, fecal material in and around the nest, abundant flakes of feather sheaths in the nest, and evidence of fledglings in the vicinity of the nest. Data on the number of nests and eggs, the number of nestlings and fledglings, and nest chronology were used to calculate nesting success statistics (Mayfield 1961, 1975).

We collected singing rate data for males associated with nests when an active nest was located. We quietly approached active nests and positioned ourselves within visual range of the nest. We observed the area around the nest until a target male was detected. Observers looked for evidence of males visiting

the nest or interacting with the female. Males associated with a nest often sang from a perch directly above the nest, or brought food to the female or nestlings. We considered these activities as confirmation that the male was associated with the nest, and we began sampling the male's songs. When the observer finished sampling, they checked the nest to determine its status. Often, no male would appear near a nest after an hour or more of observation, and we would move on to another nest. Observers sampled rates for as long as they could remain in contact with the male from a particular nest. I pooled the nest singing data across 2004 and 2005 to increase the nest stage sample sizes. Singing rate variation over the nesting cycle was analyzed with a one way ANOVA using nesting stage as the treatment. Paired comparisons were made using the least significant difference test.

We conducted a point count on each plot once a week during the 2005 season. Four observers participated in each 10 minute variable circular plot count (Reynolds et al. 1980) using the multiple independent observer (Nichols et al. 2000) and the time of detection methods (Alldredge, 2004) simultaneously. We conducted all point counts shortly after sunrise waiting 2 to 3 minutes after arriving at a point to allow birds to become accustomed to our presence. We mapped all birds heard on data sheets marked with distance rings of 25, 50, 75, 100, and 150 meters from the center point (Fig. 2.8). Each count was subdivided into four 2.5-minute segments to create the time of detection intervals. We used multicolored pens to record all detections, changing colors to correspond with each time interval. We marked the initial detection of a bird using a two or four letter species code written in the appropriate color for the current interval. If a previously detected bird was detected

again in a following interval, we underlined the initial detection code in the appropriate color for the current interval. The notation for a bird detected in all four intervals would include a code written in black underlined with three additional lines; one blue, one green, and the last red. Personnel were trained for 2 weeks before we began collecting data. We sampled each plot by point count nine times over the season. We calculated time of detection point count detection probabilities using program MARK (White and Burnham 1999) to produce plot abundance estimates for the two species. We chose five different candidate models to estimate detection probabilities for each species (Otis et al. 1978, Pollock et al. 1990). The models included; the constant detectability model M_0 , which assumes constant detectability for all individuals across all time intervals, the time model M_t , which assumed equal detection for all individuals, but differences among time periods, the behavior model M_b , which assumed an equal probability of initial detection for a bird, and a unique probability of detection for all redetections, the group difference model M_g , which assumed detection probabilities were different for each group, (or in this case plot), and the model M_{g*t} , which included both group and time effects. We used AIC (Burnham and Anderson 2002; Williams et al. 2002) to select the most parsimonious model for analysis. All data for both species were combined across weeks in the analysis and therefore do not take into account changes in probability of detection over the course of the season. We examined this effect in a second MARK analysis, grouping data by sampling date. We tested the same candidate models as described above, with the addition of a new model that incorporated a linear

temporal trend. There were too few data points to perform a proper analysis with the Black-throated Blue Warbler data, so we only used Ovenbird data for this analysis.

We spot mapped plots in 2005 using the methods outlined by the International Bird Census Committee (1970) with a few alterations. A sample spot map data sheet is presented in Fig. 2.9. Paired observers covered a single plot during each mapping event. One observer walked the A, B, and C transect lines, and the other observer walked the D, E, and F transect lines simultaneously spot mapping, nest searching, and collecting individual singing rate samples. We alternated observers and mapping routes on each mapping visit. Observers would pinpoint each bird detected and note counter-singing events with neighboring males. However, because we were simultaneously sampling singing rates, we spent at least 30 minutes with each single bird recording its movements as we were spot mapping. Our spot mapping efforts were very intensive totaling approximately 8 hours of mapping per plot each sampling day. We spot mapped each plot on a 4 to 5 day schedule producing approximately 10 map records for each plot from May 22nd to July 15th 2005. We were able to map up to 25 m beyond the boundary of each plot on all sides, effectively making each plot 300 m x 300 m square, or 9 hectares. According to the rules that I used in identifying territories, a detection cluster had to include detections on at least 3 separate days in order for the cluster to be counted as a territory. The territory estimates I made are a measure of the total number of territories present over 7 weeks of sampling. They are not estimates of the number of territories at any one single point in time. Spot map data were scored to produce territory density estimates for both species of warblers. These estimates were

compared to point count density estimates and were evaluated in relation to the singing rates recorded on the plots. I divided the weekly singing rate samples for each species among the six sampling plots to calculate singing rates per plot.

Results

I do not believe that the 2004 weekly singing data is nearly as reliable as the 2005 data due to the shorter sample lengths of 2004 samples. Therefore, I only report the 2005 weekly singing data here. During 2005, we collected 100 weekly singing samples totaling 46 hours of Ovenbird song, and 67 weekly singing samples totaling 28 hours of Black-throated Blue Warbler song over the 5 weeks of sampling for each species. These totals include only samples of 11 minutes or longer. The average sample length for Ovenbirds was 27.8 minutes, and 25.0 minutes for Black-throated Blue Warblers. Analysis of the truncated data indicates that, as predicted, average singing rates for both Ovenbirds and Black-throated Blue Warblers declined significantly over the course of the breeding season (Figs. 2.10 and 2.11). Average Ovenbird singing rates were highest at 2.2 songs per minute during the first week of data collection decreasing to a low of 0.6 songs per minute during the fifth week of data collection. These across season rate declines correspond very closely with the values Gibbs (1988) found for Ovenbirds nesting in continuous forest habitats in Missouri. Black-throated Blue Warbler data produced a similar pattern beginning at an average rate of 6.1 songs per minute during the first week of data collection and declining to an average rate of 2.0 songs per minute during the fifth week of sampling. One way ANOVAs indicated significant declines for both Ovenbirds ($p <$

0.0001) and Black-throated Blue Warbler ($p < 0.0098$) over the season. Ovenbird singing rates leveled off between weeks three and four, and declined again in week five. Black-throated Blue Warbler data showed a similar pattern with a slight increase in rates from weeks three to four, and a decline through week five.

Ovenbird availability declined throughout the season with an early season availability value of approximately 0.88 for a 3 minute count, dropping to approximately 0.65 for a similar count during the latter part of the season (Fig. 2.12). The Ovenbird availability estimates I made are similar in range to those presented by Gibbs and Wenny (1993) for Ovenbirds. To avoid any confusion, when Gibbs and Wenny refer to “detectability”, they are referring to what I call “availability”. Black-throated Blue Warbler availability estimates were also below one but remained fairly constant from early season samples to late season samples (Fig. 2.13).

In 2004 and 2005 combined, we collected 37 singing samples at nests totaling 14.2 hours of Ovenbird song, and 31 singing samples at nests totaling 10.4 hours of Black-throated Blue Warbler song. The average Ovenbird nest sample was 23.1 minutes in length, and the average Black-throated Blue Warbler nest sample was 20.2 minutes long. Singing rates across the nesting stages varied, but the one way ANOVAs for each were not significant with $p < 0.1744$ across Ovenbird nest stages and $p < 0.5370$ across Black-throated Blue Warbler nest stages (Figs. 2.14 and 2.15). The Ovenbird data, however, are similar to the data collected by Lein (1981) in Massachusetts and New Hampshire from 1970 to 1972. Direct comparisons are difficult, however, because the nesting stages defined in our studies are somewhat different. Larger sample sizes may have increased the power

of these tests, but locating the male associated with a nest was much more difficult than expected.

Neither the Ovenbird nor Black-throated Blue Warbler weekly singing rate data indicate significant singing rate differences across plots with the one way ANOVA: $p < 0.2598$ and $p < 0.7420$ respectively (Figs. 2.16 and 2.17). We created 72 separate spot map records among the six plots, resulting in 11 to 13 separate records per plot. Plot spot mapping territory density estimates for Ovenbirds ranged from as few as five territories up to as many as 13 territories across the 7-week sample period. Territory density estimates for Black-throated Blue Warblers indicate a similar pattern from a low of 4 to a high of 14 territories per plot. We collected 45 total point counts from the centers of the six plots.

The MARK analysis models tested are presented in Tables 2.1 and 2.2, including AIC values and final p 's used in plot density estimation. There was no evidence for a group effect among plots, so all plot data were pooled in estimating detection probabilities. The AIC estimates indicate approximately equal support for the behavior model M_b and the constant detectability model M_o for Ovenbirds. Therefore, the Ovenbird p estimate is based on a weighted average of the models. In the case of the Black-throated Blue Warbler, AIC indicated the behavior model M_b to be far superior to the others, and no weighted averaging was used in this case. The spot map density estimates indicate some agreement with the point count abundance calculations. The results indicate declining singing rates with increases in species density for both Ovenbird (Figs. 2-18 and 2.19) and Black-throated blue Warblers (Figs. 2.20 and 2.21) using both density estimation methods. The

relationships are weak except for a fairly strong correlation ($r^2 = 0.705$) between Ovenbird spot mapping density estimates and singing rates. In the secondary MARK analysis with Ovenbird data grouped by sampling period instead of plot, the most parsimonious model was the model incorporating a linear trend. All models tested and their AIC values are presented in Table 2.3. Using the linear trend model, estimated probabilities of detection show a regular decline as the season progresses (Fig. 2.22). This decline compares favorably with the decline in Ovenbird singing rates over the season illustrated in Fig. 2.10.

I estimated nesting success for both species during the 2004 and 2005 seasons using the methods of Mayfield (1961, 1975). I also include in the analysis unpublished 2003 Ovenbird nesting data from a previous study performed in the same area. Sample sizes are at or below the recommended 20 minimum nests needed to produce accurate estimates. These data are presented in Tables 2.4 through 2.6. The Mayfield nesting statistics are similar to those reported by Podolsky (2003) in the Great Smoky Mountains National Park between 1999 to 2001. Black-throated Blue Warbler data for 2004 and 2005 are presented in Tables 2.7 through 2.9. The nesting statistics calculated show good agreement with those reported by Weeks (2001) on the Pisgah National Forest between 1998 to 2000.

Discussion

Tracking these two species to sample singing rates was extremely difficult. We failed to collect any singing data at all on several occasions. With persistence, however, we were able to record the singing behavior of many birds. It was much

easier to detect and track the birds with faster singing rates, and these samples represent the bulk of my singing data. Only a small portion of samples are from slower singers. The data we collected represent a size-biased (Allredge 2004) sample due to the differences in detectability and “track-ability” of birds with variable singing rates. I wanted to quantify this bias, and was planning to achieve this by comparing the singing rates of two separate groups of singing samples, the first including birds detected by sound alone, the second birds detected by sight alone. A comparison of the singing rates between these two groups would have produced a direct measure of the size bias that occurs when birds are sampled by ear. Auditory detections of birds were easy to collect, but the visual detection method I designed only detected a small number of birds. An alternate approach involved truncating the data at the seventh minute of each individual record. This by no means eliminates the size bias entirely, but it must reduce it significantly. Consequently, I believe the average singing rates and availabilities reported here are overestimates of the true values. Better sampling methods may produce better estimates. Tracking males at all times using radio telemetry should produce an unbiased sample by allowing completely random sampling of the singing rates of tagged birds.

Spatial and temporal variation in the singing rates of songbirds is a real issue with real consequences for point count based abundance estimates. Separating the effects of true species abundance change from changes in the probability of detection over space and time is very difficult. My work has confirmed the importance of considering both availability and detection given availability on the probability of detection in any auditory sampling protocol, and it has demonstrated

that an analysis of singing rates can provide a good measure of availability. Most point counts are performed over a period of 8 to 10 weeks during the summer when species population change and movement are considered to be at a minimum. My data indicate significant changes in both availability and detection given availability over a similar time period. Conversely, Black-throated Blue Warbler availability appears to remain relatively constant over the same period. We have very limited power to detect real abundance change due to these confounding factors, and no easy correction factors will solve the problem.

My work has proceeded concurrently with the “All Bird Radio” project mentioned in Chapter One. We wanted to produce simulated count conditions in the “All Bird Radio” experiments that were similar to natural conditions. The singing rate data I collected were used in several simulation experiments. “All Bird Radio” experimental results indicate that the ability of observers to detect Ovenbirds and Black-throated Blue Warblers at low singing rates is quite limited.

Let us consider a hypothetical situation in which we have a population of 1000 Ovenbirds in an area. We decide to perform weekly three minute point counts at a series of randomly selected points for eight straight weeks to make an Ovenbird abundance estimate for this location. The proportion of Ovenbirds available over a three minute count during the first week of sampling is 0.88, and the detection rate given availability is 0.75. If we evenly cover the entire area, our first week abundance estimate is $0.88 \times 0.75 \times 1000 = 660$ birds. During the fourth week of sampling, availability has dropped to 0.77, and detection given availability has dropped to 0.68 due to an overall reduction in Ovenbird singing. Our abundance

estimate for this time period is $0.77 \times 0.68 \times 1000 = 524$ birds. Finally, during the eighth week of sampling, the Ovenbird availability has dropped again to 0.65, and detection given availability has dropped to 0.51. The abundance estimate we would produce during this eighth week would be $0.65 \times 0.51 \times 1000 = 332$ Ovenbirds present. We have no way of knowing of the availability and detection given availability changes however without estimating both components of probability of detection during each count throughout the season. Our first estimate in week one is only $2/3$ of the true value, and our last estimate in week eight is only $1/3$ of the true value.

I had predicted a bimodal pattern of singing rates across the season for both species as an indicator of the occurrence of double brooding. At the beginning of the nesting season, most breeders are fairly synchronized in their nesting chronology. As the season progresses, nest failures and re-nesting attempts occur. However, successful breeders of initial nesting attempts continue a synchronized breeding chronology with other successful birds. I predicted that this second nesting wave would be indicated by increasing singing rates briefly during initiation of second nests. I believe the leveling off of singing rates for Ovenbirds and the slight increase for Black-throated Blue Warblers between weeks three and four of the weekly data is evidence of these secondary nesting attempts.

Both the Ovenbird and Black-throated Blue Warbler singing rates produced in relation to spot map and point count plot density estimates indicate a decreasing pattern of song production with increasing plot densities. The relationship observed comparing Ovenbird singing rates to spot map densities is quite strong with an R^2

value of 0.7048. The other three examples were much weaker. This outcome contradicts the results reported by McShea and Rappole (1997) indicating increasing singing rate with species density. I believe this can be explained by differences in habitat quality across plots. Gibbs (1988) has demonstrated that singing rates for Ovenbirds vary between fragmented and continuous habitats, and that this difference is most likely due to pairing status differences between the two habitats. He demonstrated that a greater proportion of males found on continuous habitat are likely to be paired and show lower singing rates than those that are unpaired on more marginal fragmented sites. The same relationship may be being demonstrated with my plot singing rate data. I suspect the highest density sites had higher pairing success and lower overall singing rates because the habitat they were occupying was of higher quality. Conversely, I suspect the lowest density sites produced the highest overall singing rates because of low pairing success on lower quality habitat. The density/singing rate relationship is similar but not as strong for the Black-throated Blue Warblers. This returns us to Van Horne's assessment of habitat quality evaluation. Nesting success should provide some insights, but my sample sizes were too small to make any strong inference from my data.

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SAS. The data analysis for this paper was generated using SAS software, Version 9.1.3 of the SAS System for Windows. Copyright 2006 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

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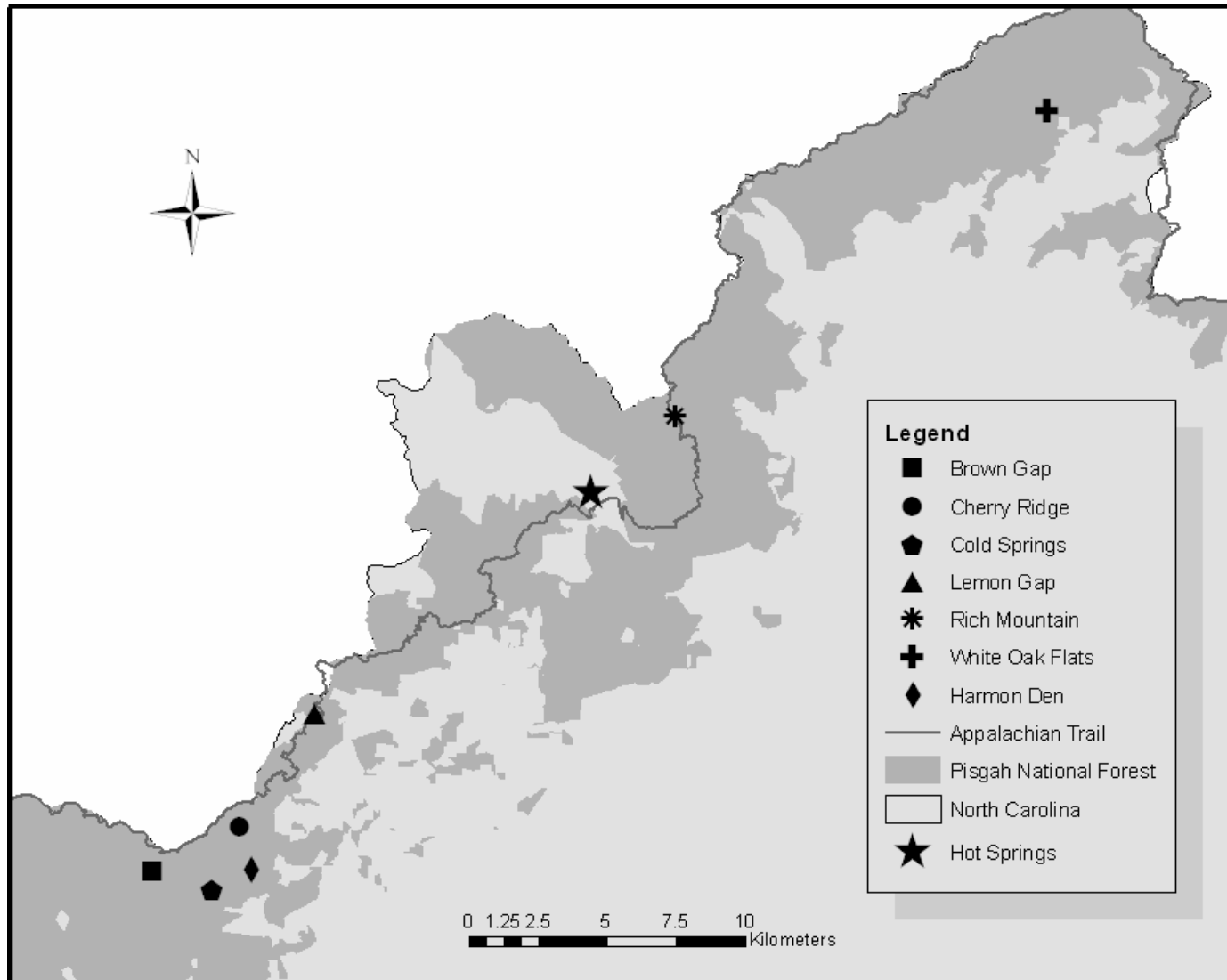


Figure 2.1 Field site locations in the Hot Springs Area



Figure 2.2 The "Call Rate Tracker" interface



Figure 2.3 Using Call Rate Tracker

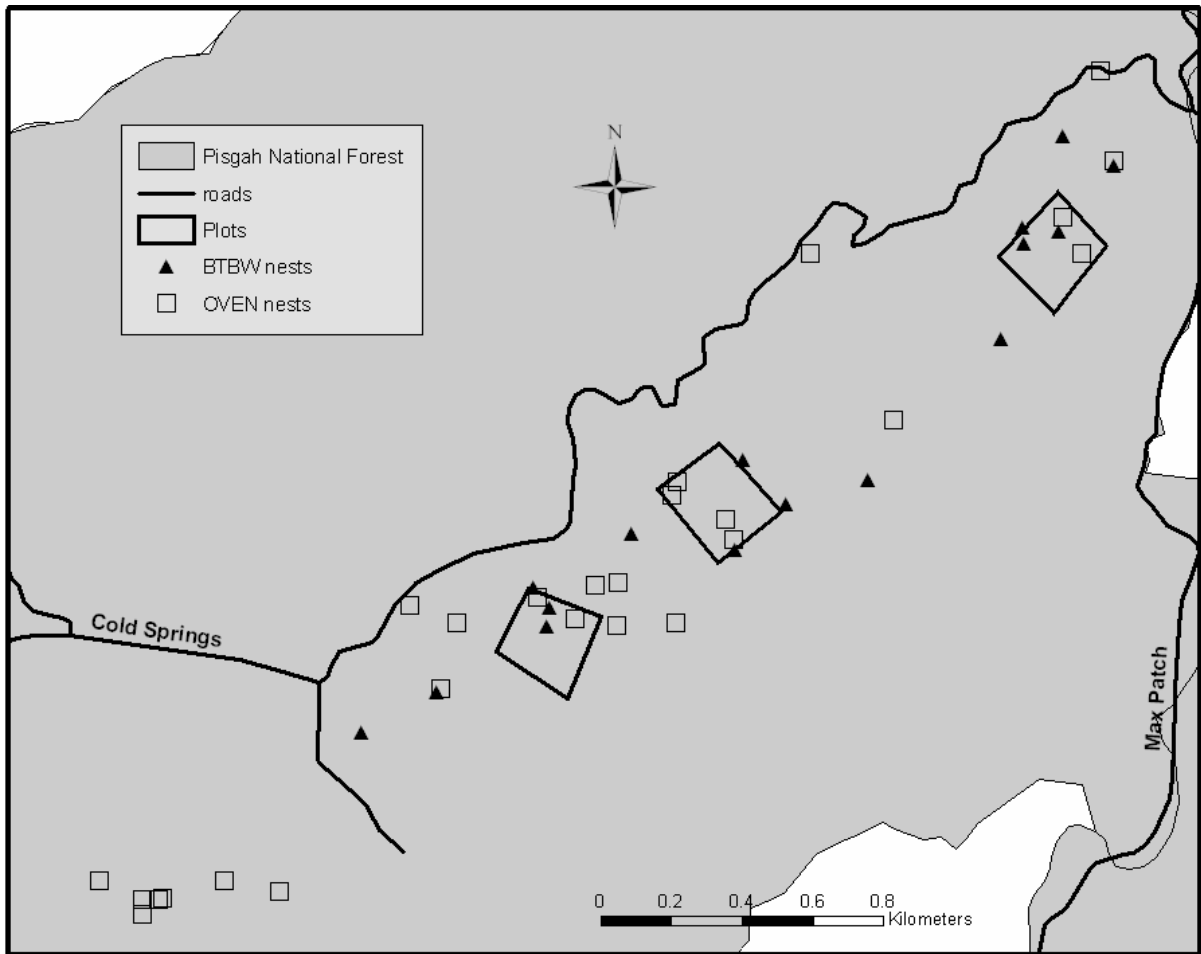


Figure 2.4 Location of three sampling plots in the Cold Springs / Harmon Den Area, and locations of all nests found for both species during 2004 and 2005.

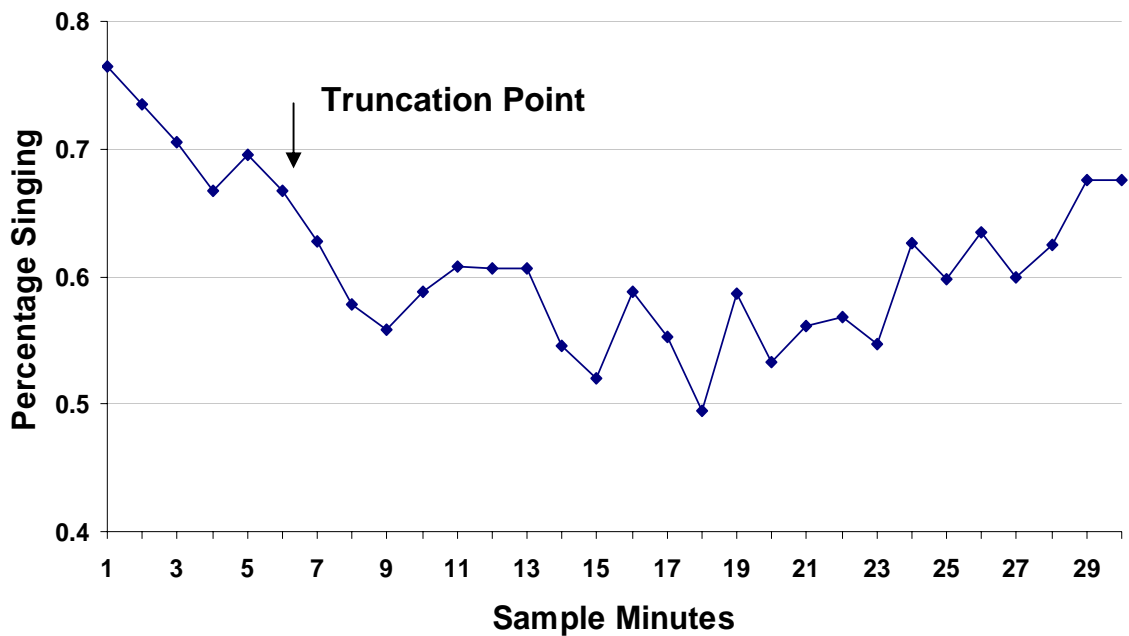


Figure 2.5 Proportion of Ovenbird singing samples showing at least one song during each sample minute. N =100, all samples ≥ 11 minutes in length. The average sample length is 27.8 minutes.

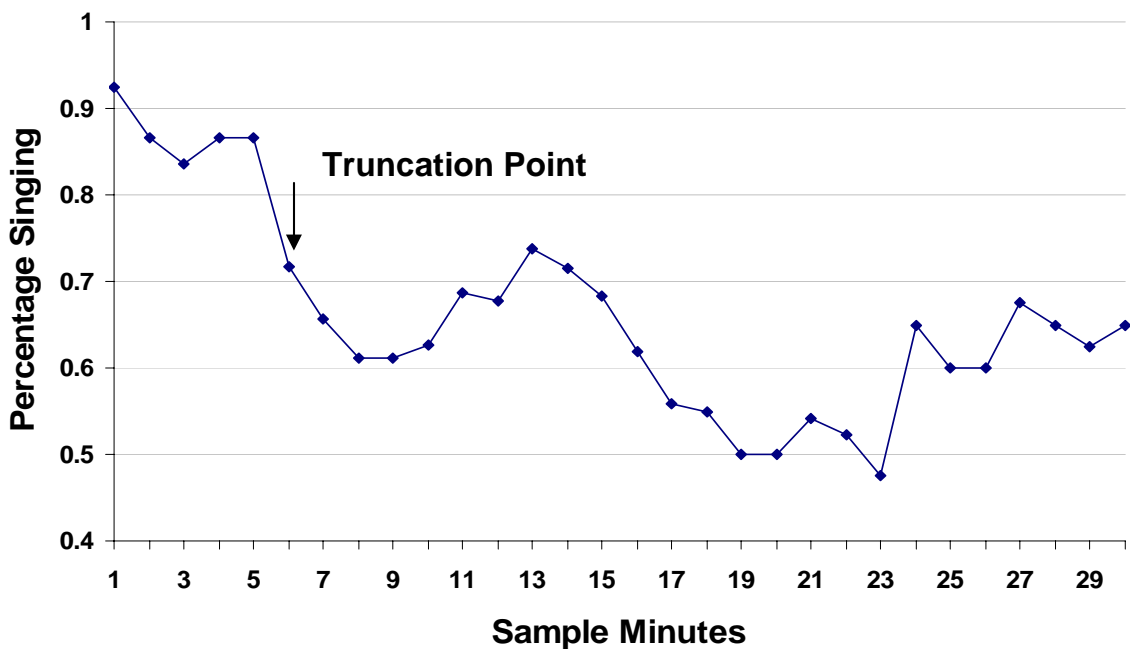


Figure 2.6 Proportion of Black-throated Blue Warbler singing samples showing at least one song during each sample minute. N = 67 samples, all ≥ 11 minutes in length. The average length is 25.0 minutes.

```

rm(list=ls(all=TRUE))

# variables need to specified #####
nsim <- 1000                                # number of simulations

data.name <- "2005_BLACK-THROATED BLUE WARBLER_secondhalf.txt" # dataset
name

int.cell <- 7                               # column number to start sampling
n.cell <- 2                                  # number of observations to be included
out.names <- c("obs1","obs2","total")       # need to match with n.cell
N <- 34                                      # number of individuals to be sampled
#####

data.in <- data.frame(read.delim(data.name,header=T))
out.sim <- data.frame(matrix(NA,N,(n.cell+1)))
colnames(out.sim) <- out.names
output <- data.frame(matrix(NA,nsim,1))
colnames(output) <- c('count')

for (k in 1:nsim) {
  x <- 1:length(data.in[,1])                 # sampling rows (i.e. individuals)
  sample.row <- sample(x,N,replace=T)

  for (i in 1:N) {
    data.temp <- data.frame(t(subset(data.in[sample.row[i],])))
    colnames(data.temp) <- c('obs')
    data.temp <- t(subset(data.temp,obs!='NA'))
    y <- 1:(length(data.temp)-(n.cell-1+int.cell-1))
    sample.col <- sample(y,1)                # sampling col. (i.e. observations)

    for (j in 1:n.cell) {                    # writing sampled observations
      out.sim[i,j] <- data.temp[sample.col+j-1+int.cell-1]
    }
    out.sim[i,(n.cell+1)] <- sum(out.sim[i,1:n.cell]) # computing total
  }
}

# counting the number of samples that has total ==0 in each simulation
no.sing <- length(subset(out.sim,total==0)[, 1])
output[k,1] <- no.sing
write.table(out.sim,file=paste("out.sim.",k,".txt",sep=""),row.names=F)
}

# computing the mean of samples that have total==0 over n simulations
# the results will be based as text file, output.txt
print(mean(output))
write.table(output,file="output.txt",row.names

```

Figure 2.7 “R” program code written to calculate true availabilities for counts ranging from one to ten minutes in length by re-sampling singing rate samples.

Plot _____
Name _____
Date _____
Time _____

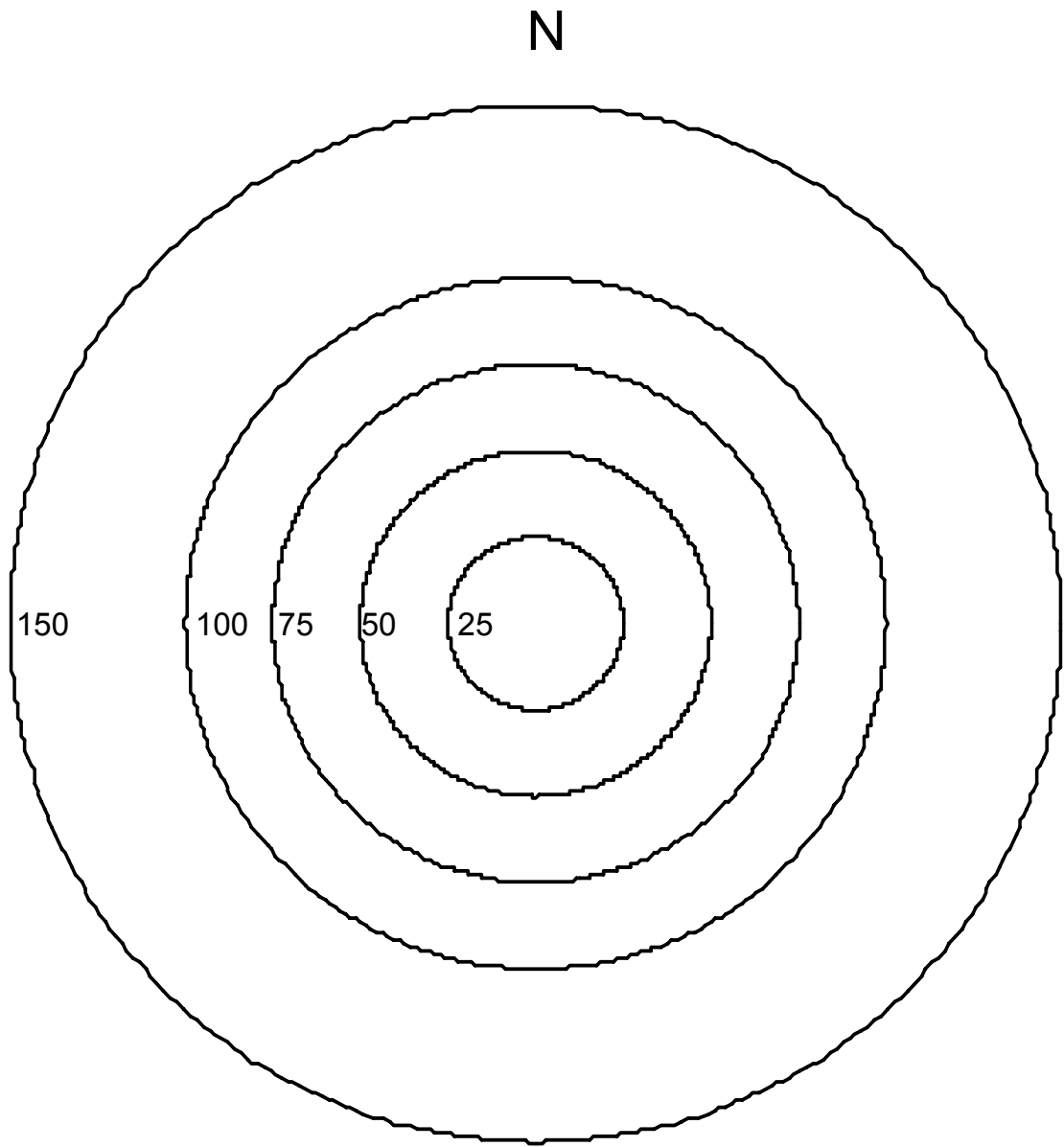


Figure 2.8 Sample point count data sheet.

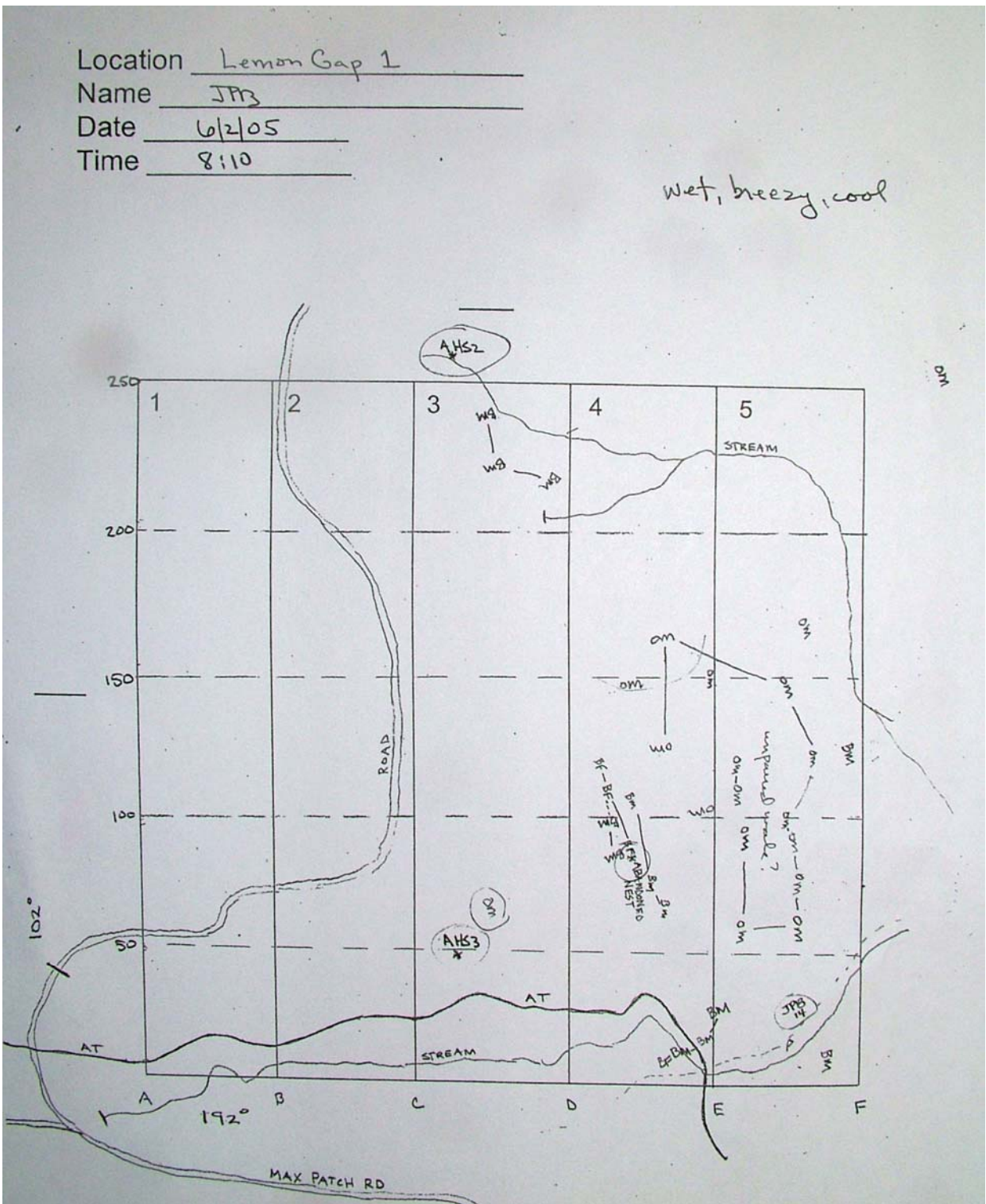


Figure 2.9 Sample spot mapping data sheet.

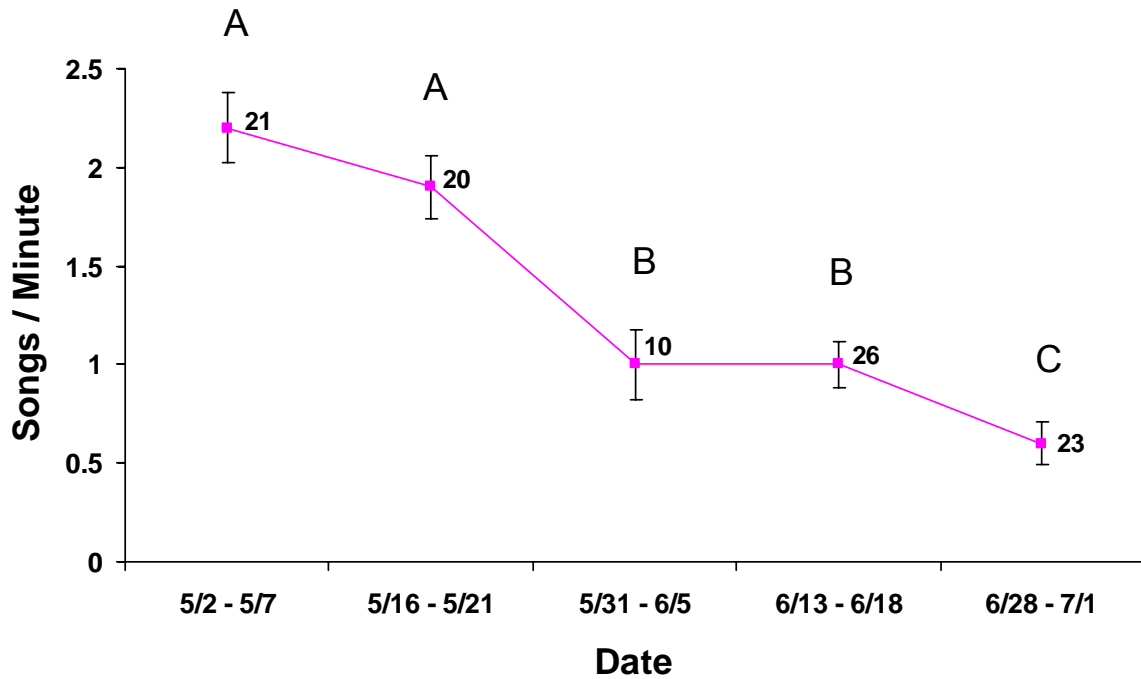


Figure 2.10 Decrease in Ovenbird singing rates through the 2005 season. Points are labeled with standard errors and sample sizes. One-way ANOVA $p < 0.0001$.

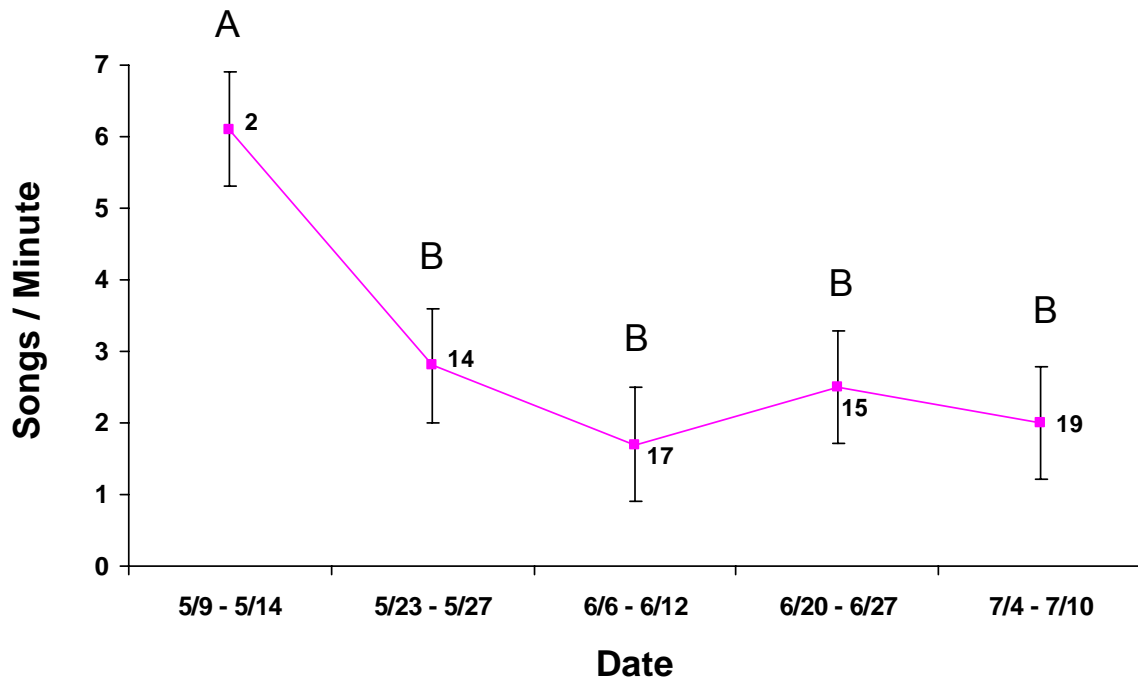


Figure 2.11 Decrease in Black-throated blue Warbler singing rates through the 2005 season. Points are labeled with standard errors and sample sizes. One-way ANOVA $p < 0.0098$.

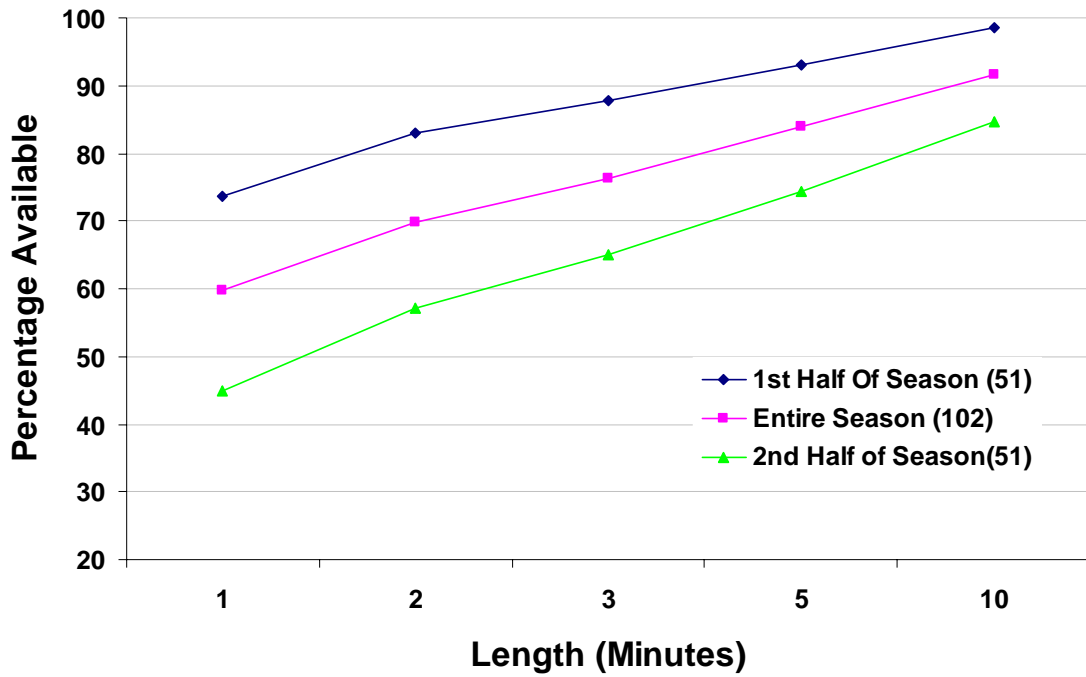


Figure 2.12 Ovenbird availabilities for counts of one to ten minutes in length. Based on 1000 re-sampling simulations using program “R”.

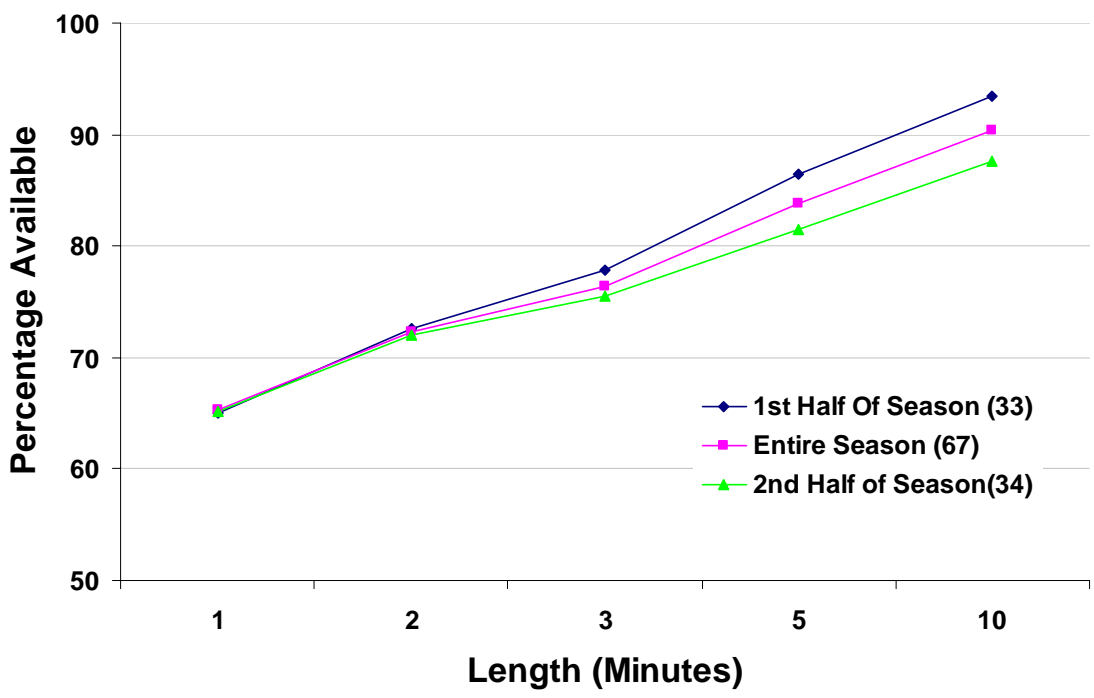


Figure 2.13 Black-throated Blue Warbler availabilities for counts of one to ten minutes in length. Based on 1000 re-sampling simulations using program “R”.

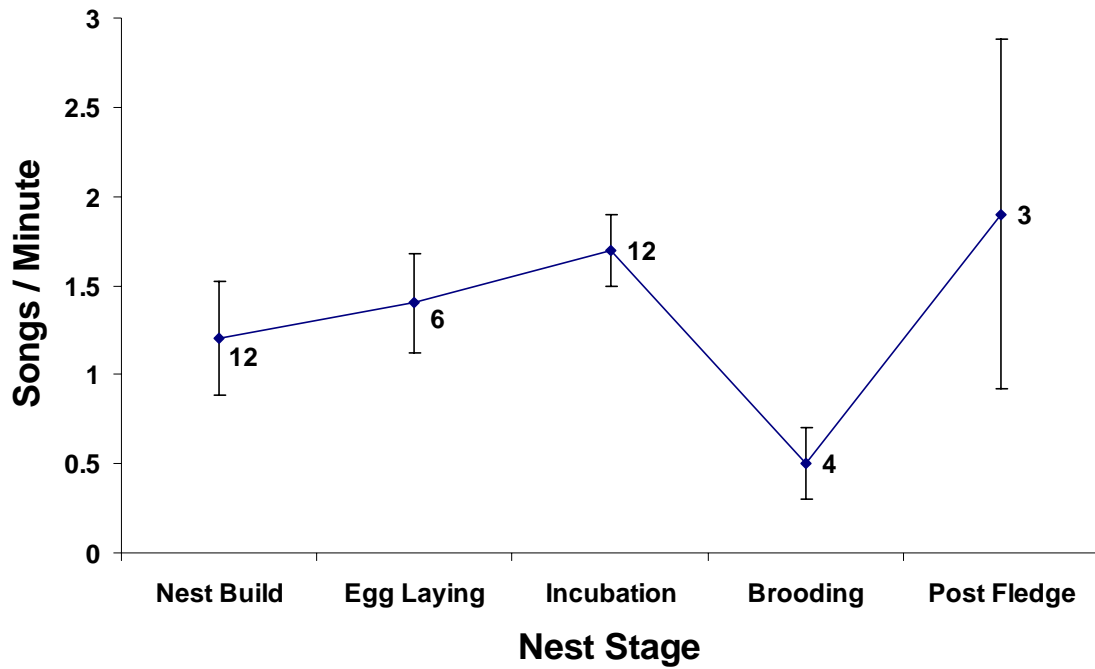


Figure 2.14 Change in Ovenbird nest stage singing rates using pooled 2004/2005 data. Points are labeled with standard errors and sample sizes. One-way ANOVA $p < 0.1744$.

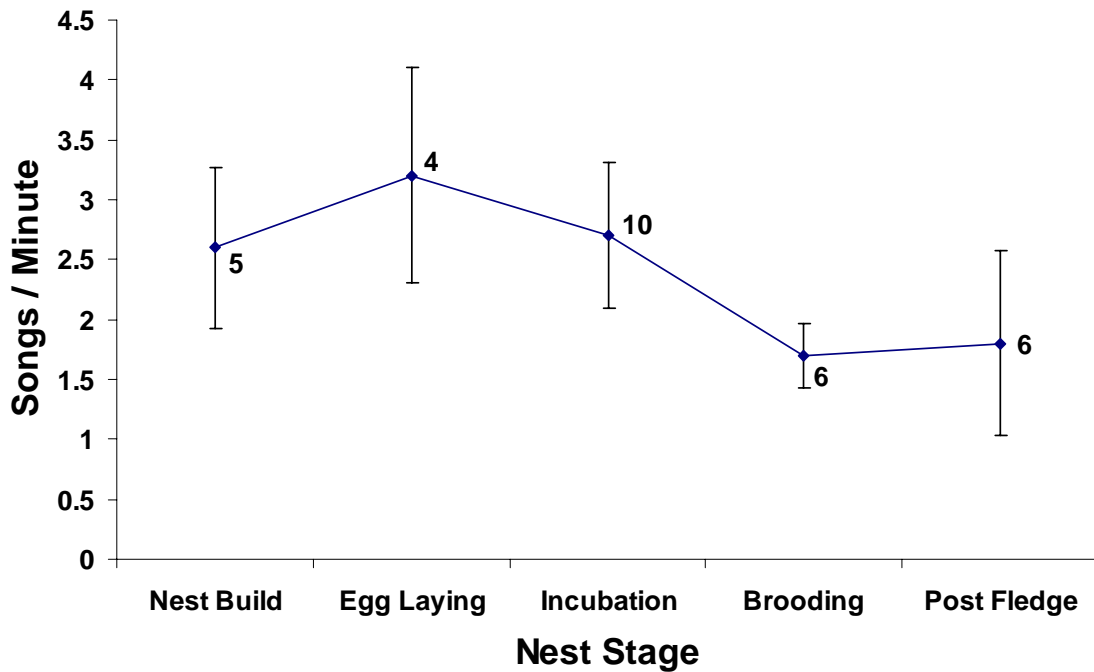


Figure 2.15 Change in Black-throated Blue Warbler nest stage singing rates using pooled 2004/2005 data. Points are labeled with standard errors and sample sizes. One-way ANOVA $p < 0.5370$.

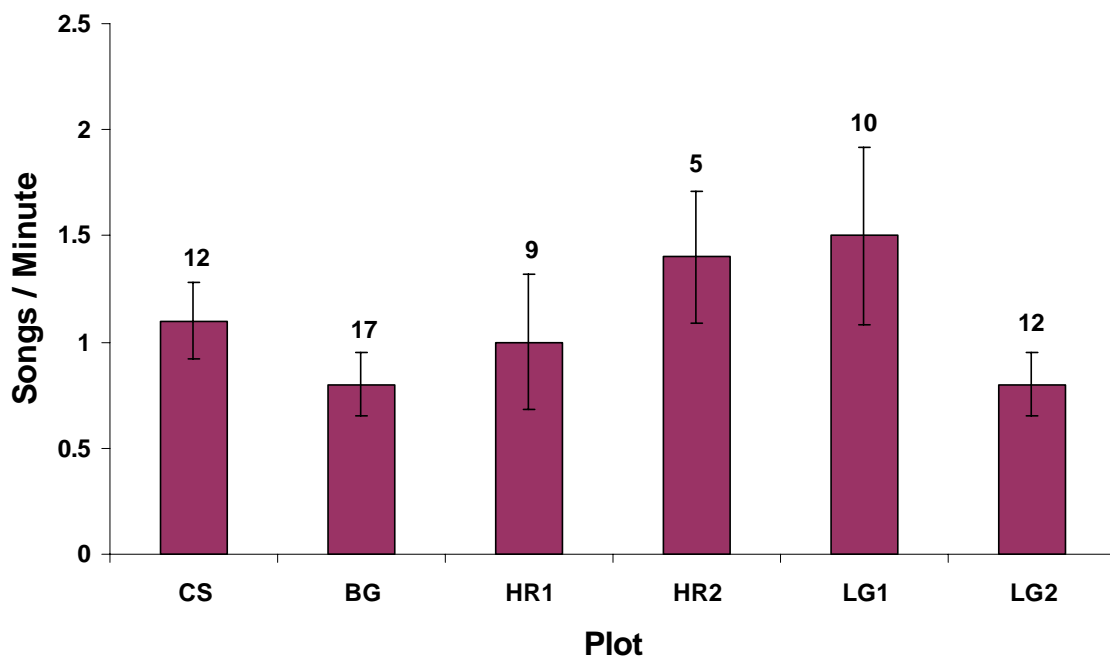


Figure 2.16 2005 Ovenbird singing rate variability across plots. Bars are labeled with standard errors and sample sizes. One-way ANOVA $p < 0.2598$.

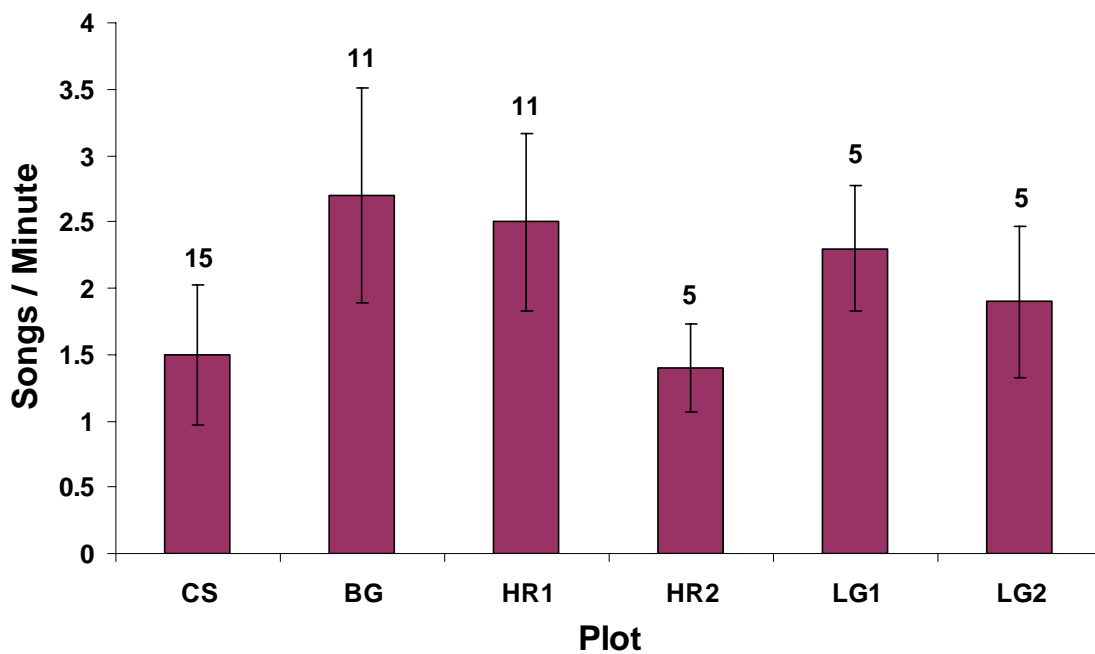


Figure 2.17 2005 Black-throated Blue Warbler singing rate variability across plots. Bars are labeled with standard errors and sample sizes. One-way ANOVA $p < 0.7420$.

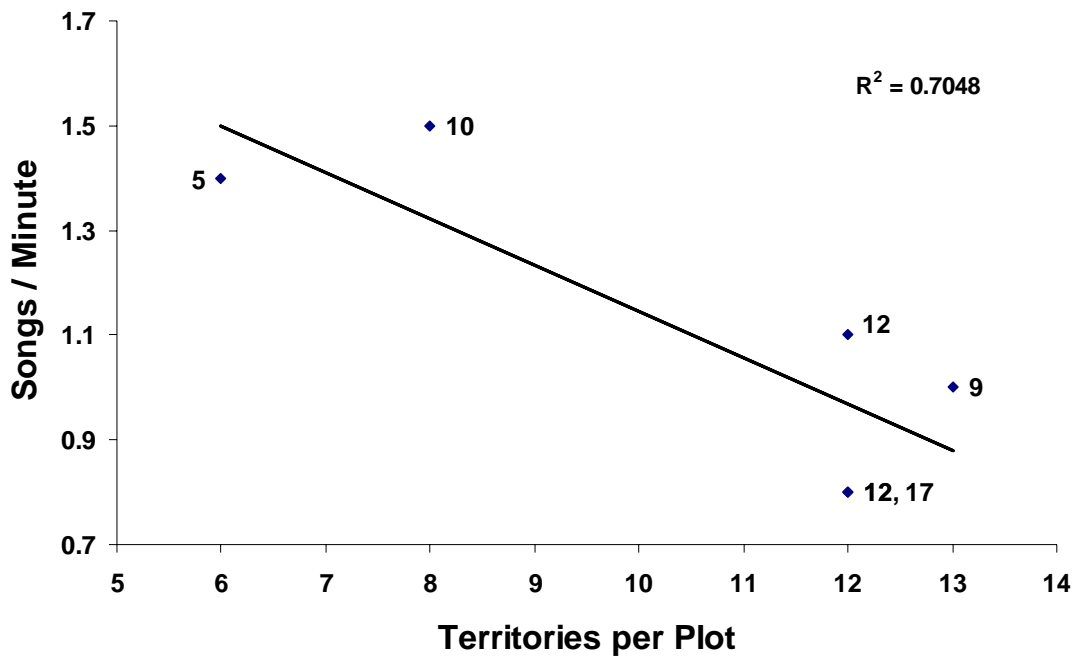


Figure 2.18 Ovenbird singing rates in relation to spot map territory density estimates. Each plot covers approximately nine hectares. An average of 12 map records was used to estimate densities. Points are labeled with sample sizes. The point indicating 12 and 17 samples indicates two separate points in the same place.

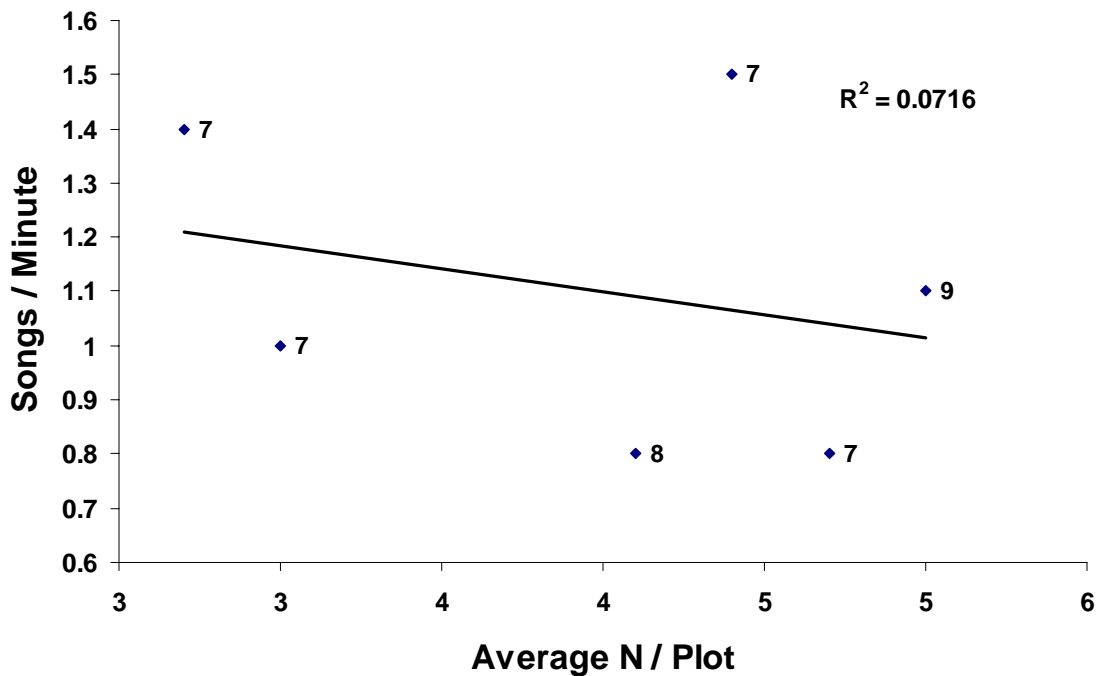


Figure 2.19 Ovenbird singing rates in relation to average N estimates per plot based on time of detection point count data analyzed in program MARK. Each plot covers approximately nine hectares. The number of counts used to calculate average N estimates are labeled beside each data point.

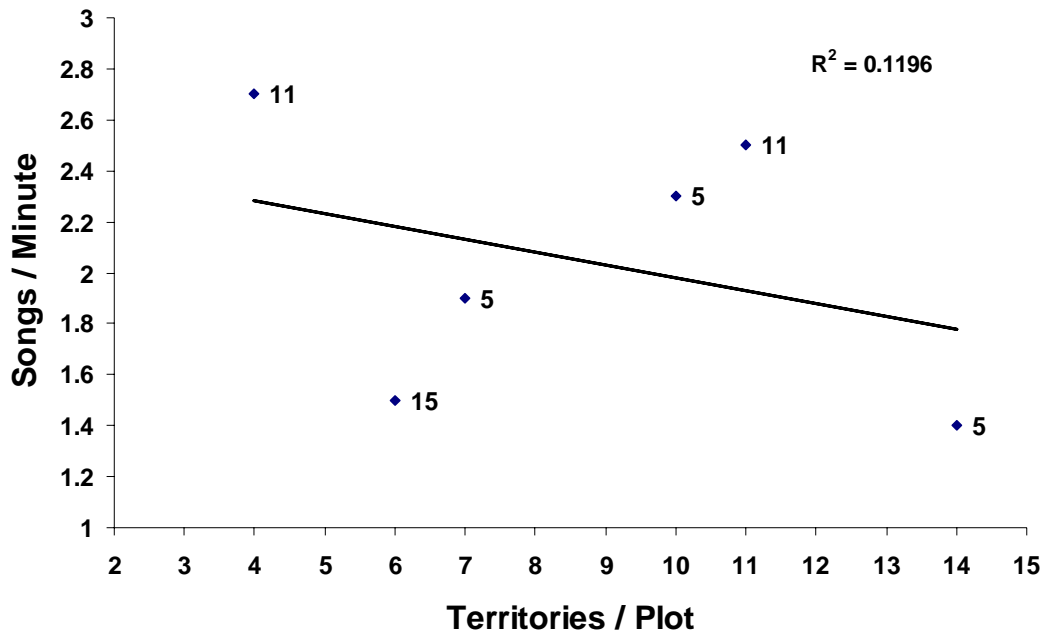


Figure 2.20 Black-throated Blue Warbler singing rates in relation to spot map territory density estimates. Each plot covers approximately nine hectares. An average of 12 map records was used to estimate densities. Points are labeled with sample sizes.

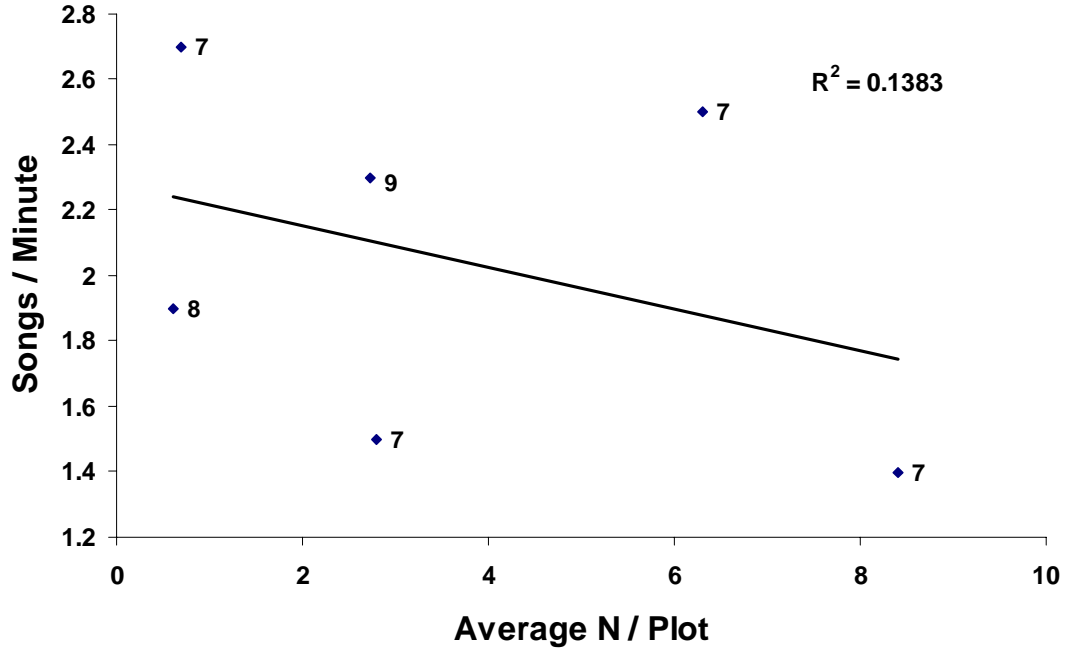


Figure 2. 21 Black-throated Blue Warbler singing rates in relation to average N estimates per plot based on time of detection point count data analyzed in program MARK. Each plot covers approximately nine hectares. The number of counts used to calculate average N estimates are labeled beside each data point.

Table 2.1 Program MARK model selection for changes in singing rate with Ovenbird density.

Model	AICc	Δ AICc	AICc Weight	Model Likelihood	Number of Parameters
M(b)	553.390	0.00	0.51317	1.0000	2
M(0)	553.653	0.26	0.44985	0.8766	1
M(t)	559.075	5.69	0.02990	0.0583	4
M(g)	561.957	8.57	0.00708	0.0138	6
M(g*t)	592.894	39.50	0.00000	0.0000	24

model average $p = 0.5794$ SE = 0.0388783

Table 2.2 Program MARK model selection for changes in singing rate with Black-throated Blue Warbler density.

Model	AICc	Δ AICc	AICc Weight	Model Likelihood	Number of Parameters
M(b)	163.342	0.00	0.98943	1.0000	2
M(t)	173.213	9.87	0.00711	0.0072	4
M(0)	175.228	11.89	0.00260	0.0026	1
M(g)	177.431	14.09	0.00086	0.0009	6
M(g*t)	196.174	32.83	0.00000	0.0000	22

M(b) model $p = 0.2041$ SE = 0.1286275
 $c = 0.6667$ SE = 0.0624391

Table 2.3 Program MARK model selection for changes in probability of detection for Ovenbirds over time.

Model	AICc	Δ AICc	AICc Weight	Model Likelihood	Number of Parameters
Linear Trend	529.838	0.0000	0.36745	1.0000	2
M(0)	529.884	0.0455	0.35919	0.9775	1
M(b)	530.758	0.9196	0.23201	0.6314	2
M(t)	534.878	5.0392	0.02958	0.0805	4
M(g)	536.721	6.8830	0.01176	0.0320	7
M(g*t)	564.227	34.388	0.00000	0.0000	28

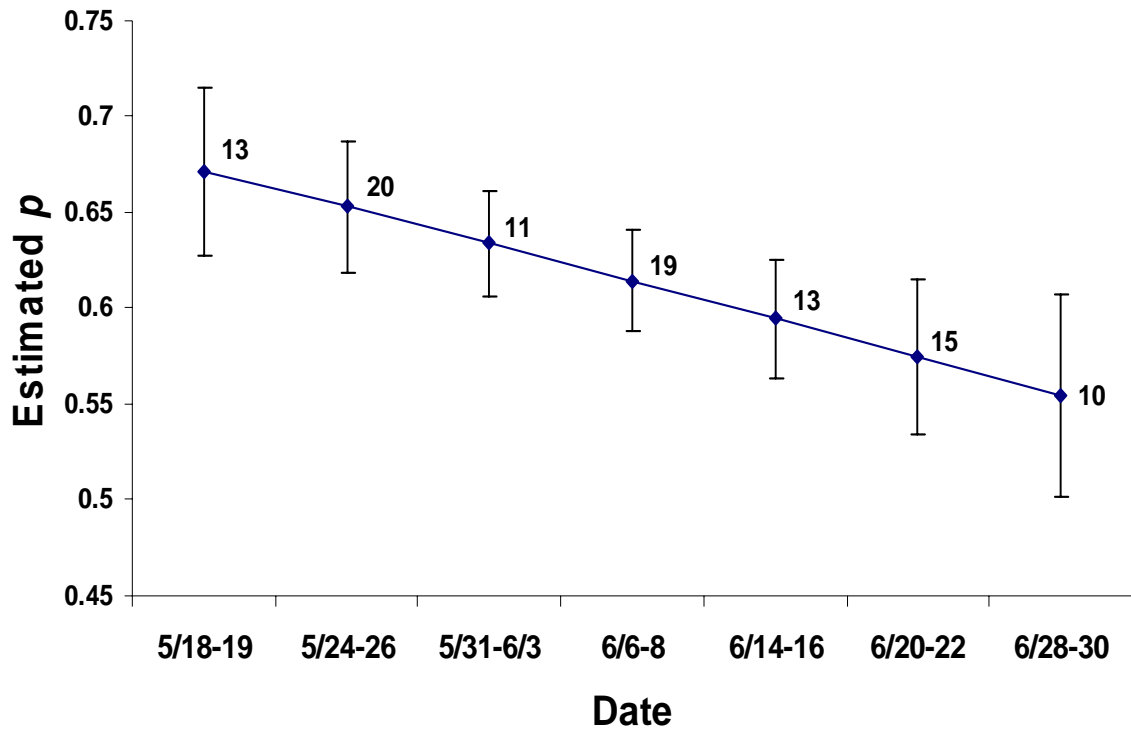


Figure 2.22 Decline in Ovenbird probability of detection through a portion of the sampling season. Sample sizes and one standard error indicated for each time period.

Table 2.4 Ovenbird yearly nest productivity from 2003 to 2005.

	2003	2004	2005
Total active nests	20	14	15
Total fledged nests	8 (40%)	11 (79%)	6 (40%)
Total failed nests	12 (60%)	3 (21%)	9 (60%)
Total fledged chicks	32	48	22
Average chicks fledged/successful nest	4.0	4.4	3.7
Predations during incubation	5 (32%)	1 (33%)	4 (44%)
Predations during brooding	7 (58%)	2 (67%)	5 (56%)
Predation rate	12 (60%)	3 (21%)	9 (60%)
Average clutch size	4.4	4.2	4.1

Table 2.5 Ovenbird daily survival rate from 2003 to 2005.

	Exposure Days	Mortality	Survival
<u>2003</u>			
Incubation	157.5	0.0317	0.9683
Brooding	74	0.0946	0.9054
Total	231.5	0.0518	0.9482
<u>2004</u>			
Incubation	60.5	0.0165	0.9835
Brooding	68	0.0294	0.9706
Total	128.5	0.0233	0.9767
<u>2005</u>			
Incubation	130	0.0308	0.9692
Brooding	66.5	0.0752	0.9248
Total	196.5	0.0458	0.9542

Table 2.6 Ovenbird nest success from 2003 to 2005.

	Hatching Rate	Probability of Egg Success	Probability of Nestling Success	Probability of Nest Success
2003	0.72	0.6574	0.4089	0.3101
2004	0.88	0.8052	0.7644	0.5947
2005	0.70	0.6661	0.4949	0.3565

Table 2.7 Black-throated Blue Warbler yearly nest productivity from 2004 and 2005.

	2004	2005
Total active nests	15	12
Total fledged nests	9 (60%)	6 (50%)
Total failed nests	5 (33%)	6 (50%)
Total fledged chicks	33	20
Average chicks fledged/successful nest	3.7	3.3
Predations during incubation	1 (20%)	2 (33%)
Predations during brooding	4 (80%)	4 (67%)
Predation rate	5 (33%)	6 (50%)
Average clutch size	3.7	3.6

Table 2.8 Black-throated Blue Warbler daily survival rate from 2004 and 2005.

	Exposure Days	Mortality	Survival
2004			
Incubation	92	0.0109	0.9891
Brooding	67	0.0597	0.9403
Total	159	0.0314	0.9686
2005			
Incubation	87	0.0230	0.9770
Brooding	44	0.0909	0.9091
Total	131	0.0458	0.9542

Table 2.9 Black-throated Blue Warbler nest success from 2004 and 2005.

	Hatching Rate	Probability of Egg Success	Probability of Nestling Success	Probability of Nest Success
2004	0.88	0.8676	0.5746	0.4951
2005	0.81	0.7391	0.4241	0.3565

Chapter 3 Hear no evil, see no evil: Songbird detection during point counts in heavily vegetated habitats.

Abstract

Habitat plays an important role in how birds are detected during counts. I conducted a field experiment to determine the relative importance of three different bird detection methods in forested habitats. Three teams of three experienced observers each, performed simultaneous three minute, variable circular plot point counts at a series of 30 points along a trail in Umstead State Park, North Carolina. During each count, one team member was blinded with a face shield, one was deafened by wearing ear plugs and head phones, and the last team member was not handicapped in any way. Observers alternated detection methods based on a predefined randomization scheme before moving from point to point. The percentage of detections made by visual means alone averaged approximately 3.5% of all detections. No handicap and hearing only detections were nearly equally effective detecting 79% and 77% of all detections respectively. No method detected all birds present. The data confirm that auditory detection of birds predominates in highly vegetated forest habitats, while visual detections are negligible. Small, inconspicuous, but vocal birds lend themselves well to auditory detection. Large, visually conspicuous birds lend themselves better to visual detection. The auditory and visual detection processes are very different from each other. Trying to use both simultaneously may reduce the effectiveness of each. For this reason, auditory and visual detections should be analyzed separately from one another.

Introduction

Habitat type plays an important role in how observers detect birds during field surveys (McShea and Rappole 1997). Two modes of detection are available to us, our eyesight and our hearing. Birds are detected by sight more easily in open habitats because they are viewed against simple backgrounds such as sand/ mud flats or the sky. Birds are often detected at great distances in these open habitats. Shore birds are sampled from airplanes for this reason. In more vegetated grassland/shrub type habitats, visibility is reduced. Birds are often camouflaged against a complex background or totally obstructed from view by vegetation. Visibility is further reduced in highly vegetated forest environments. It is often difficult to detect birds flying through structurally complex forest canopies even for highly conspicuous, colorful birds such as a Blue Jays (*Cyanocitta cristata*) or Northern Cardinals (*Cardinalis cardinalis*). Thick vegetation often completely obscures birds, making auditory cues the only means of detecting birds in these environments.

On most surveys of forested habitats, we rely almost exclusively on bird vocalizations, especially songs, for detecting and identifying species. Therefore, factors such as song volume, rate of delivery, and song duration must have important influences on detection probability. Birds that sing louder, more often, or have longer songs are more likely to be detected. Those that sing with less volume, less often, or have shorter songs are less likely to be detected. This difference in detectability will cause a size bias in any sample of birds detected by strictly auditory means. We sample a greater proportion of those birds that sing the most frequently

and miss more of those that sing less frequently. Males of many species have been shown to substantially decrease singing rates after pairing with a female (Cuthill and Hindmarsh 1985; Gibbs and Wenny 1993; Johnson 1983; Krebs et al. 1980). Thus, we can more easily detect unpaired males due to their higher singing rates, whereas slower-singing paired males are more difficult to detect (Best 1981; Gibbs and Wenny 1993). Nevertheless, we often make species density estimates and assess habitat preferences based solely on counts of singing males. Previous researchers have concluded that 81% (Scott et al. 1981), 94% (Dejong and Emlen 1985), and up to 95% (Faanes and Bystrak 1981) of birds counted in vegetated environments are detected by ear alone. However, in these studies it is impossible to separate birds that were both seen and heard from those that were only seen. I designed an experiment specifically to determine the proportion of birds detected by eyesight and hearing in forest environments. I wanted to examine the relationship between detection methods to determine if observers, using both senses, had any advantage over those using hearing alone. I wondered whether observers sometimes believe a detection was made strictly by sight because they didn't actually hear a bird call or sing, overlooking the fact that an auditory cue, however small, initially prompted them to look in the direction of the bird. Therefore, I designed the detection experiment that could distinguish between purely visual and purely auditory detections.

Methods

I performed the detection experiment in William G. Umstead State Park, Raleigh, North Carolina (35° 51.22' N 078° 44.58' W). Woodlands in the park are classified as Dry-Mesic Oak Hickory Forest type (Schafale and Weakly, 1990). Canopy cover ranged from 70% to 100% over the study area. The dominant canopy species at this sight included Loblolly pine (*Pinus taeda*), mixed oaks (*Quercus spp.*) and Tulip poplar (*Liriodendron tulipifera*). Dominant sub-canopy species included Red Maple (*Acer rubrum*), mixed oaks (*Quercus spp.*), and Sourwood (*Oxidendron arborium*). Dominant shrub layer species included Flowering dogwood (*Cornus florida*), Sourwood (*Oxidendron arborium*), and American Beech (*Fagus grandifolia*). Dominant herbaceous species included grapes (*Vitis spp.*), seedling oaks (*Quercus spp.*), and Christmas fern (*Polystichum acrostichoides*). Very little herbaceous and shrub layer vegetation cover was present at points in drier upland areas, making for long range sighting conditions under the canopy at these locations. In bottomland areas, these two layers were quite dense, limiting visibility to less than 20 m.

I selected nine experienced point count observers to participate in the experiment. All observers had extensive previous experience sampling birds in forest environments. Observers were divided into three teams of three observers each. We conducted counts at a series of 30 marked points along the Company Mill Trail in the park on Monday May 15th 2006 from 8 AM to 12 noon. Points were marked with flags and spaced a minimum of 200 meters apart. Team members performed simultaneous independent 3-minute unlimited radius point counts (Ralph et al. 1995) at each point. Observers mapped all detections on data sheets

(Figure 2.4) estimating the location and distance to each bird detected. All teams started at the first point and performed counts at all 30 points in sequence, one team following behind another. During each count, one team member was blinded to all visual input, one was deafened to all auditory input, and the last team member performed the count without any audio or visual handicap. The blind team member wore a baseball cap fitted with a vinyl face shield to block sight (Fig. 3.1). The cap allowed observers to see their feet but little else. A cardboard north-facing arrow was placed at the feet of the blinded observer so they could maintain their spatial orientation throughout the count. The deafened team member wore ear plugs and radio headphones. The headphones were adjusted to produce static noise at a volume high enough to block all outside sound. This team member stood 3-4 m away from the other two observers to prevent headphone noise from disrupting the hearing of the other two observers. Detection methods were randomized among team members at each point (Fig. 3.2). The non-handicapped observer had the added responsibility of timing the count and informing the deafened team member of count completion. This approach constitutes a randomized complete block design over the points with teams as blocks and detection methods as the treatment.

Upon completion of a count, observers matched birds mapped on their data sheets to determine the total number of individuals and species counted using all methods. If the randomization scheme called for observers to change handicaps at the next point, this was completed before observers moved to the point. Observers then walked the 200 m to the next point with their detection equipment in place, therefore eliminating any bias from hearing or seeing birds prior to starting a count at

the point. Observers recorded all birds they detected whether or not they were able to identify them to species.

I calculated the total number of detections per team at each point by scoring the count data sheets. I quantified the number of detections made using each detection method and compared them against the totals, producing proportions of detections made using each method. I conducted a randomized complete block design ANOVA on the means with method as the treatment and teams as blocks using 'proc ANOVA' in the statistical package SAS version 9.1.3 (SAS Institute, Cary, North Carolina). I also ran least significant difference tests for each pair of detection methods.

Results

On average, 9.4 total birds were detected at each point. 7.4 were detected by non-handicapped observers, 7.2 were detected by blinded observers, and 0.3 were detected by deafened observers (Fig. 3.3). Translating those figures into percentages, non-handicapped observers detected 79% of the total number, blinded observers detected 77% of the total, and deafened observers detected only 3.5% of all birds detected at each point. The analysis results indicated a significant difference among detection groups for the ANOVA ($p < 0.0001$). In the paired tests, the difference between non-handicapped observer and blinded observer detections was not significant. Detections made by deafened observers were however significantly different from both blinded and non-handicapped detections.

Of 56 species detected in this experiment, 49 species were detected by non-handicapped observers, 47 species were by blinded observers, and 18 species were detected by deafened observers (Table 3.1). Only two species were detected by sight alone, the Turkey Vulture (*Cathartes aura*) and the Belted Kingfisher (*Ceryle alcyon*). These large, active, and visually conspicuous species are most easily detected by sight. Other conspicuous species detected by sight included the Red-tailed Hawk (*Buteo jamaicensis*), Blue Jay (*Cyanocitta cristata*), Summer Tanager (*Piranga rubra*), and the Northern Cardinal (*Cardinalis cardinalis*). All of these species can be classified as visually conspicuous due to size or coloration. Conversely, at one point, a visually inconspicuous Swainson's Thrush (*Catharus ustulatus*), more known for its distinctive song and call, was detected by the deafened observer but missed by both the blinded and non-handicapped observers.

Discussion

This experiment provides the first quantitative assessment of the relative importance of visual and auditory observations used to detect birds in forested habitats. Visual detections are very rare in these environments. One observer commented that they often deliberately closed their eyes to make it easier to focus all their concentration on listening during counts. Another said he kept his eyes open but “unseeing” during counts, again to focus all attention on listening. For this observer, any visual detections were limited to birds flying directly in front of him at close range. I suspect this might be the case for many count observers. However, if you lose the ability to hear and focus your attention on sight, you will make some, if

few detections. This is demonstrated by the sighting of the Swainson's Thrush by the "Seeing Only" observer. In this case, the fact that the observer was concentrating all his attention on visual cues allowed him to detect this visually inconspicuous species. The key to the visual detection process in heavily vegetated environments is movement. It is extremely difficult to detect a stationary bird against a complex background. How many of us have had a friend attempt to point out a perched bird to us in a nearby tree with little success after giving minutes of directions? The movement not only tells us in which direction to look, but at what distance to focus our eyes as well. We can think of the amount a bird moves in the visual detection process as analogous to singing rate in the auditory process. Likewise, we can think of visual conspicuousness in visual detections as analogous to song volume in the auditory detection process. Without a movement cue, we are looking for the proverbial "needle in a haystack".

Let us examine the visual detection process during a count. Observers scan with their eyes looking for movement. When they see something move, they focus on the location of the movement to identify the source. The movement may be caused by a bird, or it may be caused by something else such as a squirrel or a leaf blowing in the wind. Visual detection becomes very difficult on breezy days. The observers must quickly decide if the movement is worth pursuing further. If they believe the movement is a bird, then they must attempt to identify the species. A bird that continues to move makes identification easy, and the observer can record it and look for another. Many times however, the bird may stop moving, or it may move behind an obstruction. The observer must then wait until the bird makes itself

visible again, which in many cases, doesn't occur during the count interval. Since observers can only examine one movement at a time, they often decide to look for other signs of movement. In any event, we are limited to looking in only one direction, and we presumably miss many birds that are out of our field of view.

The auditory detection process is very different from the visual detection process. Many inconspicuous secretive species are only detected when they call, sing, or produce non-vocal sounds such as the drumming of a woodpecker. Let us explore the auditory detection process during a count. An observer is performing a count and detects a sound. The observer must first determine whether the sound is one produced by a bird (in most cases a song or call) or whether it is background noise that can be ignored. If it is not produced by a bird, the observer focuses on the next sound, but also attempts to filter all further auditory input to screen out the initial sound from further notice. The observer hears a second sound and determines that it is a bird song and immediately focuses all concentration on hearing the song to locate its position and identify the species that produced it. If the bird is highly vocal and within close range of the observer, identification can usually be accomplished very quickly. For distant, faint, or incomplete songs or calls, the observers must do more work to make the identification. This often involves rotating their head to position their ears in the best orientation to locate and hear the song. They must then make a rapid identification decision from limited information and record the species on their data sheet. If the bird sings just once, and identification is not made from that single song, the bird although present, is not counted.

Observers continue this process until all birds are identified or the count interval ends.

Several circumstances complicate the process of identifying birds by ear. Often, many birds sing simultaneously, which can lead to several problems. One bird may be located very close to the observer, where their loud persistent songs can mask the songs of others. Another may produce a distant or weak song, also subject to masking. A second issue is the ability of observers to locate, identify, and record multiple birds simultaneously. Birds are identified and recorded in the order the observer chooses, one after the other. If one or more of those birds stops singing before the observer has had a chance to identify them, then they are not counted. The observer might then have to focus on two new birds while the previously identified bird continues to sing. Finally, observers must often filter out non-bird sounds, or songs of very common species to make identifications. Sometimes, a particular birdsong may mistakenly be miss-categorized as a non-bird sound and ignored by an observer. Other times, observers may miss a species even if it sings in close proximity because they are tuning it out to concentrate on something else.

We can see that auditory and visual detections are quite different from each other and they can often compete for an observer's attention. However, most observers use a combination of auditory and visual detections and the data from each method are usually grouped together for analysis. I believe attempting to use both simultaneously reduces the effectiveness of each. Our brains can easily become overloaded with more information than we can process. Grouping birds that

are more suitably counted using one method or the other may be preferred because the factors shaping the detection process are very different for visual and auditory detections.

Recommendations

By attempting to sample all bird species at a point during a single audio-visual detection count, the complexity of a count can become quite high, reducing overall observer effectiveness at detecting birds. It is best to reduce count complexity as much as possible, and one way to do that might be to classify all species into two or three detection groups depending on their ability to be sampled effectively using point counts. The groups might include a high and low detectability group for audio counts and a group for those species best sampled using visual counts. Some birds may not fall into any of these groups indicating their unsuitability to be sampled using the point count method at all. Each group could then be sampled separately reducing the complexity of each count and decoupling audio from visual detections, raising observer count effectiveness.

Availability is going to be high on longer counts. Ovenbirds sampled using a ten minute count performed at the beginning of the season produce availabilities approaching 1.0, and the lowest availability reached for a count of this length at the end of the season is approximately 0.84. Black-throated Blue Warbler data indicate similar results with availability never dropping below 0.87. I recommend all point counts performed during the season should use the time of detection method and be no less than 10 minutes in length, reducing the overall effect of availability as a bias

causing factor. The time of detection method produces an estimate of detection probability that includes both the availability component and the detection given availability component, although they cannot be separated. It is now well established that singing rate is related to the pairing status of many species and habitat quality. By using singing rate sampling of target species as I did in my work, we can determine availability for each species as well. Subtracting the availability value from the probability of detection estimated during time of detection counts, we can produce estimates of detection given availability for those species. This provides us with the greatest amount of information on which to base our conclusions about population trends. Analysis introducing singing rates provides useful information to estimating both species abundance, and habitat quality. This will help us to focus management efforts and strategies.

Instituting some or all of the recommendations I have made will require a greater number of sampling personnel and a greater input of on the ground time if the methods are to be used effectively. One of the reasons point counts are so popular is because they improve our ability to cover large areas quickly and cheaply. However, I would argue that point counts, as performed now, provide inadequate information to answer our questions concerning abundance change over time and space. Better estimates of detection probabilities on counts can only improve our understanding of species abundance and habitat associations.

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Figure 3.1 Cap used to eliminate visual detections.



Figure 3.2 A 3 person team performing a point count.

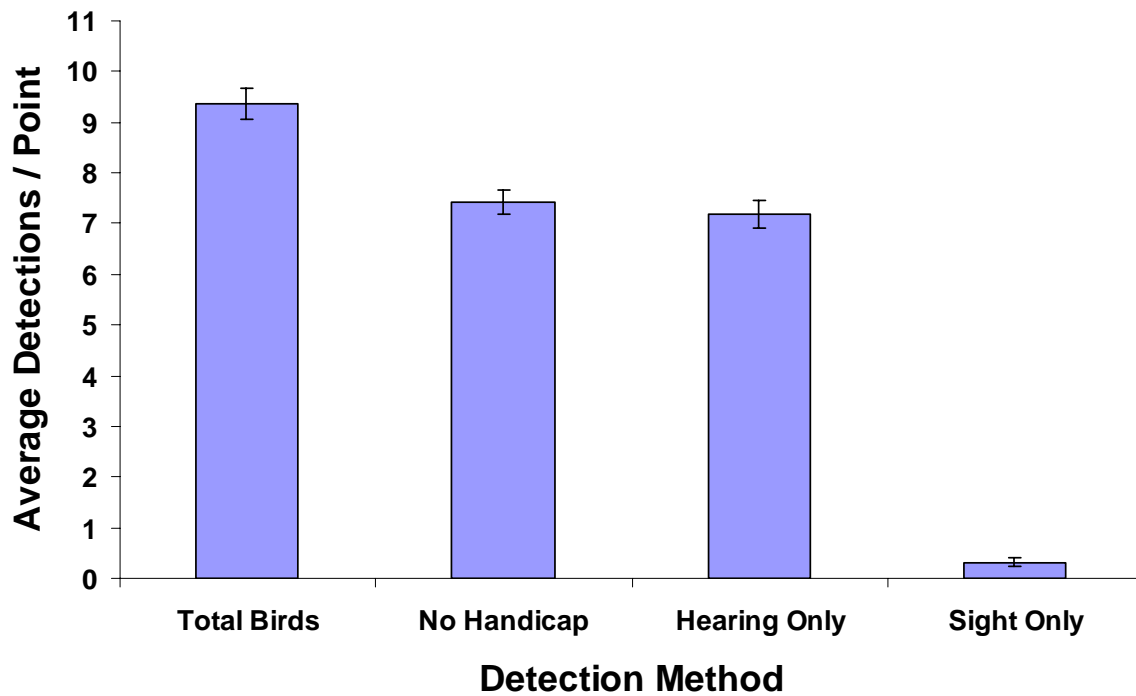


Figure. 3.3 The average number of detections made per point using the three detection methods. A one way ANOVA indicated significant differences among the 3 treatments ($p < 0.0001$). Paired analyses indicated no difference between the “No Handicap” and “Hearing Only” groups, and significant differences between the “Sight Only” group and both the “No Handicap” and “Hearing Only” groups. ($p < 0.0001$ and $p < 0.0001$ respectively)

Table 3.1 Species detections for three detection methods.

Species	No Impairment	Hearing Only	Sight Only
Canada Goose	x	x	
Turkey Vulture			xx
Red Shoulder Hawk		x	
Red Tailed Hawk	x		x
Mourning Dove	x	x	
Yellow-billed Cuckoo	x		
Ruby-throated Hummingbird	x		x
Belted Kingfisher			xx
Red-bellied Woodpecker	x	x	x
Downy Woodpecker	x	x	
Hairy Woodpecker		x	
Northern Flicker	x	x	
Pileated Woodpecker	x	x	
Eastern Wood-pewee	x	x	
Acadian Flycatcher	x	x	x
Eastern Phoebe	x		
Great-crested Flycatcher	x	x	
Red-eyed Vireo	x	x	x
Blue-headed Vireo	x	x	
Blue Jay	x	x	x
American Crow	x	x	
Tufted Titmouse	x	x	
Carolina Chickadee	x	x	
White-breasted Nuthatch	x	x	
Brown-headed Nuthatch	x	x	
Carolina Wren	x	x	
Golden-crowned Kinglet		x	
Blue-gray Gnatcatcher	x	x	x
Eastern Bluebird	x		
American Robin	x	x	x
Wood Thrush	x	x	
Swainson's Thrush	x	x	x
Cedar Waxwing	x	x	
Northern Parula	x	x	x
Black-throated Blue Warbler	x	x	
Palm Warbler		x	
Pine Warbler	x	x	x
Blackpoll Warbler	x	x	
Yellow-throated Warbler	x	x	
Black-and-white Warbler	x	x	
American Redstart	x	x	
Ovenbird	x	x	x
Northern Waterthrush	x	x	
Louisiana Waterthrush	x	x	x
Common Yellowthroat	x		
Canada Warbler		x	
Hooded Warbler	x	x	
Summer Tanager	x	x	x
Scarlet Tanager	x	x	
Eastern Towhee	x		
Northern Cardinal	x	x	x
Indigo Bunting	x	x	
Brown-headed Cowbird	x	x	x
Common Grackle	x	x	
Baltimore Oriole	x	x	
American Goldfinch	x	x	
56 Total Species	49 Species	47 Species	18 Species