

SCIENCE

Masters  
Hall

POINT COUNTS OF MICHIGAN FOREST BIRDS: IMPROVING SAMPLING  
EFFICIENCY FOR SPECIES OF CONCERN

KIMBERLY R. HALL

1996





Hall, Kimberly R. (Kimberly Reade)

POINT COUNTS OF MICHIGAN FOREST BIRDS: IMPROVING SAMPLING  
EFFICIENCY FOR SPECIES OF CONCERN

by

Kimberly R. Hall

A thesis submitted in  
partial fulfillment of the requirements  
for the degree of  
Master of Science  
(Natural Resources and Environment)  
in the University of Michigan  
December 1996

Thesis Committee:

Professor Bobbi S. Low, Chair  
Professor Gary W. Fowler

Marilyn BAE 0080



## ABSTRACT

For many years, researchers have suggested that populations of many species of neotropical migrant birds in the United States are declining. Point counts are the method most commonly used in monitoring plans for estimating the relative abundance of birds; they consist of an observer collecting data at a series of locations (or "points") for a specified period of time. Monitoring populations using point counts plays a critical role in the conservation of bird species, as these data may signal species declines. I examine methods for improving the efficiency of point count sampling in wetland and upland forests in northern lower Michigan. First, using data for two groups of species, neotropical migrants and short-distance migrants and residents, I examine the effects of (1) changing the duration of point counts and (2) changing the area covered by each count (count radius) on the number of individuals detected in wetland and upland ecosystems. Next, I compare different combinations of methods to see which produce the highest expected cumulative count per hour (a measure of sampling efficiency). For neotropical migrants in wetland sites, I found that an 8-12 minute, 100 m radius point counts would be most efficient. This radius size would also be most effective for sampling the residents and short-distance migrants using long count durations (8-12 minutes), although similar efficiency levels could be attained using shorter duration (5-6 minute) 50 m radius counts. In the uplands, the neotropical migrants had the highest expected cumulative counts with 12-minute, unlimited radius samples; residents could be sampled most efficiently using either the unlimited radius or 100 m radius size, and long counts (10-12 minutes). These results suggest that what is most efficient varies both by forest type and by migratory group in northern Michigan forests.

Next, I address species-specific effects of using different point count radii (with 10 minute count lengths) on sampling efficiency in the same ecosystems, focusing on species of conservation concern. I also examine how the mean detection rate influences the number of samples needed to detect a 40% decline in the relative abundance of a species, using different levels of statistical power. In the wetlands, two neotropical migrant species and most of the short-distance migrants and residents would all be most efficiently sampled using the unlimited radius count, while over half of the neotropical migrants, including four of conservation concern (Veery, and Nashville, Canada, and Blackburnian Warblers) would be most efficiently sampled using 100 m radius counts. In the uplands, most of the neotropical migrants, including two of conservation concern (Eastern Wood-Pewee, and Veery) would be most efficiently sampled using an unlimited radius count. The number of sampling days required to detect a 40% decline using a one-sided test ( $\alpha = 0.1$ ,  $\beta = 0.2$ ) varied widely for the species of concern. Using the count radii found to be most efficient for each species, detecting this large difference in relative abundance would require approximately 8 days of data collection for the Eastern Wood Pewee and Nashville Warbler (in upland and wetland sites, respectively), 17 and 52 days, respectively for the Canada Warbler and Blackburnian Warblers in the wetlands, and 25 days for the Veery in uplands. The last species of concern, the Great Crested Flycatcher, was detected at very low rates in both system, and as a result, detecting declines would be very difficult.

## **ACKNOWLEDGMENTS**

I am pleased to acknowledge several people from whom I received valuable advice, encouragement, and help with field work; without them my research would have been a lot more difficult, and a lot less fun.

Both members of my thesis committee contributed to my work in numerous ways, and have helped me learn to think more creatively and clearly about ecological questions. Bobbi Low gave me the freedom to follow my interests, and helped me shape these interests into a workable project through her perceptive comments, quick wit, and good humor. Gary Fowler provided cheerful advice in both the planning and analysis stages of this project; his enthusiasm has helped me learn to appreciate and actually enjoy statistical analyses.

I would like to thank Tom Dietsch for introducing me to the Biological Station, especially Reese's Swamp, and Bob Vande Kopple for providing advice and help with the logistics of my field work. My work has also benefited from feedback I received from Terry Root and students in her research seminar.

Friends and family helped me collect vegetation data in the swamp, or chase Pewees and Vireos with walkie-talkies; I would like to thank Patricia Cole, David Rothstein, Jen Parody, and Jon Rosenfield for cheerfully volunteering for these duties. I promise that someday soon I will actually write up those data .

I would like to thank all of my friends and family who encouraged and helped me complete this project, sometimes by asking me how it was coming along, and sometimes by knowing when not to ask. In particular, I'd like to thank David Rothstein for his insights and editing. Finally, I thank Patricia Cole for teaching me my first birds.

This research was made possible through funding provided by the University of Michigan's Biological Station, Rackham Graduate School, and the School of Natural Resources and Environment.

## Table of Contents

<b>Abstract</b>	ii
<b>Acknowledgments</b>	iii
<b>Table of Contents</b>	iv
<b>List of Tables</b>	v
<b>List of Figures</b>	vii
<b>Chapter 1: Introduction</b>	1
<b>Chapter 2: Overall Detection Patterns Using Different Point Count Lengths and Radii, and an Examination of the Effects of Time of Day on Rates of Detection</b>	4
Methods	7
Results	9
Discussion	12
<b>Chapter 3: Species-specific Patterns of Detection, Power Analyses, and Estimation of Most Efficient Sampling Scheme</b>	27
Methods	30
Results	31
Discussion	36
<b>Chapter 4: Summary and Conclusions</b>	59
<b>Literature Cited</b>	61
<b>Appendix A: Families and Common and Scientific Names of Species, Grouped by Status as a Neotropical Migrant, or as a Short Distance Migrant or Resident</b>	70
<b>Appendix B: Wetland Species' Detection Patterns</b>	71
<b>Appendix C: Upland Species' Detection Patterns</b>	74

## List of Tables

### Table

Table 2-1. Description of upland point count sites, based on Pearsall et al. (1995) - Appendix A.	19
Table 2-2. Number of detections for each species observed in wetland sites, along with percent this number is of total detections, number of counts where each species was detected, and percent this value is of total counts.	20
Table 2-3. Number of detections for each species observed in upland sites, along with percent this number is of total detections, number of counts where each species was detected, and percent this value is of total counts.	21
Table 2-4. Estimated mean number (SE) of individuals detected by time of day in wetland sites based on different point count durations (unlimited count radius).	24
Table 2-5. Estimated mean number (SE) of individuals detected in upland sites by time of day based on different point count durations (unlimited count radius).	25
Table 3-1. Ranking of neotropical migrants by decreasing management concern in the midwest; based on ranking system and values for species in Thompson et al. (1993 - Table 2.)	46
Table 3-2. Comparison of the mean $\pm$ (standard deviation) rate and coefficient of variation of detections per point for each wetland species for three radius sizes.	47
Table 3-3. Comparison of the mean (standard deviation) rate and coefficient of variation of detections per point for each upland species for the three radius sizes.	48
Table 3-4. Listing of species found at wetland sites for which distribution of detections with respect to distance from observer (count radius) was significantly different than either all species in the same migration group, or than all species combined (based on 10 minute counts).	49
Table 3-5. Listing of species found at upland sites for which distribution of detections with respect to distance from observer (count radius) was significantly different than either all species in the same migration group, or than all species combined (based on 10 minute counts).	50
Table 3-6. Listing of species found at wetland sites for which distribution of detections with respect to count length was significantly different than either all species in the same migration group combined, or than all species combined, based on unlimited distance counts.	51
Table 3-7. Listing of species found at wetland sites for which distribution of detections with respect to count length was significantly different than either all species in the same migration group combined, or than all species combined, based on 100 m radius counts.	52
Table 3-8. Listing of species found at upland sites for which distribution of detections with respect to count length was significantly different than either all	

species in the same migration group combined, or than all species combined, based on unlimited distance counts.

53

Table 3-9 a & b. Listing of species found at upland sites for which distribution of detections with respect to count length was significantly different than either all species in the same migration group combined, or than all species combined, based on 100 meter (a) or 50 m radius counts (b).

54

Table 3-10. Mean detections per point of birds in wetland ecosystems, and the estimated sample sizes required to detect a 40 percent difference between two estimates of the mean relative abundance (one-way test) when controlling for different levels of Type I and Type II error.

55

Table 3-11. Mean detections per point of birds in upland ecosystems, and the estimated sample sizes required to detect a 40 percent difference between two estimates of the mean relative abundance (one-way test) when controlling for different levels of Type I and Type II error.

56

Table 3-12. Comparison of the efficiency of different sampling radii in wetland sites with respect to how many sampling days would be required to detect a 40% difference between two estimates of the mean relative abundance for each species (one way test, Type I error rate set at 0.1, Type II error rate set at 0.2).

57

Table 3-13. Comparison of the efficiency of different sampling radii in upland sites with respect to how many sampling days would be required to detect a 40% difference between two estimates of the mean relative abundance for each species (one way test, Type I error rate set at 0.1, Type II error rate set at 0.2).

58

## **List of Figures**

### **Figure**

Figure 2-1. Mean (+2 SE) number of individuals detected in unlimited distance counts by time period - Wetland sites.	22
Figure 2-2. Mean (+2 SE) number of individuals detected in unlimited distance counts by time period - Upland sites.	22
Figure 2-3. Mean (+2 SE) individuals detected per point based on different count radius sizes - Wetland sites.	23
Figure 2-4. Mean (+2 SE) individuals detected per point based on different count radius sizes - Upland sites.	23
Figure 2-5. Relative efficiency of different combinations of duration and radius sizes for detecting individual neotropical migrants (migrants) and short-distance migrants and residents (residents).	26

## Chapter 1: Introduction

For many years, the future of neotropical migrant bird species in the United States has appeared to be in peril; major population declines have been suggested, but progress has been slow in documenting and explaining these declines (Maurer and Villard 1996). From Rachel Carson's (1962) Silent Spring, which warned of a future in which pesticides have silenced the songs of birds, to John Terborgh's Where Have all the Birds Gone (1989), conservationists have used the hypothesized decline of birds as a vehicle for raising public awareness and concern about environmental degradation and the loss of forests (Ehrlich et al. 1988, Maurer and Villard 1996). Testing the hypothesis of widespread declines in landbird populations is challenging for many reasons, perhaps the most important of which is that it requires consistent data that cover areas which are orders of magnitude larger than the average plot size used in scientific studies (Kareiva and Anderson 1989). In addition to the challenges of obtaining adequate data for species with large ranges, analysis of monitoring data also offers challenges for conservation workers. The choice of statistical methods is currently receiving considerable attention, but no consensus has been reached (James et al. 1996, Thomas 1996).

Documenting hypothesized large-scale declines is also hampered by the many sources of variability inherent in sampling bird populations at a local scale (e.g., papers within Ralph and Scott 1981, Taylor et al. 1985, and Ralph et al. 1995a). Point counts are the method most commonly used for estimating numbers of birds present in an area; they consist of an observer collecting data at a series of locations (or "points") for a specified period of time (Verner 1985, Ralph et al. 1995a). Although point count data are often analyzed as if they represent true "samples" of the bird population at a particular point, it is likely that more than half of the birds present in an area being sampled are not detected by the observer (Sauer et al. 1994). Even when singing, 25-50% percent of all males within hearing distance are likely to be overlooked by the observer in point counts (Scott and Ramsey 1981b, Bart and Shoultz 1984, Bart 1985). If the percentage of birds detected were relatively constant, then it would be easy to compensate for the detectability problem. However detectability is highly variable, and is affected by many factors, including diurnal and seasonal changes in song frequencies, effects of weather on singing behavior and song attenuation, differences in the density of singing birds, and differences in the abilities or attention level of observers (Ralph and Scott 1981, Bart and Shoultz 1984, Dawson 1985, Verner 1985 and 1987, Verner and Milne 1989, Ralph et al. 1995a). When studies done by different researchers are compared, all of the above factors can muddle the comparison, as can differences among bird communities, effects of habitat differences on detectability, and differences in data collection methods.

The choice of methods for conducting point counts involves determining the temporal and spatial scales at which the study will be conducted, because choosing the methods to be used means deciding the time of year to study, time of day to study, total number of years or seasons to study, length of individual observation periods, size of study area, number and geographical distribution of study areas, and counting method used (Wiens 1981, 1986, and 1989, Blondel 1985). As described in Wiens et al. (1986: 153) "the scale will dictate the methods used, the results obtained, and the interpretations that can be made of them using sound logic." All of these choices can lead to differences in results, but in many cases how these results will differ, and if they will differ in the same way across different species or ecosystems, is not known. The focus of my work is an examination of sources of variation and bias related to estimating the abundance of bird populations using point counts, with the goal of contributing to our understanding of how the scale of data collection influences the results obtained (Levin 1992).

Since most conservation programs collecting bird population data are tightly bound by resource limitations, understanding how these choices of scale are likely to impact the results of sampling is very important. The relative usefulness of data for detecting population declines can be influenced by the number of points sampled, the total area sampled, and the amount of time spent at each point. As a result, researchers must understand the impacts of these choices, so that resources can be used most effectively. This information can be used to design sampling strategies that maximize the amount of information gained from sampling within the constraints of a conservation budget, or can be used to evaluate the efficiency of a generalized program for detecting a decline in the relative abundance of species of concern.

Guidelines have been established by different governmental land management offices and conservation organizations for conducting regular surveys of bird populations in forested ecosystems (e.g., Manley 1993, Sauer 1993, Ralph et al. 1995b). However, many uncertainties remain as to the optimal design of a monitoring program based on point counts (Petit et al. 1995). Having a uniform set of standards represents another potential trade-off; since species and ecosystems vary widely, the best methods for detecting population changes are also likely to vary. The U.S. has a wide variety of forests; they vary in species composition, age, frequency of disturbance, climate, internal heterogeneity, and many other factors. The communities of birds that occupy these forests also vary widely, making it unlikely that one general approach to collecting point count data will be the best fit for all of the different situations to which it might be applied. For example, travel time between points 200 m apart is likely to be 10 minutes or less in old growth forest with sparse undergrowth. In younger forests or forests with many downed trees, this travel time can increase to 20 minutes, or more. Long travel times decrease the number of points that can be covered in one day, which may cause workers on a tight budget to reduce how many points are sampled in the more dense habitats. Similarly, a five minute point count may reliably detect birds that sing with high frequency, but may provide little information about species that sing more sporadically (Scott and Ramsey 1981a). Of particular interest to me is the efficiency of protocols outlined in recent guidelines (Ralph et al. 1995b) for detecting changes in relative abundances of species of conservation concern in northern Michigan.

A second important question that researchers need to answer is: How many samples are needed to detect biologically significant population declines? All of the decisions that go into designing a monitoring plan impact the precision of estimates that can be made based on the data, and like the questions of scale, the decision of what level of precision is desired should also be made explicit. Are we willing to accept an intensity of monitoring that allows detection of a 50% decline over a 25 year period with a probability of 0.9? This is the current criterion used for the North American Breeding Bird Survey (Sauer 1993). Although we may disagree on whether this level of power is sufficient, all workers involved in monitoring should recognize the importance of knowing what magnitude of change a particular study design can, and cannot, detect. Although the presentation of the power of statistical tests seems to be becoming more common in scientific papers (Gerrodette 1987, Taylor and Gerrodette 1993), the explicit examination of the power of monitoring plans to detect declines is often not calculated (Taylor and Gerrodette 1993). The sample size used in a monitoring plan can be chosen to provide a particular power to detect changes in relative abundance. A comparison of sample sizes needed to detect a particular change in relative abundance is the approach I have used to examine the effects of changing sampling protocols on the design of a monitoring plan.

Here, I examine the effects of two methodological decisions, (1) changing the duration of point counts and (2), the area covered by each count (count radius), in two broad categories of ecosystems: forested wetlands and forested uplands. These forest systems support different assemblages of bird species. They further differ in their structure, which affects both the detectability of the species presents, and the ease of sampling (i.e., walking between points). Within these systems, I examine two categories

of species: neotropical migrants, and short-distance migrants and residents. Although I present results for and discuss all species with sample sizes large enough for analysis, I focus my discussion and recommendations on the effects of changing sampling regime on our ability to detect changes in the population size of species considered to be of conservation concern in the midwestern U.S. (Thompson et al. 1993). Using these data, I then examine how the sample size needed to detect a particular change in relative abundance varies with the different sampling protocols. These results are then compared with proposed point count guidelines (Ralph et al. 1995b), to assess the likely effectiveness of the suggested methods for the species of conservation concern in northern Michigan ecosystems. Finally, I suggest compromise methods that may help bridge the differences between what is most efficient for monitoring rare species in Michigan, and what is most compatible with contributing to nationwide efforts to identify population trends.

The financial and time constraints that dictate the duration and intensity of most sampling efforts, as well as the inherent variability in bird count data, limit most population estimates to representing a fuzzy snapshot of the true situation (Blondel 1985, Barker and Sauer 1995). Recognition of this constraint on our ability to make observations is needed so that we do not extrapolate beyond what can logically be interpreted from the data collected (Wiens et al. 1986). Consequently, the results of my work are limited in that they are representative of conditions and bird populations present during one summer at a very specific set of locations. However, information on how varying the scale of observations within this limited slice of time and space of observations affects the power to detect population differences using statistical tests is needed if conservation workers are to maximize the amount of information they can get for their sampling budgets. We can only expect to make progress in documenting, and determining the causes behind, declines in populations of neotropical migrants if we fully understand how our methods impact our results.

## **Chapter 2: Detection Patterns Using Different Point Count Durations and Radii, Effects of Time of Day on Detection Rates, and Most Efficient Sampling Method for Groups of Species**

### **INTRODUCTION**

Point counts, which consist of an observer collecting data on birds observed at a single point for a standardized time period, are the most common method used for estimating the presence/absence and abundance of forest dwelling birds (Verner 1985, Ralph et al. 1995a). Monitoring of populations using point counts plays a critical role in conservation of bird species, in that it provides information that can be used to identify changes in distribution and abundance that may signal species' declines (James and McCulloch 1985, Goldsmith 1991, Ralph et al. 1995a). However, detection rates of birds vary widely with many factors (i.e., location, time of day, weather, time of season, etc.), and as a result estimates derived from point count data often have very high variances (Ralph and Scott 1981, Verner 1985, Ralph et al. 1995a).

For point count sampling schemes to be a useful conservation tool, the variability in point count data needs to be reduced as much as possible so that when statistical comparisons are made between data from different time periods, we are able to detect declines at an early stage (Verner 1985, Lynch 1995). My main goal for this study was to characterize how the choice of point count methods contributes to detection rate means and variances estimated from data collected in two types of forested ecosystems in northern Michigan. In particular, I am interested in improving the efficiency of monitoring plans for species of conservation concern.

Here, I address patterns of detections for two groups of species (neotropical migrants and short-distance migrants and residents), and examine how changing the point count length and point count radius influences estimates of detection rate means and variances. Using these mean detection rates, I compare the efficiency of different combinations of methods in terms of number of individuals predicted to be detected per hour. Next, because it has been suggested that longer point counts may compensate for changes in detectability (that can lead to higher variance) (Verner and Ritter 1986, Buskirk and McDonald 1995), I examine whether this potential benefit of longer counts appears to be important in these two sets of study sites.

The results of point counts can vary widely based on how they are conducted (Ralph and Scott 1981, Verner 1985, Ralph et al. 1995a); therefore developing a sampling plan should involve careful consideration of how the choice of methods is likely to impact the results obtained. Many of the choices that need to be made can be viewed as a process of determining the scale of the study (Wiens 1981, Blondel 1985). The most obvious examples of where scale choices are made in ornithological studies include time of year to study, total number of years or seasons to study, size of study area, and the number and geographical distribution of study areas. However, once decisions have been made regarding the appropriate temporal and spatial scale for a study, the consequences of the choice of point count parameters also should be examined in light of the goals of the sampling effort. Point counts can be done in many different ways, in that the observer must choose the duration of the counting period at each point, the area to be sampled (i.e., by setting a maximum distance or radius at which species heard will be counted), the time of day and weather conditions to include, and the distance that will be traveled between points (Verner 1985, Ralph et al. 1995a).

The choice of point count methods requires that researchers attempt to match the scale of their methods with the scale of the question addressed in the study. At the same

time, they must consider the relative efficiencies of different methods in the ecosystems where they conduct their research. Some generalities are likely true in all ecosystems; for example, as point count radius and length of count are increased, the number of individuals and species recorded per point will increase. However, decisions of how long to count or how large an area to cover in a count are complicated in part because the impact of changing these parameters on the detection rate varies by species. Increasing the count lengths should increase detections of species that sing at low frequencies during all or part of the sampling period, but will be inefficient for species that maintain high rates of calling (Scott and Ramsey 1981a, Verner 1985). Similarly, the detections of smaller, quieter species are likely to be less affected than those of large, highly vocal species by limiting the count radius (Lynch 1995).

Other factors to consider when choosing a count length are relative biases and effects on the variance of estimates of mean detection rates associated with short or long counts. Increasing the length of point counts may compensate for changes in singing frequencies over the course of a day, and as a result may lead to lower variances (relative to the mean, i.e., coefficient of variation) when detection rate data are pooled across hours or seasons (Verner and Ritter 1986, Buskirk and McDonald 1995). This may allow researchers to increase the total time of day or season that can be sampled, allowing a greater sample size to be obtained (Verner and Ritter 1986, Buskirk and McDonald 1995). Data based on longer counts are also likely to be less sensitive to differences between individual birds' behavior, and should show less of a bias due to skill levels of particular observers (Buskirk and McDonald 1995). Long counts may also help to compensate for among count variation in the detectability of birds due to changes in wind or weather. As a result of both increasing the total number of detections and reducing the variability between counts done at different times of day or season, or under different weather conditions, longer counts should increase the power of statistical tests to detect a particular level of decline (i.e., in terms of percent of previous population level) when compared to the same number of shorter counts (Verner 1988).

In terms of sampling efficiency, shorter counts allow more counts to be conducted in a day, allowing researchers to increase their sample size (Verner 1988, Buskirk and McDonald 1995). Other arguments for shorter counts focus on potential biases that are likely to be strongest when longer count periods are used; longer counts may increase chances of double-counting birds that move, or allow time for birds to move into the study area that weren't there, leading to a positive bias in numbers observed (Scott and Ramsey 1981a, Verner 1988). Longer counts also are inefficient for species with high calling rates, in that extra time at each point adds few individuals to the total number detected (Scott and Ramsey 1981a, Verner 1988). Researchers planning to use their data to detect species declines should also consider that Buskirk and McDonald (1995) suggest that shorter counts are more effective for actually measuring changes in abundance at particular points, because the higher means attained in longer periods lead to underestimation of these changes. Finally, a strong point in favor of short counts is that the resulting data are most comparable with the huge volume of Breeding Bird Survey (BBS) data. The BBS, which has been underway since 1966 in the United States and Southern Canada, uses clusters of fifty 3-minute roadside counts as its sampling unit (Bystrak 1981).

The pros and cons of large and small count radii are similar to those for long and short counts; one benefit of larger radius (including unlimited radius) counts is their high detection levels, which provide greater statistical power for detecting a set difference between samples (Blondel et al. 1981, Dawson 1985, Verner and Ritter 1988, Petit et al. 1995, Thompson and Schwalbach 1995). An additional benefit of unlimited radius counts is that they don't require that the observer estimate distances in order to determine whether or not a detected bird is within the area being sampled (Thompson and Schwalbach 1995). One of the strongest arguments against unlimited distance counts is that the observer does not know what amount of area is being covered by the count, so that it is not possible to use these to estimate the density of species unless the detectability with respect to distance

is known for the species of concern. However, many authors argue that even when using a fixed radius count, point count data are not accurate enough to use for estimating the density of species (Burnham 1981, Verner 1985, Barker and Sauer 1995).

Other arguments in favor of a fixed radius, especially a small (i.e., 25 or 50 meter) fixed radius, include reduced bias of counts due to observer error; this allows comparisons of relative abundances between sites and habitats to be made with more confidence (Petit et al. 1995). Petit et al. (1995) summarize the sources of bias that tend to reduce detection rates (increase observer error) and have exaggerated effects when larger radius counts are used as (1) weather (wind, dripping leaves), (2) vegetation structure (differences in detectability due to vegetation between the observer and the bird), (3) "saturation" effects (the observer is not able to record all of the birds heard because there are so many), and (4) observer limitations (differences between observers in skill level and hearing ability). In addition, many authors argue that smaller count radii can provide more information regarding the relationship between bird populations and habitat characteristics because the area being covered by the count is smaller and can be described more specifically (Koskimies 1989, Martin 1992, Petit et al. 1995).

As described above, one of the arguments in favor of longer point counts is that they may minimize differences in detection rates across different times of day (or seasons) (Robbins 1981a, Verner and Ritter 1984). As a final part of this chapter, I examine whether longer counts actually do show fewer differences in mean detection rates across different hours of a study than shorter counts in my study sites. Traditionally, point counts of birds during the breeding season have been conducted only in early morning hours, because these times tend to have the highest detection rates for most species (Verner and Ritter 1986). However, if we want to maximize the sample size in monitoring efforts, only counting in early morning hours requires increasing the number of days sampling or number of observers, both of which are likely to be more expensive than expanding time spent by observers in the field per day. If it is true that longer counts allow us to pool more data (or produce lower relative variance between counts), this is an important factor to consider when choosing count length because it may allow us to increase the efficiency of monitoring programs.

Robbins (1981a) analyzed the effect of time of day on bird activity based on more than a million 3 minute Breeding Bird Survey stops, and did find higher rates of detection in the early morning. However, using 8- and 10-minute counts (and much smaller sample size, ranging from 17 to 25 per hourly period), Verner and Ritter (1984) did not find strong hourly trends; only one of the six data sets they examined showed any significant differences in detections between a pair of hours. Other support for the idea that longer counts may show fewer hourly differences comes from Buskirk and McDonald (1995), who found a trend of decreases in detections after 0800 using 3-, 6-, and 10 minute count periods, but the differences were only found to be significant for 3 minute counts. However, other studies, such as Skirvin (1981), have found significant differences between hourly detections using longer (10 minute) counts. The goal of this part of my study is to determine if longer counts do seem to offer an advantage with respect to reducing differences between the mean detection rates at different times of day in the upland and wetland forests that I studied.

With all of these arguments for and against particular point count methods, choosing the "best" point count methods for a particular study goal is complicated, and perhaps confusing. To put all of these pros and cons into perspective and make an informed decision, a researcher must also examine how different combinations of point count radius and duration impact mean detection rates in the actual systems being studied. If one or two combinations of methods produce similar efficiencies in terms of detections of individuals per unit of sampling time, then the choice of methods can be made based on which is likely to be less biased, or which will allow the researcher to achieve a secondary goal, such as examining connections between changing bird numbers and changes in habitat. Rather than choosing methods based on what has always been done, or what has

worked in other areas, to use our conservation dollars wisely we need to evaluate potential methods in the actual areas where they will be used whenever possible. Evaluating the relative costs and benefits with respect to the efficiency of detecting individual birds is the focus of this chapter. In summary, the questions I address in this chapter are:

- (1) What effects do sampling protocols related to length of count and area covered by count (count radius) have on the estimated means and variances of detection rates?
- (2) Are there differences between the mean detection rates from different sampling hours? Does changing the count length affect whether or not differences between sampling hours are found?
- (3) Are there differences in the expected cumulative count per hour (a measure of sampling efficiency) for different combinations of point count durations and radii?

## METHODS

### Study Sites

I conducted my field work at the University of Michigan's Biological Station (UMBS), which encompasses 4000 ha in the northern lower peninsula of Michigan in Emmet and Cheboygan Counties ( $45^{\circ}35'N$  lat.,  $84^{\circ}42'W$  long.). Most forests in this region were heavily logged beginning in the late 1800s, primarily for white pine (*Pinus strobus*) (Whitney 1987). Landscape-scale wildfires, fueled by piles of logging slash, followed the logging operations (Graham et al. 1963, Pyne 1982). As a result of the logging and fires, the upland areas of the UMBS property are dominated by early successional species, such as bigtooth aspen (*Populus grandidentata*). Within UMBS, sites were selected based on a map of landscape ecosystems created for UMBS by Pearsall et al. (1995). Pearsall et al. (1995) utilized an ecological, multifactor approach to identify ecosystem types based on an integration of physiography, climate, hydrology, soil type, and vegetation (Barnes et al. 1982, Lapin and Barnes 1995, Pearsall et al. 1995, Zogg and Barnes 1995).

To choose upland sites, I first identified ecosystems that covered at least 100-200 ha within UMBS, and were present in contiguous, roughly square-shaped expanses of at least 30 - 40 ha. Since I wanted my results to be generalizable across a range of upland ecosystem types, I selected a set of types that can be seen as representing a productivity gradient from fairly low productivity (Table 2-1). Within these ecosystem types, I chose relatively flat areas with continuous canopy cover for point count transect locations.

The two wetland sites were chosen because they are each part of one half of the largest contiguous wetland area on UMBS property, Reese's Swamp. The points sampled in these sites are located in a mosaic of ecosystem types (types as defined by Pearsall et al. 1995), rather than each one being within one relatively homogeneous ecosystem type like points sampled in the upland sites. Most of the wetland area consists of northern white-cedar (*Thuja occidentalis*) swamps that are fringed by mixed hardwood uplands and bisected by numerous small streams. Adjacent to patches of cedar swamp are patches of mature hardwoods; these are often associated with sand ridges that radiate east and west from the stream. There also are dense patches of speckled alder (*Alnus rugosa*) in the wettest areas of the swamp. Where the canopy is closed, the understory vegetation is sparse; ground cover consists primarily of leaf litter with sparse ferns, moss, and herbaceous vegetation. In canopy gap areas (i.e., where one or many trees have fallen down), understory vegetation is often extremely dense, and is dominated by balsam fir (*Abies balsamea*) and red maple (*Acer rubrum*), and may include large, contiguous mats of *Sphagnum* sp.

## **Field Methods**

Point counts were conducted between 0615 and 1130 EDT from June 3 - July 19, 1995; sunrise at UMBS occurred between approximately 0520 and 0550 over the course of this study. I conducted 113 point counts in the wetland ecosystems, and 130 point counts in the upland ecosystems. Point counts were conducted along sets of marked, parallel transect lines that ranged from 300 to 750 m in length (depending on the site), and were 150 meters apart. The first point was located at a randomly selected distance (between 0 and 40 m) from the start of the transect; subsequent points were sampled at 150 m intervals. Following completion of a transect, I would go on to a new transect (using a new random start point). Following arrival at each point, I waited about two minutes before sampling to minimize possible disturbance effects. All counts lasted for 12 minutes total, and all birds that could be heard or seen were recorded. Although longer counting periods would have provided a more complete examination of the study questions, I was limited by the number of days available for sampling, and chose to increase the number of counts per day rather than the maximum count length. Twelve minutes was chosen because it incorporated 2 of the most commonly used counting periods (5 minutes and 10 minutes) and because 70-80% of birds detected in longer counts (20-32 minutes) have been detected in the first 10-12 minutes (Scott and Ramsey 1981a, Hamel 1984).

Point counts were only conducted on days without rain, and when wind speeds were less than approximately 10-12 miles per hour. If conditions changed after sampling had begun (i.e., it started to rain or wind speed went above the cutoff point), I stopped sampling for the day. At each sampling point, I recorded the date, time, location in plot, temperature, and a category value for wind strength. The wind speed categories were: (0) very little to no wind; (1) slight wind (identified in the field by movement of leaves); or (2) medium wind (identified in field by movement of leaves and small twigs). Temperatures ranged between 10 and 29 degrees Celsius (50 and 84 degrees Fahrenheit) during the counts.

I estimated how far away each detected bird was (in 10 m intervals), and also estimated the direction (in degrees) to each bird using a compass. Whenever possible, the distance estimation was made based on the first detection of the bird. At times many new birds were heard at once, and, as a result distances to some were estimated based on a second or third call. Prior to actual data collection, I practiced estimating distances to birds that were seen and/or heard and then pacing them out for approximately two weeks (Reynolds et al. 1980, Scott et al. 1981). Also, to continue checking my estimation during the field season, distances to birds directly ahead of me while I was walking between points were estimated and checked by pacing. I recorded the direction of the bird at the same time that I estimated its distance, and used these two estimates in the field to help me keep track of individual birds. If a bird appeared to move during the count, its new location was recorded as a note. Second or multiple individuals of the same species and sex were determined to be present if (1) they could be heard singing at the same or very close to the same time from different directions, or (2) they were heard at greater than an estimated 100 m away, and from areas at least 90 degrees different in direction. For species such as Black-capped Chickadees, Cedar Waxwings, and Blue Jays (scientific names for all species are in Appendix A) that often were in groups (either family groups or flocks), I recorded a maximum of two individuals for a generalized location, even if it appeared that more were singing or calling simultaneously. I collected data in two minute intervals, so for each bird recorded, I noted whether or not it was observed in each two minute periods within the twelve minute samples. Characteristics of birds that were seen, such as sex, and whether or not these birds were also singing or calling were also recorded.

## **Analytical methods**

I calculated estimates of means, standard deviations (SD), and standard errors (SE) of detection rates for each combination of point count length and count radius for all birds

together, and separated into two groups based on species' migration patterns. Species were categorized as neotropical migrants if they were listed as neotropical migrants in Thompson et al. (1993); species not listed were assumed to be short-distance migrants or residents in the midwest. Separate analyses for these groups were done as a way of gaining insight into how methodological differences might impact these two broad groups differently (Verner and Milne 1989).

While in the field, I observed an apparent difference in the frequency of different wind strength categories between the wetland and upland sites; this type of difference is likely to contribute to differences in detectability between the two forest types. I tested for differences in the distribution of wind categories using a Chi-Square Test of Independence. The distributions of detections for different migratory groups with respect to count length (0-4, 5-8, and 9-12 minutes) and count radius (50-m, 100-m, and unlimited distance radius sizes) were compared using Chi-Square Tests of Independence. For the count length analyses, I did separate tests using data from unlimited distance counts, 100-m radius counts, and 50-m radius counts, in order to see if the patterns of detections varied with the spatial scale of the samples. All Chi-Square Tests that were done met the assumptions required for a good  $\chi^2$  approximation (Sokal and Rohlf 1981).

I used One-way Analyses of Variance (ANOVAs) to test for differences in detection rates at different times of day for all species together, and for neotropical migrants and residents and short-distance migrants, using data from unlimited point counts with durations of 4, 8, and 12 minutes. For sets of data with significant results, I used the Bonferroni Multiple Comparison approach to identify all pairs of count-start times with significantly different means. I did these analyses separately for wetland and upland data. Start times of point counts were divided into 5 groups: 0615-0715, 0716-0815, 0816-0915; 0916-1015; and 1016 - 1115. I conducted all statistical tests using Systat 5.21 for the Macintosh. For the ANOVAs, data were evaluated for normality using the Lilliefors test, and examination of skewness and kurtosis coefficients; homogeneity of variances was examined using Bartlett's test. All data sets analyzed met the assumptions of normality and homogeneity of variances. The alpha level for all comparisons was set at 0.05.

To compare the efficiency of different combinations of count radius and count duration, I estimated the expected cumulative count of new individuals per hour of sampling time (Verner 1988). This estimate is based on the mean detection rate for the particular combination of methods, divided by the length of the count plus the time it takes to walk to the next point (both in minutes); this is multiplied by 60 minutes/hour to put the value into units of hours of sampling time (Verner 1988:2). Travel times for this comparison were estimated based on my actual travel times to walk the 150 m between points ( $17.4 \pm 7.8$  SD minutes in wetlands,  $14.1 \pm 7.2$  SD in uplands), but travel time differed with the radius, as it would in an actual sampling program if radius size were used to determine how far apart points should be to avoid recounting the same birds. Travel time was based on walking 100 m for 50 m radius counts, 200 m for 100 m radius counts, and 400 m for unlimited radius counts, estimated as a proportion of the 150 m rate. These values are likely to be longer than would be required simply to walk from one point to another in these ecosystems, as they are based on actual elapsed time between points on the same day, and as a result include time that I spent verifying bird identifications, etc., during a sampling day.

## RESULTS

### Weather for Conducting Point Counts

On days when I was planning to sample, 5 entire days and 9 partial days had weather that was unsuitable for sampling (6 of these partial days were cut short or started late due to high winds in upland sites, 2 were due to high winds in wetland sites, and one resulted from rain in an upland site). The 130 counts in uplands and 113 counts in wetlands were

conducted in 32 actual field days. In the wetland sites, the wind conditions for the 113 counts were recorded as 47 = 0 (42%), 43 = 1 (38%), and 23 = 2 (20%), while these values for the upland sites (130 counts) were 25 = 0 (19%), 52 = 1 (40%), and 53 = 2 (41%). The distribution of wind categories for the sets of counts was significantly different; more of the upland counts had stronger winds (category 2), while a lower proportion of upland counts had very low wind (category 0) when compared to wetland data ( $X^2 = 18.3$ , df = 2, p <0.001).

### **Species Composition and Sex Ratio of Detections**

Wetland Sites. In the 113 unlimited-distance counts conducted in wetland ecosystems, I detected 17 species of neotropical migrants (533 observations of individuals), and 16 species of short-distance migrants and residents (657 observations of individuals) (Table 2-2). The majority of detections were aural; 1178 (99%) individuals were heard only, or heard and seen, and 12 (1.0%) were seen only. The majority of these detections were of singing male birds; of those that were seen and not singing (but may have been chipping) only 16 (1.4% of total detections) could be identified as females. So that these data can be compared to a greater number of studies, the number of detections by species are presented based on 10-minute counts in Table 2-2. The same number of species was found as when using the 12-minute counts, although the overall number of detections was lower, with 500 neotropical migrants, and 616 short-distance migrants and residents detected during the counts.

Upland Sites. I identified 15 neotropical migrant species (823 observations of individuals) and 17 species of short distance migrants and residents (400 observations of individuals) in 130 unlimited distance point counts in the upland ecosystems (Table 2-3). The majority of detections were aural; 1204 (99%) individuals were heard only or heard and seen, and 19 (1.5%) were seen only. The majority of detections were of singing males; of those that could be seen and were not singing (but may have been chipping), only 15 (1.3% of total detections) could be identified as females. So that these data can be compared to a greater number of studies, the number of detections by species are presented based on 10-minute counts in Table 2-3. The same number of species were found as when using the 12-minute counts, although the overall number of detections was lower, with 763 neotropical migrants, and 374 short-distance migrants and residents detected during the counts.

### **Effects of Point Count Duration**

Wetland Sites. For neotropical migrants, four- and eight-minute point counts averaged 68 and 87% of the 12-minute mean (Figure 2-1). For short-distance migrants and residents, 70 and 89% were detected in the first 4 and 8 minutes, respectively (Figure 2-1). No significant differences were found between the distribution of detections between the 0-4, 5-8, and 9-12 minute periods for the two groups of species based on the unlimited radius, 100 m radius, and 50 m radius data.

Upland Sites. In the upland sites, four- and eight-minute point counts averaged 70 and 88% percent of the 12-minute mean for neotropical migrants (Figure 2-2). For short-distance migrants and residents, 61 and 80% of the 12-minute mean were detected in the first 4 and 8 minutes, respectively (Figure 2-2). The distributions of detections in the 0-4, 5-8, and 9-12 minute categories for the two species groups were significantly different ( $X^2= 15.3$ , df = 2, p < 0.001). The neotropical migrants were detected more often than expected in the first 4 minute period, while the residents and short distance migrants were found less often than expected in the first four minutes, and more often in the last four minute period. The same significantly different pattern was found when the time period distributions for the two migratory groups were compared using data from the 100 m and 50 m radius sizes ( $X^2= 11.0$ , df = 2, p < 0.01, and  $X^2= 8.4$ , df = 2, p < 0.05, respectively).

### **Effect of Limiting the Count Radius**

Wetland Sites. In the wetland sites, 73 and 36% of the total detections (unlimited-radius, 10-minute counts) were detected within the 100 m radius, and 50 m radius, respectively (Figure 2-3). For the residents and short-distance migrants, 64 and 42% of the total birds detected were estimated to be within the 100 m radius, and 50 m radius, respectively (Figure 2-3). The distributions of detections within each radius size were significantly different for the two migratory groups; ( $X^2 = 29.3$ , df = 2,  $p < 0.0001$ ); the neotropical migrants were detected proportionally more often in areas between 50 and 100 m away and less often than expected within the 50 m radius, or outside of the 100 m radius. The residents and short-distance migrants showed the opposite pattern; for both sets of species, the bias described for the 50-100 and 100-unlimited distance (either positive or negative) was particularly strong; the values for both within 50 are closer to the expected values.

Upland Sites. For neotropical migrants, 55% of the all of the birds recorded were detected within the 100-m radius, while only 22% were observed within the 50-m radius (Figure 2-4). For the residents and short-distance migrants, 62% of the total was detected within the 100-m radius, and 33% was detected within the 50-m radius (Figure 2-4). The distributions of detections within each radius size were significantly different for the two migratory groups; ( $X^2 = 18.1$ , df = 2,  $p < 0.001$ ); the neotropical migrants were detected proportionally more often in areas greater than 100 m away and less often within the 50 m radius, while the residents and short-distance migrants showed the opposite pattern.

### **Detection Rates at Different Hours of the Morning**

Wetland Sites. I found that detection rates of all individuals combined, and all neotropical migrants were higher in the first hour than in the fourth and/or fifth hour of sampling using data from all count lengths (Table 2-4). For the short-distance migrants and residents, no differences were found (using any of the count lengths) between mean rates of detection during different hours.

Upland Sites. In the uplands, I found differences between at least 1 pair of hours for all species combined; one significant difference (hour 2 had a higher mean than hour 5) was found for the 4-minute data, while the 8- and 12-minute data showed four and three pairs of differences, respectively (Table 2-5). For the short-distance migrants and residents; based on all count lengths, means in hours 1 and 2 were significantly higher than means in hour 3. No significant differences between hourly means were found for neotropical migrants based on data from any count length.

### **Most Efficient Combinations of Count Length and Duration**

Wetland Sites. For the neotropical migrants, the most efficient combination of methods seems to be a 100 m radius count lasting for twelve minutes; based on the trend shown, an even longer count might produce slightly larger expected cumulative counts. The values for the unlimited radius and 50 m radius counts are lower, and for counts within the usual range (5-10 minutes) are quite similar to each other; the trend for the unlimited count radius is increasing expected cumulative count with increasing duration, while the 50 m radius data shows a slight increase (from 2-4 minutes) followed by a very shallow decline in expected count with increasing radius. For the residents and short-distance migrants, both the 50 m and 100 m radius sizes produce the highest expected cumulative counts; these show very similar trends of slight increases in values from 2 to 6 or 8 minutes, followed by slight decreases at the longer counts. The unlimited radius count appears least efficient for this group as a whole, although the cumulative count increases with count duration, and at 12-minutes produces very similar values to the other two radius sizes.

Upland Sites. The unlimited radius and 100 m radius counts both produce larger expected cumulative counts than the 50 m radius for neotropical migrants; both of these are most efficient with the longest count duration examined. The 50 m radius line shows the opposite trend from the other two, with values decreasing slightly with counts longer than

4 minutes. For the residents and short-distance migrants, the pattern for the unlimited radius and 100 m radius sizes are very similar, and these become increasingly more efficient than a 50 m radius count as the duration of the count increases.

## DISCUSSION

### Total Detections and Species Composition of Study Sites

As expected, the vast majority of detections (99%) were made based on songs or calls (or both sound and sight) of birds rather than visual observations alone. This result is similar to those from other studies in forested ecosystems such as Emlen (unpublished, as cited in DeJong and Emlen 1985), and Hamel (1984), which found between 94 and 96% of 2039 detections were by ear. Also as expected, the vast majority of observations were recorded as males (>98%); this percentage is likely to over-represent detections of males, as some birds that were detected due to call notes or chipping were probably females, but were recorded as males because they were not seen, or if seen, were not of a sexually dimorphic species.

In the wetland sites, the seven most common neotropical migrant species were all warblers; two of these, the Nashville Warbler and Canada Warbler, are species of management concern in Michigan (Ewert, pers. comm.). Four other species of management concern, the Eastern Wood-Pewee, Blackburnian Warbler, Veery, and Great Crested Flycatcher, were found at lower rates in the wetland sites. The most common species detected were resident/short distance migrants (Winter Wren and Black-capped Chickadee); values for the Black-capped Chickadee are likely to be negatively biased because I did not record more than two at a particular point, even though it is likely that in many cases the frequent songs and calls that could be heard from this species were coming from more than two birds in group. However, there is a confounding problem with Chickadees in that they appeared to be attracted to me while I was collecting data; often two or more would perch within 10-m of me and sing or call. Due to these problems, Chickadees are left out of the individual species analyses in Chapter 3.

The mosaic of different ecosystem types present in the wetland sites is likely to contribute to the diversity (as indicated by a simple species count) seen in these sites (MacArthur et al. 1962, Roth 1976, James and Wamer 1982, Boecklen 1986, Freemark and Merriam 1986, Urban and Smith 1989); many of the common species are frequently found in coniferous or mixed coniferous/deciduous wetlands (e.g., Nashville Warbler, Canada Warbler, Veery, Black-and-White Warbler); however, the drier sand ridges and clumps of alder within the wetland provide other types of habitat favored by species such as the Ovenbird, and Northern Waterthrush, respectively (Brewer et al. 1991). The effects of windthrow also contributes to the heterogeneity, and as a result the species richness of the wetlands. Two species in particular tend to be found in openings in coniferous forest: Northern Parulas and Magnolia Warblers (Magnolias appear to be attracted to regenerating conifers)(Brewer et al. 1991). By sampling a gradient of upland sites, the diversity of habitats (between-site variability) represented in the upland samples is likely to be similar to that found in the wetlands due to among-site variability; this could explain the similarity in the number of species detected in both types of sites.

By far the most common bird in upland sites was the Ovenbird, which was detected at nearly all of the points. Red-eyed Vireos, Hermit Thrushes, and Black-capped Chickadees were also very common. Two of the species of management concern, the Eastern Wood-Pewee and Veery, were much more common in the upland sites than in the wetlands; the Great Crested Flycatcher was found slightly more often, while the Blackburnian warbler was detected at low rates in both the upland and wetland sites. The Brown-headed Cowbird, a species that parasitizes the nests of many neotropical migrants, was detected much more frequently in the uplands than in the wetlands.

## **Consideration of Weather and Wind Patterns in Monitoring Plans**

As might be expected in northern Michigan, when monitoring time schedules are developed, they should include enough days in the schedule to account for poor sampling conditions due to rain and strong winds. Based on one summer of data, it appears that planning for about 25% more days than the number of actual field days that are required may be a good rule of thumb, however it is likely that the usefulness of this rule will vary from year to year. It also appears that recorded patterns of wind can vary significantly between study sites that are fairly close together. This is likely due to both actual differences in wind strength in the different sites (related to topography, differences in rates of surface heating, and distance to open water), and to differences in vegetation leading to differences in how the strength of wind is perceived by the observer.

## **Effects of Varying Point Count Length**

I found that after four minutes, most of the individuals that will be detected at a particular point using a 10-12 minute count have been detected. These results are similar to those from other studies: Savard and Hooper (1995:57) found four and eight minute counts averaged 68 and 90% of the total number of individuals detected in surveys for grassland birds in British Columbia, and Gates (1995:136) recorded between 70 and 76% of total detections in the first five minutes of ten minute counts in Maryland forests. Values for the wetlands were similar for both migration groups at all radius sizes. Between 70-71% of individual were detected after four minutes and 87-89% after eight minutes for both the neotropical migrants and short-distance migrants and residents.

Although high percentages of detections were also found after 4- and 8-minute counts in the upland sites, there was a significant difference between the 2 species groups' patterns of detections (based on data from all radius sizes). I found higher rates of detections of neotropical migrants than residents and short distance migrants, and the neotropical migrants were more often detected in the early minutes of the count when compared to the other group. The percent of detections for each after 4 and 8 minutes reflect this difference; values were 70 and 88% of the total for the neotropical migrants, compared to 61 and 80%, respectively, for the short distance migrants and residents. Most of this difference probably comes from differences in calling rates of the species involved. It is likely that the high rate of detection for neotropical migrants is primarily due to the presence of many male Ovenbirds and Red-eyed Vireos in the upland sites. Both of these species tend to have high calling rates, and although the rate for the Ovenbird tends to decline later in the morning, the rate for the Red-eyed Vireo seems to remain fairly constant throughout morning hours (Robbins 1981a).

## **Effects of Varying Point Count Radius**

In both sites, and for both neotropical migrants and residents, many more individuals were detected as the size of the radius of the area sampled increased from 50 m, through 100 m, to an unlimited radius. This is a fairly obvious result that has been recorded previously (e.g., Gates 1995, Thompson and Schwalbach 1995, Savard and Hooper 1995). In both wetland and upland sites, the two migration groups varied significantly in terms of how much changing this factor affected rates of detection, but they varied in different ways. In the wetlands, with 36 and 73% of the total individuals detected in the 50 and 100 m radius sizes respectively, the increase in radius did not contribute as much to the total detections of neotropical migrants as it did for the short distance migrants and residents (42 and 64% percent of detection within 50 and 100 m from the count center, respectively), while limiting the count to 50 m would allow a greater proportion of the residents to be recorded than neotropical migrants. However, in the upland sites, only 22 and 55% of neotropical migrants were detected in the 50 and 100 m radius sizes respectively. In contrast to what was found in the wetland data, the increase in radius contributed a great deal to the total detection rate of this group. The contrast between these two results illustrates my point that to determine most efficient sampling methods, species and/or habitat specific differences

must be examined. The short-distance migrants and residents (33 and 62% of detection within 50 and 100 m from the count center, respectively), again showed proportionately higher rates of detections within the 50 m radius samples. This result suggests that using a smaller radius is less "costly" in terms of lost detections for short-distance migrants and residents than for the neotropical migrants in the upland sites, where the reverse was true in the wetland sites.

The differences in patterns found are likely to be due to both variations in the species compositions of the migratory groups in the two sites, and effects of the habitats sampled on the detectability of bird song. Many authors have described the effects of vegetation and atmospheric conditions on the detectability of bird songs; in general, song attenuation, defined as the reduction in the intensity of sound as it propagates through the environment (Wiley and Richards 1982), increases as the density of vegetation, and atmospheric disturbance (i.e., wind) increases (Marten and Marler 1977, Richards and Wiley 1980, Emlen and DeJong 1981, Richards 1981, Robbins 1981b, Wiley and Richards 1982, Bibby and Buckland 1987, Waide and Narins 1988, Wolf et al. 1995). The upland sites are likely to show more of a benefit of using a larger radius because in general the vegetation in these areas was much more open: it is likely that sound carried farther in these ecosystems. However, these areas did have significantly more counts for which winds were recorded as being in the highest category (2); this is probably due both to actual differences in the patterns of wind affecting the two sets of sites, and to higher perceived wind levels due to the primarily deciduous vegetation in the upland sites (as compared to a high percentage of "quieter" coniferous canopies in the wetland sites). In particular, the bigtooth aspen that dominated the driest upland sites seemed to magnify the effect of prevailing winds, probably due to the slender branches and long petioles on these trees. At count locations where aspens were the dominant tree species, detecting birds was much more difficult if even only a slight breeze was present.

Emlen and DeJong (1981) examined detectability differences related to effects of wind speed, and found a mean detection distance decrease of approximately 20 percent in simulated wind speeds of 13-24 km/h as compared to wind speeds of 5 km/h. These data have been used as an argument in favor of small radius sizes by Petit et al. (1995:55), who state that since detection threshold distances found by Emlen and DeJong were never less than 50 m, bias due to differences in wind speed can be minimized by using count radii of this size. Although not examined in this study, this claim could be tested by comparing the differences in mean detection rates for the three wind categories separately for the data from the three radius sizes (i.e., the same methods used in this study for looking for advantages of longer counts in terms of minimizing differences in mean detection rates between different sampling hours).

The often dense vegetation in the wetlands probably leads to lower detectabilities in these systems; however the higher humidity (occasionally taking the form of dense fog) can lead to decreased sound attenuation, increasing detectability (Wiley and Richards 1982). The variation in attenuation of bird songs due to vegetation and humidity is likely to be higher in the wetland systems, since the vegetation structure was more variable due to patches of areas with few standing trees, and these areas often were extremely humid, while the upland sites were more uniformly dry. Estimation of bias due to the effects of habitat on detectability are further complicated by the fact that the magnitude and direction of effects are likely to vary by species (Bibby and Buckland 1987). Evaluating the relative bias of each set of point count locations would require actually measuring how far particular species songs can be heard in each ecosystem under different conditions of wind and humidity; this can not be estimated from the actual distance estimates used in this study because it is likely that differences in habitat have contributed to biases in my estimates of distance (DeJong and Emlen 1985). However, I believe that the overall patterns shown in the data are likely to be valid, even if there are unknown biases due to habitat effects incorporated into my distance estimates. I tried to minimize bias by regularly evaluating my estimates throughout the study by pacing out distances to birds heard in front of me as I

was walking from point to point in all ecosystem types. Even so, I do not really have even a general indication of what the magnitude of bias may be, because the effect of this source of bias is likely to be highly variable depending on the species in question, weather conditions, etc.; really getting a handle on this would be a challenging study in itself (DeJong and Emlen 1985).

Variations in the species composition of the neotropical migrants and short-distance migrants/residents groups in the two sites are also likely to have contributed to the different patterns with respect to the effects of increasing count radius. The birds found in these sites vary in many ways that influence their detectability; for example they differ in size, song frequency (measured in kilohertz - kHz), singing height, and in how often and how long they sing (Dawson 1981, Diehl 1981, Lemon et al. 1981, Mayfield 1981, Wiley and Richards 1982, Waide and Narins 1988, Calder 1990). In general, higher frequency songs show higher rates of attenuation (Lemon et al. 1981, Wiley and Richards 1982), and smaller birds tend to have higher emphasized song frequencies than larger birds (Wallschläger 1980, Ryan and Brenowitz 1985). Larger birds also tend to produce songs with higher sound intensities (Calder 1980). One of the loudest singers found in my study, the Winter Wren, is an exception to this general pattern: Its song has been recorded at 6 milliwatts (mW) (Brackenbury 1979), as compared to values of less than 1 mW found for most species of similar body weight discussed by Calder (1990). Ovenbirds and Northern Waterthrushes are also noted as having particularly loud songs as perceived by human observers (Lemon et al. 1981).

In the wetlands, increasing the count radius had a more positive effect on detection rates for residents and short distance migrants than it did in the uplands; this is probably because of the particularly loud song of the most commonly detected short-distance migrant/resident, the Winter Wren; the Blue Jay and White-throated Sparrow (third and fourth most common in this group, respectively) also are likely to have loud, relatively low frequency songs if body size is a useful estimator of these factors. Singing height can also influence the ability of an observer on the ground to detect species; songs from birds at lower heights (all else being equal) tend to show less attenuation (Waide and Narins 1988). Although the Ovenbird, which has a loud song and a low singing height (Ficken and Ficken 1962), was commonly detected in the wetlands, many of the neotropical migrants have songs with maximum detection distances that tend to be more moderate (i.e., Black-and White Warbler), especially when compared to the Winter Wren and Blue Jay (Wolf et al. 1995). However, there were also more detections of species in the resident/short-distance migrant group that are often detected by sight (Yellow-bellied Sapsucker) or have quieter, and/or high frequency songs or calls (Black-capped Chickadee, Brown Creeper), than were found for the neotropical migrants.

In the upland sites, interspecific differences produce the opposite pattern; here there were fewer detections of short-distance migrant and resident species that have large maximum detection distances (i.e., Hermit Thrush, Blue Jay) (Wolf et al. 1995), and many detections of two loud, frequently singing neotropical migrant species, the Ovenbird and Red-eyed Vireo. Again, a higher percentage of short-distance migrants and residents were detected within 50 m when compared to the neotropical migrants; these detections can be linked primarily to Chickadees, Brown-headed Cowbirds, and Sapsuckers.

### Detections Rates at Different Times of Day

Based on my results, conducting longer (8- or 12-minute counts rather than 4-minutes) does not appear to decrease the number of detectable differences in mean number of individuals recorded during different hours of the morning. In contrast to what is often described as the general pattern, detections did not show a consistent decline across hours. For example, upland short-distance migrants and residents had their lowest means in the third hour, while neotropical migrants in the wetlands showed an increasing trend between the fourth and fifth hours (Table 2-4 and 2-5: the difference between these was not significant). Interestingly, there were not significant differences between hourly means for

the residents and short-distance migrants in the wetlands, or for the neotropical migrants in the uplands, but in each forest type the other migratory groups did show significant differences. This was unexpected, as many studies have found declines through the morning for most species detected in this study, including species in the groups for which I did not find significant differences between hours (Shields 1977, Robbins 1981a). For example, Ovenbirds, Scarlet Tanagers, Black-throated Green Warblers, and Veeries (all neotropical migrants in uplands), as well as White-throated Sparrows, Brown Creepers, and woodpeckers (all short-distance migrants or residents in the wetlands) tended to show either steady or gradual declines in Robbins' (1981a) analysis of 15 years of BBS data (sets of fifty 3-minute, roadside counts - sample sizes for all species were in the tens of thousands).

However, as suggested by Verner and Ritter (1986), species specific differences in patterns are likely to compensate to some extent for trends in other species, leading to total detections that remain fairly steady. In a transect study in New Jersey, Shields (1977) found that Blue Jays did not show significant decreases in number recorded per transect between samples begun at 0600 and ones started at 0730, while 14 of the 18 species sampled did show significant declines. A similar constant rate of detections was found by Robbins (1981a) based on 15 years of BBS data. It seems likely that the Blue Jay, as well as perhaps the Winter Wren, which showed only gradual declines by hour in Robbins (1981a) analysis of BBS data, and the Chickadee which tended to have peak detections at midmorning (Robbins 1981a), may have provided enough calls later in the morning to keep the means relatively steady in my study. In the uplands, where the Blue Jay was detected less often and the Winter Wren was not present, significant differences were found between hours. Red-eyed Vireos have been found to be detected at fairly constant calling rates during morning hours; this common species in the uplands may have helped the means in these sites remain fairly steady (Robbins 1981a).

Verner and Ritter (1986) note that the rapid changes in the detectability of many species that occurs in the very early morning may produce sets of counts with particularly high variances. They suggest that this can result in researchers needing to conduct more counts at that time of day to detect differences between samples, even though mean rates of detection are likely to be higher. For neotropical migrants and residents in both the uplands and wetlands, coefficients of variation (C.V.) tended to decrease with increasing count length. Patterns in C.V. with respect to time of day were more variable: For migrants in both sites and residents in uplands, the C.V.s tended to increase later in the day, while for residents in wetlands they showed a general decrease from early to late morning. An interesting exception to the trend for decreasing C.V. with increasing count length shows up in the wetlands, where shorter counts had lower C.V.s in the earliest sampling hour.

It is likely that more differences would be detected with a larger sample size at each hour, as is suggested by comparing the enormous sample sizes of the study by Robbins (1981a) that did find differences by hour, and those finding no difference between hours such as Verner and Ritter (1984), and the upland neotropical migrants and wetland residents and short distance data from this study. However, based on these data, I agree with Verner and Ritter (1984) that counts should not be restricted to just the very early morning hours, because this limits the number of samples that can be collected in a day, without offering a convincing benefit in terms of higher, less variable, rates of detection. The benefits seem slight because, although rates of detection were often higher in the first hour or two, in general the variance for same hour counts tends to be large compared to between-hour differences in means (Verner and Ritter 1984), and because the trends from my study sites did not suggest steady declines. As stated above, the argument for longer counts based on fewer differences between hours doesn't appear convincing, because in my study there was no relationship between the length of the count and the number of differences between sampling hours.

### **Most Efficient Combinations of Count Length and Duration**

The results of the comparison of different combinations of count duration and count radius suggest that the most efficient combination varies by both forest type and migratory group in northern Michigan forests. For neotropical migrants in wetland sites, the 100 m radius count appears likely to produce the highest cumulative count per hour sampled, and this radius size is most efficient when the count length is 8-12 minutes. In this system the 100 m radius would also be quite effective for sampling the residents and short distance migrants using long count durations, although for this group similar results could be obtained using shorter duration (5-6 minute) 50 m radius counts. In contrast, in the uplands the neotropical migrants had the highest expected cumulative counts based on 12-minute, unlimited-distance counts. Short-distance migrants and residents could be sampled most efficiently using either the unlimited radius or 100 m radius size, and long counts (10-12 minutes). In the wetlands, with the exception of the data for the neotropical migrants using the unlimited-distance radius, it appears that 12 minutes was a reasonable maximum duration to test. However, the trend of increasing efficiency with increasing count length in these wetland data, and in the both sets of unlimited radius data in the uplands, suggest that higher expected cumulative counts may be achieved with even longer count durations. These data also suggest that the trade-offs between count radii can change with species and forest types; for example, if researchers choose to use 50 m radius counts so that bird data can be more closely linked to habitat data (Koskimies 1989, Martin 1992), this would lead to a greater sacrifice of efficiency in the uplands than in wetlands, with particular reduction in the number of neotropical migrants detected.

These variations can be boiled down to differences in means and differences in non-counting time during a count. Using point count data collected in the Sierra National Forest (central California), Verner (1988) found that when non-counting time was estimated at 5 minutes, a value slightly lower than what I estimated for 50 m radius counts, the most efficient count length was 4 minutes. When he incorporated a non-counting time of 10 minutes, the most efficient counts were longer (7-8 minutes), and when he examined non-counting times more similar to those found for 100 m and unlimited radius counts in my study, (ranging from 15-30 minutes), the peak for expected cumulative counts was at 10 minutes, the longest time considered. In summing up his findings, Verner suggests that the proportional gain in efficiency of longer counts increased with longer travel times, and points out that differences in travel times had "considerably more" effect on count efficiency than did differences in counting time (1988:2). In areas with difficult terrain, such as those (especially in the wetlands) sampled in this study, 10 minute counts appear to be most efficient, for all but the smallest radius. For this reason, the individual species examinations in Chapter 3 focus on this count length.

Although it may seem that longer counts could be even more efficient (at least when unlimited-distance counts are used), I suggest that 10 minutes should be considered a maximum, because there is likely to be a continued decline in the rate of detections per additional minute of counting. For example, Hamel (1984) found that about 70% of individuals detected in 20-minute counts were heard in the first 10 minutes (50% were detected in the first five minutes) in South Carolina forests, while Fuller and Langslow (1984), working in a variety of habitats in England found that the percent of total detections heard after 10 minutes in 20 minute counts ranged from 65 - 75%. Using 10 minute counts also provides the benefit of count results being comparable to those done in many other studies, and allows the researcher to conform to national guidelines suggested by Ralph et al. (1995b).

As I discussed in the Introduction, there are many arguments for and against using particular count radius sizes and count durations. However, to effectively weigh the costs and benefits of particular methods, it is critical that the most important effect, the effect of the methods on our ability to meet our research goals, is carefully examined. To detect species declines, our goal is to maximize the power of statistical tests used to indicate changes in population size. This requires that we find a balance between increasing the

mean detection rate, decreasing the variance of that mean rate, and maximizing sample size, all within the financial constraints of a sampling budget. Based on these efficiency results, it is clear that one set of methods will not be the most efficient for all situations in which they could be applied. Differences in efficiencies are likely to be related to habitat- and species-specific differences in detection probabilities. This study suggests that trends in efficiency are likely to be predictable, if, for example, one would like to compare the efficiency of different count lengths in ecosystems with different travel times, or the efficiency of different count radii for loud versus quiet species. However, specific recommendations (i.e., exactly how long of a count should be used) will require analysis of actual data from the areas being sampled, as efficiency calculations should integrate habitat- and species-specific characteristics. In conclusion, this chapter offers general patterns, representing averages for many species that may or may not have similar detection probabilities. If the goal of a sampling program is to monitor population changes in one or a few species of particular conservation concern, these efficiency results can only provide general suggestions, rather than the specific information that is needed by researchers trying to determine the most effective way to spend monitoring resources. In Chapter 3, I address the need for species-specific data, and identify differences in patterns that are found when each species is compared to the means presented here.

Table 2-1. Description of upland point count sites, based on Pearsall et al. (1995) - Appendix A. The five ecosystem types were grouped into 3 productivity levels, indicated in the first column. The dominant overstory species and most common understory species are based on values in Pearsall et al. (1995) for current vegetation with relative density values of 10% or higher (listed from highest relative density value to lowest).

Ecosystem Number	# of points	Soil Description	Dominant Overstory Species (Understory species) <sup>1</sup>	Ground Cover Indicator Species and Notes
36 (low)	16	Excessively drained medium sand.	Bigtooth aspen, red oak, red pine (white pine, red maple, red pine).	Sparse; species characteristic of dry, acid, infertile sites, mosses and lichens, evidence of burning.
37 (low)	25	Excessively drained medium sand.	Bigtooth aspen, red oak, red maple (red maple, white pine, beech, red oak).	Sparse; species characteristic of dry, acid, infertile sites, evidence of burning.
44 (med.)	55	Excessively drained to somewhat excessively drained medium sand, calcareous in C horizon.	Bigtooth aspen, red maple, red oak (red maple, beech, white pine, red oak).	Species characteristic of dry, calcareous, moderately fertile sites.
41 (high)	14	Well drained, banded medium sand.	Red maple, sugar maple, beech (beech, sugar maple, red maple).	Species indicating dry to somewhat moist, fertile to very fertile sites.
45 (high)	20	Somewhat excessively drained medium sand, calcareous in C horizon.	Sugar maple, beech, red maple (sugar maple, beech).	Species indicating dry to somewhat moist, fertile to very fertile sites.

<sup>1</sup>Scientific names of tree species listed:

Bigtooth aspen - *Populus grandidentata*

Red Oak - *Quercus rubra*

Red Pine - *Pinus resinosa*

White Pine - *Pinus strobus*

Sugar Maple - *Acer saccharum*

Red Maple - *Acer rubrum*

American Beech - *Fagus grandifolia*

Table 2-2. Number of detections for each species observed in wetland sites, along with the percent this number is of total detections, number of counts where each species was detected, and percent this value is of total counts. Based on 10-minute, unlimited-distance counts.

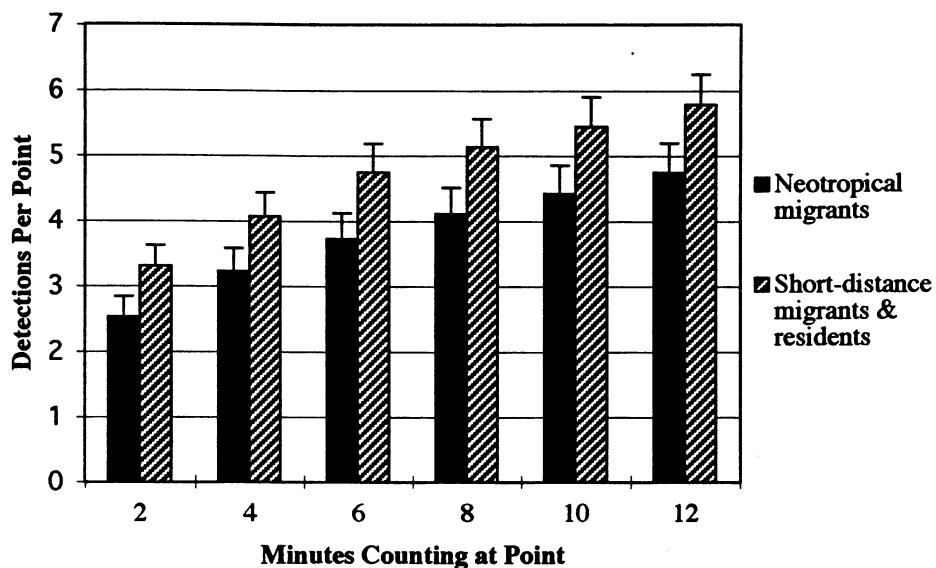
Wetland Species	Number detected (% of total detections for all species)	Number of counts where found (% of 113)
<b>NEOTROPICAL MIGRANTS</b>		
Nashville Warbler	85 (7.6%)	61 (54%)
Ovenbird	76 (6.8%)	46 (41%)
Black-and-white Warbler	70 (6.3%)	54 (48%)
Canada Warbler	61 (5.5%)	47 (42%)
Black-throated Green Warbler	55 (4.9%)	47 (42%)
Northern Waterthrush	37 (3.3%)	22 (19%)
Northern Parula	29 (2.6%)	29 (26%)
Eastern Wood-Pewee	20 (1.8%)	19 (17%)
Blackburnian Warbler	14 (1.3%)	14 (12%)
Veery	14 (1.3%)	11 (9.7%)
Scarlet Tanager	11 (<1%)	11 (9.7%)
Red-eyed Vireo	10 (<1%)	10 (8.8%)
Magnolia Warbler	9 (<1%)	8 (7.1%)
Great Crested Flycatcher	3 (<1%)	2 (1.8%)
Yellow-throated Vireo	3 (<1%)	3 (2.7%)
Solitary Vireo	1 (<1%)	1 (<1%)
Black-throated Blue Warbler	1 (<1%)	1 (<1%)
Rose-breasted Grosbeak	1 (<1%)	1 (<1%)
<b>SHORT-DISTANCE MIGRANTS &amp; RESIDENTS</b>		
Winter Wren	146 (13%)	100 (88%)
Black-capped Chickadee	111 (9.9%)	70 (62%)
Blue Jay	85 (7.6%)	60 (53%)
White-throated Sparrow	65 (5.8%)	56 (50%)
Red-breasted Nuthatch	46 (4.1%)	41 (36%)
Yellow-bellied Sapsucker	44 (3.9%)	41 (36%)
American Robin	38 (3.4%)	37 (33%)
Brown Creeper	27 (2.4%)	26 (23%)
Hermit Thrush	11 (<1%)	11 (9.7%)
Mourning Dove	8 (<1%)	8 (7.1%)
Hairy Woodpecker	8 (<1%)	7 (6.2%)
Yellow-rumped Warbler	7 (<1%)	7 (6.2%)
Northern Flicker	6 (<1%)	5 (4.4%)
Brown-headed Cowbird	4 (<1%)	4 (3.5%)
American Crow	4 (<1%)	4 (3.5%)
Common Raven	3 (<1%)	3 (2.7%)
Pileated Woodpecker	2 (<1%)	2 (2.8%)
Northern Cardinal	1 (<1%)	1 (<1%)

\* For this species, the maximum recorded per point was 2 (see methods).

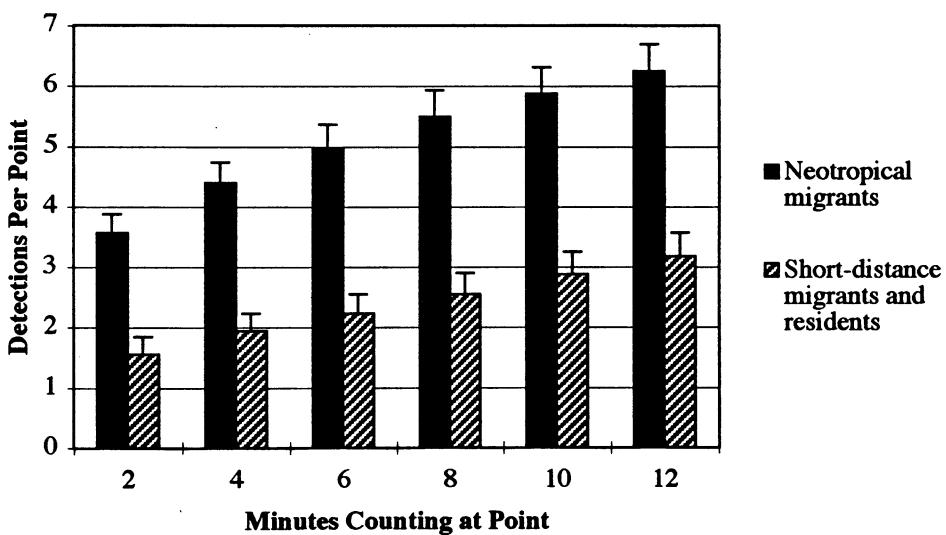
Table 2-3. Number of detections for each species observed in upland sites, along with the percent this number is of total detections, number of counts where each species was detected, and percent this value is of total counts. Based on 10-minute, unlimited-distance counts.

Upland Species	Number detected (% of total detections for all species)	Number of counts where found (% of 130)
<b>NEOTROPICAL MIGRANTS</b>		
Ovenbird	272 (24%)	123 (95%)
Red-eyed Vireo	154 (14%)	96 (74%)
Eastern Wood-Pewee	101 (8.9%)	80 (62%)
Veery	52 (4.6%)	41 (32%)
Black-throated Green Warbler	50 (4.4%)	42 (32%)
American Redstart	46 (4.0%)	25 (19%)
Scarlet Tanager	39 (3.4%)	35 (27%)
Great-crested Flycatcher	12 (1.1%)	12 (9.2%)
Rose-breasted Grosbeak	11 (<1%)	10 (7.7%)
Blackburnian Warbler	10 (<1%)	10 (7.7%)
Yellow-throated Vireo	4 (<1%)	4 (3.3%)
Least Flycatcher	4 (<1%)	3 (2.3%)
Black-throated Blue Warbler	2 (<1%)	2 (1.5%)
Northern Oriole	2 (<1%)	2 (1.5%)
Solitary Vireo	1 (<1%)	1 (<1%)
Nashville Warbler	1 (<1%)	1 (<1%)
<b>SHORT-DISTANCE MIGRANTS &amp; RESIDENTS</b>		
Black-capped Chickadee*	87 (7.7%)	48 (37%)
Hermit Thrush	83 (7.3%)	56 (43%)
Brown-headed Cowbird	47 (4.1%)	41 (32%)
Common Raven	29 (2.6%)	29 (22%)
Yellow-bellied Sapsucker	32 (2.8%)	28 (22%)
American Robin	21 (1.8%)	19 (15%)
White-breasted Nuthatch	11 (<1%)	11 (8.5%)
Cedar Waxwing*	11 (<1%)	11 (8.5%)
Pine Warbler	11 (<1%)	10 (7.7%)
Blue Jay	9 (<1%)	8 (6.2%)
Brown Creeper	8 (<1%)	7 (5.4%)
American Crow	6 (<1%)	6 (4.6%)
Mourning Dove	5 (<1%)	5 (3.8%)
Yellow-rumped Warbler	5 (<1%)	5 (3.8%)
Northern Flicker	3 (<1%)	3 (2.3%)
Red-breasted Nuthatch	2 (<1%)	2 (1.5%)
Hairy Woodpecker	2 (<1%)	2 (1.5%)
Chipping Sparrow	2 (<1%)	2 (1.5%)

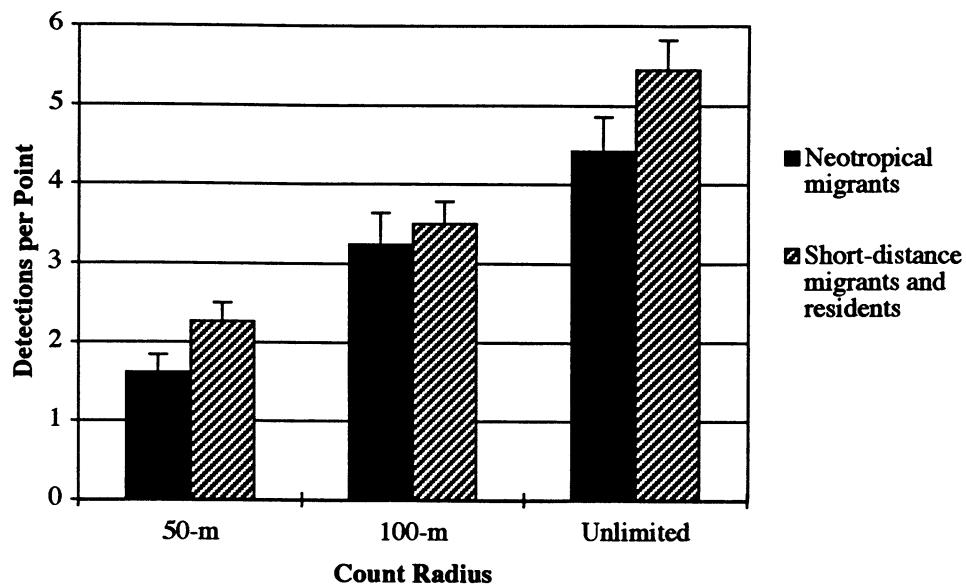
\* For these species, the maximum recorded per point was 2 (see methods).



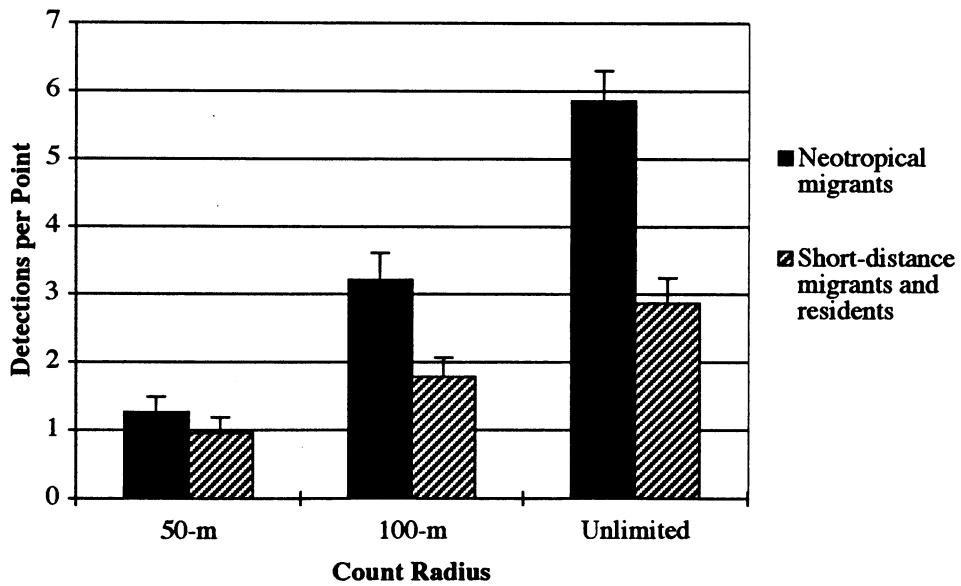
**Figure 2-1. Mean (+2 SE) Number of Individuals Detected in Unlimited Distance Counts - Wetland Sites (N=113)**



**Figure 2-2. Mean (+2 SE) Number of Individuals Detected in Unlimited Distance Counts - Upland Sites (N=130)**



**Figure 2-3. Mean (+2 SE) Individuals Detected Per Point Based on Different Count Radius Sizes - Wetland Sites (N=113)**



**Figure 2-4. Mean (+2 SE) Individuals Detected Per Point Based on Different Count Radius Sizes - Upland Sites (N=130)**

Table 2-4. Estimated mean number (SE) of individuals detected by time of day in wetland sites based on different point count durations (unlimited count radius). Significant differences ( $p < 0.05$ ) in means between times of day are identified under the "ANOVA results" heading with an "S", followed by the pair(s) of counts with significantly different values (Bonferroni procedure). Sets of data with no significant differences have "NS" in this column.

Count length (min.)	Hour count began (EDT)					ANOVA results
	(1) 0615 (n=16)	(2) 0715 (n=22)	(3) 0815 (n=26)	(4) 0915 (n=25)	(5) 1015 (n=24)	
<b>Individuals of all species</b>						
4	8.8 (0.6)	7.0 (0.4)	7.7 (0.5)	6.8 (0.4)	6.7 (0.4)	S <sup>a</sup> : 1&4, 1&5
8	11.3 (0.8)	9.1 (0.5)	9.3 (0.6)	8.9 (0.5)	8.3 (0.5)	S <sup>b</sup> : 1&5
12	12.8 (0.8)	10.7 (0.6)	10.7 (0.7)	10.0 (0.5)	9.2 (0.5)	S <sup>c</sup> : 1&4, 1&5
<b>Neotropical migrants</b>						
4	4.6 (0.4)	3.0 (0.4)	3.5 (0.3)	2.4 (0.4)	3.1 (0.4)	S <sup>d</sup> : 1&4
8	5.3 (0.6)	4.3 (0.4)	4.4 (0.4)	3.2 (0.3)	3.8 (0.4)	S <sup>e</sup> : 1&4
12	6.1 (0.7)	5.2 (0.4)	5.3 (0.5)	3.6 (0.4)	4.0 (0.3)	S <sup>f</sup> : 1&4, 1&5
<b>Short-distance migrants and residents</b>						
4	4.3 (0.7)	4.0 (0.4)	4.2 (0.3)	4.4 (0.4)	3.6 (0.3)	N S <sup>g</sup>
8	5.9 (0.9)	4.8 (0.5)	4.9 (0.3)	5.7 (0.5)	4.6 (0.3)	N S <sup>h</sup>
12	6.6 (0.8)	5.5 (0.6)	5.5 (0.3)	6.4 (0.5)	5.1 (0.4)	N S <sup>i</sup>

<sup>a</sup> ANOVA,  $F(4,108) = 3.1$ ,  $p = 0.019$

<sup>b</sup> ANOVA,  $F(4,108) = 3.2$ ,  $p = 0.017$

<sup>c</sup> ANOVA,  $F(4,108) = 3.7$ ,  $p = 0.007$

<sup>d</sup> ANOVA,  $F(4,108) = 3.9$ ,  $p = 0.005$

<sup>e</sup> ANOVA,  $F(4,108) = 2.9$ ,  $p = 0.026$

<sup>f</sup> ANOVA,  $F(4,108) = 4.2$ ,  $p = 0.003$

<sup>g</sup> ANOVA,  $F(4,108) = 0.62$ ,  $p = 0.65$

<sup>h</sup> ANOVA,  $F(4,108) = 1.5$ ,  $p = 0.22$

<sup>i</sup> ANOVA,  $F(4,108) = 1.5$ ,  $p = 0.22$

Table 2-5. Estimated mean number (SE) of individuals detected in upland sites by time of day based on different point count durations (unlimited count radius). Significant differences ( $p < 0.05$ ) in means between times of day are identified under the "ANOVA results" heading with an "S", followed by the pair(s) of counts with significantly different values (Bonferroni procedure). Sets of data with no significant differences have "NS" in this column.

Upland Sites						
Count length (min.)	Hour count began (EDT)					ANOVA results
	(1) 0615 (n=21)	(2) 0715 (n=32)	(3) 0815 (n=30)	(4) 0915 (n=25)	(5) 1015 (n=22)	
<b>Individuals of all species</b>						
4	7.2 (0.4)	7.3 (0.4)	5.9 (0.4)	5.7 (0.4)	5.5 (0.4)	S <sup>a</sup> : 2&5
8	9.7 (0.5)	9.1 (0.4)	7.5 (0.5)	7.2 (0.5)	6.7 (0.5)	S <sup>b</sup> : 1&3, 1&4 1&5, 2&5
12	11.0 (0.6)	10.6 (0.5)	8.9 (0.5)	8.5 (0.6)	7.9 (0.5)	S <sup>c</sup> : 1&4, 1&5 2&5
<b>Neotropical migrants</b>						
4	4.5 (0.4)	4.8 (0.4)	4.6 (0.3)	4.1 (0.4)	3.9 (0.5)	NS <sup>d</sup>
8	5.9 (0.5)	6.0 (0.5)	5.7 (0.4)	5.2 (0.5)	4.5 (0.5)	NS <sup>e</sup>
12	6.6 (0.5)	6.8 (0.5)	6.5 (0.4)	6.0 (0.6)	5.0 (0.5)	NS <sup>f</sup>
<b>Short-distance migrants and residents</b>						
4	2.7 (0.4)	2.5 (0.3)	1.3 (0.3)	1.6 (0.3)	1.6 (0.3)	S <sup>g</sup> : 1&3, 2&3
8	3.8 (0.5)	3.1 (0.3)	1.8 (0.4)	2.0 (0.4)	2.2 (0.4)	S <sup>h</sup> : 1&3, 2&3
12	4.4 (0.6)	3.8 (0.4)	2.4 (0.4)	2.6 (0.4)	2.8 (0.4)	S <sup>i</sup> : 1&3, 2&3

<sup>a</sup> ANOVA,  $F(4,125) = 4.6$ ,  $p = 0.002$

<sup>b</sup> ANOVA,  $F(4,125) = 6.7$ ,  $p = 0.00007$

<sup>c</sup> ANOVA,  $F(4,125) = 5.9$ ,  $p = 0.0002$

<sup>d</sup> ANOVA,  $F(4,125) = 0.89$ ,  $p = 0.47$

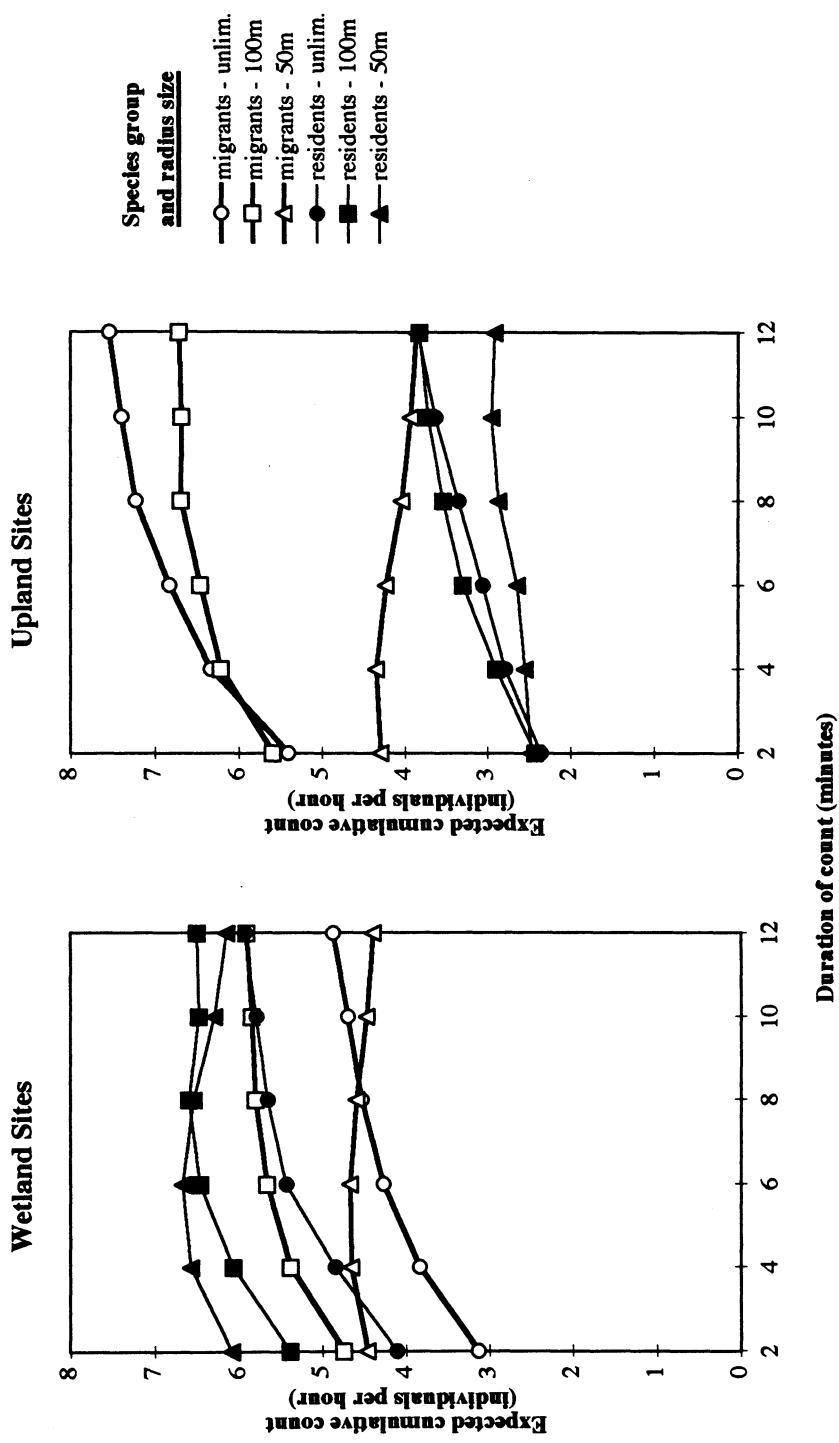
<sup>e</sup> ANOVA,  $F(4,125) = 1.6$ ,  $p = 0.19$

<sup>f</sup> ANOVA,  $F(4,125) = 1.8$ ,  $p = 0.13$

<sup>g</sup> ANOVA,  $F(4,125) = 4.1$ ,  $p = 0.004$

<sup>h</sup> ANOVA,  $F(4,125) = 4.6$ ,  $p = 0.002$

<sup>i</sup> ANOVA,  $F(4,125) = 4.0$ ,  $p = 0.004$



**Figure 2-5.** Relative efficiency of different combinations of duration and radius sizes for detecting neotropical migrants (migrants) and short-distance migrants and residents (residents).

## **Chapter 3: Species-specific Patterns of Detection, Power Analyses, and Estimation of Most Efficient Sampling Scheme**

### **INTRODUCTION**

For many years, researchers have suggested that population sizes of many neotropical migrant bird species appear to be declining (Keast and Morton 1980, Robbins et al. 1989, Terborgh 1989, Askins et al. 1990, Hagan and Johnston 1992, DeGraaf and Rappole 1995, Peterjohn et al. 1995). To speed our progress in testing hypotheses of declines in individual species, we need to examine closely the data collection tools that we are using in our monitoring efforts. In particular, to better understand and document declines of individual species, we must understand the species-specific results of different sampling protocols. It is important to examine how different methods of conducting point counts affect results, because this data collection method is the one most commonly used for monitoring bird populations (Verner 1985, Ralph et al. 1995a).

Since many point count sampling schemes are designed to maximize the rate of detections for all birds as a group, or to maximize the rate of detections of some subset of the group, it is important to determine the direction of detection biases for individual species with respect to changing length of count, or changing count radius, relative to results from combined species. The goals of this chapter are to (1) estimate how different methods for conducting point counts affect sampling results for individual species, and (2) to use this information to determine what sampling scheme would be most efficient for detecting declines of that species at a given level of statistical power. Finally, I will explore ways to group species in order to maximize sampling efficiency within the same ecosystem, with special emphasis on species of concern in northern Michigan.

Point count sampling efficiency is a measure of the number of bird detections obtained per unit of sampling time; it represents a tradeoff between the time spent sampling or walking between points and the amount of data collected at each sampling point (Verner 1985, 1988). The design of an efficient point count sampling plan requires that researchers balance the conflicting goals of maximizing the number of birds detected and collecting a large enough sample of points (Verner 1988). The total number of detections (i.e., of birds of all species) at a particular point can be increased by increasing the amount of time spent recording birds at each point, and by increasing the radius of the point count sample (Ralph and Scott 1981, Verner 1985, Ralph et al. 1995a, Chapter 2). The number of points that can be sampled in a sampling period is determined by the duration of the point count, and by the distance between points. The distance between points, along with characteristics of the habitat being sampled, determine the duration of travel, or non-sampling time, within a sampling day. Determination of the distance between points requires consideration of both the travel time and the radius of the point count, since to prevent overlap of counting area points should be at least two times the radius apart from each other.

As was seen in Chapter 2, as point count radius and length of count are increased, the number of individuals and species recorded per point will increase. However, these changes are likely to have different effects on different species; increasing the length of counts should increase detections of species that sing at low frequencies during all or part of the sampling period, but will be inefficient for species that maintain high rates of calling (Scott and Ramsey 1981a, Fuller and Langslow 1984). Similarly, the detections of smaller, quieter species are likely to be less affected than those of large, highly vocal species by limiting the count radius (Lynch 1995).

Making decisions related to how a particular set of point counts will be done should involve careful consideration of the goals of the count program, and an examination of

what type of data would best allow the sampling plan to meet those goals (Blondel 1985, Dawson 1985, Verner 1985, Dawson et al. 1995). A key goal in the conservation field may be to monitor the relative abundance of one or more species of concern. Although a number of studies have examined sampling efficiency by comparing detections-over-time curves for all species or all individuals present in a particular location (Verner 1988, Cyr et al. 1995, Petit et al. 1995, Smith et al. 1995), few studies have been done that examine the efficiency of a set of point count methods for individual species (Verner 1985; studies that have looked at single species include Hanowski et al. 1990, and Savard and Hooper 1995). As a result, many of the analyses of efficiency are limited in their value to conservation workers. By grouping all species or individuals together, it is possible to determine what combination of methods maximize total detections (see Chapter 2), but if the detectability of a species of concern is significantly different from the mean for all species (due to a different calling rate, visibility, or to differences in how far the sound of the call carries), then this set of methods is not likely to be the most efficient method for monitoring the particular species.

Although looking at efficiency on a species-specific basis is a good start, to design a sampling plan that will allow conservation workers to detect changes in relative abundance, this information should be combined with an analysis of statistical power. The relative power of a test is equal to  $1 - \beta$ , where  $\beta$  is equal to the rate of a Type II error. The Type II error rate is defined as the probability of accepting the simple null hypothesis when some simple alternative hypothesis is true; this rate increases as the rate of Type I error (the probability of rejecting the null when it is actually true, or  $\alpha$ ) decreases. Taylor and Gerrodette (1993:497) describe three ways that power analysis can be used in the field of conservation biology; these are to "(1) decide whether the proposed research can answer our question, (2) choose among alternative experimental designs, and (3) interpret the results in such a way that it is clear exactly what we can and cannot state given our data." For the purposes of this study, I am using power analysis in a way that combines purposes (1) and (2).

I estimate how many point counts would be needed to detect a large decline (40%) in mean relative abundance between two sets of monitoring data. The actual data collected represent a hypothetical "first season" of data; the mean for the "second season" is calculated by subtracting 40% from the mean detection rate found, and the variance for the second set of data is assumed to be the same as was estimated from the "first season" data. To compare sample size estimates based on different point count methods, these calculations are done using the detection rate data from three different point count radius sizes. Such calculations can provide conservation workers with the tools they need to estimate how many person-days must be spent collecting data to obtain information for making management decisions, or can alert researchers when a sampling plan will not provide information about potential declines because of low power (Taylor and Gerrodette 1993). When these data are combined with efficiency data (with respect to sampling design), a sample size and design can be selected that maximizes the amount of information gained about species of concern, while minimizing unnecessary or pointless sampling.

When determining sample sizes needed in a monitoring plan, careful thought must be given to the level of Type I and Type II errors that will be accepted. In the context of monitoring, Type I error is the probability of falsely concluding that there is a decline or difference in relative abundance, and Type II error is the probability of falsely concluding that there is no difference or decline (Gerrodette 1987, Taylor and Gerrodette 1993, Thompson and Schwalbach 1995). When monitoring a declining population, the consequences of accepting a false null hypothesis can be severe if failure to detect the decline early leads to missed chances for management that may have helped to prevent further declines (Taylor and Gerrodette 1993). As the chosen alpha decreases, the probability of a Type II error increases, so what appears to be a more conservative test based on the alpha level can lead to increased chances for errors in statistical inferences if

the power of the test is not evaluated (i.e., when a null hypothesis is accepted, but the power of the test to detect a difference was low, and was not examined) (Forbes 1990). For purposes of comparison, I examine two levels of power in my analyses.

Similarly, when designing a monitoring plan, the relative benefits of using a one-tailed versus a 2-tailed test should be considered. By choosing to use a one-tailed test, a researcher gains the benefit of not needing as large of a sample size to detect a particular difference at a given level of power, but sacrifices the ability to detect changes in the other direction (in a conservation based monitoring plan intended to detect declines, this would mean not being able to detect population increases). Monitoring programs that have limited funds and are most concerned with detecting declines would benefit from the reduced sample sizes needed to attain the same level of statistical power; researchers examining changes in population size in general (positive and negative) would need to use two-tailed tests. For comparative purposes, I present estimates of sample sizes needed for both one- and two-tailed tests.

An additional goal for this work is to contribute to the discussion of national standards for point count protocols by examining how standards might hinder our ability to most efficiently monitor rare species in a particular location. There is strong impetus to define standards for point count methods, as they would facilitate regional comparisons of population trends (Manley 1993, Ralph 1993, Ralph et al. 1995b). There are likely to be drawbacks, however, because the efficiency of a sampling scheme will vary for different species and in different ecosystems (Verner and Milne 1989). An understanding of which species will be affected and in what way is an important area that needs to be addressed before national protocols can be assembled. To address this need, I group species into categories of those that will be more efficiently sampled using a particular count radius, and discuss this with respect to the relative conservation concern of different neotropical migrant species on my study sites.

The discussion of species of management concern is based on a ranking system devised by Thompson et al. (1993) for neotropical migrant species in the Midwestern U.S. This system takes a mean of 7 scores (ranging from 1 to 5, with 5 being of highest concern) in categories titled: (1) global abundance, (2) extent of winter distribution, (3) threats on wintering grounds, (4) extent of breeding distribution, (5) breeding area threats in the Midwest, (6) importance of the Midwest to the species, and (7) population trends (from Breeding Bird Survey Data) (Thompson et al. 1993). Neotropical migrant species present on my study sites, and their rank in each category, are presented in Table 3-1. Six of these, the Nashville Warbler, Canada Warbler, Eastern Wood-Pewee, Veery, Great Crested Flycatcher, and the Blackburnian Warbler have been identified as species of conservation concern in Michigan by Dr. David Ewert of the Michigan Chapter of The Nature Conservancy (Ewert, pers. comm.).

In summary, the objectives of my study were to use point count data collected in upland and wetlands sites to address the following questions:

- (1) What effects do sampling protocols (length of count and count radius) have on the mean and variance of the number of individuals of different species detected per point?
- (2) How do patterns of detections for individual species vary from those for all species in the same migratory category, or from all other species detected combined?
- (3) How do variations in the means and variances of detection rates influence the number of samples needed to detect a 40% decline in species of concern under different power scenarios?

- (4) What protocols allow the most efficient monitoring of trends in relative abundance for species of concern?

## METHODS

### Study Areas and Field Methods.

The study sites and methods for collecting point count data were the same as those described in Chapter 2. As in Chapter 2, data from the upland and wetland sites were examined separately; species found in both sets of sites were analyzed twice.

### Data Analysis.

Species-specific patterns of detection were examined for all species with a mean detection rate (based on a 10-minute, unlimited radius count) of at least 0.15 in either upland or wetland sites. For these species, I calculated estimates of mean rates of detection, standard deviations of the means, and standard errors of these means for data from radii of 50, 70, 100, and 130 meters, and unlimited radius counts, using 4, 8, 10, and 12 minutes of count data. I chose periods of 4, 8, and 12 minutes from the data available (in two minute intervals: see Chapter 2) to show the effect of increasing time by a constant interval of 4 minutes. Ten minute data are presented for radius comparisons and used in power analyses because 10 minutes is the most commonly used point count length, making these data more directly comparable to those from other studies.

I compiled 4, 8, and 12 minute data at each radius size so that I could examine patterns of detection under different combinations of count length and radius protocols; this was done for each species for which the mean detection rate for a 12-minute unlimited-distance count was 0.15 detections per point or greater. I did not calculate estimates of the mean rate of detection for two species, the Black-capped Chickadee and the Common Raven. Chickadees were left out of the analyses because I often heard what sounded like many birds, but was unable to determine numbers of individuals, and because they appeared in many cases to be attracted to my presence (see Chapter 2). I left the Common Raven out of the individual species analyses because it was never detected within an estimated 200 m from the point count location.

I compared the distribution of observations for individual species with respect to either count duration or count radius to the distribution of detections found for all other species of the same migratory group (neotropical migrants or short distance migrants and residents), and to the distribution of detections for all other species combined using Chi-Square Tests of Independence. I also used Chi-Square Tests of Independence to test for differences in the frequency distribution of first detections in the three time periods (1-4, 5-8 and 9-12 minutes of counting) using data from three different radius sizes (unlimited, 100 m, and 50 m). In all of these comparisons, the totals in each category reflected only the additional detections recorded in that category - for example the 5-8 minute category in a time distribution only shows birds recorded in the fifth through eighth minute, not the cumulative total recorded from 0 - 8 minutes. Chi-Square Tests were only done when species had enough detections so that the assumptions of the  $\chi^2$  distribution were not violated (i.e., no values less than one, and not more than 20% of values less than 5) (Sokal and Rohlf 1981). To meet the assumptions of the test, species had to have a total of at least 18-20 detections (mean of about 0.15 detections per point using 10-minute counts with an unlimited radius) for the comparison of distribution of detections by count radius. Valid tests for the distribution of detections by time period required higher total numbers of detections (means rates of about 0.25) because expected values for the 5-8, and 9-12 minute periods were often low. This meant that for a comparison using the 100 m radius data, the cumulative mean for a species after 12 minutes would have to be 0.25 in order to keep at least 80% of the expected values above 5. I set alpha at 0.05 for all comparisons, and used Systat 5.21 for the Macintosh for all statistical tests.

To estimate the sample size required to detect a 40% decrease between two estimates of mean relative abundance, I used the 10-minute mean detection rates and variances estimated in this study, and formulas for determining necessary sample size (tests for differences between means with equal variances and sample sizes) in Snedecor and Cochran (1989:102) (Equation 3-1). I calculated sample sizes needed to detect this 40% decline in relative abundance for each species using 2 levels each of Type I ( $\alpha$ ) and Type II error rates ( $\beta$ ); one set of values was calculated based on a Type I error rate of 0.10 and a Type II error rate of 0.20, and the second set of sample sizes is based on smaller acceptable error rates of 0.05 (Type I) and 0.10 (Type II). I calculated sample sizes for each species with a mean detection rate higher than 0.10 detections per point in either the upland or wetland sites. For comparative purposes, I also calculated the same set of values for a two-tailed test, and a one-tailed test using a 20% decline in relative abundance, based on the table in Snedecor and Cochran (1989). These results are presented as ratios to allow the reader to estimate about how many more samples would be needed if these changes were made in the monitoring scheme.

For a one-tailed test with  $\alpha$  and  $\beta$  set at 0.10 and 0.20, respectively, the formula for calculating sample size is as follows:

$$N = 4.5 (2 * \sigma^2) / \delta^2 \quad \text{Equation 3-1}$$

For each species, I used the sample variance as an estimate of  $\sigma^2$ . Two-times the variance is divided by  $\delta^2$ ;  $\delta$  is the actual difference in means that I want to be able to detect between the two hypothetical sets of monitoring data. This was calculated for each species as 0.40 times the mean detection rate, representing a 40% decline in the relative abundance (using one-tailed tests) (Snedecor and Cochran 1989). The number in bold is a multiplier from Table 6.14.1 in Snedecor and Cochran (1989:104). To estimate sample sizes for a one-tailed test with  $\alpha$  and  $\beta$  set at 0.05 and 0.10, this number changes to 6.6. For two-tailed tests with the less conservative error rates, the multiplier is 6.2, and for the more conservative two-tailed test, the multiplier is 10.5 (Snedecor and Cochran 1989). As Snedecor and Cochran (1989) suggest, I added one to the results of these calculations of N because this "short cut" estimator produces values that are slightly lower than those obtained using other methods.

To estimate the most efficient point count radius for each species, I started with the sample sizes required to detect a 40% decline between two estimates of mean relative abundance based on the one-tailed test (Type I error rate = 0.10, Type II error rate = 0.20) for the 50m radius, 100 m radius, and unlimited radius data. I then calculated how long it would take to achieve this sample size incorporating a 10 minute count at each count location, and an estimate of travel time between points. Based on my daily point count logs, traveling 150 meters requires 14.0 (7.2 SD) minutes in upland sites and 17.4 (7.8 SD) minutes in wetland sites. From these values, I estimated how long it would take to travel 100 and 200 m (distances between 50 m radius and 100 m radius counts that should ensure a reasonable amount of independence between counts while minimizing between count distance). I set a cutoff for unlimited counts at 400 meters apart, and used the same travel time estimates to approximate the amount of time needed to travel between count sites using this travel distance.

## RESULTS

### Numbers of Detections and Mean Detection Rates: Wetland Sites

I estimated the mean detection rates at 50 m, 100 m, and unlimited-distance radius sizes for 17 species in the wetland sites (10 neotropical migrants and 7 short-distance

migrants/residents: Table 3-2), and 11 species from the upland sites (7 neotropical migrants and 4 short-distance migrants/residents: Table 3-3). In the wetland sites (113 counts), the maximum mean detection rate for an unlimited-radius count was 1.29 (0.69 SD) detections/point for the Winter Wren. The difference in species' means between radius size categories was quite variable; e.g., the Winter Wren and Blue Jay showed large drops from unlimited radius values to 100 m radius means, while the Northern Parula Warbler, Black-and-white Warbler, and the Yellow-bellied Sapsucker showed much less of a change between radius sizes (Table 3-2).

For all species, the standard deviations associated with each mean were quite high, as is expressed in the coefficient of variations (CV). In general, the CVs increased with decreasing means within a radius size, and increased from the large radius size to the smaller radii. I detected eight neotropical migrants and 8 short-distance migrants/residents fewer than 11 times in 113 counts (Table 2-2).

#### **Numbers of Detections and Mean Detection Rates: Upland Sites**

In the upland sites (130 point counts), the maximum mean detection rate for an unlimited radius count was 2.10 (1.10 SD) detections per point for the Ovenbird. The next highest mean, for the Red-eyed Vireo, was almost an entire detection per point lower, and the next most common species, the Eastern Wood-Pewee again showed a large decrease in detections relative to the first two. As I found in the wetland data, the by-species difference in means between radius size categories was quite variable; the Ovenbird, Pewee, and Hermit Thrush showed large drops from unlimited radius values to 100 and 50 m radius means, while the American Redstart, Brown-headed Cowbird, and Yellow-bellied Sapsucker showed much less of a change between radius sizes. For all species, the variances associated with means was quite high, especially for species with smaller means and for each species at the smaller radius sizes. Eight neotropical migrants and 11 short-distance migrants or residents were detected fewer than 13 times in 130 counts (Table 2-3)

#### **Detailed Detection Patterns by Species**

Mean detection rates based on various combinations of duration and count radii are presented in Appendix B for 8 neotropical migrants and 7 short-distance migrants. Species-specific patterns of detections for 7 neotropical migrants and 4 short-distance migrant or residents found in the upland sites are presented in Appendix C.

#### **Biases in Detection Patterns Related to Count Radius: Wetland Sites**

Of the 15 species with high enough detection rates to conduct the Chi-Square Tests of Independence, 11 had distributions of detections with respect to count radius that were significantly different from distributions for all other species from the same migration group (neotropical migrant or resident/short-distance migrant) and/or from patterns for individuals of all other species (Table 3-4). When neotropical migrants were compared to only neotropical migrants, the Black-and-white Warbler and the Northern Waterthrush were more likely than expected to be detected within the 50 m radius, the Nashville Warbler showed higher than expected detections in the 50 - 100 m range, and the Ovenbird and Black-throated Green Warbler were found less often than expected in the 0 - 50 m and 0 - 100 m zones, respectively. When residents and short distance migrants were compared to all other species in the same migration group, the Brown Creeper and the Yellow-bellied Sapsucker were more likely than expected to be detected within the 50 m radius, the Winter Wren and White-throated Sparrow were found less often than expected between 0 - 50 m from the point count center, and the Blue Jay was found less often than expected within an 100 m radius.

When the wetland species listed above were compared to all species combined, most showed the same pattern at the same level of significance, although there were some differences in the strength of the differences observed (Table 3-4). A species not discussed

above, the Northern Parula, showed a significant difference when compared to all species: it was detected more often than expected in the 50-100 m range.

#### **Biases in Detection Patterns Related to Count Radius: Upland Sites**

Of the 11 upland species with high enough detection rates to conduct the Chi-Square Tests of Independence, 5 had distributions of detections with respect to distance from observer that were significantly different from distributions for all other species from the same migration group and from patterns for individuals of all other species combined (Table 3-5). When neotropical migrants were compared to others in this group, the American Redstart was less likely than expected to be detected at distances greater than 100 m, and the Ovenbird was more likely than expected to be detected in the longest distance category. When residents and short-distance migrants were examined, the Brown-headed Cowbird and the Yellow-bellied Sapsucker were more likely than expected to be detected within the 50 m radius, and the Hermit Thrush was detected less often than expected within a 0-100 m radius. When these the distributions of detections by count radius for these species were compared to all species combined, they all showed the same pattern of bias at the same level of significance.

#### **Biases in Detection Patterns Related to Count Duration: Wetland Sites**

Unlimited Distance Data. Of the 14 wetland species with enough detections to allow testing with a Chi-Square Test of Independence, 4 had distributions of detections with respect to count duration that were significantly different from patterns for all other species from the same migration group, and from patterns for all birds combined (Table 3-6). The only neotropical migrant with a significantly different distribution was the Nashville Warbler; it had fewer detections than expected between minutes 9 - 12 of the count. When residents and short distance migrants were compared, the Winter Wren had lower rates of detection than expected in minutes 5 - 12 of the count, while both the Brown Creeper and Red-breasted Nuthatch were more likely than expected to be detected during these last eight minutes. When compared to all species combined, all but the Brown Creeper showed slightly different results (Table 3-6)

100 m Radius Data. When I examined the detection pattern biases related to count length using the 100 m radius data, of the 10 wetland species with mean detections rates higher than 0.25, 3 had distributions that were significantly different from distributions for all other species' from the same migration group, and from distributions for individuals of all other species combined (Table 3-7a). The only neotropical migrant with a significantly different distribution was the Ovenbird, which had more detections than expected between minutes 5-8 of the count, and fewer than expected in the first and last portions of the count. Short-distance migrants or residents with significant results were the Winter Wren and Brown Creeper; the Winter Wren showed a strong bias toward being detected in the first 4 minutes, while Brown Creeper had the opposite pattern, being detected more often than expected in the last 8 minutes. For these two species, I found the same pattern of bias using the 100 m radius data as I did in the unlimited radius data (see above). For all three species, the same patterns described here were found when the distribution of detections was compared to that for all species combined (Table 3-7a).

50 m Radius Data. When bias related to count length was examined using the 50 m radius data, 4 wetland species had mean detections rates higher than 0.25 detections per point (based on a 50 m radius, 12 minute count); none of these showed significantly different distributions when compared to their own migration group or all species combined (Table 3-7b).

#### **Biases in Detection Patterns Related to Count Length: Upland Sites**

Unlimited Radius Data. Of the 10 upland species with enough data to use the Chi-Square Test of Independence, 4 had distributions of detections with respect to count duration that were significantly different from patterns for either all other species from the same

migration group, or from those for all other species combined (Table 3-8). Two neotropical migrants had significantly different distributions when compared to other migrants: the Ovenbird was detected less often than expected in the last 4 minutes, while the Scarlet Tanager showed the opposite pattern, with the strongest source of bias being higher than expected values in the last 4 minutes. When residents and short distance migrants were compared, only the Hermit Thrush showed a significantly different distribution of detections. When the upland species listed above were compared to all species combined, the Scarlet Tanager was no longer significantly different, and the Ovenbird showed a different pattern (Table 3-8). When compared to all species, the strength of bias shifted for the Hermit Thrush toward a greater importance of high values in the last four minutes. The Yellow-bellied Sapsucker showed a significantly different distribution of detections when compared to all species; it had higher rates of detection than expected in the last eight minutes, with particularly different rates in the last 4 minutes.

100 m Radius Data. When I examined detection pattern bias related to count length using the 100 m radius data, 9 upland species had enough data to do the statistical test, and I found that 4 of these species' distributions were significantly different from patterns for all other species from the same migration group or from patterns for individuals of all other species combined (Table 3-9a). Three neotropical migrants had a significantly different distributions when compared to other migrants; for the American Redstart and the Scarlet Tanager, the main sources of bias were lower and higher, respectively, than expected rates of detection in the last 4 minutes. The Eastern Wood-Pewee showed no strong source of bias - it had lower than expected rates of detection in the middle 4 minutes and higher than expected rates at each end of the count. None of the short distance migrants or residents had significantly different distributions of detections when compared to their own migration group. When the individual species were compared to all species combined, the American Redstart had the same pattern described above, while the distributions for the other two neotropical migrants were not significantly different. As was found with the unlimited distance results, when compared to all species, the Yellow-bellied Sapsucker showed a significant bias toward higher than expected rates of detection in the last eight minutes, particularly in the last four minutes.

50 m Radius Data. Two upland species had mean detection rates higher than 0.25 detections per point based on the 50 m radius data; the Ovenbird and Brown-headed Cowbird showed significantly different distributions when compared to their own migration group or all species combined (Table 3-9b). Both the Ovenbird and the Cowbird were found to have a strong bias toward higher than expected detections in minutes 5-8 when compared to all species; this difference in distributions also was found to be significant for the Ovenbird when compared to the appropriate migratory group.

#### **Estimation of Sample Sizes Needed to Detect Declines: Wetland Sites**

Sample sizes required to detect a 40% decrease between the detection means found in this study and a hypothetical second set of data (Type I error rate of 0.1 and a Type II error rate of 0.2) varied greatly between species as a function of both the means and the variances (Table 3-10). The estimated sample sizes based on an unlimited radius ranged from 16 counts for the very common and easy to detect Winter Wren to 663 counts for the Veery, which had a low mean and particularly high CV (see Table 3-2). Based on the 100 m and 50 m radii, the Winter Wren still would require the fewest point counts (69 and 190, respectively), and the Veery would require the most (1,098 and 2,080, respectively). The relative increase in sample size from the largest radius to the smallest also varied greatly between species; these are linked to how much the detection rate decreased when the amount of area sampled was reduced that contained within the 100 m and/or 50 m radius sizes. The Winter Wren, Blue Jay, and Black-throated Green Warbler, showed the greatest relative increase in the number of sample required using the smaller radii, while the Black-and-white Warbler and Brown Creeper showed more similar sample sizes across the radius categories.

### **Estimation of Sample Sizes Needed to Detect Declines: Upland Sites**

As I found in the wetland sites, the sample sizes required to detect a 40% decrease between two estimates of relative abundance with a Type I error rate of 0.1 and a Type II error rate of 0.2 based varied greatly between upland species as a function of both the mean and variance of detection rates (Table 3-11). The estimated sample sizes based on an unlimited radius ranged from 16 counts for the extremely common Ovenbird to 361 counts for the American Robin. As was seen in the wetland data, the pattern of increase from the largest radius to the smallest also varied greatly between species. Species such as the Ovenbird, Eastern Wood-Pewee, and Black-throated Green Warbler showed the greatest relative increases in the required sample size based on the smaller, rather than unlimited, radii, while the American Redstart and Yellow-bellied Sapsucker showed more similar values across the radius categories.

### **Comparisons With Other Sample Size Estimates**

For both wetland and upland species, the sample size requirements for a Type I error rate of 0.05 and a Type II error rate of 0.10 were approximately 91% higher than those for the larger error rates. Using a two-tailed test would require 22 and 37% more samples than those presented in Tables 3-10 and 3-11 for the Type I = 0.05, Type II = 0.1 and for the Type I = 0.10 and Type II = 0.20, power scenarios, respectively. To detect a 20% difference in the relative abundance of each species rather than a 40% difference would require 4 times as many counts as are shown in Tables 3-10 and 3-11.

### **Most Efficient Count Radius: Wetland Sites**

In the wetland sites, the number of sampling days required to detect a 40% decline in relative abundance at the different radius sizes varied greatly between species (Table 3-12), following the pattern set by the number of point required discussed above. In general, the values were highest in the 50 m category.

The most efficient radius size for detecting population declines also varied by species, as did the magnitude of the difference between the efficiency of the different radii. The Black-throated Green Warbler, Eastern Wood-Pewee and most of the short-distance migrants and residents would all be most efficiently sampled using the unlimited radius count, while over half of the neotropical migrants (Ovenbird, Veery, and Nashville, Canada, Northern Parula, and Blackburnian Warblers) would be most efficiently sampled using the 100 m radius (Table 3-12). The 50 m radius would require to fewest sampling days for detecting potential declines in Black-and-white warblers, Northern Waterthrush, Yellow-bellied Sapsuckers, and Brown Creepers.

### **Most Efficient Count Radius: Upland Sites**

As described above, the number of sampling days required to detect a 40% decline in relative abundance using upland data from different radius sizes varied greatly between species (Table 3-13). As was seen in the wetland data, for most species the number of sampling days required were highest in the 50 m radius category.

Again, the most efficient radius size for detecting population declines varied by species, as did the magnitude of the difference between the efficiency of the different radii. Here, most of the neotropical migrants (Ovenbird, Red-eyed Vireo, Black-throated Green Warbler, Eastern Wood-Pewee, and Veery) as well as the Hermit Thrush would all be most efficiently sampled using the unlimited radius count. The other two neotropical migrants, the American Redstart and the Scarlet Tanager, as well as the Brown-headed Cowbird and the American Robin would be most efficiently sampled using the 100 m radius. In the upland sites, only the Yellow-bellied Sapsuckers would be most efficiently sampled using a 50 m radius.

## DISCUSSION

### Detection Patterns Related to Count Duration

As has been seen in other studies, and demonstrated in Chapter 2, the majority of birds that will be detected at a point are detected within the first 3-5 minutes of counting; there is a diminishing rate of return for counting effort that extends beyond this period (Scott and Ramsey 1981a, Fuller and Langslow 1984, Verner 1985 and 1988, Hamel 1988, Dawson et al. 1995, Gates 1995, Buskirk and McDonald 1995, Welsh 1995). However, as has been found here and elsewhere, the shape of the return curve as count length increases is not the same for all species, and as a result the choice of point count length has the potential to have a strong impact on mean detection rates for some species (Scott and Ramsey 1981a, Buskirk and McDonald 1995, Gates 1995). In general, patterns of detections for individual species at upland sites were comparable to those from other studies looking at count duration (Buskirk and McDonald 1995, Gates 1995); specific species are addressed below.

### Count Duration Bias

Although many researchers have identified species-specific differences in detection patterns (Scott and Ramsey 1981a, Emlen and DeJong 1981, Fuller and Langslow 1984, Wolf et al. 1995), efficiency of sampling is often estimated based on detection curves for all species together (Verner 1988, Cyr et al. 1995, Petit et al. 1995, Smith et al. 1995), or for groups of species such as neotropical migrants vs. short distance migrants and residents (see Chapter 2). This practice makes sense if the goal of the sampling regime is to maximize total detections per unit of sampling time, but is likely to lead to inefficiencies when the primary goal is to monitor one or a few species of concern (Barker et al. 1993, Welsh 1995). Also, efficiency with respect to count duration may be estimated using one radius size, but if a researcher is trying to make the duration decision while also deciding on a most efficient radius size, interactions between these factors need to be considered. A key limitation that is inherent in making the comparison of potential count duration biases between radius sizes is that sample sizes are reduced as the radius decreases, suggesting that my ability to detect differences in distributions is lower at these smaller radii. For example, only four species in each forest type had enough data to test for differences using a Chi-Square Test at the 50m radius: bias at this and the 100 m radius size has not been as thoroughly investigated as for the unlimited radius.

Duration Bias: Unlimited Radius. Based on my unlimited-distance data from the wetland sites, a count length based on an efficiency analysis using just the neotropical migrant data is likely to suggest a count length longer than what would be most efficient for one of Michigan's species of concern, the Nashville Warbler. If a researcher were to examine the grouped efficiency estimates for unlimited-radius data in Figure 2-5, she would conclude that a twelve minute (or longer) count would produce the highest number of detections per unit sampling time; this is probably longer than what is most efficient for Nashvilles, since detections for this species were lower than expected in last four minute interval. This problem could be exacerbated if efficiency is estimated using the data from all species; here the Nashville detections are lower in both the 5-8 and 9-12 minute counting periods. The identical pattern was seen for the Ovenbird in the upland sites (although not in wetland sites). Also in the upland sites, I found that the Scarlet Tanager showed the opposite bias from the species above when compared to neotropical migrants, suggesting that "optimal" count lengths estimated from Figure 2-5 would be too short for efficiently sampling this species. However, the Tanager showed no significant bias when compared to all species together. All of the other neotropical migrants (using both wetland and upland data) did not have significantly different patterns of detection with respect to count length at this radius size.

As was found for the Ovenbird and Nashville Warbler, the most efficient sampling duration for the Winter Wren (wetland data) would also be shorter than is likely to be

estimated using grouped data (i.e. using Figure 2-5). The two other wetland species with significant results, the Brown Creeper, and Red-breasted Nuthatch, would be more efficiently sampled using longer counts than those likely to be chosen based on either set of grouped data, while the Yellow-bellied Sapsucker showed this same bias in the upland sites, but not in the wetlands. The pattern for the Hermit Thrush when compared to its own species groups is hard to interpret with respect to the effect of estimating efficiency using the pooled data, but when compared to all species it would appear to require longer counts than would be most efficient for all species as a whole.

Duration Bias: 100-m Radius. The bias described above for the Nashville Warbler was not found in the 100 m count radius data. At this radius, the appropriate neotropical migrant curve shown in Figure 2-5 will provide a reasonable estimate of how sampling efficiency for this species changes with duration. The Ovenbird showed a significant bias (towards being most efficiently sampled using shorter counts than the neotropical mean would suggest) in the wetland data, but no bias in the upland data. Both of these results suggest that the patterns found at different radius sizes and in different forest types are likely to be different, and that this difference should be considered when sampling decisions are made if the goal of a program is to provide the most efficient monitoring scheme for a particular species.

Another species of particular concern in Michigan, the Eastern Wood-Pewee, shows a difficult to interpret pattern here; when compared to other neotropical migrants, it shows a positive bias at each end (i.e., has higher than expected values in first and last thirds of the count), but neither bias is particularly strong. The Scarlet Tanager has the same general pattern, but with a stronger difference in the last four minutes, suggesting again that efficient counts for this species may be longer than those for all neotropical migrants together, as shown in Figure 2-5. Neither of these patterns was significant when compared to all species. In the wetland sites, the Brown Creeper and Winter Wren showed the same general pattern as seen at the unlimited radius, this was also true for the Sapsucker in the uplands. Interestingly, the same pattern was not found for Sapsuckers in the upland sites, even though sample sizes were comparable, again suggesting that forest type (probably as it impacts the observer's detection abilities), can influence detection patterns.

Duration Bias: 50 m Radius. At the 50 m radius, I was not able to detect any significant differences among the wetland species with enough data for conducting Chi-Square Tests. Based on the upland data, the Ovenbird showed the same pattern previously seen in the wetland 100 m radius data: a strong positive bias in the middle four minute period (when compared to others in its migratory group - the bias was not found when compared to all species). Based on this result, the decreasing trend in expected cumulative counts from durations of 4 to 8 minutes (shown in Figure 2-5) for neotropical migrants at this radius size is likely to be even steeper for Ovenbirds. Again, this pattern is unlike that seen for the Ovenbird in the unlimited radius upland data, demonstrating how the point count methods used can impact results.

Welsh (1995) found some similar species-specific biases when comparing individual species patterns to those for all species detected during 3-, 5-, and 10-minute unlimited distance counts in forested study sites in eastern Ontario. Twelve species in his study had distributions that were significantly different; none of those listed were of particular concern in Michigan. These included some species that showed the same basic trend as found in this study for unlimited radius counts (Ovenbird and Yellow-bellied Sapsucker from upland sites, Red-breasted Nuthatch from wetlands) and some that did not (the Red-eyed Vireo had higher detections in the 3 minute period with lower values afterwards; the Hermit Thrush was higher than expected during both the 3 and 5 minute periods, but lower than expected after 10 minutes of sampling).

Howe et al. (1995) in Wisconsin, and Gates (1995) in Maryland forests, compared individual species' results to those for all species detected during the first and second halves of 10-minute, unlimited radius counts. Both found disproportionately more

observations of Red-eyed Vireos in the first 5 minutes; Howe et al. found more Winter Wrens, and Gates found more detections than expected of Ovenbirds, Eastern Wood-Pewees, and Scarlet Tanagers (significant at one of two sites) in the first five minutes. Species with a bias in the other direction included American Robins and Scarlet Tanagers (Howe et al. 1995), and Great Crested Flycatchers, Brown-headed Cowbirds, and American Redstarts (at one of two sites) (Gates 1995). According to Gates (1995:89), "this implies that 2 five minute counts at separate points are not equivalent to a single 10-minute count, even if bird distributions are uniform in space, because the 10-minute counts will include a higher proportion of wide-ranging birds." All of these data support the idea that to develop a plan for efficiently monitoring one or a few species of concern, researchers must collect, or have access to species-, and probably also habitat-specific results that demonstrate the relative efficiency of different point count methods.

Within a forest type, the trends described above are likely to reflect a number of interspecific behavioral differences in traits such as calling rates, since most other differences between species (in factors related to detectability) should remain constant across the 12-minute sampling period. Rates of songs and calls (i.e., number per minute) have been found to vary between species, however a problem with many studies that examine calling rate is that researchers start measuring rates once the species is already calling (i.e., Wolf et al. 1995). These data are not particularly useful in determining how likely a researcher is to detect a species during a point count, because what is really important in the sampling context is the time between bouts of singing, since an observer only needs to hear a bird once to record it at a point. Data on how often birds sing should be collected on larger scales (i.e., number of 5 or 10 minute periods during a day in which birds are detected - Mayfield 1981) so that this species-specific information can be incorporated in study designs.

Differences in bias between samples taken in different forest types are probably related to differences in detectability due to forest structure, and possibly behavioral differences in the different habitats related to differences in the density of conspecifics. Potential effects of different vegetation type and structure on species' detectability are described in Chapter 2. Within a species, the density of conspecifics may affect detectability; for example, Verner (unpublished data, as cited in Verner 1985), has described decreased song rates and duration of song bouts by male marsh wrens (*Cistothorus palustris*) in a low density population compared with a high-density one in another year on the same study plot. This type of effect is likely to confound attempts to estimate any difference in detectability between habitats, as different habitats are likely to support different densities of individuals.

### Count Radius Bias

Differences in detection rates related to count radius have not been studied as much as those due to count duration, probably because of the difficulty associated with estimating distances to birds, especially those that are far away. However, the effects of radius determine to a large extent how many birds are detected per point, and directly influence travel time between points, so potential sources of bias should be investigated. In this study, many more species showed significant bias related to distance from the observer than did in relation to count duration, however, only one (the Nashville Warbler) was a neotropical migrant of special concern in Michigan. In general the biases found followed well established patterns of song detectability. Significant positive biases were found in the greater than 100 m category for species that have loud songs or calls such as the Ovenbird (in both forest types), Black-throated Green Warbler (wetland sites only), Winter Wren, White-throated Sparrow, Hermit Thrush, and Blue Jay. There were some difference within this group for the middle category (50-100 m); but in general this was not the part of the distribution that contributed strongly to the significance of the test. Many researcher have identified one or more of these species, especially the Winter Wren and Ovenbird, as

having songs that can be heard across long distances (Brackenbury 1979, Emlen and DeJong 1981, Lemon et al. 1981, Calder 1990, Wolf et al. 1995).

Similarly, species with particularly quiet songs such as the Black-and-white Warbler, Brown Creeper, and Brown-headed Cowbird (Emlen and DeJong 1981, Wolf et al. 1995) had significantly higher rates of detection than expected in the 0-50 m category. Yellow-bellied Sapsuckers also were heard significantly more often in the 0-50 m category in both forest types; this is probably due to both a relatively quiet call, and to the fact that due to the high visibility of their nest holes (and often squeaking nestlings), they were often seen at the nest without being heard. Two wetland species, the Nashville Warbler (both comparisons) and the Northern Parula (compared to all species only) showed patterns of high detections at the middle distance that contribute strongly to the  $\chi^2$ , and low values at either end. This pattern suggests that these species may sing less when an observer is nearby, while also not singing loud enough to be commonly heard at distances greater than 100 m. Also, the Northern Waterthrush, which seemed very loud when I was sampling, had proportionately high rates of detection at the smallest radius size. This is probably due to the fact that it was often found in more open areas of the wetland where visibility was higher than in other locations.

### Statistical Power Analysis

Although many studies have demonstrated significant differences between mean rates of detections for all species or individuals using different lengths or radii of counts (e.g., Buskirk and McDonald 1995, Thompson and Schwalbach 1995), in a practical sense this is not really the issue when sampling protocols are being decided. What is important is how this difference between methods affects our ability to detect declines, and how much each method will cost to use. Ensuring that sampling protocols will provide enough statistical power (i.e., estimating the probability of accepting a false null hypothesis) to provide indications of species declines while there are still management options open should be the real goal of monitoring programs (Taylor and Gerrodette 1993). Since statistical power increases with increasing sample size, increased size of the effect we are trying to detect, and decreased variability in the data, all of these factors need to be considered in the development of a sampling plan (Gerrodette 1987, Taylor and Gerrodette 1993).

Based on the results of the statistical power analysis, if these data are thought of as the first year's data in a two year monitoring plan, this number (113) of unlimited-distance point counts, would allow me to detect a 40% declines in the relative abundance (using the less conservative Type I and Type II error rates) of Nashville Warblers, Black-and-white Warblers, Canada Warblers, Black-throated Green Warblers, Winter Wrens, Blue Jays, White-throated Sparrows, and Yellow-bellied Sapsuckers. Using the more conservative Type I and Type II error rates (0.05 and 0.10, respectively) would only allow me to detect declines in Winter Wren relative abundance. Reducing the radius size to 100 m radius, also decreased my ability to detect species declines (with a set number of counts); using the less conservative error rates I would only be able to detect declines for only the Nashville and Black-and-white Warblers, and the Winter Wren. Although a 40% decline in relative abundance over two years is likely to be important biologically, if I designed a sampling plan using 113 counts and the more conservative error rates at the 100-m radius, or using either set of error rates and the 50 m radius, I would not be able to detect this large percent difference between samples for any species. Of particular importance for the species of conservation concern that are found in Michigan wetlands, only declines for the Nashville Warbler and Canada Warbler could be detected using this sample size and any radius; the Eastern Wood Pewee, Blackburnian Warbler, and Veery would require a minimum of 296, 401, and 663 point counts, respectively. The Great Crested Flycatcher was recorded only 3 times in the wetland sites, and is not likely to ever be sufficiently sampled in a monitoring scheme in this limited area.

If I conducted a similar "hypothetical" monitoring project in the uplands, even though the number of counts conducted in upland sites was slightly higher than for wetlands, I could detect the 40% decline for fewer species (based on two samples of 130 unlimited distance counts). I could potentially detect a 40% decline in relative abundance using the less conservative Type I and Type II error rates (0.10 and 0.20, respectively) for the Ovenbird, Red-eyed Vireo, Eastern Wood-Pewee, and Hermit Thrush based on unlimited radius data; using the more conservative Type I and Type II error rates, or data from the 100-m counts with less conservative error rates, I could still detect declines for the first three species. The Ovenbird had such high detection rates that, even using the more conservative error rates at the 100-m radius, I could still detect this large percent decline. Of the species of particular concern, declines for the Eastern Wood-Pewee could be detected using three of the radius size and error rate combinations, and, although the requires samples for the Veery were still high (as they were in the wetlands), the sample sizes are much closer here to what I actually did collect (156 counts using unlimited counts and less conservative error rates - Table 3-11). The other 4 four species either were not found in the upland sites, or were detected at rates too low to be useful for monitoring. Even though the Great Crested Flycatcher was found 4 times as often here as it was in wetlands, detecting declines for this species would probably require over 500 counts.

### **Most Efficient Sampling Radius**

In the wetland sites, most of the neotropical migrants, including three of the species of particular concern (Nashville, Canada, and Blackburnian Warblers), would be most efficiently sampled using a 100 m radius count. For the Blackburnian Warbler, using this radius would save about 21 observer days of sampling over the unlimited radius count; for most species the difference between the efficiency of these two radii was slight, ranging from less than 2 days for the Canada warbler to 6 days for the Northern Parula. Similarly, when compared to the 50 m radius, there were differences between species in the relative merit of the 100-m radius. The 100 m radius offers an advantage over the 50 m for sampling Veeries, requiring 28 fewer observer days, and was twice as efficient as the 50 m for the Nashville. It would also save about 4 days of sampling for the Canada Warbler and 15 for the Ovenbird. With all of these wetland neotropical migrant species most efficiently sampled using the 100 m radius size, the higher relative efficiency of this method found in Chapter Two (Figure 2-5) makes sense. Four species for which relative efficiency would not be well predicted using the means seen in Figure 2-5 are the Black-throated Green Warbler and Eastern Wood-Pewee (best sampled using the unlimited radius), and the Black-and-white Warbler and the Northern Waterthrush (most efficiently sampled using a 50 m radius count).

To maximize ability to detect declines in the wetlands for species of concern, I recommend the 100 m radius count, which was most efficient for both species of concern that are found primarily in wetland ecosystems, the Nashville and Canada Warblers. This radius is also most efficient for the Blackburnian Warbler and Veery, although many more sampling days would be required to detect declines in the relative abundance of these species. The 100 m radius was only slightly less efficient for the Pewee than the unlimited radius.

In contrast to the neotropical migrants, none of the residents and migrants from the wetland sites would be most efficiently sampled using the 100 m radius; 5 out of 7 would require the fewest sampling days using unlimited radius counts. For the Blue Jay and Winter Wren, two species that showed particularly strong biases toward being detected at greater than 100 m away, using the 100 or 50 m radius would require more than 2 (100 m radius) or 3 (50 m radius) times as many sampling days. Similarly, the Yellow-bellied Sapsucker and Brown Creeper were the only two species that had lowest values in the 50 m radius column, and they showed a significant bias when compared to other species toward being found within the 50 m radius. Choosing the 100 m radius to maximize detections of species of concern would sacrifice efficiency in detecting declines of all of

these species. However, all of these species required fewer total sampling days for detecting declines than would be needed for Blackburnian Warbler or Pewees, so it is likely that a plan designed to detect population changes for these species would also detect declines in these residents and short-distance migrants.

In the upland sites, the neotropical migrants showed a different pattern from that seen in the wetlands, with most species requiring the least sampling days to detect a 40% difference between samples using an unlimited radius count. This was true for the two species of concern commonly found in the upland sites, the Eastern Wood-Pewee and Veery. The reduction in sampling effort for these species using the unlimited radius was not very large; in both cases using the 100 m radius would only require less than three more sampling days. Although most efficiently sampled using the 100 m radius in the wetland sites, the Ovenbird would require about one day less of sampling using unlimited counts in uplands; using either radius would require fewer than 4 days for this species due to its high rate of detections. The overall pattern again matches that for the "mean" neotropical migrant efficiency shown in Figure 2-5. Species not well represented by this pattern of mean efficiency were the American Redstart, which showed a significant negative bias against being detected at distances greater than 100 m (Table 3-5), and the Scarlet Tanager (100 m was slightly more efficient).

Again, it seems that one radius size (unlimited) would be most efficient for the two neotropical migrant species of concern in the uplands, and would also be most efficient for the majority of migrants. The difference between what was best for species of concern in the uplands versus the wetlands appears clear cut, and is likely to be related to the long travel times and often thick vegetation (leading to increased sound attenuation --see Chapter 2) found in the wetland sites.

In contrast to the upland sites, two of the residents and short-distance migrants from the wetland sites would be most efficiently sampled using the 100 m radius; these were the Brown-headed Cowbird, which showed a strong bias toward not being found more than 100 m from the count center, as well as the Robin, which did not show a significant bias. The Hermit Thrush, a species with a strong bias compared to other species toward being detected in the farthest radius category, would be most efficiently sampled using unlimited distance counts, while, as was seen in the wetland sites, the Yellow-bellied Sapsucker would require the fewest sampling days using the smallest radius, although the 50 m and 100 m values were very similar. A study designed to efficiently sample Veeries and Pewees in the uplands should also be effective for detecting declines in Hermit Thrushes and Cowbirds, but not in American Robins or Sapsuckers.

I have only been able to find one other study that examined sampling efficiency in a similar way; Hanowski et al. (1990) examined the most efficient transect length to use in transect-based counts designed to detect differences in the number of birds detected in Wisconsin and northern Michigan forests. The transects were of different lengths, but for all lengths only birds detected within 100 m on either side of the transect were counted. In terms of overall results, Hanowski et al. found that fewer samples were needed to detect a 15% difference ( $\alpha = 0.05$ ,  $\beta = 0.20$ ) in number of total individuals per transect when longer (500 to 1050 m transects) were used, but that less total sampling days were needed to detect the same level of decline when shorter transects were used (100 m to 350 m in length), due to the higher number of sample sizes possible using shorter transects. These differences would lead to 8 days of censusing using the 1000 m transect, versus 4 days using the 100 m long transect samples.

As in my study, Hanowski et al. (1990) found different trends for individual species; the Ovenbird and Red-eyed Vireo showed a generally linear trend in increasing sampling effort needed with increasing transect length, while the Black-throated Green Warbler and White-throated Sparrow were most efficiently sampled using a 100 or 350, and 500 m transect, respectively. The Nashville Warbler had similar values for 100, 250 and 500 m transects, with the 350 m and >500 m transects requiring more sampling days.

These differences are a bit perplexing, as they can't easily be explained by differences in at what distance species were most often detected, since all counts were based on a 200 meter wide strip that only varied in length.

### Power Analysis Decisions

Although the focus of this study is determination of the most efficient methods for sampling species of concern in Northern Michigan, consideration of the "hypothetical" modeling data highlights many other factors that conservation workers need to address when developing a monitoring plan. One key question that needs to be addressed is: "What is an acceptable value for beta?" Although .05 has come to be the standard in terms of the probability of a Type I error (and may not be the most appropriate level to use in monitoring), there doesn't seem to be a similarly accepted value for beta (Toft and Shea 1983, Gerrodette 1987, Taylor and Gerrodette 1993). One might choose to set  $\beta$  at the same level as  $\alpha$ , which would suggest that the null and alternative hypotheses are being examined using the same standard (Toft and Shea 1983, Rotenberry and Wiens 1985), or a cost/benefit analysis of the consequences of each type of error could be done, and the values for each could be chosen based on the relative costs (Rotenberry and Wiens 1985). Toft and Shea (1983: 619) suggest that in basic research, the cost of a Type I error (for example, claiming a pattern exists when it does not) "most often greatly exceeds" the cost of a Type II error. The opposite is likely to be true in a monitoring context, especially if the size of the smallest detectable difference is as large as 40% (Taylor and Gerrodette 1993, Thompson and Schwalbach 1995), although there are certainly financial costs associated with responding to population declines if some type of management action is taken when perhaps it was unnecessary (a Type I error in this case). Considering the importance of Type II errors, in many cases researchers may decide to weight them more heavily or at least equally to Type I errors.

Also of major importance is determination of the level of decline that our monitoring plan is powerful enough to detect. Obviously, we would like to do better than being only able to detect a 40% decline, but deciding on an appropriate level is very challenging, and as the amount of difference that can be detected decreases, the sample size needed to detect this difference often dramatically increases (Rotenberry and Wiens 1985). For example, based on Snedecor and Cochran (1989, Table 6.14.1., p. 104 - see Results), when testing for a difference between means (one-tailed test), reducing the difference between samples from 40% to 20% requires four times as many samples, which would lead to four times the expense in terms of conservation dollars. How do we determine how much of a decline is biologically significant? Although I do not have an answer to this question, or even a good guess, it is important that this question be raised whenever changes in population size are discussed.

Similarly, how much information are we losing by doing a one-tailed test? One-tailed tests have no power to detect differences or trends in the opposite direction; any increase in relative abundance would be missed (Gerrodette 1987). In the case of conservation programs that are purely concerned with detecting declines, the increased power of a one-tailed test is likely to outweigh the cost of not being able to detect population increases. However, if monitoring also is required to meet the goal of evaluating the effect of a management plan or some type of disturbance, most researchers would be equally interested in population increases. This decision could be made on a species by species basis, with common species being evaluated using a two-tailed test, and less common species being tested only for declines, or perhaps the guild approach described by Verner (1988) could be used for looking at the effects of habitat changes on groups of species.

Perhaps a better way to use power analysis in this context would be to assume that the hypothesis of a population decline is to be tested using linear regression of estimated relative abundance against time - a significant result would be indicated by a regression line

with a slope significantly different from zero (Gerrodette 1987, Taylor and Gerrodette 1993). In this case, the efficiency of the sampling protocol is evaluated by examining which methods lead to minimization of the mean squared error of the trend estimate. This difference in the statistical "goal" is likely to lead to a different optimization as compared to those found here for the difference between samples (Barker et al. 1993, Barker et al. 1995). Gerrodette (1987) presents a set of formulas for detecting trends in a series of surveys; using these requires that the researcher make assumptions regarding whether the changes in abundance are occurring in constant increments or at a constant rate (linear and exponential models, respectively), and as to whether the coefficient of variation for abundance estimates is constant, proportional to the square root of abundance, or proportional to the inverse of the square root of the abundance. Although using these formulas for all of the species detected was beyond the scope of this study, conservation workers developing monitoring plans for particular species should use this more realistic approach, since most monitoring efforts are designed to last for more than two sampling periods.

### Evaluation of Proposed Standard Methods

Recently, there has been movement towards coming up with a standard method for conducting point counts (Ralph et al. 1995b). Setting standards is problematic, because although there are many benefits to standardization, one standard is not likely to provide the most useful data for all researchers (Lynch 1995). Standards suggested by Ralph et al. (1995b: 161) are designed to be used during the breeding season to "(1) provide trend data for monitoring population changes; and (2) predict population responses to habitat manipulations." The goals stated here seem compatible with the approach I have taken, but the methods suggested would probably reduce sampling efficiency for at least the wetland species of concern discussed in this study.

For count radius, the standards suggest that observers count all birds within an unlimited radius, but sub-tally within a 50 m radius (Ralph et al. 1995b). This is designed to maximize detections per point, while also allowing the observer to use the 50 m data for comparing relative abundance between different areas, or to determine habitat associations. Based on my results, this would be inefficient for species that are best sampled using a smaller radius, even if data for a 50 (and any other radius size) are available, because, with respect to sampling efficiency, the benefit of using the smaller radius is lost if you still walk just as far between points (reducing the number of points that can be covered in a sampling day). However, Ralph et al. (1995b) suggest a rather low minimum distance of 250 m between points for these unlimited-distance counts, which is quite a bit smaller than the 400 m distances used to estimate efficiency in this study. Using this shorter travel time would basically negate the loss in efficiency that was found for some species in this study between the 100 m and unlimited-distance radii.

Unfortunately, this short distance between points is likely to lead to double counting of birds by observers. Ralph et al. (1995b) support this small minimum distance by citing a study by Scott et al. (1981), in which 95% of all birds were estimated to be detected within 125 m of the observer. However, this study was done in Hawaii, and it's likely that a "95% of all detections distance" would be much larger in many North American ecosystems, especially in dry, open forests like those that were included in my upland sites. Ralph et al. (1995b) suggest that this short distance is acceptable because the maximum detection distance for nearly all species is less than 250 m; in effect, their method requires that observers remember what they have heard from one point to the next, and make an effort to not count the same bird twice. I think that remembering birds from one point to the next is too difficult, and would recommend a larger distance between points, or a smaller radius count to avoid double counting.

The standards proposed by Ralph et al. (1995b) suggest 5 minute counts when travel time is less than 10 minutes, and 10 minutes of counting for longer travel times. Unlike the radius suggestion, this standard would not require compromising sampling

efficiency in these northern Michigan field sites, because, due to the long travel times, 10 minute counts are likely to be among the most efficient (see Chapter 2). This choice of methods (as opposed to the radius size choice), allows a researcher to be flexible; longer counts could be used as long as the observer makes a notation on the data sheet to indicate when 3, 5, or 10 minutes have gone by so that birds recorded during these time intervals can be compared with other studies (Buskirk and McDonald 1985).

### **Limitations of study**

One thing that is clear from the discussion of detection distances and sampling bias is that 150 m (the distance between my points) is not far enough to approach conditional independence; this assumption is violated when birds are recounted at neighboring points, or when the calling rate of one bird influences the chance of detecting a bird at a neighboring point (Pendleton 1995). The fact that my samples are collected using systematic sampling rather than random sampling exacerbates this problem, in that neighboring values are likely to be correlated, due to similar habitat conditions (unconditional dependence) (Whysong and Miller 1987, Pendleton 1995). As a result of both of these, it is likely that the variances estimated in my study are too small, suggesting that the estimates of samples needed to detect particular changes in relative abundance are also too small (Whysong and Miller 1987, Pendleton 1995).

### **Problems with Point Counts in General**

As described by Barker and Sauer (1995: 130), "The dominant feature of point counts is that they do not census birds, but instead provide incomplete counts of individuals present within a survey plot." Most researchers make this problem worse by analyzing point count data using standard sampling estimation procedures, acting as if these indices that we can't even accurately evaluate (in terms of how many birds have been missed) can be substituted for exact measurements of the birds present within each sampling area (Sauer et al. 1994, Barker and Sauer 1995). David (1981) and Blondel (1985) argue that many researchers acknowledge that their work involves many assumptions, such as the assumption that all birds at a point are counted, but do nothing to compensate for the biases introduced into their analysis as a result of these assumptions.

Burnham (1981:325) strongly criticizes the use of unadjusted point counts as an index of abundance, calling this practice "neither scientifically sound nor reliable" because these data lack any clear connection to biological parameters such as population densities. Many other authors do not make such a strong statement against unadjusted point counts, but agree that point count data, as well as data from other similar counting methods (i.e., transect counts) should not be used to estimate species densities because of the very low accuracy of these data (Verner 1985, Verner and Milne 1989). However, point counts are seen by many as the method of choice for detecting annual trends, because these counts allow the time sampling to be controlled (as opposed to transect sampling or mapping studies), and allow the sampling of many sites (Dawson 1981, Verner 1985, 1988, Verner and Milne 1989).

However, even if we were able to collect extremely accurate point count data, the problem of picking the correct scale for a study may hinder our ability to accurately describe patterns of abundance over space and time (Wiens 1981). If the scale of a study does not match the scale of the processes that are influencing the population, collecting "perfect" data and making sure to sample enough points so that statistical tests can be performed at a desired level of power is not enough to prevent researchers from coming to erroneous conclusions (Wiens 1981). Because of these many limitations to point count data, assumptions regarding their use should always be stated, and conclusions regarded with care; however at this time they are likely to be our best early-warning system for detecting population declines because they are relatively inexpensive, are widely used, and because they are the only type of long-term data we have for many species (Barker and Sauer 1995).

In situations where point counts are the most appropriate method for monitoring rare species, what do we do when the detection rates for the species are consistently low, requiring extremely large sample sizes to have the power to detect population declines? Monitoring species that are already rare, or are widely dispersed within ecosystems offers an additional set of challenges for researchers. Two of the neotropical migrant species of concern in Michigan, the Blackburnian Warbler and Great Crested Flycatcher seem to fit this description, at least in the forests that I studied. The Blackburnian Warbler may be at risk in northern Michigan due to declines in natural conifers such as white pine, red pine, eastern hemlock (*Tsuga canadensis*), and balsam fir that have occurred in mesic upland sites in northern Michigan (Doepker et al. 1992). These authors sampled for Blackburnians at 384 listening points in the Escanaba River State Forest in the Upper Peninsula of Michigan, and only detected them at 9 (2.3%) of these points (1992:368). Since the power to detect declines decreases as means decrease, our ability to detect declines in these species is likely to be very low in northern Michigan ecosystems (Taylor and Gerrodette 1993). Taylor and Gerrodette (1993) suggest that in cases where the power to detect declines is limited in this way, detection of a decline should not be required before conservation measures are enacted.

For some species of conservation concern, methods for increasing mean detections may improve the efficiency of monitoring plans. One option for increasing detection rates is to use playbacks (recordings of male songs) to encourage singing by territorial males; this can be done after the regular point count is completed, so that "regular" and playback data are collected at each point (Johnson et al. 1981, Sliwa and Sherry 1992, Johnson 1995, Lynch 1995). Another way to improve the detections of species of concern is to have researchers focus on a subset of species, rather than recording data on all; Scott et al. (1981) found that counts done by "specialists" were higher than for those counting all species for 5 of 7 species tested (significantly higher for two). So to improve detectability, maybe limiting the observer in what they record will improve frequencies of detections by keeping the observer from becoming "saturated" with cues from birds (Verner 1985). Finally, points can be chosen that maximize the chances of detecting the species of concern.

## Conclusions

Since individual species of conservation concern may vary widely in their singing behaviors and conspicuousness in forested ecosystems, monitoring programs for one or more rare species may have to be specially tailored to serve the purpose of detecting their population changes in specific ecosystems (Verner and Ritter 1984). As a result, sampling plans based on optimizing the efficiency of sampling for all species combined will not be the most efficient for all individual species (Barker and Sauer 1995). For all species, there is a general trend of increasing rate of detections with increasing count length and count radius, however the strength and actual pattern of this trend is quite variable. Prior to establishing a sampling plan for a particular species of concern, it makes sense to investigate these patterns so that the species can be sampled with greater efficiency, and limited conservation funds are not wasted.

Table 3-1. Ranking of neotropical migrants by decreasing management concern in the midwest; based on ranking system and values for species in Thompson et al. (1993 - Table 2.) For each category, higher numbers indicate that the species is more at risk; for example a (5) in the global abundance category is defined as very rare to rare, while a (1) is abundant or demonstrably secure (Thompson et al. 1993). The table includes all species observed at least 10 times in wetland and upland sites, combined.

Species	Global abundance	Winter distribution	Winter threats	Breeding distribution	Breeding threats	Importance of Midwest	Population trend	Mean Score
Nashville Warbler	3	4	3	3	2	5	4	3.43
Canada Warbler	2	4	4	3	3	4	4	3.43
Eastern Wood-Pewee	2	4	3	3	2	4	5	3.29
Veery	2	3	3	3	3	4	5	3.29
Great Crested Flycatcher	2	4	4	3	2	4	4	3.29
Ovenbird	2	3	3	3	3	5	3	3.14
Blackburnian Warbler	3	4	4	3	3	4	1	3.14
Rose-breasted Grosbeak	2	3	3	3	2	4	5	3.14
Scarlet Tanager	2	4	4	3	3	4	1	3.00
Black-thr. Green Warbler	3	3	3	3	3	4	2	3.00
American Redstart	2	2	3	2	3	3	5	2.86
Northern Waterthrush	2	2	4	2	2	3	3	2.57
Northern Parula	2	3	3	3	3	3	1	2.57
Black-and-white Warbler	2	2	3	2	3	4	1	2.43
Red-eyed Vireo	1	3	2	2	2	4	1	2.14

Table 3-2. Comparison of the mean (standard deviation) rate and coefficient of variation of detections per point for each wetland species for three radius sizes. Based on 113 10-minute counts. Only species with mean detection rates higher than 0.10 for unlimited distance counts are listed.

Wetland Species	Unlimited Radius Counts		100 m Radius Counts		50 m Radius Counts	
	Mean (SD) n = 113	Coefficient of Variation	Mean (SD) n = 113	Coefficient of Variation	Mean (SD) n = 113	Coefficient of Variation
<b>NEOTROPICAL MIGRANTS</b>						
Nashville Warbler	0.75 (0.82)	1.1	0.58 (0.68)	1.2	0.19 (0.40)	2.0
Ovenbird	0.67 (1.00)	1.5	0.42 (0.73)	1.7	0.12 (0.36)	2.9
Black-and-white Warbler	0.62 (0.76)	1.2	0.57 (0.74)	1.3	0.41 (0.62)	1.5
Canada Warbler	0.54 (0.72)	1.3	0.39 (0.65)	1.7	0.20 (0.47)	2.3
Black-throated Green Warbler	0.49 (0.64)	1.3	0.21 (0.45)	2.1	0.071 (0.26)	3.6
Northern Waterthrush	0.33 (0.78)	2.4	0.33 (0.78)	2.4	0.23 (0.59)	2.6
Northern Parula	0.26 (0.44)	1.7	0.20 (0.40)	2.0	0.071 (0.26)	3.6
Eastern Wood-Pewee	0.18 (0.41)	2.3	0.10 (0.30)	3.1	0.062 (0.24)	3.9
Blackburnian Warbler	0.12 (0.33)	2.7	0.11 (0.31)	2.9	0.071 (0.26)	3.6
Veery	0.12 (0.43)	3.4	0.09 (0.39)	4.4	0.053 (0.32)	6.1
<b>SHORT-DISTANCE MIGRANTS &amp; RESIDENTS</b>						
Winter Wren	1.29 (0.69)	0.53	0.62 (0.69)	1.1	0.27 (0.50)	1.8
Blue Jay	0.75 (0.81)	1.1	0.23 (0.55)	2.4	0.16 (0.47)	3.0
White-throated Sparrow	0.58 (0.64)	1.1	0.33 (0.57)	1.8	0.12 (0.36)	2.9
Red-breasted Nuthatch	0.41 (0.59)	1.5	0.28 (0.56)	1.8	0.17 (0.46)	2.7
Yellow-bellied Sapsucker	0.39 (0.54)	1.4	0.34 (0.53)	1.6	0.27 (0.50)	1.8
American Robin	0.34 (0.49)	1.5	0.22 (0.44)	2.0	0.11 (0.34)	3.2
Brown Creeper	0.24 (0.45)	1.8	0.23 (0.44)	1.9	0.19 (0.41)	2.2

Table 3-3. Comparison of the mean (standard deviation) rate and coefficient of variation of detections per point for each upland species for the three radius sizes. Based on 130 10-minute counts. Only species with mean detection rates higher than 0.10 for unlimited distance counts are listed.

Upland Species	Unlimited Radius Counts		100 m Radius Counts		50 m Radius Counts	
	Mean (SD) n = 130	Coefficient of Variation	Mean (SD) n = 130	Coefficient of Variation	Mean (SD) n = 130	Coefficient of Variation
<b>NEOTROPICAL MIGRANTS</b>						
Ovenbird	2.10 (1.10)	0.53	0.95 (0.81)	0.84	0.26 (0.47)	1.8
Red-eyed Vireo	1.20 (0.91)	0.77	0.63 (0.83)	1.3	0.30 (0.52)	1.7
Eastern Wood-Pewee	0.77 (0.73)	0.94	0.46 (0.65)	1.4	0.14 (0.35)	2.5
Veery	0.40 (0.67)	1.7	0.28 (0.62)	2.2	0.12 (0.34)	3.0
Black-throated Green Warbler	0.38 (0.64)	1.6	0.16 (0.45)	2.8	0.054 (0.23)	4.2
American Redstart	0.35 (0.85)	2.4	0.29 (0.73)	2.6	0.12 (0.44)	3.8
Scarlet Tanager	0.30 (0.52)	1.7	0.21 (0.44)	2.1	0.092 (0.34)	3.7
<b>SHORT-DISTANCE MIGRANTS &amp; RESIDENTS</b>						
Hermit Thrush	0.64 (0.84)	1.3	0.16 (0.43)	2.6	0.053 (0.23)	4.2
Brown-headed Cowbird	0.36 (0.61)	1.7	0.33 (0.59)	1.8	0.19 (0.50)	2.6
Yellow-bellied Sapsucker	0.25 (0.50)	2.0	0.24 (0.49)	2.1	0.18 (0.46)	2.5
American Robin	0.16 (0.41)	2.5	0.092 (0.29)	3.1	0.023 (0.15)	6.5

Table 3-4. Listing of species found at wetland sites for which distribution of detections with respect to distance from observer (count radius) was significantly different than either all species in the same migration group, or than all species combined (based on 10-minute counts). Directions of biases found in detections are shown for each radius grouping; parts of the distribution that had individual cell values for  $\chi^2$  greater than 4 (i.e., that contributed large values to the total  $\chi^2$ ) are in **BOLD**. Species with results in boxes had the same detection pattern bias and significance level when compared to all species and to only their migratory group; these values are not repeated in the "all species combined" group.

Species (Total Detected)	Significance	Distance from observer		
		0 - 50 m	50 - 100 m	> 100 m
<u>Neotropical migrants compared to combined other neotropical migrants</u>				
Black-and-white Warbler (70)	***	<b>higher</b>	lower	<b>lower</b>
Northern Waterthrush (37)	***	<b>higher</b>	lower	<b>lower</b>
Nashville Warbler (85)	**	lower	<b>higher</b>	lower
Ovenbird (76)	**	<b>lower</b>	higher	higher
Black-thr. Green Warbler (55)	***	<b>lower</b>	lower	<b>higher</b>
<u>Residents &amp; short distance migrants (r &amp; sdms) compared to combined other r &amp; sdms.</u>				
Brown Creeper (27)	***	<b>higher</b>	lower	<b>lower</b>
Yellow-bellied Sapsucker (27)	***	<b>higher</b>	lower	<b>lower</b>
White-throated Sparrow (65)	***	lower	<b>higher</b>	higher
Winter Wren (146)	***	<b>lower</b>	higher	higher
Blue Jay (85)	***	<b>lower</b>	lower	<b>higher</b>
<u>Compared to all other species combined</u>				
Northern Waterthrush (37)	***	<b>higher</b>	higher	<b>lower</b>
Northern Parula (29)	*	lower	<b>higher</b>	lower
Ovenbird (76)	**	<b>lower</b>	higher	<b>higher</b>
White-throated Sparrow (65)	***	<b>lower</b>	higher	<b>higher</b>
Winter Wren (146)	***	<b>lower</b>	lower	<b>higher</b>

Notes:

1. Significance level of results: \* =  $P<0.05$ ; \*\* =  $P<0.01$ ; \*\*\* =  $P<0.001$ .

Species for which there were enough detections to test (mean of at least 0.15 at an unlimited radius), but distributions were not significantly different at the 5% level (number of detections is in parentheses): Canada Warbler (61), Eastern Wood-peewee (20), American Robin (38), Red-breasted Nuthatch (46).

Table 3-5. Listing of species found at upland sites for which distribution of detections with respect to distance from observer (count radius) was significantly different than either all species in the same migration group, or than all species combined (based on 10 minute counts). Directions of biases found in detections are shown for each radius grouping; parts of the distribution that had individual cell values for  $\chi^2$  greater than 4 (i.e., that contributed large values to the total  $\chi^2$ ) are in **BOLD**. Species with results in boxes had the same detection pattern bias and significance level when compared to all species and to only their migratory group; these values are not repeated in the "all species combined" group.

Species (Total Detected)	Significance <sup>1</sup>	Distance from observer		
		0 - 50 m	50 - 100 m	> 100 m
<u>Neotropical migrants compared to combined other neotropical migrants</u>				
American Redstart (46)	**	higher	higher	<b>lower</b>
Ovenbird (272)	***	<b>lower</b>	lower	<b>higher</b>
<u>Residents &amp; short distance migrants (r &amp; sdms) compared to combined other r &amp; sdms.</u>				
Brown-headed Cowbird (47)	***	<b>higher</b>	lower	<b>lower</b>
Yellow-bellied Sapsucker (32)	***	<b>higher</b>	lower	<b>lower</b>
Hermit Thrush (83)	***	<b>lower</b>	<b>lower</b>	<b>higher</b>
<u>Compared to all other species combined (no additional species or changes from patterns shown above)</u>				

Notes:

1. Significance level of results: \* =  $P<0.05$ ; \*\* =  $P<0.01$ ; \*\*\* =  $P<0.001$ .

Species for which there were enough detections to test (mean of at least 0.15 at unlimited radius), but distributions were not significantly different at the 5% level (number of detections is in parentheses): Black-throated Green Warbler (50), Eastern Wood-pewee (101), American Robin (21), Scarlet Tanager (39), Veery (52), Red-eyed Vireo (154).

Table 3-6. Listing of species found at wetland sites for which distribution of detections with respect to count length was significantly different than either all species in the same migration group combined, or than all species combined, based on unlimited distance counts. Directions of biases found in detections are shown for each radius grouping; parts of the distribution that had individual cell values for  $\chi^2$  greater than 4 (i.e., that contributed large values to the total  $\chi^2$ ) are in **BOLD**. Species with results in boxes had the same detection pattern bias and significance level when compared to both all species and just species in the same migratory group; these values are not repeated under the "all species combined" heading.

#### Wetland - Unlimited radius counts

Species (Total Detected)	Significance	Minutes of Count		
		1 - 4 min	5 - 8 min	9 - 12 min
<u>Neotropical migrants compared to combined other neotropical migrants</u>				
Nashville Warbler (88)	*	higher	higher	<b>lower</b>
<u>Residents &amp; short distance migrants (r &amp; sdms) compared to combined other r &amp; sdms.</u>				
Winter Wren (147)	***	higher	<b>lower</b>	<b>lower</b>
Brown Creeper (31)	*	lower	higher	higher
Red-breasted Nuthatch (48)	**	lower	higher	<b>higher</b>
<u>Compared to all other species combined</u>				
Winter Wren (147)	***	higher	<b>lower</b>	lower
Nashville Warbler (85)	**	lower	<b>higher</b>	lower
Brown Creeper (31)	*	lower	higher	higher
Red-breasted Nuthatch (48)	**	lower	higher	higher

#### Notes:

1. Significance level of results: \* =  $P < 0.05$ ; \*\* =  $P < 0.01$ ; \*\*\* =  $P < 0.001$ .

Species for which there were enough detections to test (mean of at least 0.25 at an unlimited radius), but distributions were not significantly different at the 5% level (number of detections is in parentheses): Black-and-White Warbler (76), Black-throated Green Warbler (63), Blue Jay (93), Canada Warbler (68), Ovenbird (81), Northern Parula (30), Northern Waterthrush (39), American Robin (39), White-throated Sparrow (73), Yellow-bellied Sapsucker (47).

Table 3-7. Listing of species found at wetland sites for which distribution of detections with respect to count length was significantly different than either all species in the same migration group combined, or than all species combined, based on 100 m radius counts (top table). No significant differences were found based on 50 m radius data; species with enough data to test are listed under the 50 m radius heading. Directions of biases found in detections are shown for each radius grouping; parts of the distribution that had individual cell values for  $\chi^2$  greater than 4 (i.e., that contributed large values to the total  $\chi^2$ ) are in **BOLD**. Species with results in boxes had the same detection pattern bias and significance level when compared to both all species and just species in the same migratory group; these values are not repeated under the "all species combined" heading.

#### **Wetland - 100 m radius counts**

Species (Total Detected)	Significance	Minutes of Count		
		1 - 4 min	5 - 8 min	9 - 12 min
<u>Neotropical migrants compared to combined other neotropical migrants</u>				
Ovenbird (50)	***	lower	<b>higher</b>	lower
<u>Residents &amp; short distance migrants (r &amp; sdms) compared to combined other r &amp; sdms.</u>				
Winter Wren (70)	**	higher	<b>lower</b>	<b>lower</b>
Brown Creeper (29)	*	lower	higher	higher
<u>Compared to all other species combined</u> (No additional species or changes in patterns)				

#### Notes:

1. Significance level of results: \* =  $P < 0.05$ ; \*\* =  $P < 0.01$ ; \*\*\* =  $P < 0.001$ .

Species for which there were enough detections to test (mean of at least 0.25 based on a 100 m radius), but distributions were not significantly different at the 5% level (number of detections is in parentheses): Black-and-White Warbler (69), Canada Warbler (50), Nashville Warbler (69), Northern Waterthrush (39), Red-breasted Nuthatch (34), White-throated Sparrow (42), Yellow-bellied Sapsucker (41).

#### **Wetland - 50 m radius counts**

No significant differences. Species for which there were enough detections to test (mean of at least 0.25 based on a 50 m radius), but distributions were not significantly different at the 5% level (number of detections is in parentheses): Black-and-White Warbler (50), Canada Warbler (28), Winter Wren (31), Yellow-bellied Sapsucker (32).

Table 3-8. Listing of species found at upland sites for which distribution of detections with respect to count length was significantly different than either all species in the same migration group combined, or than all species combined, based on unlimited-distance counts. Directions of biases found in detections are shown for each radius grouping; parts of the distribution that had individual cell values for  $\chi^2$  greater than 4 (i.e., that contributed large values to the total  $\chi^2$ ) are in **BOLD**.

**Upland - Unlimited radius counts**

Species (Total Detected)	Significance <sup>1</sup>	Minutes of Count		
		1 - 4 min	5-8 min	9-12 min
<u>Neotropical migrants compared to combined other neotropical migrants</u>				
Ovenbird (283)	*	higher	higher	lower
Scarlet Tanager (45)	*	lower	higher	<b>higher</b>
<u>Residents &amp; short distance migrants (r &amp; sdms) compared to combined other r &amp; sdms.</u>				
Hermit Thrush (95)	*	higher	<b>lower</b>	higher
<u>Compared to all other species combined</u>				
Ovenbird (283)	**	higher	lower	<b>lower</b>
Yellow-bellied Sapsucker (37)	**	lower	higher	<b>higher</b>
Hermit Thrush (95)	**	lower	lower	<b>higher</b>

Notes:

1. Significance level of results: \* =  $P<0.05$ ; \*\* =  $P<0.01$ ; \*\*\* =  $P<0.001$ .

Species for which there were enough detections to test (mean of at least 0.25 after 12 minutes), but distributions were not significantly different at the 5% level (number of detections is in parentheses): American Redstart (46), Black-throated Green Warbler (53), Brown-headed Cowbird (53), Eastern Wood-pewee (105), Veery (59), Red-eyed Vireo (161).

Table 3-9 a & b. Listing of species found at upland sites for which distribution of detections with respect to count length was significantly different than either all species in the same migration group combined, or than all species combined, based on 100 meter (a) or 50 m radius counts (b). Directions of biases found in detections are shown for each radius grouping; parts of the distribution that had individual cell values for  $\chi^2$  greater than 4 (i.e., that contributed large values to the total  $\chi^2$ ) are in **BOLD**). Species with results in boxes had the same detection pattern bias and significance level when compared to both all species and just species in the same migratory group; these values are not repeated under the "all species combined" heading.

**(a) Upland - 100 m radius counts**

Species (Total Detected)	Significance <sup>1</sup>	Minutes of Count		
		1 - 4 min	5-8 min	9-12 min
<u>Neotropical migrants compared to combined other neotropical migrants</u>				
American Redstart (37)	*	higher	higher	<b>lower</b>
Eastern Wood-Pewee (62)	*	higher	lower	<b>higher</b>
Scarlet Tanager (32)	*	higher	lower	<b>higher</b>
<u>Residents &amp; short distance migrants (r &amp; sdms) compared to combined other r &amp; sdms.</u>				
(none)				
<u>Compared to all other species combined</u>				
Yellow-bellied Sapsucker (35)	**	lower	higher	<b>higher</b>

Species for which there were enough detections to test mean of at least 0.25 at a 100 m radius), but distributions were not significantly different at the 5% level (number of detections is in parentheses): Brown-headed Cowbird (47), Hermit Thrush (27), Ovenbird (131), Veery (39), Red-eyed Vireo (88).

**(b) Upland - 50 m radius counts**

Species (Total Detected)	Significance <sup>1</sup>	Minutes of Count		
		1 - 4 min	5-8 min	9-12 min
<u>Neotropical migrants compared to combined other neotropical migrants</u>				
Ovenbird (36)	***	lower	<b>higher</b>	lower
<u>Residents &amp; short distance migrants (r &amp; sdms) compared to combined other r &amp; sdms.</u>				
(none)				
<u>Compared to all other species combined</u>				
Brown-headed Cowbird (27)	*	lower	<b>higher</b>	lower

Notes:

1. Significance level of results: \* =  $P<0.05$ ; \*\* =  $P<0.01$ ; \*\*\* =  $P<0.001$ .

Species for which there were enough detections to test (mean of at least 0.25 at a 50 m radius), but distributions were not significantly different at the 5% level (number of detections is in parentheses): American Redstart (46), Red-eyed Vireo (43).

Table 3-10. Mean detections per point of birds in wetland ecosystems, and the estimated sample sizes required to detect a 40 percent difference between two estimates of the mean relative abundance (one-tailed test) when controlling for different levels of Type I and Type II error. Estimates are provided based on an unlimited, 100 m, or 50 m radius point-count, with a 10 minute count length. Only species with mean detection rates higher than 0.10 for unlimited distance counts are listed.

Species	Unlimited Distance Counts				100 m Radius Counts				50 m Radius Counts			
	Required Sample Size				Required Sample Size				Required Sample Size			
	Mean (SD) n= 113	I = 0.10 II = 0.20	I = 0.05 II = 0.10	Mean (SD) n= 113	I = 0.10 II = 0.20	I = 0.05 II = 0.10	Mean (SD) n= 113	I = 0.10 II = 0.20	I = 0.05 II = 0.10	Mean (SD) n= 113	I = 0.10 II = 0.20	I = 0.05 II = 0.10
<b>NEOTROPICAL MIGRANTS</b>												
Nashville Warbler	0.75 (0.82)	67	127	0.58 (0.68)	76	145	0.19 (0.40)	235	449			
Ovenbird	0.67 (1.00)	123	235	0.43 (0.73)	166	317	0.12 (0.36)	467	892			
Black-and-white Warbler	0.62 (0.76)	85	162	0.57 (0.74)	97	185	0.41 (0.62)	131	251			
Canada Warbler	0.54 (0.72)	100	191	0.39 (0.65)	155	297	0.20 (0.47)	294	563			
Bl.-thr. Green Warbler	0.49 (0.64)	98	187	0.21 (0.45)	255	487	0.07 (0.26)	745	1,424			
Northern Waterthrush	0.33 (0.78)	323	617	0.33 (0.78)	323	617	0.23 (0.59)	380	726			
Northern Parula	0.26 (0.44)	164	314	0.20 (0.40)	222	424	0.07 (0.26)	745	1,424			
Eastern Wood-Pewee	0.18 (0.41)	296	566	0.10 (0.30)	526	1,006	0.06 (0.24)	859	1,642			
Blackburnian Warbler	0.12 (0.33)	401	767	0.11 (0.31)	478	913	0.07 (0.26)	745	1,423			
Veery	0.12 (0.43)	663	1,267	0.09 (0.39)	1,098	2,098	0.05 (0.32)	2,080	3,976			
<b>SHORT-DISTANCE MIGRANTS &amp; RESIDENTS</b>												
Winter Wren	1.29 (0.69)	16	31	0.62 (0.69)	69	132	0.27 (0.50)	190	363			
Blue Jay	0.75 (0.81)	65	124	0.23 (0.55)	322	617	0.16 (0.47)	497	951			
White-throated Sparrow	0.58 (0.64)	69	132	0.33 (0.57)	173	330	0.12 (0.36)	467	892			
Red-breasted Nuthatch	0.41 (0.59)	119	227	0.28 (0.56)	218	418	0.17 (0.46)	422	808			
Yellow-bellied Sapsucker	0.39 (0.54)	109	208	0.34 (0.53)	139	265	0.27 (0.50)	190	363			
American Robin	0.34 (0.49)	121	231	0.22 (0.44)	220	421	0.11 (0.34)	567	1,083			
Brown Creeper	0.24 (0.45)	198	379	0.23 (0.44)	209	399	0.19 (0.41)	278	531			

Table 3-11. Mean detections per point of birds in upland ecosystems, and the estimated sample sizes required to detect a 40 percent difference between two estimates of the mean relative abundance (one-sided test) when controlling for different levels of Type I and Type II error. Estimates are provided based on an unlimited, 100 m, or 50 m radius point-count, with a 10 minute count length. Only species with mean detection rates higher than 0.10 for unlimited distance counts are listed.

Species	Unlimited Distance Counts				100 m Radius Counts				50 m Radius Counts			
	Required Sample Size				Required Sample Size				Required Sample Size			
	Mean (SD) n= 113	I = 0.10 II = 0.20	I = 0.05 II = 0.10	Mean (SD) n= 113	I = 0.10 II = 0.20	I = 0.05 II = 0.10	Mean (SD) n= 113	I = 0.10 II = 0.20	I = 0.05 II = 0.10	Mean (SD) n= 113	I = 0.10 II = 0.20	I = 0.05 II = 0.10
<b>NEOTROPICAL MIGRANTS</b>												
Ovenbird	2.09 (1.10)	16	30	0.95 (0.81)	40	77	0.26 (0.47)	186	354			
Red-eyed Vireo	1.18 (0.91)	33	64	0.63 (0.83)	97	185	0.30 (0.52)	171	323			
Eastern Wood-Pewee	0.78 (0.73)	50	95	0.46 (0.65)	111	212	0.14 (0.35)	353	674			
Veery	0.40 (0.67)	156	298	0.28 (0.62)	285	544	0.12 (0.34)	500	956			
Bl.-thr. Green Warbler	0.38 (0.64)	155	297	0.16 (0.45)	428	818	0.054 (0.23)	996	1,903			
American Redstart	0.35 (0.85)	327	624	0.29 (0.73)	369	705	0.12 (0.44)	828	1,582			
Scarlet Tanager	0.30 (0.52)	171	327	0.21 (0.44)	257	491	0.092 (0.34)	762	1457			
<b>SHORT-DISTANCE MIGRANTS &amp; RESIDENTS</b>												
Hermit Thrush	0.64 (0.84)	97	184	0.16 (0.43)	395	754	0.053 (0.23)	996	1,904			
Brown-headed Cowbird	0.36 (0.61)	160	306	0.33 (0.59)	178	341	0.19 (0.50)	380	725			
Yellow-bellied Sapsucker	0.25 (0.50)	231	442	0.24 (0.49)	242	463	0.18 (0.46)	353	674			
American Robin	0.16 (0.41)	361	690	0.92 (0.29)	558	1065	0.023 (0.15)	2,399	4,586			

Table 3-12. Comparison of the efficiency of different sampling radii in wetland sites with respect to how many sampling days would be required to detect a 40% difference between two estimates of the mean relative abundance for each species (one-sided test, Type I error rate set at 0.1, Type II error rate set at 0.2). Using the sample size calculations shown in Table 3-10, these estimates are based on a 5 hour sampling day, a travel rate of 11.6 min / 100 m (400 m between unlimited radii, 200 between 100 m radii, and 100 between 50 m radii), and a 10 minute count at each point.

Species	Number of Sampling Days Required to Detect a 40% Decline in Relative Abundance		
	Unlimited Distance Count	100 m Radius Count	50 m Radius Count
<b>NEOTROPICAL MIGRANTS</b>			
Black-throated Green Warbler	<b>18.4</b>	28.2	53.6
Eastern Wood-Pewee	<b>55.6</b>	58.2	61.8
Nashville Warbler	12.6	<b>8.4</b>	16.9
Canada Warbler	18.8	<b>17.1</b>	21.2
Ovenbird	23.1	<b>18.4</b>	33.6
Northern Parula Warbler	30.8	<b>24.5</b>	53.6
Blackburnian Warbler	75.3	<b>52.9</b>	53.6
Veery	124.5	<b>121.4</b>	149.7
Black-and-white Warbler	16.0	10.7	<b>9.4</b>
Northern Waterthrush	60.7	35.7	<b>27.3</b>
<b>SHORT-DISTANCE MIGRANTS &amp; RESIDENTS</b>			
Winter Wren	<b>3.0</b>	7.6	13.7
Blue Jay	<b>12.2</b>	35.6	35.8
White-throated Sparrow	<b>13.0</b>	19.2	33.6
Red-breasted Nuthatch	<b>22.4</b>	24.1	30.4
American Robin	<b>22.7</b>	24.3	40.8
Yellow-bellied Sapsucker	20.5	<b>15.4</b>	<b>13.7</b>
Brown Creeper	37.2	23.1	<b>20.0</b>

Table 3-13. Comparison of the efficiency of different sampling radii in upland sites with respect to how many sampling days would be required to detect a 40% difference between two estimates of the mean relative abundance for each species (one-sided test, Type I error rate set at 0.1, Type II error rate set at 0.2). Using the sample size calculations shown in Table 3-11, these estimates are based on a 5 hour sampling day, a travel rate of 9.4 min / 100 m (400 m between unlimited radii, 200 between 100 m radii, and 100 between 50 m radii), and a 10 minute count at each point.

Species	Number of Sampling Days Required to Detect a 40% Decline in Relative Abundance		
	Unlimited Distance Count	100 m Radius Count	50 m Radius Count
<b>NEOTROPICAL MIGRANTS</b>			
Ovenbird	<b>2.5</b>	3.8	12.0
Red-eyed Vireo	<b>5.2</b>	9.3	11.0
Eastern Wood-Pewee	<b>7.9</b>	10.6	22.7
Veery	<b>24.6</b>	27.2	32.2
Black-throated Green Warbler	<b>24.5</b>	40.9	64.2
American Redstart	51.6	<b>35.3</b>	53.4
Scarlet Tanager	26.9	<b>24.6</b>	49.1
<b>SHORT-DISTANCE MIGRANTS &amp; RESIDENTS</b>			
Hermit Thrush	<b>15.3</b>	37.7	64.2
Brown-headed Cowbird	25.2	<b>17.0</b>	24.5
American Robin	57.0	<b>53.3</b>	154.6
Yellow-bellied Sapsucker	36.4	23.1	<b>22.7</b>

## Chapter 4: Summary and Conclusions

For many years, researchers have suggested that populations of many species of neotropical migrant birds in the United States are declining. In order to test this hypothesis, we need to understand how the methods that we use for collecting data impact the results we obtain, and, if we are not careful, the conclusions that we draw based on our data. I examined methods for improving the efficiency of point count sampling in wetland and upland forests in northern lower Michigan. In Chapter 1, the question of what is the most efficient combination of sampling methods was addressed using two groups of species, neotropical migrants and short-distance migrants and residents. Here, I compared the effects of (1) changing the duration of point counts, and (2) changing the count radius in wetland and upland ecosystems. Next, I compared different combinations of point count durations and radii to see which produced the highest expected cumulative count per hour (a measure of sampling efficiency). There was a lot of variation in the patterns for the two species groups, suggesting that combining the groups into "all species" would further reduce the potential value of these detection pattern "means" for estimating the most efficient set of methods to use for a particular species or ecosystem type.

For neotropical migrants in wetland sites, I found that an 8-12 minute, 100 m radius point counts would be most efficient. This radius size would also be most effective for sampling the residents and short-distance migrants using long count durations (8-12 minutes), although similar efficiency levels could be attained using shorter duration (5-6 minute) 50 m radius counts. In the uplands, the neotropical migrants had the highest expected cumulative counts with 12-minute, unlimited radius counts; residents could be sampled most efficiently using either the unlimited radius or 100 m radius size and long counts (10-12 minutes). These results suggest that what is most efficient varies both by forest type and by migratory group in northern Michigan forests.

Next, I addressed species-specific biases, and effects of using different point count radii (with 10 minute count lengths) on sampling efficiency in the same ecosystems, focusing on species of conservation concern. Based on my unlimited-distance data from the wetland sites, if a researcher were to choose a count length based on efficiency analyses using pooled neotropical migrant data, it is likely that the chosen count duration would be slightly longer than what would be most efficient for one of Michigan's species of concern, the Nashville Warbler. I predict that this problem could be exacerbated if efficiency is estimated using the data from all species, because compared to all species, detection rates were lower than expected for Nashvilles in the last two-thirds, rather than just last third, of the sampling period (12 minutes). None of the other wetland species of concern showed a significant bias at this radius size, however sample sizes for the all but the Canada and Nashville Warbler were fairly low. Similarly, no significant bias related to count duration was found for the any of the wetland species of concern using the 100 m radius data. At this radius, it appears that appropriate wetland neotropical migrant curve shown in Figure 2-5 will provide a reasonable estimate of how sampling efficiency for a species changes with duration. Another species of particular concern in Michigan, the Eastern Wood-Pewee, showed a significantly different detection pattern in the upland sites; when compared to other neotropical migrants, it had a positive bias at each end (i.e., has higher than expected values in first and last thirds of the count), but neither bias is particularly strong.

I also examine how the mean detection rate influenced the number of samples needed to detect a 40% decline in the relative abundance of a species, using different levels of statistical power. In the wetlands, two neotropical migrant species and most of the

short-distance migrants and residents would all be most efficiently sampled using the unlimited radius count, while over half of the neotropical migrants, including four of conservation concern (Veery, and Nashville, Canada, and Blackburnian Warblers) would be most efficiently sampled using 100 m radius counts. In the uplands, most of the neotropical migrants, including two of conservation concern (Eastern Wood-Pewee, and Veery) would be most efficiently sampled using an unlimited radius count. The number of sampling days required to detect a 40% decline using a one-sided test ( $\alpha = 0.1$ ,  $\beta = 0.2$ ) varied widely for the species of concern. Using count radii found to be most efficient for each species, detecting this large difference in relative abundance would require approximately 8 days for the Eastern Wood Pewee and Nashville Warbler (in upland and wetland sites, respectively), 17 and 52 days, respectively for the Canada Warbler and Blackburnian Warblers in the wetlands, and 25 days for the Veery in uplands. The last species of concern, the Great Crested Flycatcher, was detected at very low rates in both systems, and, as a result, detecting declines of this species would be very difficult. To Detect declines of 20% rather than 40% would require four times as many sampling days.

In conclusion, this study highlights the fact that the most efficient methods for sampling bird species of conservation concern are likely to change with each species, and each situation. Although some generalities can be made with respect to how the ruggedness of the terrain, or level of sound output from a species may indicate what type of methods are appropriate, educated guesses are not likely to be good substitutes for pilot studies. Similarly, if a researcher wants to monitor populations of rare species, they should also make sure that the number of samples being taken is sufficient for actually detecting changes in population size. Following a set of guidelines without testing them in the actual study areas beforehand could lead to wasted time, money, and perhaps most importantly, a missed opportunity to identify a species decline while there is still time for conservation actions to work.

## LITERATURE CITED

- Askins, R.A., J.F. Lynch, and R. Greenberg. 1990. Population declines in migratory birds in eastern North America. In: Johnston, R.F., editor. *Current Ornithology*, Volume 7. New York: Plenum Press; 1-57.
- Barker, R.J., J.R. Sauer, and W.A. Link. 1993. Optimal allocation of point-count sampling effort. *Auk* 110: 752-758.
- Barker, R.J., and J.R. Sauer. 1995. Statistical aspects of point count sampling. In: Ralph, C.J., J.R. Sauer, and S. Droege, editors. *Monitoring Bird Populations by Point Counts*. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 125-130.
- Barnes, B.V., K.S. Pregitzer, T.A. Spies, and V.H. Spooner. 1982. Ecological forest site classification. *Journal of Forestry* 80: 493-498.
- Bart, J. 1985. Causes of recording errors in singing bird surveys. *Wilson Bulletin* 97: 161-172.
- Bart, J., and J. Herrick. 1984. Diurnal timing of bird surveys. *Auk* 101: 384-387.
- Bart, J., and J.D. Shoultz. 1984. Reliability of singing bird surveys: changes in observer efficiency with avian density. *Auk* 101: 307-318.
- Best, L.B. 1981. Seasonal changes in detection of individual bird species. In: Ralph, C.J., and J.M. Scott, editors. *Estimating the Number of Terrestrial Birds. Studies in Avian Biology* 6; 252-261.
- Bibby, C.J., and S.T. Buckland. 1987. Bias of bird census results due to detectability varying with habitat. *Acta Oecologia* 8: 103-112.
- Blondel, J. 1985. Bird distribution and abundance: some technical and theoretical comments. In: Taylor, K., R.J. Fuller, and P.C. Lack, editors. *Bird Census and Atlas Studies*. Tring, England: British Trust for Ornithology; 3-14.
- Blondel, J., C. Ferry, and B. Frochot. 1981. Point counts with unlimited distance. In: Ralph, C.J., and J.M. Scott, editors. *Estimating the Number of Terrestrial Birds. Studies in Avian Biology* 6; 414-420.
- Boecklen, W.J. 1986. Effects of habitat heterogeneity on the species-area relationships of forest birds. *Journal of Biogeography* 13: 59-68.
- Brackenbury, J.H. 1979. Power capabilities of the avian sound producing system. *Journal of Experimental Biology* 78: 163-166.

- Brewer, R., G.A. McPeek, and R.J. Adams Jr. 1991. The Atlas of Breeding Birds of Michigan. Michigan State University Press: East Lansing, MI.
- Burnham, K.P. 1981. Summarizing remarks: environmental influences. In: Ralph, C.J., and J.M. Scott, editors. Estimating the Number of Terrestrial Birds. Studies in Avian Biology 6; 324-325.
- Buskirk, W.H., and J.L. McDonald. 1995. Comparison of point count sampling regimes for monitoring forest birds. In: Ralph, C.J., J.R. Sauer, and S. Droege, editors. Monitoring Bird Populations by Point Counts. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 25-34.
- Bystrak, D. 1981. The North American Breeding Bird Survey. In: Ralph, C.J., and J.M. Scott, editors. Estimating the Number of Terrestrial Birds. Studies in Avian Biology 6; 34-41.
- Calder, W.A. 1990. The scaling of sound output and territory size: are they matched? *Ecology* 71: 1810-1816.
- Carson, R. 1962. Silent Spring. Boston: Houghton Mifflin Co.
- Cyr, A., D. Lepage, and K. Freemark. 1995. Evaluating point count efficiency relative to territory mapping in cropland birds. In: Ralph, C.J., J.R. Sauer, and S. Droege, editors. Monitoring Bird Populations by Point Counts. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 63-66.
- David, F. N. 1981. Statistics for the birds. In: Ralph, C.J. and J.M. Scott, editors. Estimating the Number of Terrestrial Birds. Studies in Avian Biology 6; 566-569.
- Dawson, D. G. 1985. A review of methods for estimating bird numbers. In: Taylor, K., R.J. Fuller, and P.C. Lack, editors. Bird Census and Atlas Studies. Tring, England: British Trust for Ornithology; 27-33.
- Dawson, D.K., D.R. Smith, and C.S. Robbins. 1995. Point count length and detection of forest neotropical migrant birds. In: Ralph, C.J., J.R. Sauer, and S. Droege, editors. Monitoring Bird Populations by Point Counts. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 35-44.
- DeGraaf, R.M., and J.H. Rappole. 1995. Neotropical Migratory Birds: Natural History, Distribution, and Population Change. Comstock Publishing Associates: Ithaca, NY.
- DeJong, M.J., and J.T. Emlen. 1985. The shape of the auditory detection function and its implications for songbird censusing. *Journal of Field Ornithology* 56: 213-223.
- Diehl, B. 1981. Bird populations consist of individuals differing in many respects. In: Ralph, C.J., and J.M. Scott, editors. Estimating the Number of Terrestrial Birds. Studies in Avian Biology 6; 225-229.

- Doeppker, R.V., R.D. Earle, and J.J. Ozoga. 1992. Characteristics of blackburnian warbler, *Dendroica fusca*, breeding habitat in Upper Michigan. Canadian Field-Naturalist 106: 366-377.
- Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1988. The Birder's Handbook: A Field Guide to the Natural History of North American Birds. New York: Simon and Schuster Inc.
- Emlen, J.T., and M.J. DeJong. 1981. The application of song detection threshold distance to census operations. In: Ralph, C.J. and J.M. Scott, editors. Estimating the Number of Terrestrial Birds. Studies in Avian Biology 6; 346-352.
- Ewert, David. Michigan Chapter of the Nature Conservancy, Personal Communication.
- Falls, J.B. 1981. Mapping territories with playback: an accurate census method for songbirds. In: Ralph, C.J., and J.M. Scott, editors. Estimating the Number of Terrestrial Birds. Studies in Avian Biology 6; 86-91.
- Ficken, M.S. and R.W. Ficken. 1962. The comparative ethology of wood warblers: a review. Living Bird 1:103-121.
- Forbes, L.S. 1990. A note on statistical power. Auk 107: 438-439.
- Freemark, K.E., and H.G. Merriam. 1986. Importance of area and habitat heterogeneity to bird assemblages in temperate forest fragments. Biological Conservation 36: 115-141.
- Fuller, R.J., and D.R. Langslow. 1984. Estimating bird numbers by point counts; how long should the counts last? Bird Study 31: 195-202.
- Gates, J.E. 1995. Point count modifications and breeding bird abundances in Central Appalachian forests. In: Ralph, C.J., J. R. Sauer, and S. Droege, editors. Monitoring Bird Populations by Point Counts. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 135-144.
- Gerrodette, T. 1987. A power analysis for detecting trends. Ecology 68: 1364-1372.
- Goldsmit, B. 1991. Preface. In: Goldsmith, B., editor. Monitoring for Conservation and Ecology. New York: Chapman and Hall; vii-xiv.
- Graham, S.A., J.R.P. Harrison, and J.C.E. Westell. 1963. Aspens: Phoenix Trees of the Great Lakes Region. Ann Arbor, MI: University of Michigan Press.
- Hagan, J.M. and D.W. Johnston, editors. 1992. Ecology and Conservation of Neotropical Migrant Landbirds. Washington, D.C.: Smithsonian Institution Press.
- Hamel, P.B. 1984. Comparison of variable circular-plot and spot map censusing methods in temperate deciduous forest. Ornis Scandinavica 15: 266-274.

- Hanowski, J.M., G.J. Niemi, and J.G. Blake. 1990. Statistical perspectives and experimental design when counting birds on line transects. *Condor* 92: 326-335.
- Howe, R.H., A.T. Wolf, and T. Rinaldi. 1995. Monitoring birds in a regional landscape: lessons from the Nicolet National Forest bird survey. In: Ralph, C.J., J. R. Sauer, and S. Droege, editors. *Monitoring Bird Populations by Point Counts*. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 83-92.
- Hutto, R.L., S.M. Pletschet, and P. Hendricks. 1986. A fixed-radius point count method for nonbreeding and breeding season use. *Auk* 103: 593-602.
- James, F.C., and C.E. McCulloch. 1985. Data analysis and the design of experiments in ornithology. In: Johnston, R.F., editor. *Current Ornithology, Volume 2*. New York: Plenum Press; 1-63.
- James, F.C., C.E. McCulloch, and D.A. Wiedenfeld. 1996. New approaches to the analysis of population trends in land birds. *Ecology* 77: 13-27.
- James, F.C., and N.O. Warner. 1982. Relationships between temperate forest bird communities and vegetation structure. *Ecology* 63: 159-171.
- Johnson, D.H. 1995. Point counts of birds: what are we estimating? In: Ralph, C.J., J. R. Sauer, and S. Droege, editors. *Monitoring Bird Populations by Point Counts*. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 117-124.
- Johnson, R.R., B.T. Brown, L.T. Haight, and J.M. Simpson. 1981. Playback recordings as a special avian censusing technique. In: Ralph, C.J., and J. M. Scott, editors. *Estimating the Number of Terrestrial Birds. Studies in Avian Biology* 6. 68-75.
- Kareiva, P., and M. Anderson. 1989. Spatial aspects of species interactions: the wedding of models and experiments. In: Hastings, A., editor. *Community Ecology*. New York: Springer-Verlag; 35-50.
- Keast, A., and E.S. Morton, editors. 1980. *Migrant Birds in the Neotropics: Ecology, Behavior, Distribution, and Conservation*. Washington, D.C.: Smithsonian Institution Press.
- Koskimies, P. 1989. Birds as a tool in environmental monitoring. *Annales Zoologica Fennici* 26: 153-166.
- Lapin, M., and B.V. Barnes. 1995. Using the landscape ecosystem approach to assess species and ecosystem diversity. *Conservation Biology* 9: 1148-1158.
- Lemon, R.E., J. Struger, M.J. Lechowicz, and R.F. Norman. 1981. Song features and singing heights of American warblers: maximization or optimization of distance. *Journal of the Acoustical Society of America* 69: 1169-1176.

- Levin, S.A. 1992. The problem of pattern and scale in ecology. *Ecology* 73: 1943-1967.
- Lynch, J.F. 1995. Effects of point count duration, time-of-day, and aural stimuli on detectability of migratory and resident bird species in Quintana Roo, Mexico. In: Ralph, C.J., J. R. Sauer, and S. Droege, editors. *Monitoring Bird Populations by Point Counts*. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 1-6
- MacArthur, R.H., J.W. MacArthur, and J. Prees. 1962. On bird species diversity II. Prediction of bird census from habitat measurements. *American Naturalist* 96:167-174.
- Manley, P. 1993. USDA Forest Service goals and programs for monitoring neotropical migratory birds. In: Finch, D.M., and Stangel, P.W., editors. *Status and Management of Neotropical Migratory Birds*. Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, CO; 252-257.
- Marten, K., and P. Marler. 1977. Sound transmission and its significance for animal vocalization. I. Temperate habitats. *Behavioral Ecology and Sociobiology* 2: 271-290.
- Martin, T.E. 1992. Breeding productivity considerations: what are the appropriate habitat features for management? In: Hagan, J. M., and D.W. Johnston, editors. *Ecology and Conservation of Neotropical Migrant Landbirds*. Washington, D.C.: Smithsonian Institution Press; 455-473.
- Maurer, B.A., and M.-A. Villard. 1996. Introduction to Special Feature - Continental scale ecology and Neotropical migratory birds: how to detect declines amid the noise. *Ecology* 77: 1-2.
- Mayfield, H.F. 1981. Problems in estimating population size through counts of singing males. In: Ralph, C.J., and J.M. Scott, editors. *Estimating the Number of Terrestrial Birds*. Studies in Avian Biology 6; 220-224.
- Pearsall, D.R., B.V. Barnes, G.R. Zogg, M. Lapin, And R.R. Ring. 1995. Landscape ecosystems of the University of Michigan Biological Station. School of Natural Resources and Environment. University of Michigan, Ann Arbor, MI. 66 pp. + Appendix.
- Pendleton, G.W. 1995. Effects of sampling strategy, detection probability, and independence of counts on the use of point counts. In: Ralph, C.J., J.R. Sauer, and S. Droege, editors. *Monitoring Bird Populations by Point Counts*. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 131-134.
- Peterjohn, B.G., J.R. Sauer, and C.S. Robbins. 1995. Population trends from the North American Breeding Bird Survey. In: Martin, T.M., and D.M. Finch, editors. *Ecology and Management of Neotropical Migratory Birds*. Oxford University Press: New York; 3-39.
- Petit, D.R., L.J. Petit, V.A. Saab, and T.E. Martin. 1995. Fixed-radius point counts in forests: factors influencing effectiveness and efficiency. In: Ralph, C.J., J.R. Sauer,

and S. Droege, editors. Monitoring Bird Populations by Point Counts. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 49-56.

Pyne, S.J. 1982. Fire in America. Princeton University Press: Princeton, NJ.

Ralph, C.J., and J.M. Scott, editors. 1981. Estimating the Number of Terrestrial Birds. Studies in Avian Biology 6.

Ralph, C.J., S. Droege, and J.R. Sauer, editors. 1995a. Monitoring Bird Populations by Point Counts. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA.

Ralph, C.J., S. Droege, and J.R. Sauer. 1995b. Managing and monitoring birds using point counts: standards and applications. In: Ralph, C.J., J.R. Sauer, and S. Droege, editors. Monitoring Bird Populations by Point Counts. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 161-168.

Reynolds, R.T., J.M. Scott, and R.A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82: 309-313.

Richards, D.G. 1981. Environmental acoustics and censuses of singing birds. In: Ralph, C.J., and J.M. Scott, editors. Estimating the Number of Terrestrial Birds. Studies in Avian Biology 6; 297-300.

Richards, D.G., and R.H. Wiley. 1980. Reverberations and amplitude fluctuations in the propagation of sounds in a forest: implications for animal communications. American Naturalist 115: 381-399.

Robbins, C.S. 1981a. Effect of time of day on bird activity. In: Ralph, C.J. and J.M. Scott, editors. Estimating the Number of Terrestrial Birds. Studies in Avian Biology 6; 275-286.

---. 1981b. Bird activity levels related to weather. In: Ralph, C.J. and J.M. Scott, editors. Estimating the Number of Terrestrial Birds. Studies in Avian Biology 6; 301-310.

Robbins, C.S., J.R. Sauer, R.S. Greenberg, S. Droege. 1989. Population declines in North American birds that migrate to the neotropics. Proceedings of the National Academy of Sciences 86: 7658-7662.

Rotenberry, J.T., and J.A. Wiens. 1985. Statistical power analysis and community wide patterns. American Naturalist 125: 164-168.

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

Ryan, M.J., and E.A. Brenowitz. 1985. The role of body size, phylogeny, and ambient noise in the evolution of bird song. American Naturalist 126: 87-100.

- Sauer, J.R. 1993. Monitoring goals and programs of the U.S. Fish and Wildlife Service. In: Finch, D.M., and Stangel, P.W., editors. *Status and Management of Neotropical Migratory Birds*. Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, CO; 245 -251.
- Sauer, J.R., R.J. Barker, P.H. Geissler. 1994. Statistical aspects of modeling population changes from population size data. In: Kendall, R.I., and T.E. Lacher, Jr., editors. *Wildlife Toxicology and Population Modeling: Integrated Studies of Agroecosystems*. Boca Raton, FL: CRC Press; 541-466.
- Savard, J.L., and T.D. Hooper. 1995. Influence of survey length and radius size on grassland bird surveys by point counts at Williams Lake, British Columbia. In: Ralph, C.J., J.R. Sauer, and S. Droege, editors. *Monitoring Bird Populations by Point Counts*. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 57-62
- Scott, J.M., and F.L. Ramsey. 1981a. Length of count period as a possible source of bias in estimating bird densities. In: Ralph, C.J. and J.M. Scott, editors. *Estimating the Number of Terrestrial Birds*. *Studies in Avian Biology* 6; 409-413.
- . 1981b. Effects of abundant species on the ability of observers to make accurate counts of birds. *Auk* 98: 610-613.
- Scott, J.M., F.L. Ramsey, and C.B. Kepler. 1981. Distance estimation as a variable in estimating bird numbers from vocalizations. In: Ralph, C.J. and J.M. Scott, editors. *Estimating the Number of Terrestrial Birds*. *Studies in Avian Biology* 6; 334-340.
- Shields, W.M. 1977. The effect of time of day on avian census results. *Auk* 94: 380-383.
- Skirvin, A.A. 1981. Effect of time of day and time of season on the number of observations and density estimates of breeding birds. In: Ralph, C.J., and J.M. Scott, editors. *Estimating the Number of Terrestrial Birds*. *Studies in Avian Biology* 6; 271-274.
- Sliwa, A., and T.W. Sherry. 1992. Surveying wintering warbler populations in Jamaica: point counts with and without broadcast vocalizations. *Condor* 94: 924-936.
- Smith, W.P., D.J. Twedt, R.J. Cooper, D.A. Wiedenfeld, P.B. Hamel, and R.P. Ford. 1995. Sample size and allocation of effort in point count sampling of birds in bottomland hardwood forests. In: Ralph, C.J., J. R. Sauer, and S. Droege, editors. *Monitoring Bird Populations by Point Counts*. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 7-18.
- Snedecor, G.W., and W.G. Cochran. 1989. *Statistical Methods*. 8th Edition. Ames, IA: Iowa State University Press.
- Sokal, R.R., and F.J. Rohlf. 1981. *Biometry*. New York: W.H. Freeman and Co.
- Taylor, K., R.J. Fuller, and P.C. Lack, editors. 1985. *Bird Census and Atlas Studies*. Tring, England: British Trust for Ornithology.

Taylor, B.L., and T. Gerrodette. 1993. The uses of statistical power in conservation biology: the vaquita and the Northern Spotted Owl. *Conservation Biology* 7: 489-300.

Terborgh, J. 1989. Where Have All the Birds Gone? Princeton, NJ: Princeton University Press.

Thomas, J. 1996. Monitoring long-term population change: why are there so many analysis methods? *Ecology* 77: 49-58.

Thompson, F.R., S.J. Lewis, J. Green, D. Ewert. 1993. Status of neotropical migrant landbirds in the midwest: identifying species of management concern. In: Finch, D.M., and Stangel, P.W., editors. *Status and Management of Neotropical Migratory Birds*. Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, CO; 145-158.

Thompson, F. R., and M. J. Schwalbach. 1995. Analysis of sample size, counting time, and plot size from an avian point count survey on Hoosier National Forest, Indiana. In: Ralph, C.J., J. R. Sauer, and S. Droege, editors. *Monitoring Bird Populations by Point Counts*. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 45-48.

Toft, C. A., and P. J. Shea. 1983. Detecting community-wide patterns: estimating power strengthens statistical inference. *American Naturalist* 122: 618-625.

Urban, D.L. and T.M. Smith. 1989. Microhabitat pattern and the structure of forest bird communities. *American Naturalist* 133: 811-829.

Verner, J. 1985. Assessment of counting techniques. In: Johnston, R. F., editor. *Current Ornithology*, Volume 2. New York: Plenum Press; 247-302.

---. 1987. Preliminary results from a system for monitoring trends in bird populations in oak-pine woodlands. In: Plumb, T., and N. H. Pillsbury, editors. *Proceedings of the Symposium on Multiple-Use Management of California's Hardwood Resources*; November 12-14, 1986, San Luis Obispo, California. Gen. Tech. Report PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, USDA; 214-222.

---. 1988. Optimizing the duration of point counts for monitoring trends in bird populations. Research Note PSW-395. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, USDA. 4 pp.

Verner, J., and K.A. Milne. 1989. Coping with sources of variability when measuring population trends. *Annales Zoologica Fennici* 26: 191-199.

Verner, J.R., and L.V. Ritter. 1986. Hourly variation in morning point counts of birds. *Auk* 103: 117-124.

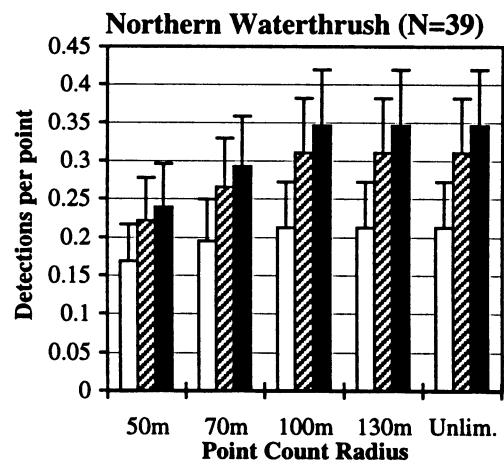
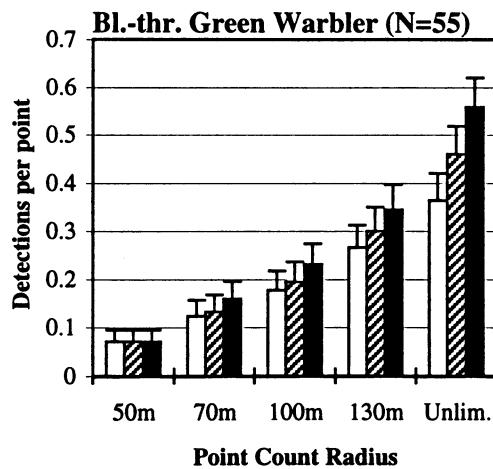
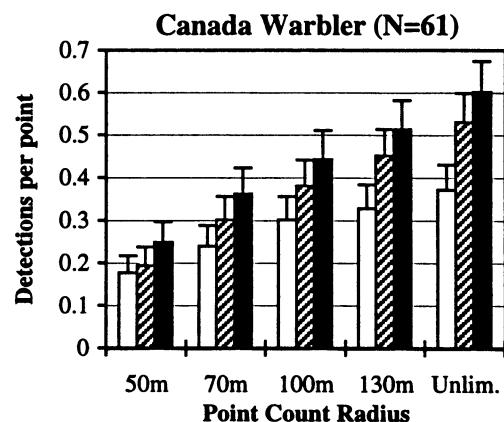
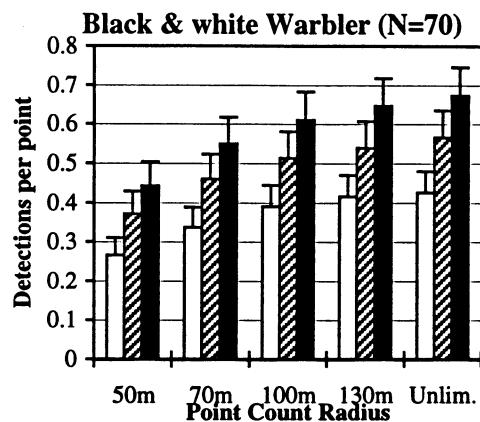
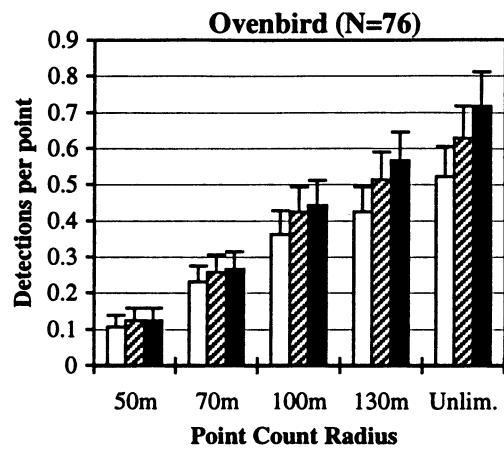
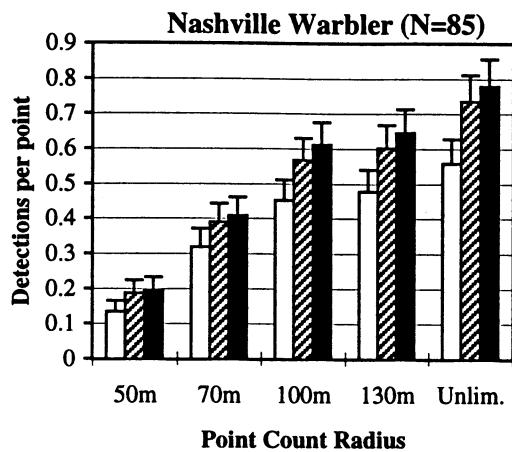
Waide, R.B., and P.M. Narins. 1988. Tropical forest bird counts and the effect of sound attenuation. *Auk* 105 (296-302):

- Wallschläger, D. 1980. Correlation of song frequency and body weight in passerine birds. *Experientia* 36: 412.
- Welsh, D.A. 1995. An overview of the Forest Bird Monitoring Program in Ontario, Canada. In: Ralph, C.J., J.R. Sauer, and S. Droege, editors. *Monitoring Bird Populations by Point Counts*. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 93-98.
- Whitney, G.G. 1987. An ecological history of the Great Lakes forests of Michigan. *Journal of Ecology* 75: 667-684.
- WhySong, G.L., and W.H. Miller. 1987. An evaluation of random and systematic plot placement for estimating frequency. *Journal of Range Management* 40: 475-479.
- Wiens, J.A. 1981. Scale problems in avian censusing. In: Ralph, C.J., and J.M. Scott, editors. *Estimating the Number of Terrestrial Birds. Studies in Avian Biology* 6; 513-521.
- . 1986. Spatial scale and temporal variation in studies of shrubsteppe birds. In: Diamond, J., and T.J. Case, editors. *Community Ecology*. New York, New York, USA: Harper and Row; 154-172.
- . 1989. Spatial scaling in ecology. *Functional Ecology* 3:385-397.
- Wiens, J.A., and J.T. Rotenberry. 1981. Censusing and the evaluation of avian habitat occupancy. In: Ralph, C.J., and J.M. Scott, editors. *Estimating the Number of Terrestrial Birds. Studies in Avian Biology* 6; 522-532.
- Wiens, J.A., J.F. Addicott, T.J. Case, and J. Diamond. 1986. Overview: the importance of spatial and temporal scale in ecological investigations. In: Diamond, J., and T.J. Case, editors. *Community Ecology*. New York, New York, USA: Harper and Row; 145-153.
- Wiley, R.H., and D.G. Richards. 1982. Adaptations for acoustic communication in birds: sound transmission and signal detection. In: Kroodsma, D. E., and E. H. Miller, editors. *Acoustic Communication in Birds, Volume 1*. New York: Academic Press; 131-181.
- Wolf, A.T., R.W. Howe, and G.J. Davis. 1995. Detectability of forest birds from stationary points in northern Wisconsin. In: Ralph, C.J., J. R. Sauer, and S. Droege, editors. *Monitoring Bird Populations by Point Counts*. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA; 19-24.
- Zogg, G.R., and B.V. Barnes. 1995. Ecological classification and analysis of wetland ecosystems, northern Lower Michigan, U.S.A. *Canadian Journal of Forest Research* 25: 1865-1875.

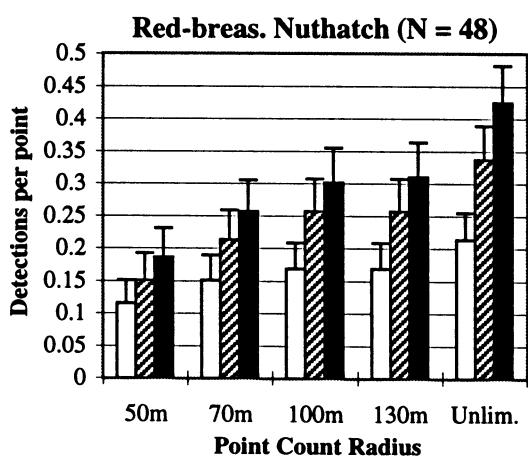
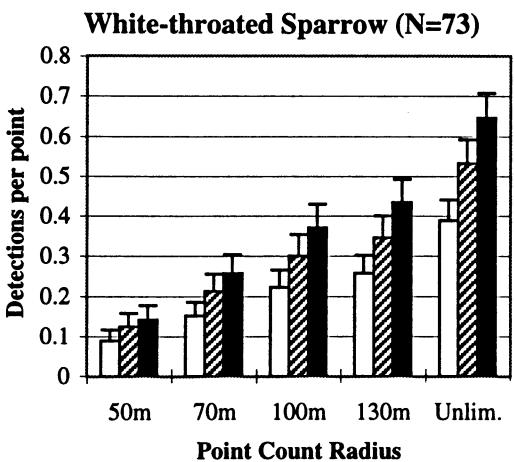
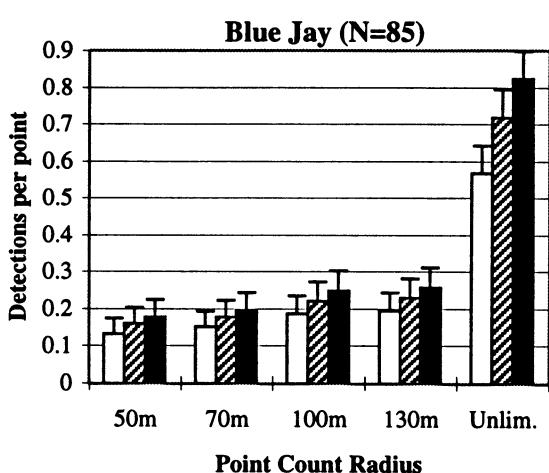
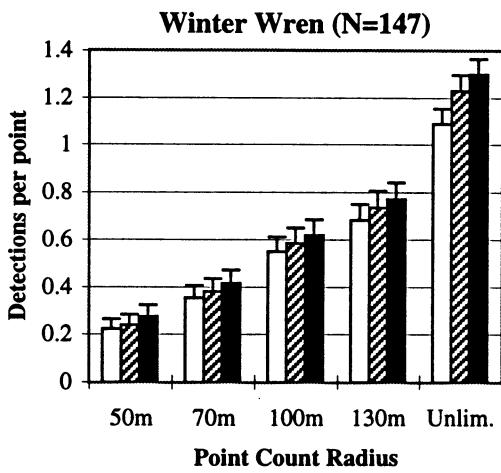
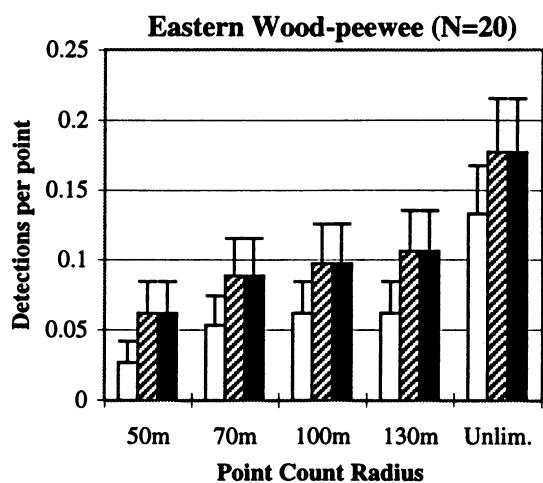
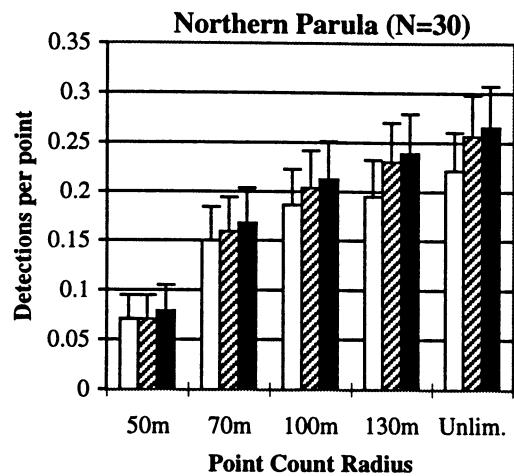
Appendix A. Families and common and scientific names of species, grouped by status as a neotropical migrant, or as a short distance migrant or resident.

Family Name	Common Name	Scientific Name
<b>NEOTROPICAL MIGRANTS</b>		
Tyrannidae	Eastern Wood-Pewee Least Flycatcher Great Crested Flycatcher	<i>Contopus virens</i> <i>Empidonax minimus</i> <i>Myiarchus crinitus</i>
Muscicapidae	Veery	<i>Catharus fuscescens</i>
Vireonidae	Solitary Vireo Yellow-throated Vireo Red-eyed Vireo	<i>Vireo solitarius</i> <i>Vireo flavifrons</i> <i>Vireo olivaceus</i>
Emberizidae	Nashville Warbler Northern Parula Magnolia Warbler Black-throated Blue Warbler Black-throated Green Warbler Blackburnian Warbler Black-and-white Warbler American Redstart Ovenbird Northern Waterthrush Canada Warbler Scarlet Tanager Rose-breasted Grosbeak Northern Oriole	<i>Vermivora ruficapilla</i> <i>Parula americana</i> <i>Dendroica magnolia</i> <i>Dendroica caerulescens</i> <i>Dendroica virens</i> <i>Dendroica fusca</i> <i>Mniotilla varia</i> <i>Setophaga ruticilla</i> <i>Seiurus aurocapillus</i> <i>Seiurus noveboracensis</i> <i>Wilsonia canadensis</i> <i>Piranga olivacea</i> <i>Pheucticus ludovicianus</i> <i>Icterus galbula</i>
<b>SHORT-DISTANCE MIGRANTS AND RESIDENTS</b>		
Columbidae	Mourning Dove	<i>Zenaida macroura</i>
Picidae	Yellow-bellied Sapsucker Downy Woodpecker Hairy Woodpecker Northern Flicker Pileated Woodpecker	<i>Sphyrapicus varius</i> <i>Picoides pubescens</i> <i>Picoides villosus</i> <i>Colaptes auratus</i> <i>Dryocopus pileatus</i>
Corvidae	Blue Jay American Crow Common Raven	<i>Cyanocitta cristata</i> <i>Corvus brachyrhynchos</i> <i>Corvus corax</i>
Paridae	Black-capped Chickadee	<i>Parus atricapillus</i>
Sittidae	Red-breasted Nuthatch White-breasted Nuthatch	<i>Sitta canadensis</i> <i>Sitta carolinensis</i>
Certhiidae	Brown Creeper	<i>Certhia americana</i>
Troglodytidae	Winter Wren	<i>Troglodytes troglodytes</i>
Muscicapidae	Hermit Thrush American Robin	<i>Catharus guttatus</i> <i>Turdus migratorius</i>
Bombycillidae	Cedar Waxwing	<i>Bombycilla cedrorum</i>
Emberizidae	Yellow-rumped Warbler Pine Warbler Northern Cardinal Chipping Sparrow White-throated Sparrow Brown-headed Cowbird	<i>Dendroica coronata</i> <i>Dendroica pinus</i> <i>Cardinalis cardinalis</i> <i>Spizella passerina</i> <i>Zonotrichia albicollis</i> <i>Molothrus ater</i>

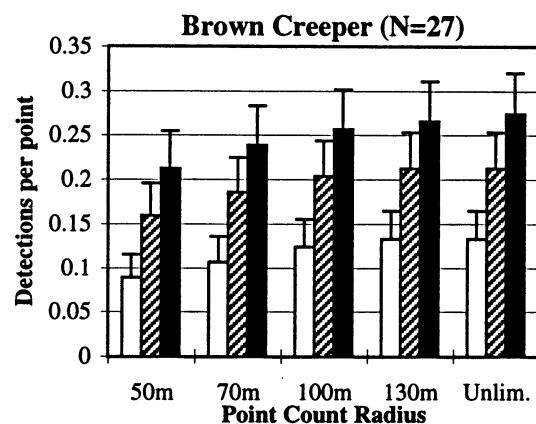
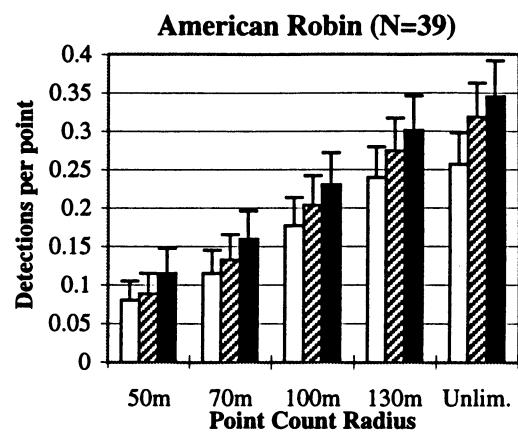
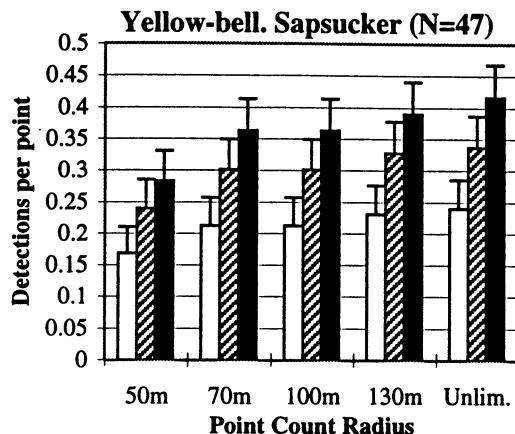
**Appendix B. Wetland species' detection patterns.** Open, striped, and solid bars are detection means (+2 SE) from 4-, 8-, and 12-minute counts, respectively.



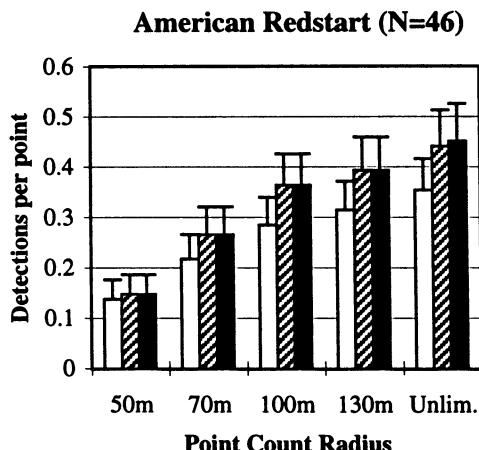
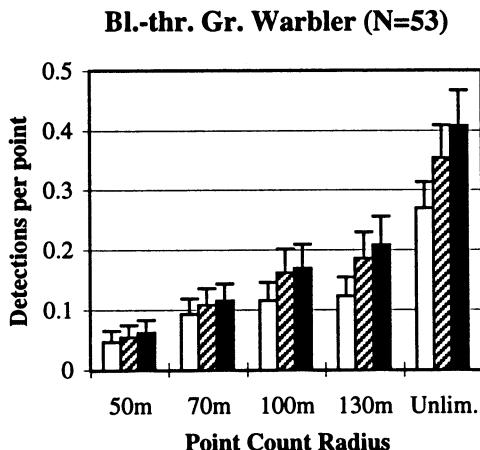
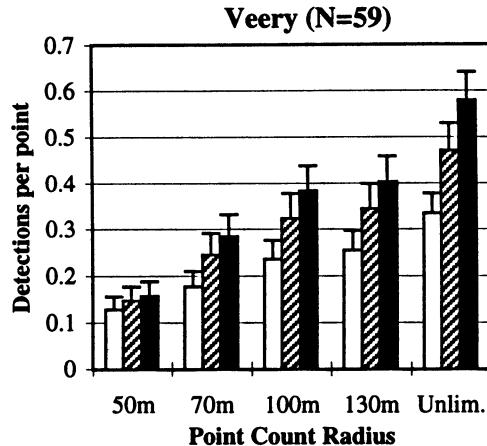
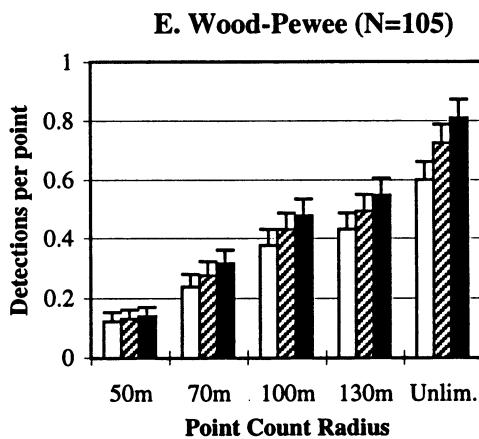
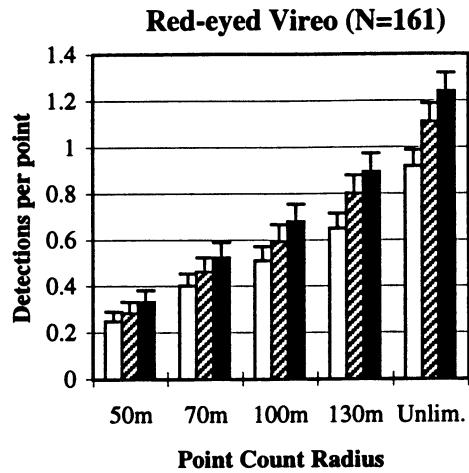
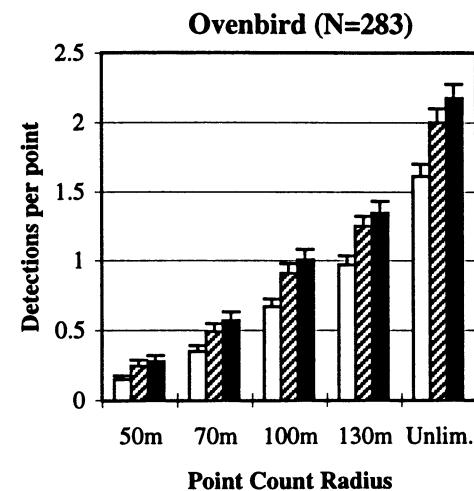
**Appendix B (continued). Wetland species' detection patterns.** Open, striped, and solid bars are detection means (+2 SE) from 4-, 8-, and 12-minute counts, respectively.



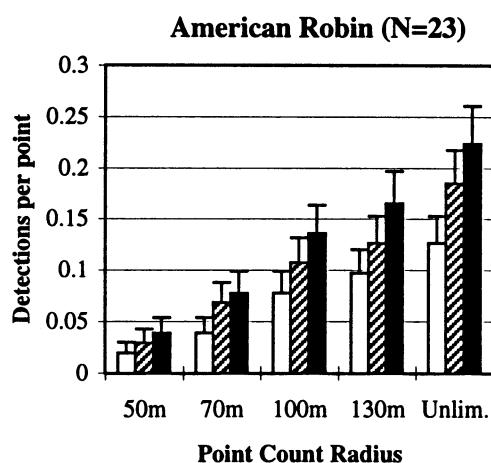
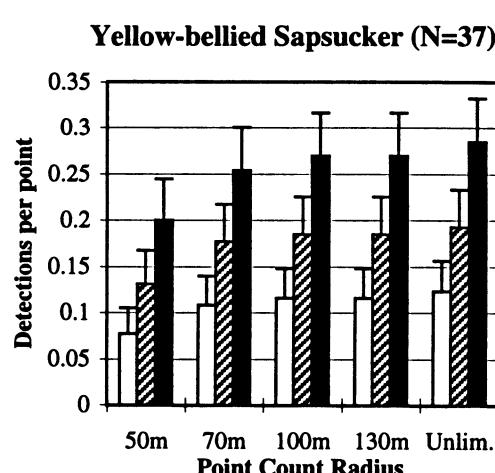
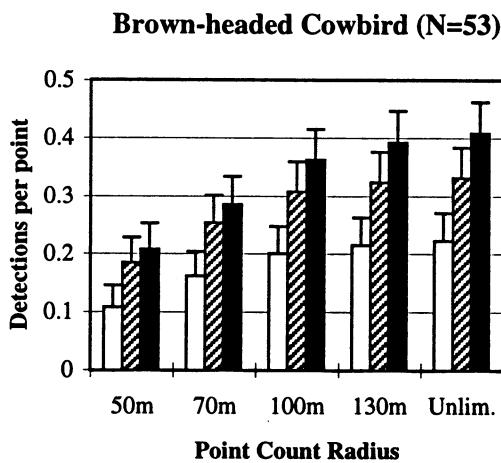
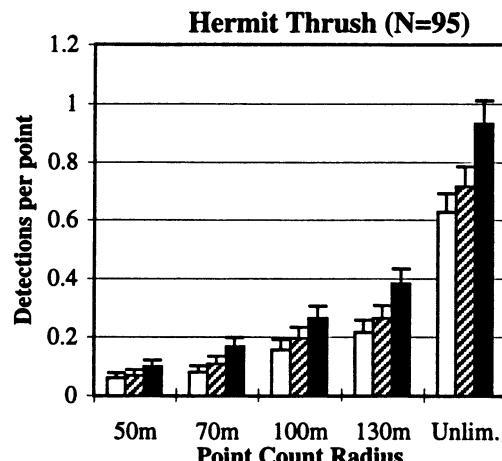
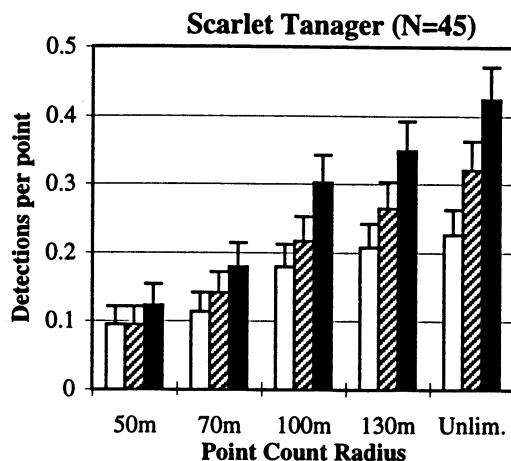
Appendix B (continued). Wetland species' detection patterns. Open, striped, and solid bars are detection means (+2 SE) from 4-, 8-, and 12-minute counts, respectively.



**Appendix C. Upland species' detection patterns.** Open, striped, and solid bars are detection means (+ 2 SE) from 4-, 8-, and 12-minute counts, respectively.



**Appendix C (continued). Upland species' detection patterns.** Open, striped, and solid bars are detection means (+ 2 SE) from 4-, 8-, and 12-minute counts, respectively.







UNIVERSITY OF MICHIGAN



3 9015 03812 1219

