as published in *J. Field Ornithol.* 77(2):207–211, 2006

The Effect of Moonlight on Detection of Whip-poor-wills: Implications for Long-term Monitoring Strategies

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Abstract. Understanding variation in the detectability of birds is fundamental to determining the reliability of survey methods. We examined the influence of lunar light conditions on the detection probability of Whip-poor-will's through repeated sampling of 78 point count stations over two lunar cycles. The probability of detection was positively related to moonlight intensity measured as the percent of moon-face illuminated and moon height above the horizon. These results were used to show how the reliability of long-term monitoring strategies can be improved by sampling design. Surveys conducted on nights when the moon-face was > 50% illuminated were less variable and provided more statistical power to long-term monitoring results compared to surveys that were conducted across all nights. Stratifying surveys for Whip-poor-wills during bright moonlight provides greater statistical power for monitoring programs that inevitably allows better scientific conclusions to be drawn from collected data.

Key Words – bird detection, *Caprimulgus vociferous*, population monitoring, statistical power, survey design, survey techniques, Whip-poor-will

INTRODUCTION

Changes in activity levels and conspicuousness contribute to spatial and temporal variation in the detection of birds during population surveys (Dawson 1981, Ralph 1981, Bibby et. al. 1992, Ralph et al. 1993). Because activity patterns may be influenced by time of day (Robbins 1981, Palmeirim and Rabaca 1994), time of season (Wilson and Bart 1995, Selmi and Boulinier 2003), breeding stage (Best 1981), and weather (Robbins 1981), the timing of surveys may influence the results.

Sampling design is critical to population monitoring because it affects the quality and reliability of resulting population estimates. Reliability is best characterized by the ability to detect actual trends and is expressed in units of statistical power (1 – the probability of not rejecting a null hypothesis when the null hypothesis is incorrect) (Nur et al. 1999). A monitoring program with high statistical power permits detection of small population changes over short periods of time. Monitoring programs with low statistical power may only detect catastrophic changes. The power of a monitoring program can be strengthened by taking measures to reduce within-site temporal variance (Link et al. 1994, Carlson and Schmiegelow 2002). One way to do this is to surveys detection rates are known to be consistent or high.

Concerns about the population status of Whip-poor-wills (*Caprimulgus vociferous*) and other Caprimulgids have created the need for efficient and powerful monitoring programs. Considering Whip-poor-will activity patterns in designing such programs will increase the statistical power of these programs. Like most Caprimulgids, Whip-poor-wills are nocturnal. However, during the night, activity levels of Whip-poor-wills are positively influenced by moonlight (Cooper 1981, Mills 1986, Wilson 2003). Our objective was to examine the influence of moonlight conditions on the probability of detecting Whip-poor-wills during surveys and to demonstrate the gain in statistical power achieved by stratifying samples by moonlight.

METHODS

Study Area. Our study was conducted on a 30,000 ha forested tract in eastern North Carolina (approximately 35 30 N, 76 60 W) managed primarily as a loblolly pine (*Pinus taeda*) plantation. The entire tract is divided among 1,010 parcels individually managed on a 30 - 35 year rotation schedule. Mature stands are harvested by clear-cutting. The staggered regime of timber harvesting plus a network of logging roads create a spatial mosaic different-aged stands separated by distinct hard boundaries. Recently-harvested parcels (1-6 years after planting) are characterized by a dense cover of grasses and shrubby plants including switch cane (*Arundinaria gigantea)*, sweet pepperbush (*Clethra anifolia*), highbush blueberry (*Vaccinium corymbosum*), and blackberry (*Rubus sp.*). Mature stands are characterized by dense understory vegetation and a midstory of trees including red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), red bay (*Persea borbonia*), sweet bay (*Magnolia virginiana*), and tulip poplar (*Lirodendron tulipifera*). A statistical description of these habitats is provided by Wilson and Watts (1999).

Bird Surveys. We established 78 500-m radius survey plots throughout the study area. The center these plots was positioned on roads such that they were placed directly between two managed parcels and 750 m or greater from one another. All surveys were conducted from 13 May and 17 July, 1999 by the same observer who stood at the center of the plot and counted birds for a period of five minutes per visit. Only birds that performed at least one note of the three-note "whip-poor-will" song (Cink 2002) were counted. Surveys are assumed to have a bias for detecting calling males because they are the only sex known to routinely use this specific vocalization. Movement of individual birds was tracked to avoid double counting birds when they changed location. Detections based on visual observations and other vocalizations were not recorded to avoid biased counts near the road edge.

We divided plots into two groups (35 and 43 respectively) to meet the needs of another study (Wilson 2003). Survey dates were chosen to sample the groups of points on consecutive nights in different periods of the lunar phase (new moon, first quarter, full moon, and last quarter). Each group was sampled on 14 nights and surveyed in reverse sequence each visit to reduce time of night effects. Surveys began within 0.5 hrs after dusk and ended 1 h before sunrise. Percent cloud cover was visually estimated at each survey point. Surveys were not conducted during rain, when winds were > 30 km/h, or if roads were impassable.

Statistical Analyses. We examined the influence of lunar condition on detection rates using data summarized over the entire study period. Lunar light intensity increases with the percentage of moon-face illuminated (lunar phase) and moon height above the horizon, and decreases with cloud cover. Therefore, survey nights were grouped into four categories of moon-face illuminated: < 10%, 10-25%, 50-75%, and 76-100%. Survey points were also subdivided into three categories based on moon height at the time of survey (measured as minutes above horizon): 0 or below horizon, 1-120 min, and > 120 min. Lunar phase and moonrise dates and times were calculated using the Astronomical Almanac (Vohden and Smith 1999) and corrected for the coordinates of our study site. Cloud cover was not included in analyses because over 85% of all surveys were conducted when cloud cover was less than 20%.

The influence of moon-face illumination on detection probability was examined using a one-way, nested ANOVA design that nested the repeated measures at each plot under the main factor of moon-face categories. Detection probability was calculated for the result of each plot visit as the ratio of the number of birds detected during that visit to the peak number of birds observed at that plot over the entire course of the study. The influence of moon height on detection probability was examined for nights when surveys began before moonrise or were terminated after moon set. Kruskal-Wallis ANOVA was used to compare the average detection probability for each moon height category using the qualifying survey nights as replicates.

We examined the power gained by reducing within-site temporal variance by comparing samples collected during bright moon nights (> 50% illuminated) (N = 5) to samples collected across all nights (N = 14). The Coefficients of Variation (CV) were 0.27 and 0.56 for these two groups, respectively. For this analysis we assumed that the CV calculated for either group was similar to what would be obtained from one-time annual visits to each plot over N respective years. Power was calculated for 2-tailed probabilities ($\alpha = 0.05$) of detecting incremental annual population changes ranging from 0.01 to 0.35 over a period of 10 and 20 years using TRENDS software (Gerodette 1987, 1991). CV was set to change proportionately with $1/\sqrt{\text{abundance}}$.

RESULTS

Moonlight effects on Detection. We detected a total of 698 Whip-poor-wills during surveys. Average detection probability was significantly influenced by the percent of moonface illuminated ($F_{3,938} = 32.79$, $P < 0.001$) (Fig. 1). Whip-poor-wills were 2.02 times more likely to be detected when the moon was $\geq 50\%$ illuminated than when $\leq 25\ \%$ illuminated. The highest counts were recorded during one full moon visit to all plots (N = 91 birds) and one three-quarter moon visit to all plots (N = 76 birds) in May and the lowest counts (N = 3, 12, and 14) were recorded between the last quarter (waning) moon and first quarter (waxing) moon visits in July. Detection probability was also significantly influenced by repeated measures ($F_{10,938} = 10.30$, $P < 0.001$). Post-hoc analysis (Tukey's HSD) indicated that overall decline in values on the last two survey nights contributed to statistically significant differences in repeated measures. This only affected the < 10 % and 10-25 % moon-face categories ($P < 0.05$). Repeated measures within all other moon-face categories were not statistically different (all other $P > 0.20$). Detection probability was also positively influenced by moon height (K-W ANOVA H = 26.2, $P < 0.001$). Whip-poor-wills were nearly twice as likely to be detected when plots were surveyed while the moon was above the horizon as when below the horizon. Mean (± SD) detection probabilities (x 100) were 22.1 ± 7.5, 36.1 ± 8.4, and 46.2 ± 7.9 for moon below horizon, 1-120 min above horizon, and > 120 min above horizon, respectively.

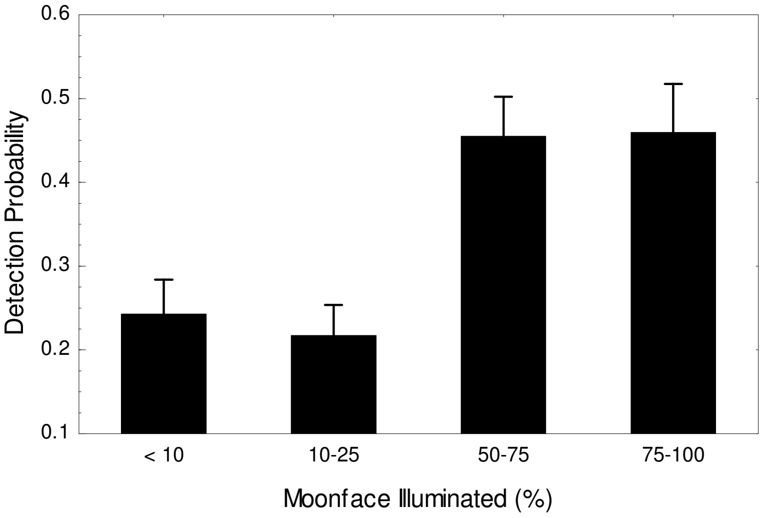

Figure 1. The influence of moonlight on Whip-poor-will detection probability. Values are expressed as mean ± SD.

Moonlight effects on Statistical Power. Samples obtained only on bright moonlit nights provided a distinct power gain over samples obtained across all nights (Fig. 2). The variance of surveys conducted on bright moonlit nights resulted in 80% power to detect a 2% or greater change in annual populations if monitored over 20 years. By comparison, the variance obtained from all nights indicated that 20 years of monitoring will only detect a 9% or greater annual change at the 80% power level. Power curves also demonstrate a distinct loss of power if the monitoring program is shortened to only 10 years. The variance of surveys conducted on bright moonlit nights resulted in an approximate 80% power to detect at least a 12% annual change over 10 years, whereas surveys conducted across all nights can only detect a 35% or greater annual change over 10 years.

DISCUSSION

Our results indicate that moonlight is a critical parameter to consider when designing population surveys for Whip-poor-wills. Similarly, Cooper (1981) reported that Whip-poor-wills were detected 2.23 times more frequently when the moon was greater than half full compared to when less than half full. Mills (1986) also reported an increase in singing, foraging, and nest departure rates by Whip-poor-wills with increasing moonlight. Whip-poor-wills depend on vision during foraging and use short upward flights initiated on or near the ground. Moonlight may provide better light conditions for Whip-poor-wills foraging on backlit aerial insect prey.

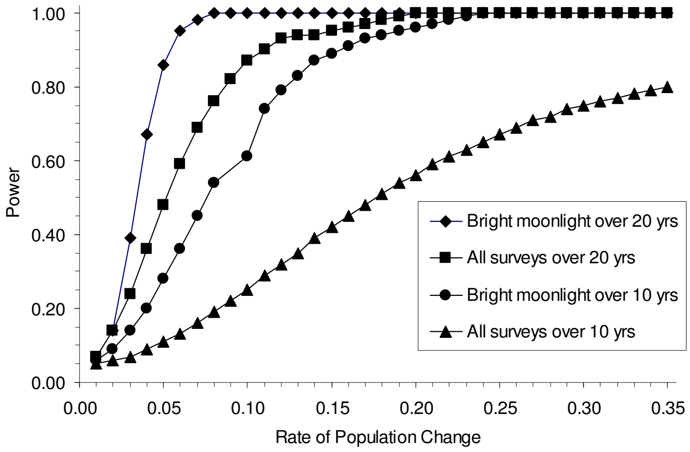

Figure 2. Response of statistical power to detect incremental annual population changes over 10 yrs and 20 yrs of monitoring. Bright moonlight surveys are conducted only during periods when the moon is ≥ 50% illuminated. All surveys indicate the power obtained when moonlight is not controlled by a sampling design.

Restricting surveys to bright moonlit nights increases the accuracy (by providing an estimate closer to the true value) and precision (by reducing within-site temporal variance) of population estimates. Surveying for Whip-poor-wills on bright moonlit nights provides greater statistical power in detecting population trends over shorter time periods.

Restricting surveys to bright moonlit nights for one-time annual surveys also represents the most cost effective strategy to improve monitoring programs. Other strategies, such as increasing the number of surveys per year (Carlson and Schmiegelow 2002) or using double observers (Bart and Shoultz 1984, Nichols et. al. 2000), will provide no additional benefit unless also conducted during bright moonlit nights. Further, these alternative strategies would require additional time and observers. Nonetheless, repeated surveys during bright moonlights do appear beneficial because detection rates were still below 50% of the peak.

Our results provide some insight into possible correction factors that may be applied to past surveys that were not controlled for moonlight. Using our estimates, Whip-poor-will detection rates collected during dim moonlight (< 50 %) should be at least doubled to make them comparable to bright (> 50 %) moonlit nights. Although not specifically examined, we believe this correction factor may be applied broadly by assuming it is independent of sample size, sampling interval, and duration of counts.

ACKNOWLEDGMENTS

This study was funded through a cooperative agreement between Weyerhaeuser Company and the College of William and Mary. We thank T. Melchoirs and D. Miller for administrative support to conduct the study and B. Barber and K. O'Kane for assistance in selecting study sites. We thank J. Cameron for field assistance and L. Whitaker, C. Adams, R. Peace, A. Womack, G. Sciole, M. Roberts, and C. Pope for important additional administrative support. Finally we thank M. Brigham, A. Mills, D. Miller, and G. Ritchison for editorial suggestions to the final manuscript.

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