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Reduced sampling frequency can still detect changes in abundance and phenology of migratory landbirds

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ABSTRACT

Many monitoring programs, such as bird banding stations, would benefit from improvements in their sampling designs. Autumn bird migration records from Manomet in southeastern Massachusetts from 1969 to 2012, collected 5 days a week, every year, show strong evidence of changes in bird migration cohort sizes and average arrival dates. Using these previously identified trends for five common species, we subsampled days of the week and total years to simulate different sampling frequencies, and we varied the length of the study by subsampling time periods. Even with 60% reduced sampling from five days to just two days per week, trends in abundance were still statistically detectable and most patterns of changing phenology were still present. Sampling every other year had no effect on the ability to detect changing abundance or phenology, and most of the effects were still detected with sampling every third or fourth year. The observed trends in abundance and phenology for the full 44-year data set were not statistically detectable in simulated shorter study durations of 22, 15 and 11 years. These results suggest that sampling over long periods using constant methods is key to detecting changes over time in abundance and phenology; in many cases these methods can be made more efficient by reducing sampling intensity without losing the ability to detect trends. This study also provides corrected results for an earlier study on autumn migration times by Ellwood et al. (2015), which incorporate recently identified changes in sampling design.

1. Introduction

Global climate change has led to significant changes in phenology across taxa (Walther et al., 2002; Stenseth et al., 2002; Bauböck et al., 2012), including well-documented changes for many migratory songbird species across regions (Butler, 2003; Sparks et al., 2005; Hüppop and Hüppop, 2003; Wilson, 2012; Miller-Rushing et al., 2008), though with some contrasting results between studies (Cotton, 2003; MacMynowski and Root, 2007; Van Buskirk et al., 2009; Gordo and Sanz, 2005). Shifts in the phenology of migratory birds and their insect prey can potentially lead to ecological mismatch, a phenomenon that occurs when the timing between an organism's arrival and the timing of the availability of its food source differ in their responses to climate change (Schweiger et al., 2008). In addition, many long-term monitoring studies have shown decreases in the numbers of observations per year of migratory birds and decreases in estimated migration cohort sizes (Sokolov, 2000; Sokolov et al., 2000; Lloyd-Evans and Atwood, 2004; Miller-Rushing et al., 2008). Such long-term studies are regarded as crucial to determining if populations of birds and other animal and plant species are stable, increasing, or decreasing, and can help inform decisions on conservation management.

The accuracy of studies of how organisms are responding to climate change and conservation management depends on the intensity of sampling, the length of the study, and the rate of change and variability of the populations (Bigger et al., 2006). Because funding and human resources are limited, there is a need to optimize sampling frequency in monitoring studies to get necessary information in an efficient manner. In fact, all biologists, from avian ecologists to fisheries managers to plant ecologists, need to create sampling methods that are both cost-effective and thorough. Although statisticians have considered issues of sampling using sophisticated modeling and simulations using several years of data, there is a surprising lack of basic and practical rules that conservation biologists can rely on in establishing programs to monitor animal and plant populations for changes in phenology and abundance

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(Miller-Rushing et al., 2008).

Maximizing the efficacy of sampling while minimizing expense and effort could be extremely important for successful protocol development at bird-banding stations and other programs that monitor biodiversity. Eliminating unnecessary sampling can ensure that such monitoring programs can operate over many years and balance time and effort effectively between maintaining long-term sampling and utilizing emerging technologies. This is of current concern given the large numbers of citizen science networks currently being established throughout the world to monitor the changing abundance and phenology of plants and animals (Chandler et al., 2016).

In this study, we examine how changes in sampling intensity and duration can affect the ability to detect changing phenology and abundance using the entire banding data set from Manomet, a long-term bird banding station in Plymouth, Massachusetts. Manomet has conducted constant-effort bird monitoring since 1969 (Ellwood et al., 2015; Rimmer et al., 2004). Previous examination of these banding records has identified significant changes over time in the abundance and average spring and autumn passage dates of many passerine migrants (Lloyd-Evans and Atwood, 2004; Miller-Rushing et al., 2008; Ellwood et al., 2015). Manomet is especially valuable because of the longevity and intensity of its sampling program, which has been carried on without interruption and with minimal changes for the past 47 years.

Using this data set, we are able to investigate if the trends of abundance and phenology observed at Manomet could have been detected if the researchers there had sampled less intensively, with a lower investment of funds and human resources. More specifically, if the researchers had sampled birds for fewer days per week, would they have seen the same trends? What if they sampled only every other year, or every third or fourth year? And what if the researchers had sampled for a shorter number of years? This study represents a contrast with previous studies that have used power analyses with several years of data to estimate the sampling design needed to detect changes in population size over longer periods of time (Carlson and Schmiegelow, 2002; Bigger et al., 2006; Meyer et al., 2010; Rhodes and Jonzén, 2011). In our case, we are able to directly investigate the effects of different sampling designs by subsampling the data set, rather than using power analysis that uses several years of data to estimate optimal strategies for long-term studies (Bolmgren et al., 2013).

If the same trends are still apparent with a reduced intensity of sampling, this would imply that Manomet's intensive sampling protocol could potentially be reduced. This finding would also have applications to other long term monitoring programs already in existence and just being established.

2. Materials and methods

2.1. Banding data

All bird banding data were recorded at Manomet, a 7-hectare coastal preserve in Manomet, Massachusetts (41° 50′ N, 70° 30′ W). Banding protocols, including net locations, have been consistent at Manomet for the past 47 years, from 1969 to 2015 (Lloyd-Evans and Atwood, 2004). Under fair weather conditions, all 50 mist nets are opened at sunrise and remain open until sunset, 5 days per week, during the spring (April 15–June 15) and fall (Aug 15–Nov 15) migration seasons. Mist nets used are nylon 12 × 2.6 m, 36 mm mesh for a maximum total length of 600 m. The data used in this analysis are from the fall banding seasons from 1969 to 2012, and exclude recaptures from the same season (Rimmer et al., 2004; Ellwood et al., 2015; Williams et al., 1981).

2.2. Species-specific subsampling

In the present study, we focus on five species that are comparatively abundant, and changing either in abundance or phenology or both based on the earlier study by Ellwood et al. (2015). Three species are decreasing in abundance and arriving later over time: the American Redstart (*Setophaga ruticilla*), Blackpoll Warbler (*Setophaga striata*), and Red-eyed Vireo (*Vireo olivaceus*). Gray Catbirds (*Dumetella carolinensis*) are not changing in abundance and are arriving earlier over time. Yellow-rumped Warblers (*Setophaga coronata*)—here always called Myrtle Warblers— are decreasing in abundance and are not changing in phenology.

To simulate the impacts of reduced sampling, we subsample in three different ways: first, by reducing the number of days sampled per week; second, by reducing the frequency of years sampled; and third, by reducing the total length of years of the sampling period. We also carry out this subsampling for species that do not show significant trends in phenology or abundance when using the full data set: this includes the abundance of Gray Catbirds and the phenology of Myrtle Warblers.

Subsampling of days includes samples of four days per week, three days per week, and two days per week, all of which include all years of data collected. For each of these levels, we use four arbitrarily chosen combinations of days of the week, hereafter referred to as trials. Subsampling of years includes all five weekdays of data, with samples for every other year, every three years, and every four years. For each of these iterations, we test all possible patterns (for instance, for every other year, we present two analyses: odd years, and even years). This results in two trials of biannual sampling, three trials of triennial sampling, and four trials of quadrennial sampling.

To identify the overall length of sampling (in years) needed to observe trends in phenology and abundance, we further subsample the data set for Blackpoll Warblers. We selected this species because it shows significant changes in both phenology and abundance in the full 44-year data set. In order to identify how many consecutive years of data collection are necessary to see a significant trend, we subsample migration records to create smaller durations, and analyze them independently. From the original 44 years of Blackpoll Warbler data spanning from 1969 to 2012, we generated two sequential 22-year durations, four 11-year durations, and three durations of 14 or 15 years (1969–1983, 1984–1998, and 1999–2012). We analyze each of these trials separately for changes in phenology and abundance.

2.3. Statistical analyses

All statistical analyses were conducted using R statistical software (R Core Team, 2014). We use linear regression to determine the slope and significance for all changes in phenology and migratory cohort sizes over time. We consider trends from linear regressions to be significant with a *p*-value of < 0.05. In cases where we analyze multiple trials for a single subsampling (for instance, five different trials of sampling four days per week, or two different trials of biennial sampling) we apply Bonferroni corrections to avoid incorrectly overestimating the number of significant trends. We deliberately selected all of these analytical approaches to be easily understood by field ecologists and protected area managers. We will make this data set available to researchers interested in carrying out additional analyses.

2.4. Corrected estimates of changing phenology & abundance

The foundation for this study is the analysis of changing mean passage date and changing cohort size for 37 common species using Manomet's autumn data set (from 1969 to 2012) by Ellwood et al. (2015). While at the time of that study it was believed that the sampling intensity had not

changed since 1969, our preliminary subsampling analysis showed that weekend sampling was conducted from 1969 to 1982, but tapered off in the early 1980s and then completely ended; in effect, there were 40% more days sampled during the early years of the study which would result in more birds being caught per season. As part of this