The influence of LiDAR acquisition time lag on bird species distribution models

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Abstract

This is the abstract.

It consists of two paragraphs.

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1. Introduction

LiDAR has the potential to improve bird models by providing high resolution structural covariates which, when paired with bird monitoring data, can give insight into bird-habitat relationships [1]. However, LiDAR acquisitions do not always coincide in time with point count surveys. It is unclear how much this temporal misalignment can influence bird distribution models that use LiDAR derived predictor variables. As disturbance-succession cycles change vegetation structure, eventually LiDAR metrics will no longer reflect ground conditions. Their usefulness as explanatory variables will degrade [2]. Here, we evaluated how time lag between LiDAR acquisitions and bird surveys influenced model robustness for early successional, mature forest, and forest generalist birds.

The composition and structure of forests are changing in response to climate change, shifts to natural disturbance regimes, and increasing industrial development [3]. Predictive models linking field observations to environmental variables can reveal how birds respond to these changes [4–7]. Broadly known as species distribution models (SDMs), this family of statistical methods predict bird distributions by comparing habitat where individuals were observed against habitat where they were absent [8]. SDMs and resulting predictive distribution maps are used to understand bird habitat preferences and the drivers of broad scale population declines and have applications in conservation management planning and environmental impact assessments [5,9].

Many factors influence the predictive capacity of SDMs, but the inclusion of ecologically relevant spatial covariates are key drivers of model accuracy [10–12]. Bird SDMs often rely on categorical predictors derived from digital maps delineating land cover, vegetation composition, and human footprint. While useful, they often miss key forest features driving habitat selection, namely those related to vegetation structure.

Vegetation structure influences the abundance, distribution, and behavior of birds [14]. The height and density of vegetation influence where birds perch, feed, and reproduce [1] by mediating microclimates, providing shelter from weather [15], concealment from predators [16], and creating habitat for insect prey [17]. Light Detection and Ranging (LiDAR) can characterize these three-dimensional forest structures [18]. Common LiDAR derived metrics correspond with vegetation height, cover, structural complexity, and density of forest strata [14,19–22]. Used as predictor variables, LiDAR metrics can improve the predictive power of bird SDMS [26].

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[1] This is the first author footnote.

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Publicly funded regional LIDAR data and space-based sensors like NASA's Ice, Cloud and Land Elevation Satellite-2 (ICESat-2) and Global Ecosystem Dynamics Investigation (GEDI), have made large amounts of wall-to-wall structural data available to researchers [27–29]. However, LiDAR continues to be under-used in bird ecology. The limited temporal resolution of most LiDAR products may be a factor. LiDAR is often limited to a single season, with long multiyear gaps between repeat surveys. Temporal misalignment between wildlife surveys and LiDAR is common.

Temporal misalignment occurs when wildlife surveys and LiDAR acquisitions are done at different times [2]. It's unclear how much temporal misalignment influences the performance of LiDAR based SDMs. Disturbance-succession cycles drive changes in vegetation structure, and eventually, LiDAR gathered over a season will no longer reflect ground conditions. This can occur when the surveyed forest transitions between stages of stand development, e.g. from stand initiation to stem exclusion [30,31]. Temporal misalignment can impact the power of bird SDMs as successional changes in forest structure influence habitat selection by birds [32].

Consider Canada's boreal forests. It is a dynamic successional mosaic driven by forestry, fire, and energy exploration [3,33]. The landscape is a patchwork of early to late successional stands with distinct structural characteristics [34] and bird communities [35]. In early successional forests, bird communities are dominated by species that nest and forage in open vegetation, wetlands, and shrubs, along with some habitat generalists. As trees regenerate and the stand's structural properties change, open habitat species give way to species associated with corresponding forest age classes and strata [36].

Thus, succession occurring between LiDAR and wildlife surveys may influence SDM performance. Consequently, LiDAR's usefulness as a source of explanatory variables can degrade as temporal misalignment increases. For researchers pairing LiDAR covariates with long-term wildlife survey data, this can lead to a trade-off: (1) minimize temporal misalignment by reducing the sample size to survey data gathered near the time of the LiDAR acquisition, or (2) maximize sample size and risk sacrificing model power.

To inform this trade-off, we addressed the question of how much temporal misalignment is acceptable in LiDAR based SDMs. Our objectives were to (1) evaluate how the time lag between LiDAR acquisitions and bird surveys influence the performance of SDMs across a gradient of 0 to 15 years, (2) compare the influence of temporal misalignment on models for early successional, mid-successional, mature forest, and forest generalist birds, and (3) assess how differences in resultant predictive distribution maps correlate with forest age.

The effects of temporal misalignment on SDMs will likely vary by habitat type (e.g. forest age, disturbance history, and dominant vegetation) and the life history characteristics of the study species. We predicted that the performance of SDMs will decrease with increased temporal misalignment and that the magnitude of change will vary according to the habitat associations of the focal species. We predicted that (1) SDMs for early successional specialists, Mourning Warbler (*Geothlypis philadelphia*) and White-throated Sparrow (*Zonotrichia albicollis*), would be most affected by temporal misalignment because of faster vertical growth rates of establishment trees and loss of dense shrub layers [37–39]. (2) SDMs for mid-seral species like American Redstart (*Setophaga ruticilla*) that are associated with dense midstory vegetation, would see moderate declines in performance as temporal misalignment increases due to self-thinning during the stem exclusion stage of succession [31,40]. And (3) mature forest associates, Black-throated Green Warbler (*Setophaga virens*), will be least effected by temporal misalignment as the processes effecting mature forest canopy structure (insect defoliation and windthrow) happen at too small a scale to effect overall model performance [2,41]. For all species, we predicted that differences in distribution maps will be negatively correlated with forest age.

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