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.

Keywords: Avian, Boreal, Forestry, LiDAR

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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.

2. Methods

Our methodological workflow is illustrated in Figure 1. Analyses were done using R statistical software [**R-base?**]. We built SDMs using bird data from the Calling Lake Fragmentation project [**Schmiegelow1997?**].

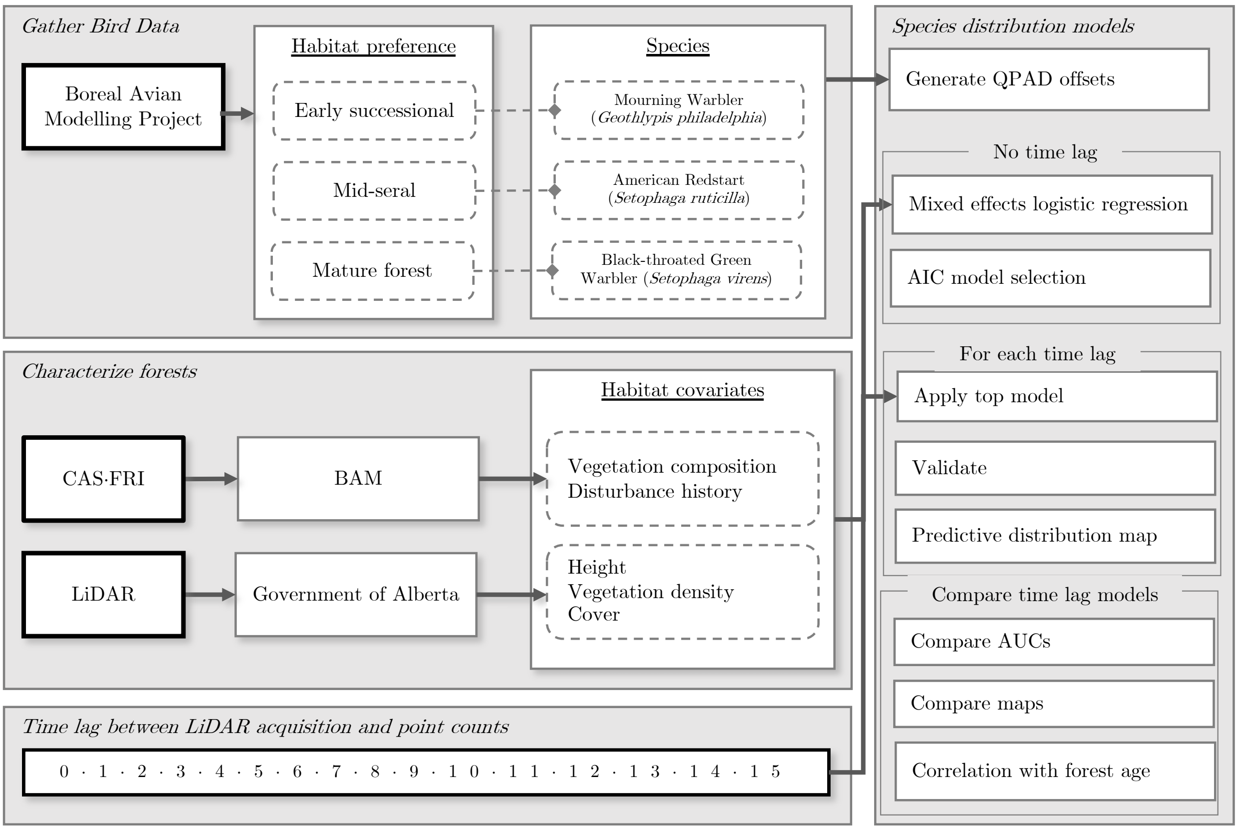

Figure 1: Conceptual diagram of our methodology. SDM methods were repeated at every time lag for each species. SDMs were compared using AUC and correlation between predictive maps.

2.1. Study area

We used bird survey data from the Calling Lake Fragmentation Experiment [**Schmiegelow1997?**]. Surveys were conducted across ≈ 14,000 ha of boreal mixedwood forests near Calling Lake, in northern Alberta, Canada (55º14'51'' N, 113º28'59'' W) (Figure 2). The experiment was designed to study the long-term impacts of forest harvesting on birds [36,42,**Schmiegelow1997?**]. The study's experimental harvest treatments have led to a landscape patchwork of early- to mid- successional stands surrounded by tracts of unharvested mature forests. When the experiment began in 1994, the landscape was dominated by older mixedwood forests composed of trembling aspen (*Populus tremuloides*, balsam poplar (*Populus balsamifera*) and white spruce (*Picea glauca*) and treed bogs containing black spruce (*Picea mariana*) and larch (*Larix laricina*). Understory vegetation in the mixedwood forests was composed mostly of alder (*Alnus spp.*) and willow species(*Salix spp.*).

2.2. Bird data

As part of the Calling Lake Fragmentation Experiment, long term bird monitoring via annual repeated point counts was done for 20 consecutive breeding seasons (from 1995-2015). As the experiment's study area overlaps spatially with government wall-to-wall LiDAR coverage, there is an opportunity to study the impacts of LiDAR/wildlife survey temporal misalignment on bird SDMs.

We used detection data from 187 stations where consecutive annual point counts were conducted from zero to sixteen years of the LiDAR acquisition date. Stations were spaced ≈ 200 m apart. At each station, three to five morning point count surveys were conducted over each breeding season(May 16 to July 7) between sunrise and 10:00 h. Observers recorded the species detected during each five minute point count

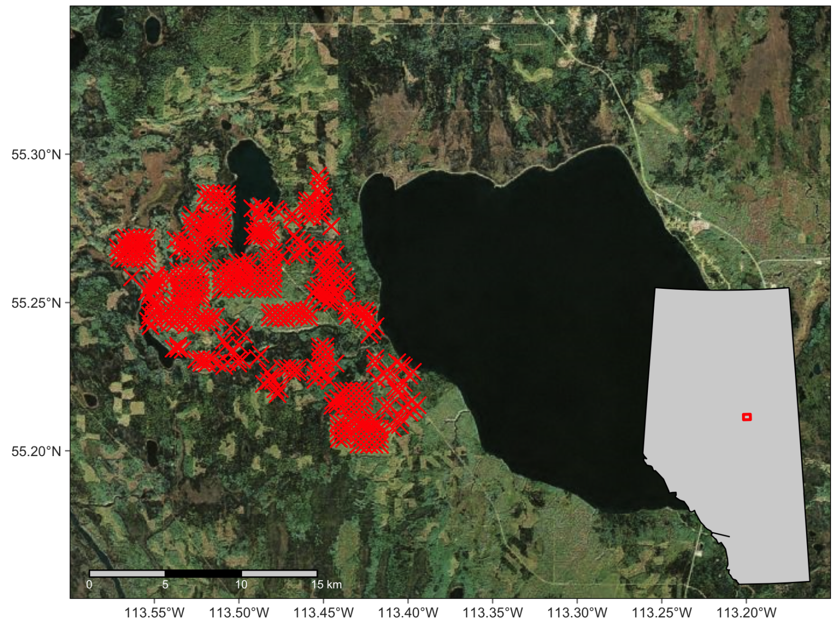

Figure 2: Locations of point count survey sites from the Calling Lake Fragmentation Study near Calling Lake, Alberta (@Schmiegelow1997). Repeat point counts were conducted during the breeding seasons from 1993 and 2015.

interval within sampling radii of 50 and 100 meters. Please see Schmiegelow et al. -[**Schmiegelow1997?**] for further information on the Calling Lake Fragmentation Experiment's study design and point count protocols.

We performed our time lag analysis on seven bird species associated with different nesting and foraging guilds, forest strata, habitat structures, and forest age classes (TABLE). [**EltonTraits2021?**].

Species were selected that exhibited low variability in the total number of detections each year across the 16 years modelled (CV < 0.5). To ensure that the selected species was abundant enough to model, we chose species that were detected in $> 10\%$ of all point count events. Variability of detections between years

The seven selected species included early successional specialists: mature forests species, habitat generalist … American Redstart (*Setophaga ruticilla*), Black-throated Green Warbler (*Setophaga virens*), and Swainson's Thrush (*Catharus ustulatus*), Mourning Warbler (*Geothlypis philadelphia*), White-throated Sparrow (*Zonotrichia albicollis*), , Winter Wren(*Troglodytes hiemalis*).

Based on this, we selected Black-throated Green Warbler (BTNW), a mature forest species; Swainson's Thrush (SWTH) a forest generalist; and Mourning Warbler (MOWA) an early-seral specialist. YBSA Yellow-bellied Sapsucker AMRE American redstart (mid seral) WTSP White throated sparrow (early)

To minimize the influence of forest edges and adjacent differently aged forest, we excluded point count stations with high variation of forest age classes within a hundred meter radius (SD >5 yrs)

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