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Citizen science and field survey observations provide comparable results for mapping Vancouver Island White-tailed Ptarmigan (*Lagopus leucura saxatilis*) distributions

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ABSTRACT

Wildlife in alpine ecosystems can be elusive and difficult to survey, yet knowledge of their distributions is critical as these habitats are threatened by climate change. Opportunistic "citizen science" observations submitted by hikers in remote alpine regions can be valuable, as coverage can be extensive compared to scientific field surveys. Here, we compare the performance of two regression and three machine learning statistical modeling approaches and an ensemble model to predict the distribution of the Vancouver Island subspecies of White-tailed Ptarmigan (*Lagopus leucura saxatilis*) based on two datasets: (1) field survey observations from radio-telemetry and call-playbacks, and (2) opportunistic citizen science observations submitted by hikers. Predictions of suitable habitat for the Vancouver Island subspecies varied from 370 to 1039 km^2 based on field survey observations and from 404 to 1354 km^2 based on public observations. All models had fair accuracy (kappa > 0.45) when tested on an independent dataset, but Generalized Linear Models and Generalized Additive Models tended to over-predict ptarmigan occurrence, had the lowest accuracy, and were most sensitive to the type of response data used. All the machine learning modeling techniques differed little between the datasets. These comparable results are encouraging for the continued use of citizen science monitoring programs, which can save both time and expense while involving and educating the public about threatened species. We advocate the use of opportunistic citizen science data and machine learning modeling techniques (Random Forest, Boosted Regression Trees, and Maxent) for predicting alpine vertebrate species distributions.

1. Introduction

In the past decade, public participation in science (a.k.a. "citizen science") has gained widespread support and recognition (Bonney et al., 2014; Miller-Rushing et al., 2012). Opportunistic observations of species submitted by citizen scientists can be useful for monitoring distributions and abundance of elusive species (Bonney et al., 2009) and have been critical for documenting or predicting climate-driven range shifts for numerous species worldwide (Abolafya et al., 2013; Breed et al., 2012; Hickling et al., 2006; Parmesan et al., 1999). Citizen science observation programs also spread environmental awareness and knowledge among participants (Brossard et al., 2005; Evans et al., 2005; Jordan et al., 2011) and reinforce existing community-based resource management systems (Danielsen et al., 2005).

Citizen science represents a uniquely valuable monitoring tool in alpine regions. Many species of alpine wildlife are threatened as these habitats shrink due to climate change processes including shrub and treeline encroachment (Gehrig-Fasel et al., 2009; Hallinger et al., 2010; Kullman and Öberg, 2009; Martin and Wiebe, 2004; Myers-Smith et al., 2011) and increased competition from invasive species and low elevation generalists (Duursma et al., 2013; Jankowski et al., 2010). Climate change is amplified in high mountains (Dirnböck et al., 2011); therefore, monitoring of alpine wildlife is increasingly critical in order to detect changes in species distributions and population trends (Martin, 2013). However, animals that spend their entire life history at high elevation tend to be solitary with cryptic appearances and behaviors (Martin, 2013). These characteristics combined with poor accessibility of alpine ecosystems make systematic field surveys of alpine wildlife challenging. On the other hand, the challenging terrain of alpine ecosystems is precisely what drives hundreds of hikers to visit remote mountain peaks each year. Therefore, opportunistic

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citizen science programs are especially well suited for alpine regions that would require immense time and expense for a team of field scientists to access.

Despite the apparent benefits of citizen science monitoring, biases exist in citizen science data that may be minimized in field survey data. These include higher variability among data collected by citizen scientists compared to experts (Ericsson and Wallin, 1999; Genet and Sargent, 2003), over- or underestimates of species abundance (Bray and Schramm, 2001; Galloway et al., 2006) and misidentification of species (Brandon et al., 2003; Genet and Sargent, 2003). Additionally, opportunistic data typically consists only of species presence locations, without information on where a species was not observed. However, the benefits of citizen science programs may outweigh their limitations (Crall et al., 2010; Danielsen et al., 2005) and newer, advanced statistical tools are continually being developed that can address potential biases in citizen science datasets (Hegel et al., 2010; Kelling et al., 2009). More comparisons between citizen science and expert-driven field survey data are needed in order to evaluate and improve citizen science monitoring programs and to evaluate the potential of citizen science as a viable tool for conservation (Conrad and Hilchey, 2011; Dickinson et al., 2010).

One challenge to modeling species' distributions in alpine environments is that climate and topographic variables tend to be highly correlated (e.g., temperature and elevation). Parametric models such as logistic regression cannot handle highly correlated predictor variables, so often the most biologically relevant variable in a correlated pair is used for model selection while the other is discarded. Machine learning techniques such as Boosted Regression Trees, Random Forest, and Maxent are more robust to the inclusion of several correlated variables (Archer and Kimes, 2008), but drawbacks are that they can be difficult to interpret, complex, and often computationally intensive. Several authors recommend using ensemble predictions from multiple models, as they are often more robust than predictions from a single model (Araujo and New, 2007; Marmion et al., 2009; Oppel et al., 2012; Thuiller et al., 2009).

Here, we compare the performance of five statistical modeling approaches and an ensemble model to predict the distribution of the endemic Vancouver Island subspecies of White-tailed Ptarmigan (*Lagopus leucura saxatilis*), an alpine specialist bird that spends its entire life above treeline. We apply each modeling technique to two datasets: (1) a field survey dataset consisting of radio-telemetry and call-playback survey observations, and (2) an opportunistic citizen science dataset consisting of occurrence locations submitted by hikers. Specifically, we ask: *How do model accuracy and predictions of suitable summer habitat for Vancouver Island White-tailed Ptarmigan differ between citizen science and field survey response data and across five statistical modeling techniques*? Our study aims to inform scientists and managers about the current distribution and habitat availability of Vancouver Island White-tailed Ptarmigan while illuminating the potential usefulness of opportunistic observations submitted by citizen scientists. Through our model comparisons, we aim to provide information about which statistical modeling techniques are most useful for predicting the distribution of an alpine specialist species and whether the "best" modeling approach differs depending on the type of dataset used.

2. Methods

2.1. Study area and species

The study area encompassed all of Vancouver Island, located on the southwest coast of British Columbia, Canada (between 47° and 52°N latitude and 123° and 128°W longitude). At 460 km long (north to south) and 80 km wide (east to west; 32,134 km^2), Vancouver Island is the largest island on the North American west coast. Elevation varies from 0 to 2200 m a.s.l. A central spine of mountains spans the length of the island, with highest elevations located in the center of the island within Strathcona Provincial Park. These mountains create a rain shadow on the eastern side, resulting in a strong east–west precipitation gradient across the island. The biogeography of the island has been classified into biogeoclimatic (BEC) zones by the provincial government that represent vegetation, soil, and climate conditions. Four BEC zones exist on Vancouver Island, including Coastal Douglas Fir, Coastal Western Hemlock, Mountain Hemlock and Alpine Tundra.

The Vancouver Island White-tailed Ptarmigan was designated as an endemic subspecies in 1939 based on unique morphological characteristics (Campbell et al., 1990; McTaggart-Cowan, 1939), and was blue-listed (vulnerable status) by the British Columbia government in 1992 given its endemic status and low density (Martin et al., 2004). Smaller and heavier than mainland White-tailed Ptarmigan, the Vancouver Island subspecies also lives at lower elevations and utilizes more habitat types than their mainland counterparts (Martin et al., 2004). They are threatened primarily by climate change, as alpine habitat on Vancouver Island is relatively low elevation compared to inland mainland alpine and will likely become highly fragmented and disappear most rapidly (Fraser et al., 1999). Because Vancouver Island mountains contain few trails and sparse road access, systematic field surveys of this listed subspecies are difficult. However, ptarmigan are charismatic and often encountered at close range and easily photographed by hikers, rendering them good candidates for monitoring via opportunistic citizen science observations.

2.2. Bird data

We used two sources of distributional data for Vancouver Island White-tailed Ptarmigan. The first consisted of ptarmigan presence locations from a field survey conducted by K. Martin from 1995 to 1999. Birds were located using playbacks of male territorial calls and chick distress calls, then captured with snare attached to an extendable pole (Zwickel and Bendell, 1967) and outfitted with a necklace collar radio transmitter (RI-2D/2B, 18 mo battery life, weight 6–9 gm, Holohil Systems Ltd., Carp, Ontario). K. Martin and field crews tracked the radio-collared birds over the 4-year period on foot during summer and by helicopter during winter, and recorded encounters with other uncollared birds using playbacks and incidental encounters. GPS coordinates were recorded at each bird location.

From this dataset (hereafter referred to as the field survey), we extracted summer (June–October) observations and eliminated sightings of juveniles, since they were usually found at or near the same GPS coordinate as their parent during the summer period. We then eliminated duplicates at the same GPS point (i.e., if a flock of several birds was recorded at one point, only one observation was included in the final dataset). To minimize bias due to certain individuals being observed more than others, we first eliminated records from the same individual that were <1 day apart, and then randomly selected two records per individual. Lastly, we randomly selected one observation within each 100-m grid cell of the environmental predictor GIS layers. Grid cells with >1 ptarmigan observation were up-weighted in some of the distribution models. This resulted in a final sample size of 207 sightings representing 120 individual birds (Fig. 1A).

In order to supplement the field survey records, an opportunistic citizen science program was initiated in partnership between the Strathcona Wilderness Institute and K. Martin at the Centre for Alpine Studies, University of British Columbia. Notices were