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Simulating range-wide population and breeding habitat dynamics for an endangered woodland warbler in the face of uncertainty

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ABSTRACT

Population viability analyses provide a quantitative approach that seeks to predict the possible future status of a species of interest under different scenarios and, therefore, can be important components of large-scale species' conservation programs. We created a model and simulated range-wide population and breeding habitat dynamics for an endangered woodland warbler, the golden-cheeked warbler (*Setophaga chrysoparia*). Habitat-transition probabilities were estimated across the warbler's breeding range by combining National Land Cover Database imagery with multistate modeling. Using these estimates, along with recently published demographic estimates, we examined if the species can remain viable into the future given the current conditions. Lastly, we evaluated if protecting a greater amount of habitat would increase the number of warblers that can be supported in the future by systematically increasing the amount of protected habitat and comparing the estimated terminal carrying capacity at the end of 50 years of simulated habitat change. The estimated habitat-transition probabilities supported the hypothesis that habitat transitions are unidirectional, whereby habitat is more likely to diminish than regenerate. The model results indicated population viability could be achieved under current conditions, depending on dispersal. However, there is considerable uncertainty associated with the population projections due to parametric uncertainty. Model results suggested that increasing the amount of protected lands would have a substantial impact on terminal carrying capacities at the end of a 50-year simulation. Notably, this study identifies the need for collecting the data required to estimate demographic parameters in relation to changes in habitat metrics and population density in multiple regions, and highlights the importance of establishing a common definition of what constitutes protected habitat, what management goals are suitable within those protected areas, and a standard operating procedure to identify areas of priority for habitat conservation efforts. Therefore, we suggest future efforts focus on these aspects of golden-cheeked warbler conservation and ecology.

1. Introduction

Population viability analyses (PVAs) can be important components of large-scale species' conservation programs (Caswell, 2001; Beissinger and McCullough, 2002; Morris and Doak, 2002; Akçakaya et al., 2004). Such models provide a quantitative approach through computer modeling to predict the possible future status of a species of interest under different environmental and management scenarios. The precision and bias of a PVA are directly related to the precision and bias of demographic parameter estimates (and the parameters of the functional relationships that govern these parameters), our understanding of the population structure of the species of interest, and the available information on the extent, configuration, and temporal dynamics of the species' habitat. Therefore, the structure and parameters of such models must be updated periodically with inferences from recent and on-going research to remain relevant and make meaningful contributions to conservation efforts.

The golden-cheeked warbler (*Setophaga chrysoparia*; hereafter warbler) is a Neotropical migrant passerine that is a habitat specialist, breeding exclusively in the mature mixed woodlands of central Texas, USA that are comprised primarily of oak (*Quercus*

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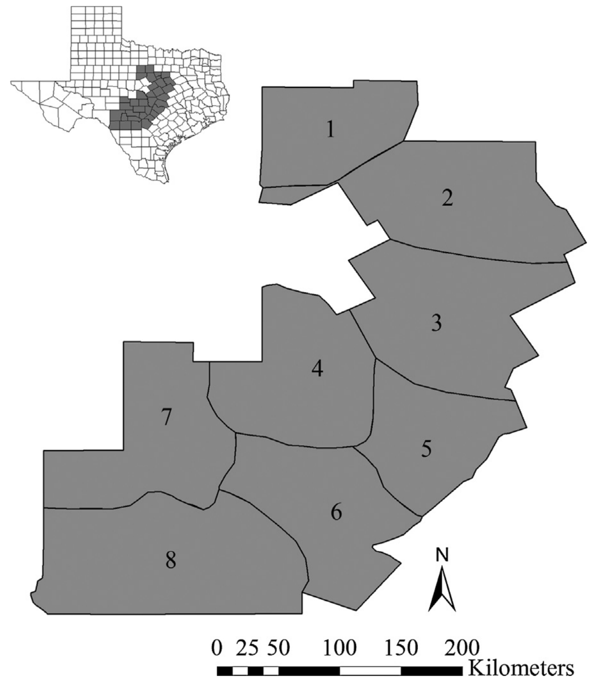

Fig. 1. Golden-cheeked warbler (*Setophaga chrysoparia*) breeding range and federally-designated recovery units in Texas, USA.

spp.) and Ashe juniper (*Juniperus ashei*; Pulich, 1976). Perceived loss of warbler breeding habitat and the species' limited breeding range ultimately led to the warbler being listed as endangered by U.S. Fish and Wildlife Service (USFWS) in 1990 (USFWS, 1990; Wahl et al., 1990). Shortly afterwards, USFWS developed a recovery plan that listed specific goals and objectives needed to achieve the downlisting of the species (USFWS, 1992). In that plan, eight regions were delineated across the species' breeding range to manage the recovery process (Fig. 1), and one of the objectives set by this plan was to protect sufficient breeding habitat "to ensure the continued existence of at least one viable, self-sustaining population in each of eight regions." (USFWS, 1992:iv).

As with many other species of concern, PVAs are currently being used in large-scale warbler conservation programs (reviewed in Hatfield et al., 2012). Previous warbler PVAs estimated the minimum amount of protected habitat required to meet the recovery objectives (USFWS, 1996), assessed the importance of dispersal among habitat patches (Alldredge et al., 2004), and simulated potential land change scenarios to examine their impact on projected population dynamics (Vaillant et al., 2004; Horne et al., 2011). Each of these models provided direction toward fruitful areas of further study, but each was also hampered by the paucity of information then available concerning warbler demography, distribution, abundance, dispersal, and habitat change.

In recent years, much effort has been expended to update our knowledge on these information gaps. Current research suggests the warbler is relatively abundant (Mathewson et al., 2012), widely distributed (Collier et al., 2012), has little genetic differentiation across its breeding range (Lindsay et al., 2008), and has high movement rates among habitat patches (Duarte et al., 2015). Despite the seemingly positive outlook for warbler conservation, large-scale habitat loss and fragmentation have continued to occur across the species' breeding range (Duarte et al., 2013), and survival of adult warblers may actually be 16% lower than what was previously reported (Duarte et al., 2014).

We simulated range-wide warbler population and breeding habitat dynamics. There were three primary objectives for this study. First, we estimated habitat-transition probabilities across the warbler's breeding range. To accomplish this objective, we combined National Land Cover Database (NLCD) imagery with multistate modeling to estimate habitat-transition probabilities. Given current land-cover-change estimates reported by Duarte et al. (2013), we hypothesized that recovery units five, six, and eight would have the highest rates of habitat loss. It likely takes many decades for Ashe juniper to mature sufficiently to become warbler breeding habitat (J. S. Hatfield, *unpublished data*). Thus, we also hypothesized that habitat transitions will be unidirectional, whereby it will be more likely for an area to undergo habitat loss than habitat regeneration. Second, we wanted to simulate warbler population dynamics in response to habitat change and a range in estimates of vital rates to examine if warbler viability is possible given the current knowledge of the species and its breeding habitat. Here, we also assessed various scenarios with differing levels of dispersal since this parameter has yet to be estimated for warblers. Lastly, we evaluated if protecting a greater amount of habitat would increase the number of warblers that can be supported in the future. This last objective seems somewhat intuitive. A greater amount of protected habitat should lead to a higher carrying capacity (K). This might not be the case, however, if the amount of protected habitat is relatively small compared to the total available habitat. To achieve this objective, we systematically increased the amount of protected habitat at the onset of the simulation and compared the estimated terminal K for each recovery unit at the end of 50 years of simulated habitat change.

It is important to point out the distinctions between our modeling approach and the others carried out to simulate warbler population dynamics because our approach is unlike the previous warbler PVAs in several aspects. First, we used a pre-breeding census projection model as opposed to a post-breeding census model, although this should have no effect so long as all models were parameterized correctly. A pre-breeding census model was used because the number of adult territorial males is often the population abundance estimate that is accessible in warbler conservation efforts because of the territorial nature of the species. Second, we integrated a stochastic habitat change component into our model based on real-world data using a novel method to estimate landscape change. Previous warbler population models that incorporated habitat change relied on deterministic changes based on perceived probable scenarios. Third, we simulated warbler population dynamics assuming the entire breeding range consisted of one large population. This population structure was used because current research indicates warblers are a single population distributed patchily across the landscape, rather than a collection of subpopulations with infrequent dispersal events (i.e., a metapopulation; reviewed in Morrison et al., 2012). Many of the previous warbler PVAs (e.g., Alldredge et al., 2004; Vaillant et al., 2004; Horne et al., 2011) presumed a metapopulation structure. However, we note that the difference (i.e., modeling a metapopulation versus a single population) when compared to Alldredge et al. (2004) is primarily based on terminology rather than model structure, given their model did not incorporate a natal-site dispersal-distance limitation and they considered relatively high dispersal probabilities. Fourth, we incorporated dispersers into the model differently. For example, in previous models the dispersers were second-year birds that survived, returned to the habitat patch they hatched in, and then dispersed. In our model, dispersers were sampled from birds that would have been in their second year but did not return to their natal site from the previous year. Dispersers were calculated using these individuals because survival estimates for the species represent apparent, not true, survival. Thus, the survival estimates for the species are the probability an individual survives and returns to the area. By modeling dispersal this way, we were able to directly use the survival estimates for the species within the model, rather than inflating juvenile survival estimates to accommodate