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The Importance of Regional and Landscape Context and Climate Change to Northern Bobwhite Management

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THE IMPORTANCE OF REGIONAL AND LANDSCAPE CONTEXT AND CLIMATE CHANGE TO NORTHERN BOBWHITE MANAGEMENT

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ABSTRACT

Long-term declines in northern bobwhite (*Colinus virginianus*) in the United States are presumably due to decades of habitat loss or degradation at a national scale. Food and fiber production characterized by replacement of open woodlands and savannas by dense forest, intensification of agriculture, and conversion of native grasslands to nonnative pastures have degraded habitats for most grassland and early successional birds. Declines in bobwhite and associated species occurred within this context at a scale that has overwhelmed wildlife management efforts. However, with understanding of scale and context, managers could sustain these species in some future landscapes. Increasing urbanization over the next century will result in loss of millions of acres of forests, grasslands, and agricultural lands used by bobwhite and associated species, and climate change will affect abundance and distribution of shortleaf (*Pinus echinata*), loblolly (*P. taeda*), and longleaf (*P. palustris*) pine woodlands. I highlight modeling tools and planning efforts that demonstrate how conservation planning can address these changes. I suggest that focusing management in the correct landscape contexts and accounting for land use and climate change is more likely to be successful than management that does not and conservation partnerships and management efforts across public and private lands are required to affect regional bobwhite populations.

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Northern bobwhite (*Colinus virginianus;* hereafter, bobwhite) populations have declined consistently at a rate of 4%/year since 1966. Abundance measured by the North American Breeding Bird Survey (BBS) in 2013 averaged 8 birds/route, which is only 16% of the 50 birds/route in 1966 (Sauer et al. 2014). As bad as this decline is, it is not unique: 64% and 48% of grassland and early successional or scrub breeding birds, respectively, also exhibit significant declines based on the BBS (Sauer et al. 2014). It is generally accepted that long-term declines in bobwhite and many associated species are due to habitat loss, fragmentation, or degradation at a national scale (Brennan and Kuvlesky 2005, Hernández et al. 2012). The replacement of open woodlands and savannas by dense forest, the intensification of agriculture, and the conversion of native grasslands to pastures of exotic forages have degraded habitats for bobwhites and most grassland and early successional birds (Hernández et al. 2012, National Bobwhite Technical Committee 2012). These processes have taken decades and occurred throughout the United States and were driven by the economics of food and fiber production.

The ecological, landscape, and societal changes driving declines in bobwhite and associated species have often overwhelmed local and limited wildlife-management efforts. Management focused only at the local scale needs to be very intensive, sometimes including supplementation of populations and predator control, to sustain huntable populations of bobwhites. It will likely require many years of landscape-scale habitat restoration to halt the regional decline of bobwhites. It will require purposeful management and habitat restoration on public and private lands in agriculture, grassland, and forest, and include practices such as prescribed fire to return disturbance to these landscapes (Hernández et al. 2012, National Bobwhite Technical Committee 2012). The National Bobwhite Conservation Initiative 2.0 (NBCI) is a range-wide plan for recovering bobwhites (National Bobwhite Technical Committee. 2012). The NBCI is a landmark in bobwhite conservation because it provides a starting point for conservation planning. It includes a tool to aid planning and implementation of conservation at national, regional, state, and local scales. It identifies high, medium, and low-priority areas for bobwhite restoration to help agencies and organizations more effectively target management. I believe this type of multiscale, regional-to-landscape approach to prioritize areas where restoring adequate habitat is possible and landscapes are capable of sustaining bobwhite populations is critical to bird conservation in general (Probst and Gustafson 2009) and is certainly applicable to bobwhites. These ideas are not

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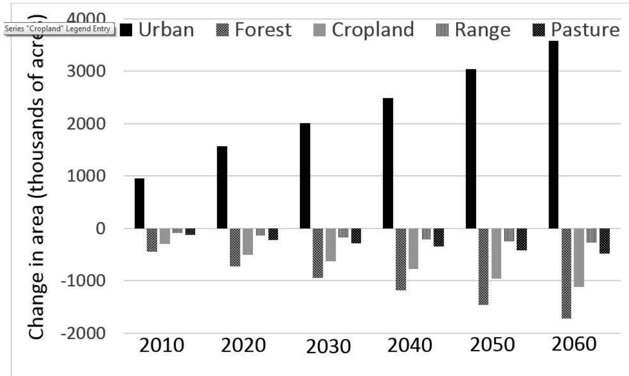

Fig. 1. Changes in urban, forest, cropland, range, and pasture land use in the southeastern United States 2010–2060. Values are averaged across predictions for the 4 Cornerstone futures developed in the Southern Forest Futures Project (Wear and Greis 2013).

necessarily new to bobwhite management; others have stated in various ways the need to have landscapes with enough habitat preserved through time to provide a critical mass of bobwhites to sustain a population (Stoddard 1931, Guthery 1997, Brennan 2011).

The NBCI provides a great foundation for bobwhite conservation because it addresses the importance of landscape context but it also provides a framework for continual improvements to its conservation planning tool. Among several of the suggested areas for improvement in NBCI are planning for climate change and urban growth and incorporating other grassland species (e.g., Butler et al. 2017, Joos et al. 2017) to optimize conservation efforts (National Bobwhite Technical Committee 2012). Future landscape- and regional-scale changes in forests, agriculture, urbanization, and climate will provide great challenges to bobwhite conservation.

Although landscape change and habitat loss are important drivers of present-day species declines and extinction (Sodhi et al. 2009), climate change is expected to become equally or more important in the coming decades as it interacts with these threats (Brook et al. 2008, Rodenhouse et al. 2008, Stralberg et al. 2009). Climate change has been called the single biggest threat to birds with more than half of bird species in North America at risk of losing more than half their current geographic range (National Audubon Society 2015). The indirect effects of climate change on forest ecosystems will result in habitat changes for birds across the eastern United States (Rodenhouse et al. 2008, Matthews et al. 2011). Furthermore, climate change will interact with important ecological process that also affect bobwhite habitat, such as fire (Guyette et al. 2014).

Here, I briefly review how 3 important aspects of regional and landscape context—climate, land use, and forests—are projected to change over the next 60–100 years within the core of the northern bobwhite range. I then demonstrate how conservation that acknowledges these aspects of context and scale can be more effective at sustaining grassland and shrub-scrub species than management that ignores these factors. I do this by reporting on some modeling tools and planning efforts that demonstrate how management that accounts for landscape context and acknowledges succession, management, urbanization, and climate change is more likely to be successful than management that ignores these factors.

CHANGES IN THE REGIONAL CONTEXT: CLIMATE AND LAND USE

The Southern Forest Futures Project forecasted changes in the South's climate, land use, and forests over the next century and provides a valuable assessment of factors that will influence conservation of northern bobwhite and associated species (Wear and Greis 2013). The project is focused on 13 southeastern states from Virginia to Texas and therefore covers much of the northern bobwhite range. The project constructed forecasts based on a set of 4–6 future scenarios that included assumptions about economic growth, population growth, climate, timber prices, and forest planting to the year 2060. Although the original results are presented by scenario, I averaged model results across scenarios to provide an overview of these forecasted regional changes in climate and land use.

The climate change summaries presented in the Southern Forest Futures Project are based on 4 different climate models (MK2, MK3.5, HadCM3, and MIROC 3.2) and 2 different emission scenarios (A1B, B2) from climate predictions by Intergovernmental Panel on Climate Change (IPCC 2007, Wear and Greis 2013). On average, the south is expected to experience warmer temperatures in the future but precipitation patterns vary with model and scenario from wet and warm to dry and hot. Recent historical climate (2001–2009) had an average annual temperature of 16.97° C and 1,136 mm of precipitation. The forecasted average annual temperature and total precipitation in 2090 range from 20° to –22° C and 860 to 1,220 mm, respectively, depending on scenario (Wear and Greis 2013). However, these averages can be misleading because climate forecasts, especially precipitation, vary spatially (e.g., under 2 of the scenarios, portions of the region experience >20% decreases in precipitation). As I discuss later, these changes have the potential to affect ecosystem productivity and affect distributions of tree species that influence wildlife habitat.

Although the impacts of regional climate change on northern bobwhite may be difficult to assess, the effects of land use change are more directly apparent. Simply put, any land use that is of any value to northern bobwhites and associated species will decline over the next century. The amount of urban land is projected to double by 2060 from a base of 30 million acres (approx. 12,000,000 ha) in 1997, expanding from approximately 7% to 13–16% of the region. Although this increase comes at the expense of forest, cropland, range, and pasture (Fig. 1), the total loss of forest area is forecasted to range from 4 to 21 million acres (approx. 1,600,000 to 8,500,000 ha; 2–10%) by 2060 (Wear and Greis 2013).

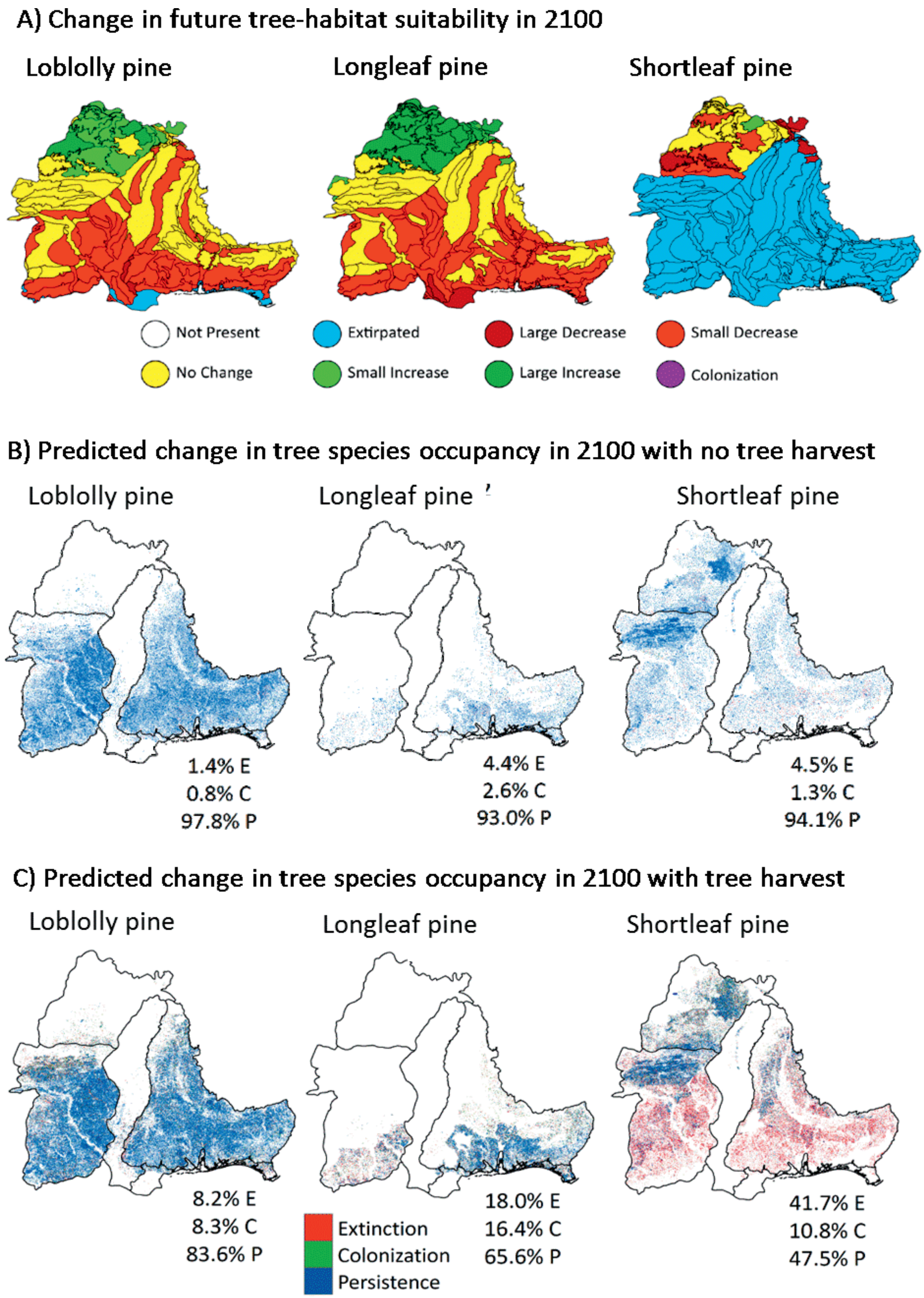

Fig. 2. Predicted changes in (A) tree habitat suitability and (B) tree species occupancy in 2100 without tree harvest, and (C) tree species occupancy in 2100 with tree harvest under climate change in the Gulf Coast Plains and Ozarks region of the southern United States. Changes in habitat suitability are based on early growth and survival of trees simulated by LINKAGES 3.0. Predicted tree species occupancy are based on forest landscape change simulations with LANDIS PRO and include current levels of fire and tree harvest or no tree harvest. Results presented are for the CanESM2 RCP 8.5 scenario, which represented an intermediate level of climate change compared with the other 2 scenarios considered (He and Thompson 2016).

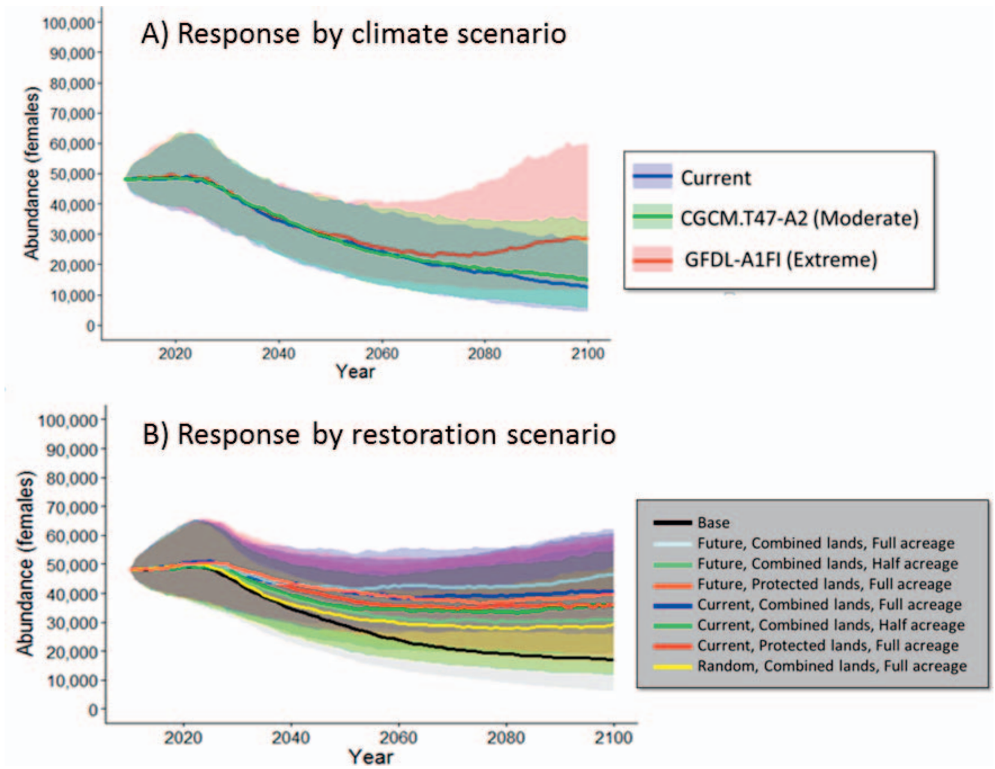

Fig. 3. Projected population growth of prairie warbler population in the Ozark Highlands (A) by climate scenario but with no habitat restoration and (B) by habitat restoration scenario averaged across climate scenarios. Shaded regions indicate 85% credible intervals. Predictions are based on dynamic-landscape metapopulation models applied to landscapes projected under urbanization and current climate, moderate (CGCM.T47-A2), and extreme (GFDL.A1Fi) climate change. Habitat restoration scenarios vary by whether restoration is located based on future or current landscapes, or random; occurs on public, private, or combined lands; and no restoration (base), half, or full acreage is implemented; see Bonnot et al. (2016) for details.

The same drivers affecting land use will also have implications for the types of forest uses. Changes in hardwood forests were most influenced by urbanization, whereas changes in softwood types were most influenced by timber markets. Land use changes and conversion to pine (*Pinus* spp.) plantations is predicted to increase the area of planted pine while decreasing the area of naturally regenerated pine. At present planted pine comprises approximately 19% of southern forests but by 2060 it could represent 24–36% of southern forests. Upland hardwood forest are forecasted to decrease 8–14% (Wear and Greis 2013).

CHANGES IN LANDSCAPE CONTEXT

I have been working with a team to investigate the effects of climate change, urbanization, and forest management on forest landscape change and selected wildlife focal species in the Gulf Coastal Plains and Ozarks (GCPO) and Central Hardwood Forest Region (Wang et al. 2015, Bonnot et al. 2016, He and Thompson 2016). The GCPO is a 180-million acre (approx. 72,800,000 ha) region that includes portions of Texas, Oklahoma, Missouri Arkansas, Louisiana, Mississippi Illinois, Kentucky, Tennessee, Alabama, Georgia, and Florida; it is in the heart of the northern bobwhite range. Here I present our approach and some findings because they provide insight into landscape changes and context that are particularly relevant to northern bobwhite and are an example of how these drivers of landscape and wildlife population change can be integrated into conservation planning at a scale that can make a difference to regional wildlife populations.

We used a modeling framework to address climate change, urbanization, and management impacts on 29 tree species over the next 100–300 years in the GCPO (He and Thompson 2016). Our modeling framework couples the forest landscape change model LANDIS PRO (Wang et al. 2014, 2015) with the forest ecosystem model LINKAGES 3.0 (Dijak et al. 2017) and downscaled climate forecasts from several scenarios and general circulation models from the fifth phase of the Coupled Model Intercomparison Project (IPCC 2014). We account for urban growth by using urban growth projections for the southeastern United States based on the SLUETH model (Belyea and Terando 2015). We determined changes in tree habitat suitability as the ratio of future to current early growth and survival of tree species (measured as biomass for years 1–30) from LINKAGES predictions (Dijak et al. 2017, Iverson et al. 2017). We used LANDIS PRO to simulate the impacts of scenarios that included different levels and combinations of climate change, forest management, and urbanization on tree species basal area, density, importance value, and occurrence in the region over the next 100–300 years. A key feature of this framework is it allows comparison of change in future habitat suitability for trees under climate change based on the LINKAGES model with the actual forecasted change in tree species abundance and occurrence as affected by succession, disturbance, management, and climate simulated by LANDIS; these often differ because trees are long-lived and have limited dispersal abilities (Wang et al. 2015, Iverson et al. 2017).

Key findings from the Linkages model were the general movement northward of potential habitat for most species. The extent of this was great enough for some species, such as sugar maple (*Acer saccharum*) and white oak (*Quercus alba*), that it implied their near potential extirpation from the region. However even common species saw decreases in habitat suitability in the southern part of the region. For example, habitat suitability for loblolly (*Pinus taeda*) and longleaf (*P. palustris*) pine decreased in the southern part of the region, no change in the Ouachita Highlands, and increased in the Ozark Highlands. Shortleaf pine (*Pinus echinata*) had zero habitat suitability in much of the southern part of the region and the Ozark Highlands was a mix of decrease, no change, and increase (Fig. 2A). Another important finding was the reduction in tree carrying capacity, expressed as the ratio of current to future maximum biomass, for varying extents of the region depending on the climate scenario. Reductions in tree carrying capacity could represent shifts in sites from forest to woodland or savanna.

The LANDIS model simulations generally confirmed that species with the greatest predicted loss in potential habitat had the greatest realized change over the next 100 years. For example, loblolly and longleaf pine persisted across most of their current range and extinction events were balanced by colonization events, with or without tree harvest (Fig. 2B, C). However with tree harvest shortleaf pine went extinct on 41.7% of pixels while it only colonized 10.8% and extinctions were concentrated across the southern part of the region (Fig. 2C). The role of harvest or management was very important because it provided the opportunity for forest turnover to more adapted species under future climates, which was particularly evident in the increase in extinction events for shortleaf pine from 4.5% to 41.7% when tree harvest was included (Fig. 2C). In other scenarios not summarized here we demonstrated how planting could greatly increase shortleaf pine woodland in the Ozark Highlands under future climates (He and Thompson 2016).

So what is the relevance of all this to northern bobwhite and other associated species? Interest in the value of pine woodlands, especially longleaf and shortleaf pine, for wildlife has risen in recent years (GCPO Open Pine Projects, http://api.ning.com/files/AgFOgF-tqnT8VX2dQgzdApbW98ZiEu*nvjJsWQ3WCOod558hPRQR1l2QoDNPmaQwkB8zJVzgoJG9jtZ-hHGdW02w*mf*utSi/InActionOpenPineFACTSHEET62915.pdf). Our models demonstrate potential shift in the amount of and location of these ecosystems. On the negative side there could be a loss of shortleaf pine throughout much of the southern part of the region. On the positive side there is the potential for a transition of some forest to woodland and an increase in loblolly and shortleaf pine woodland in the Ouachita and Ozark regions. Importantly, He and Thompson (2016) also demonstrate how management can be used to achieve objectives of forest-land management while accounting for climate change. So although papers in this symposium address how to manage longleaf pine in current landscapes for northern bobwhite and associated species (Butler et al. 2017, Rosche et al. 2017, Terhune et al. 2017), considering how to encourage its establishment in future suitable landscapes will be necessary if climate warms to the extent predicted.

In addition to its effect on vegetation, climate change can affect bobwhite survival, abundance, and distribution directly. Lebrun et al. (2016) related bobwhite abundance on North American Breeding Bird Survey routes to weather and land cover variables; abundance was positively related to average winter temperature and negatively related to average winter precipitation. Lebrun et al. (2017) used these relationships to predict changes in bird abundances, including bobwhites, for southern Missouri over the next 100 years in response to management and climate change. Bobwhite abundance increased 33% under the scenario that assumed management as usual and climate based on the Hadley Centre Coupled Model version 3 with A1fi emission scenario, which projected a 3.13° C increase in mean winter temperature. Although LeBrun found relationships with seasonal mean temperatures, the mechanisms behind these relationships are likely at least partly due to finer scale temporal and spatial relationships with climatic extremes. For example bobwhite space use is constrained by extreme heat (>35° C) and cold (<15° C) and survival reduced by weekly periods of extreme cold (Tanner et al. 2016). So direct effects of climate warming could increase winter survival of birds in northern parts of their range but have negative consequences for birds in the southern parts of their range.

INCORPORATING LANDSCAPE AND CLIMATE CHANGE IN WILDLIFE CONSERVATION PLANNING

Bonnot (2016) integrated the climate and landscape change modeling framework described above with a wildlife meta-population model (Bonnot et al. 2011, 2013) into a dynamic landscape metapopulation model (DLMP) and demonstrated how this approach can be used to forecast effects of climate change, succession, and land management on regional wildlife populations. Bonnot et al. (2016) used the DLMP approach within a structured decision-making framework to demonstrate its usefulness in overcoming the uncertainties and complexities that are inherent in the process of long-term, large-scale conservation planning, especially when it involves climate change. I review some of their results here because they examined several species associated with northern bobwhites, and there are ongoing efforts to apply this approach to northern bobwhites. Furthermore, it illustrates that large-scale conservation planning, when it addresses landscape context, can reverse population declines.

The DLMP approach is based on matrix-based population models in which demographic parameters such as carrying capacity, productivity, and survival are linked to attributes of the habitat patch in which a subpopulation resides. Patches change over time, as simulated by the forest landscape change model LANDIS, and forest landscape change can be affected by climate effects on the establishment and early growth of trees as predicted by the LINKAGES model. Bonnot et al. (2016) applied this approach to the Ozark Highlands, a subregion within the GCPO, to evaluate 8 habitat restoration scenarios under 3 climate scenarios. The scenarios were spatially explicit plans for restoration of 1.5 or 3 million acres (approx. 607,000 or 1,210,000 ha) of glades, woodlands, and forest. These activities were targeted on either private, public, or private and public lands, and areas were prioritized based on current landscapes or future landscapes accounting for urbanization and climate change. All scenarios also included current levels of forest management and fire and wind disturbance.

Bonnot et al. (2016) predicted impacts on 6 focal species but here I focus on results for the prairie warbler (*Setophaga discolor*) because it breeds in many of the same vegetation communities that provide high-quality habitat for northern bobwhites (e.g., shrub-scrub, glades, woodlands) and both species respond positively to fire. In the absence of habitat restoration (but with current the level of forest management and fire) and under current climate, prairie warbler populations continued to decline at a rate consistent with recent historical declines (Fig. 3A). This decline was largely the result of forest succession resulting in more mature forests with more closed canopies, which reduced carrying capacity. However, under 2 climate change scenarios, reduced precipitation and warmer temperatures began to affect forest structure and resulted in more open canopies by the end of the century and, after an initial period of decline, the prairie warbler population began to increase near the end of the century (Fig. 3A). Habitat restoration interacted with climate change to produce interesting effects as well; prairie warbler abundances were twice as great under some restoration scenarios compared with the base scenario with no habitat restoration (Fig. 3B). Prairie warbler populations rebounded better when areas for restoration accounted for climate change and urbanization. Interestingly increases were only in part due to an increase in carrying capacity but also substantially due to more of the population residing in more favorable landscapes with less fragmentation and greater productivity—in other words, better landscape context. Reversing population declines also required restoration on both public and private lands because acreage targets could not be met on public lands alone. The Greater Red Hills region of northern Florida and southern Georgia is a real world example of how intentional management for northern bobwhite on private lands involving fire and sound forest management can result in sustained abundance at a regional level (Terhune et al. 2017).

MANAGEMENT IMPLICATIONS

My premise for these management implications and conclusions has been to highlight some recent developments in wildlife and landscape ecology that will let us take conservation for northern bobwhite and associated species to the next level. Climate change and the ensuing landscape change that will result from climate, along with other important drivers such as urbanization and land management, present substantial challenges for conservation planning. The NBCI provides a sound foundation for addressing the importance of landscape context to management. Conservation planning approaches, such as those we have worked on with the GCPO Landscape Conservation Cooperative, can provide the next steps in addressing conservation of northern bobwhite and associated species. The examples I have highlighted rely heavily on models and model forecasts, which to some extent are inaccurate, but nevertheless still useful for planning and assessment (Millspaugh et al. 2009).

These examples demonstrate several important points for conservation of bobwhite and associated species. As we lose forest, grassland, and agricultural land to urbanization, how and where we manage lands will be increasingly important (Bonnot et al. 2013). Climate will likely have important effects on the structure and composition of forests in the long term (e.g., 100–300 yr). However, management will have a much greater effect in the short term and can help either promote resilience and mitigate forest changes, facilitate change in desired directions, and determine how quickly climate-driven changes are realized. Management and restoration will likely need to occur across public and private lands to affect regional populations. However, when conservation is planned at regional scales and implemented on a large scale it can have population consequences, including reversing population declines.

Given the importance of management, one of the important factors limiting the success of bobwhite conservation is how much management and restoration we can accomplish on the ground. We are becoming more effective at landscape to regional to national planning through partnerships such as Landscape Conservation Cooperatives, the National Bobwhite Conservation Initiative, and Partners in Flight. Now, we need to establish the proposed management on the ground across multiple partners and ownerships. Efforts are underway to do this through NBCI on public and private forests and grasslands under the umbrella of management, monitoring, policy, partnerships and outreach (National Bobwhite Technical Committee 2012, NBCI 2016 SOTB, http://bringbackbobwhites.org/). Specific examples include efforts of the Wildlife Habitat Federation (http://www.whf-texas.org/) to help landowners establish native habitats for bobwhite in Texas and restoration of thousands of hectares of pine woodlands in multiple states by the U.S. Forest Service Cooperative Forest Landscape Restoration Program (https://www.fs.fed.us/restoration/CFLRP/). So to summarize in a single statement, bobwhite conservation will be more successful if we consider what the future is likely to bring and establish more management on the ground and in the correct places and NBCI is a valuable framework to guide us.

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