SECTION 1. ADMINISTRATIVE INFORMATION:

Principal Investigator: Benjamin Zuckerberg, University of Wisconsin-Madison
Co-Principal Investigator: Christine Ribic, U.S. Geological Survey, Wisconsin Cooperative Wildlife Research Unit

Agency or Institution of the recipient: University of Wisconsin-Madison

Project title: Fitting the Climate Lens to Grassland Bird Conservation: Assessing Climate Change Vulnerability Using Demographically-Informed Species Distribution Models

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Actual total cost of the project: $176,359

SECTION 2. PUBLIC SUMMARY: The Earth is warmer today than it has been during most of the last 11,000 years; as warming trends approach unprecedented levels, there is little doubt that future climate change will have profound effects on species conservation and management. Grassland ecosystems and many grassland-dependent birds are particularly vulnerable to rapid shifts in climate variability and associated changes in drought and extreme weather events. For grassland birds, climate change is likely to exacerbate environmental threats such as habitat loss due to shifting agricultural practices and housing sprawl. Our goal was to identify how certain grassland bird species are sensitive to climate variability and which regions have the highest level of exposure to future climate change. To do so, we convened a core group of managers to identify vulnerable grassland bird species, developed models to estimate how climate change may impact future grassland bird populations, and identified how current grassland bird management and conservation might lessen the impacts of future climate change impacts. Using this approach, we successfully organized an initial meeting of managers and identified two species, Henslow's Sparrows and Bobolinks, as species that are of managerial interest and may be vulnerable to changes in temperature and precipitation. We uncovered an important climate-demography linkage for Henslow's Sparrows and Bobolinks: summer precipitation, and to a lesser degree, temperature positively affected nest success. We found that future climatic conditions—primarily changes in rainfall—will likely contribute to reduced population persistence and range contraction for many grassland birds. However, many of these future changes can be lessened through grassland management and conservation. Large grassland patches, the most common metric of grassland conservation, appear to moderate the effects of weather on grassland birds and could be an effective component of climate-change adaptation.

SECTION 3. PROJECT SUMMARY: The management and conservation of grassland systems and their dependent species often focuses on habitat protection and restoration, but there is growing recognition that grassland bird densities and reproductive performance are sensitive to climate variability such as drought, heat waves, and flooding. Consequently, continuing climate change will affect the efficacy of current grassland bird management, and conservation efforts must account for this future variability and the landscape context in which conservation occurs. Our goal was to develop a Climate Change Vulnerability Assessment (CCVA) framework for identifying demographic sensitivities of grassland birds to past and future climate variability in their breeding habitat thereby providing guidance on the future management and selection of grassland conservation areas. Our objectives included 1) developing a partnership among managers and researchers to identify climate-change vulnerable grassland bird species of managerial concern; 2) building a demographic database for a candidate group of grassland bird species; 3) developing spatially-explicit and temporally dynamic species distribution models for select grassland birds parameterized based on demographic sensitivities to past and future climate variability and site-specific information on land-use change, and 4) evaluating current "on-the-

ground" prairie and grassland management practices and the placement of existing and proposed conservation areas relative to future climate change. We created a database of available demographic parameters for our selected grassland bird species (Henslow's Sparrow and Bobolink). We estimated relationships between demographic rates and climate and land-use both through statistical modeling (e.g., survival analysis) and from published studies. These relationships were used to parameterize spatially explicit demographic models within an individual-based, stochastic simulation framework (using the HexSim software platform). Using this approach, we produced demographically-informed species distribution maps projecting spatiotemporal variation in population characteristics and the relative impact of future climatic and land-use variability on these characteristics in different regions over time.

SECTION 4. Objectives, Approach, and Findings

Purpose and Objectives:

Our project addresses Science Theme 5 (Priority 5) of the Northeast Climate Adaptation Science Center by studying the effects of climate change and environmental stressors on prairie ecosystems with implications for adaptive management of grassland bird communities, and further addresses national CASC science priorities by advancing the science of climate change vulnerability assessments and producing regional-scale science products that inform conservation and management.

Objective 1: Develop a strong partnership among managers and researchers to understand how climate change could be accounted for in conservation and management planning for grassland birds throughout the NE CASC region. This partnership will be tasked with building a demographic database for a candidate group of grassland bird species. **Product:** We organized a stakeholder meeting and identified candidate species.

***Objective 2*:** Develop spatially-explicit and temporally dynamic species distribution models for a select group of grassland birds, which will be parameterized based on demographic sensitivities to past and future climate variability and site-specific information on land-use change. **Product:** We developed models for Henslow's Sparrows and Bobolinks. The Henslow's model was published and the Bobolink model is ongoing as of 31 Oct 2018.

Objective 3: Evaluate current "on-the-ground" prairie and grassland management practices and the placement of existing and proposed conservation areas relative to future climate change. **Product:** We were not able to employ various grassland management scenarios as part of our models. The models are spatially-explicit, however, and will allow for managers to use predictions for purposes of regional conservation. We also completed a meta-analysis to quantify the effects of managing grassland patch size on mediating the impacts of extreme weather on grassland bird demography.

Organization and Approach:

Demographic Databases and Climate Sensitivity

We focused our population modeling efforts on two species: Henslow's Sparrow and Bobolink. These species were chosen based on group input and the availability of appropriate demographic data. We completed the models for Henslow's Sparrow and have a manuscript describing the results of the model published in Landscape Ecology (McCauley et al. 2017). We found that Henslow's Sparrow nest success is sensitive to breeding season temperature and especially, precipitation. We found that the demographic niche of the species is concentrated in the southwest portion of the range and that future climate change is expected to further concentrate the demographic niche in the same region. We completed the statistical models for Bobolink based on input from our scientific advisory board, nest success predictions were made throughout the range, and we are calibrating the demographic models. We have developed a database of daily nest survival for multiple grassland species and developed models combining those data with climate and land use information. We found that across a dozen species, interannual changes in temperature and precipitation influences nest success, but these effects are mediated by grassland patch size. A manuscript of these results was published in Conservation Biology (Zuckerberg et al. 2018).

In the future, we will continue calibrating the demographic model in HexSim for Bobolink and run initial models for the past to present years (contemporary period). We will draft a model assessment approach with independent occurrence

information and revise the models as necessary. We have two additional objectives for the Bobolink models. First, we will explore whether model-based outputs of Bobolink persistence can be used in conjunction with existing layers for grassland bird conservation in the US to test for important overlaps. Second, we will use the climate-demographic relationships to evaluate patterns of demographic velocity for multiple grassland birds in the US. No additional funds have been secured for this work, but the model is developed and we are attempting to move forward with an analysis.

Project Results, Analysis and Findings:

Grassland Bird Climate Change Vulnerability Assessment Meeting

On Dec 4-5, 2013, a group of NE CASC-funded scientists met in Madison, WI, with managers involved in grassland bird conservation to begin building a demographic database for a select group of grassland bird species. The purpose of this meeting was to gather collaborators for the NE CASC-funded "Fitting the climate lens to grassland bird conservation: Assessing climate change vulnerability using demographically informed species distribution models" project. In attendance at the meeting were Christine Ribic (co-PI; USGS/UW Madison), Benjamin Zuckerberg (co-PI; USGS/UW Madison), Lisa McCauley (project postdoc; UW Madison), James Ellis (IL Natural History Survey, Prairie TAG Coordinator for ETPBR LCC), Scott Hull (WI DNR), David King (US Forest Service), Katie Koch (participating remotely; US FWS), Melinda Knutson (US FWS), David Lorenz (UW-Madison), Lars Pomara (UW Madison), Rosalind Renfrew (Vermont Center for Ecostudies), David Rugg (US Forest Service), David Sample (WI DNR), Susan Skagen (USGS), Gwen White (ETPBR LCC Science Coordinator), Tom Will (US FWS).

Goals for this meeting included: (1) establishing relationships among collaborators and project leaders; (2) reminding collaborators of the project objectives/goals; (3) selecting and prioritizing model species; (4) discussing climate sensitivities of grassland birds; (5) gathering information about demographic data for grassland birds to begin building the demographic database; and (6) discussing current grassland bird projects and management and how this project can inform those projects. We selected and prioritized indicator grassland bird species: (1) Henslow's sparrows; (2) Prairie chicken; (3) Bobolink; and (4) Horned Lark. We discussed specific sensitivities of grassland birds to potential climate change and the vital rates to include in models. Collaborators suggested that land use change will be an important part of any future modeling and we discussed the possibilities of incorporating scenarios of future land use changes (e.g. a conservation-minded future, a biofuel-centric future, a business-as-usual future). We gathered a list of potential demographic datasets and the contact information for the gatekeepers of those datasets. Each participant in the meeting discussed the ongoing grassland bird projects in their region and potential ways that we could intertwine this project with those. General conclusions were that this project may be useful from a regional conservation planning scale but may not be able to provide information for on-the-ground management. We also discussed data management and the consequences of using other people's data, how we will be archiving the data for this project, and options available for data archiving. We ended the meeting with action items that included creating a data agreement to provide data gatekeepers when we request use of their data. We agreed to include language to suggest the Avian Knowledge Network serve as gatekeepers to archive the data because our project will only archive summaries and estimates from gathered datasets. The project leaders agreed to investigate the possibility of using land use change scenarios in the project and potential datasets for this. Finally, we agreed that future communication among the group will be on an as-needed basis. Project updates will be made via email and future conferences will be conducted as collaborator input is required.

Climate Change Vulnerability Assessment of Henslow's Sparrow

Temperate grasslands and their dependent species are exposed to high variability in weather and climate due to the lack of natural buffers such as forests. Grassland birds are particularly vulnerable to this variability, yet have failed to shift poleward in response to recent climate change like other bird species in North America. However, there have been few studies examining the effect of weather on grassland bird demography and consequent influence of climate change on population persistence and distributional shifts. The goal of this study was to estimate the vulnerability of Henslow's Sparrow (*Ammodramus henslowii*), an obligate grassland bird that has been declining throughout much of its range, to past and future climatic variability. We conducted a demographic meta-analysis from published studies and quantified the relationship between nest success rates and variability in breeding season climate. We projected the climate-demography relationships spatially, throughout the breeding range, and temporally, from 1981 to 2050. These

projections were used to evaluate population dynamics by implementing a spatially explicit population model. We uncovered a climate-demography linkage for Henslow's Sparrow with summer precipitation, and to a lesser degree, temperature positively affecting nest success. We found that future climatic conditions—primarily changes in precipitation—will likely contribute to reduced population persistence and a southwestward range contraction. Future distributional shifts in response to climate change may not always be poleward and assessing projected changes in precipitation is critical for grassland bird conservation and climate change adaptation.

Meta-analysis: Effects of temperature and precipitation on grassland bird nesting success as mediated by patch size
Grassland birds are declining faster than any other bird guild across North America. Shrinking ranges and population declines are attributed to widespread habitat loss and increasingly fragmented landscapes of agriculture and other land uses that are misaligned with grassland bird conservation. Concurrent with habitat loss and degradation, temperate grasslands have been disproportionally affected by climate change relative to most other terrestrial biomes. Distributions of grassland birds often correlate with gradients in climate, but few researchers have explored the consequences of weather on the demography of grassland birds inhabiting a range of grassland fragments. To do so, we modeled the effects of temperature and precipitation on nesting success rates of 12 grassland bird species inhabiting a range of grassland patches across North America (21,000 nests from 81 individual studies). More precipitation in the preceding year were associated with higher nesting success, but wetter conditions during the active breeding season reduced nesting success. Extremely cold or hot conditions during the early breeding season were associated with lower rates of nesting success. The direct and indirect influence of temperature and precipitation on nesting success was moderated by grassland patch size. The positive effects of precipitation in the preceding year on nesting success were strongest in relatively small grassland patches and had little effect in large patches. Conversely, warm temperatures reduced nesting success in small grassland patches but increased nesting success in large patches. Mechanisms underlying these differences may be patch-size-induced variation in microclimates and predator activity. Although the exact cause is unclear, large grassland patches, the most common metric of grassland conservation, appears to moderate the effects of weather on grassland-bird demography and could be an effective component of climate-change adaptation.

Collaborations
Because we involved the US Forest Service Research Data Archivist in our project, we leveraged his expertise to develop and run a data management workshop for The Wildlife Society 2014 meeting. The Research Data Archivist revised the workshop and ran it again at the 2016 annual meeting to a larger audience. The 2014 workshop also resulted in the Sutter et al. (2015) publication which has had 16 citations and is in the top 25% of all research outputs scored by Altmetric. We leveraged our work by collaborating with Tom Will (USFWS) and Rosalind Renfrew (Vermont Ecostudies) to add a climate change component to the Bobolink Conservation Plan; specifically, we provided and wrote the text for the conceptual model for climate change impacts for the full annual cycle of the Bobolink that we developed as part of this project.

Conclusions and Recommendations:
Our research has provided novel advancements in the use of spatially-explicit and climate-informed demographic models for assessing the persistence of grassland birds under different climate change scenarios. These were significant advancements in species distribution modeling by incorporating demographic responses to weather and climate. We collaborated with various managers to help identify specific species and develop conceptual models identifying important climate-demographic linkages. In addition, we worked with climatologists to capture extreme weather events. These partnerships would not have been possible without the funding and support of the NE Climate Adaptation Science Center. By incorporating information on future climate change, we identified regions where Henslow's Sparrows, a species of increasing conservation concern, are likely to face unsuitable conditions for reproduction. In addition, we identified areas that will serve as likely refugia for this species in the future. We performed the first-ever exploration of the synergistic effects of weather and grassland patch size, the most common currency of grassland bird conservation and management. We found that large grasslands serve as an important buffer of extreme temperature and precipitation on grassland bird nesting success, which provided an additional rationale for focusing effort on increasing grassland patch size for grassland bird conservation. Future work should continue to focus

on the mechanisms driving climate-demographic linkages for grassland birds and future evaluation of grassland bird conservation areas.

Outreach and Products:

Publications

Zuckerberg, B., C.A. Ribic, and L.A. McCauley. 2018. Effects of temperature and precipitation on grassland bird nesting success as mediated by patch size. Conservation Biology 32(4): 872-882.

McCauley, L., C. A Ribic, L. Y. Pomara, and B. Zuckerberg. 2017. The future demographic niche of a declining grassland bird fails to shift poleward in response to climate change. Landscape Ecology 32(4): 807–821.

Sutter, R.D., S.B. Wainscott, J.R. Boetsch, C.J. Palmer, and D.J. Rugg. 2015. Practical Guidance for Integrating Data Management into Long-Term Ecological Monitoring Projects. Wildlife Society Bulletin 39(3):451–463.

Conference Presentations and Webinars

Zuckerberg, B. Climate Change Vulnerability Assessments. USFWS NCTC Climate Academy. 1 January 2017. [Invited]

Zuckerberg, B. Modern climate Change and wildlife populations: Understanding vulnerability and conservation in a novel future. Natural Areas Association Webinar, 23 August 2016. [Invited]

Ribic, C.A., L.A. McCauley, and B. Zuckerberg. Climate impacts on grassland bird demography are mediated by patch size. North American Ornithological Congress, Washington DC. 16-20 August 2016. [Invited]

McCauley, L.A., B. Zuckerberg, and C.A. Ribic. Assessing climate change vulnerability of grassland birds using demographically informed species distribution models. Tyson Research Center, Washington University, St. Louis, MO. 21 July 2016. [Invited]

Zuckerberg, B., C. Ribic, and L. McCauley. Assessing Climate Change Vulnerability of Grassland Birds Using Demographically Informed Species Distribution Models. Central Hardwoods Joint Venture technical committee. March 2016. [Invited]

Zuckerberg, B., C. Ribic, and L. McCauley. Assessing climate change vulnerability of grassland birds using demographically informed species distribution models. Northeast Climate Adaptation Science Center Webinar, Nov. 18, 2015. [Invited]

Zuckerberg, B. Sentinels of climate change. Earth Day Conference, Madison, WI, 22 April, 2014. [Invited]

Zuckerberg, B. Wildlife ecology in a changing climate. Joint Meeting Minnesota and Wisconsin State Chapters of The Wildlife Society, Duluth, Minnesota, 17-19 February, 2015. [Invited]

McCauley, L.A., B. Zuckerberg, C.A. Ribic. Assessing climate change vulnerability of grassland species using demographically informed species distribution models. Midwest Bird Conservation and Monitoring Workshop, Port Washington, WI. 4-8 August 2014. [Invited Plenary]

McCauley, L.A., B Zuckerberg, CA Ribic. Assessing climate change vulnerability of grassland species using demographically informed species distribution models. National Workshop on Large Landscape Conservation. Washington, D.C., 23-24 October, 2014. [Invited]

Zuckerberg, B. Climate change and wildlife. Forum on Climate Change and Wisconsin Hunting and Fishing, Baraboo, WI, 1 April, 2014. [Invited]

Workshops

As part of his collaboration with this project, the US Forest Service Research Data Archivist co-led an 8-hour workshop on “Data Management Fundamentals for Long-term Wildlife Studies” at The Wildlife Society meeting in Raleigh, NC on Saturday October 15, 2016. He and his two co-presenters discussed the elements of data management plans, including QA for field data; the importance of writing high quality metadata for the study team and other users; what high quality metadata consists of; and provided an exercise in learning the Metavist metadata program. There were 28 attendees at this workshop; more than twice as many as at the 2014 version of the workshop. Reviews from the attendees were highly complementary.

Databases

We produced demographic databases “Grassland Bird Daily Survival Rate Compilation” to “Grassland Bird Demographic Parameters Compilation”, input data input for “Grassland Bird Occurrence and Abundance Compilation” with potential

sources for the data (e.g., eBird, BBS). The Bird Occurrence and Abundance data sets and their associated metadata are publicly available (Cornell Lab of Ornithology), have institutional data quality checks (error-checking systems), and have no data use restrictions. Data used in the Zuckerberg et al. (2018) Conservation Biology paper was published in the data product: Ribic, C.A., McCauley, L.A., and Zuckerberg, B. 2017. Daily survival rates of grassland passerines and associated weather variables (1978-2013). US Geological Survey data release. https://doi.org/10.5066/F7028QQF

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