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Bird species richness in the Tuolumne River watershed over an elevational gradient: Effects of climate change and implications for conservation

Introduction

Bird ranges have shifted in response to climate change in the Sierra Nevada over the past 100 years (Tingley et al., 2012). Bird species vary in their climate sensitivity and ability to respond physiologically or behaviorally, so effects have been species specific (Langham et al., 2015). Bird ranges are subject to complex, interacting abiotic, biotic, and internal factors such as physiology, vagility, and life history, all of which affect ranges and therefore species richness. This paper will examine current drivers of bird richness by elevation in the Tuolumne River watershed and explore potential changes due to climate change. Lastly, the long-term viability of the most vulnerable species will be discussed.

Bird Richness in the Tuolumne River watershed

The Tuolumne River watershed comprises multiple habitat types over a 13,000-foot elevation change (BR – Park Ranger/Resource Management and Science Liaison, 2013). The lower reaches of the Tuolumne are a patchwork of riparian forest, foothill grassland, wetlands, agriculture, and urban environments. Habitats in this area have been fragmented by human activity, negatively affecting species like the Chipping Sparrow but benefiting others like the Brown-headed Cowbird (Beedy and Pandolfino, 2013). Common species include Acorn Woodpecker, American Kestrel, California Scrub-Jay, and European Starling (Beedy and Pandolfino, 2013). The next highest habitat types, found between 2,000-8,500 feet, are mixed conifer and pine-oak forest. This band of habitats is altered by periodic fire regimes which change tree density, habitat heterogeneity, and prompt new vegetation growth, which also affect local bird species composition. Common species in this zone include evergreen-loving species such as Cassin's Vireo, Pileated Woodpecker, and Steller's Jay. The highest habitat type is the alpine zone at over 8,500 feet, where climate and soil conditions are too harsh for all but the hardiest grasses and shrubs to survive. These areas are seasonally active and support breeding species such as Calliope Hummingbird, Mountain Bluebird, and Horned Lark. Another important habitat type found within the mid-elevation and alpine zones is wet meadows. Like fell-fields, meadows are seasonally active and dominated by grasses, but meadows are also bounded by forest. They support forest edge species such as Willow Flycatcher, Red Crossbill, and Mountain Chickadees (Loffland et al., 2011). In general, species richness decreases with elevation in the Sierra Nevada (Tingley and Beissinger, 2013). Many species can be found in multiple habitat types across the Tuolumne watershed; their ranges are shaped by interspecies interaction, vagility, severity of winter conditions, and, more recently, by shifting climatic conditions (Purcell, 2002).

Effects of Climate Change

Every species is constrained by a suite of physiological limitations that define the range of climatic conditions that it can tolerate (Tingley et al., 2009). This condition is called the "climatic envelope" or "climatic niche," and it plays a significant role in shaping species distributions. Climatic niches expand or contract when abiotic factors alter the weather patterns of an area, causing species to emigrate newly-unsuitable areas and colonize newly-suitable ones. A Tingley et al. 2009 survey found that 90% of Sierra species ranges have shifted upslope or downslope since 1911, evidence of a large-scale, multispecies climatic niche shift triggered by global warming.

Temperature is one of the most important factors in the climatic niche because it exerts physiological stress on individuals. Since the original 1911 Grinnell surveys, temperature increased between by 1-2 degrees Celsius on average across the Sierra Nevada (Tingley et al., 2012). Warming occurred uniformly in the Central and Southern range, but the Northern range experienced warming at low elevations and cooling and higher elevations (Tingley et al., 2012). A few species such as Anna's Hummingbird and Hutton's Vireo have already increased in elevation since the 1970s because of warmer temperatures (Beedy and Pandolfino, 2013). Sierra Nevada species are predicted to move upslope on average to cooler habitat to escape rising temperatures at low elevations (Siegel et al., 2014).

Changing precipitation is another driving factor in altitudinal migration. Climate change in California alters the proportion of precipitation falling as rain rather than snow, frequency of winter floods, spring snowmelt runoff timing, and increases the risk of prolonged drought, all of which affect Tuolumne habitats (Siegel et al., 2014). The interaction between temperature and precipitation is complex, highly dependent upon local topography, elevation, and climate. Temperature and precipitation trends are inverse along elevational gradients with precipitation increasing as elevation increases and temperature increasing as elevation decreases (Tingley et al., 2012). One resurvey of Sierra Nevada birds found that precipitation and temperature shifts were responsible for 82% of range shifts in the past 100 years (Tingley et al., 2012). Increasing temperature generally caused upslope migration because higher elevations provide respite from heat while increasing precipitation generally caused downslope migration. Birds sensitive to both temperature and precipitation clearly face a dilemma; indeed, the Tingley et al. 2012 resurvey found that some species' suitable habitat contracted in upslope and downslope directions concurrently since 1911.

Though temperature and precipitation are the most well-studied and influential factors, interspecies interactions and phenology can also be significant depending on the species. Plant communities and corresponding fire regimes, for example, are changing in response to shifting temperature and precipitation patterns, too, which affects bird distributions indirectly (Santos et al., 2014). Recent surveys suggest that plant communities in California have shifted since the 1930s because of increased precipitation at higher elevations (Crimmins et al., 2011). Conversely, extreme heat and reduced precipitation during drought years stress trees during the summer, drying out forests and drastically raising the risk of wildfire. Wildfires—shown to be migrating altitudinally in response to warming—alter plant communities, thereby compounding the effects of shifting plant distributions on animal ranges (Ferreira Dos Santos et al., 2015). Counter to expectations, bird species in the mixed-conifer zone and forest-chaparral edge—such as Blue-gray Gnatcatcher and Dusky Flycatcher—may benefit from increasing fire frequency because it drives greater heterogeneity in stand size, age, and species composition (Beedy and Pandolfino, 2013; Tingley et al., 2016).

The sheer amount of variation in species responses to temperature, precipitation, and other factors demonstrates the need for a species-specific approach to conservation in the Tuolumne.

The Most Vulnerable Species

A "climate-sensitive species" is defined as one likely to lose 50% of suitable winter or summer habitat due to climate change effects by 2050 (Langham et al., 2015). A comprehensive vulnerability assessment by Siegel et al. 2014 found that individual species vulnerability is somewhat tied to habitat preference. Aquatic species such as Common Merganser, American Dipper, Bald Eagle, and Osprey, despite their current ubiquity, are at-risk because the riverine habitats they rely on are directly impacted by changing snowpack (Beedy and Pandolfino, 2013). Species restricted to a climate-vulnerable habitat such as Gray-crowned Rosy Finch were found to be most at risk of population decrease due to climate change because of their own and their habitat's narrow climatic niche is threatened by diminishing climatic suitability (Langham et al., 2015). Alpine species such as White-tailed Ptarmigan are particularly vulnerable because, unlike low- and mid-elevation habitats, alpine habitats cannot expand to escape warming temperatures, they can only retreat over an already-limited area over time (Beedy and Pandolfino, 2013; Siegel et al., 2014).

Climate change mitigation in the context of wildlife management remains controversial because of the uncertainty surrounding individual species responses and the driving factors behind sensitivity (Langham et al., 2015). Additionally, there has been limited time and opportunity to rigorously study individual methods within that period. The Tuolumne and surrounding areas are classified as low-change areas with a low projected species turnover (9-14% of summer species and 12-16% of winter species, compared to 53% of total species in North America) even under the highest emissions scenarios, so the need for climate change mitigation is less dire relative to other North American regions (Wu et al., 2018; National Park Service, 2018; Langham et al., 2015). That said, there are a few approaches currently being considered in the Sierra Nevada.

The National Parks Service, 2018 climate assessment recommends managers in low-change regions focus their efforts on habitat restoration and maintaining disturbance regimes, while considering species-specific solutions when possible. One important early step is to assess the which species are especially vulnerable. Yosemite National Park's conservation efforts will focus on protecting the habitat of 16 climate-sensitive species because the park's low climate status will likely render it a future climate refugia. This includes birds whose winter and/or breeding ranges are increasingly unsuitable, including Red Crossbill, White-headed Woodpecker, and Gray-crowned Rosy-Finch (National Park Service, 2018). A key part of protecting climate-sensitive species is long-term monitoring, which allows managers to track positive and negative population trends, and quickly implement effective adaptive management practices.

There is no panacea for climate-sensitive species, which presents a challenge for managers in the Tuolumne. But these species' prospects for long-term persistence in the Tuolumne can be improved by immediate action: individual species prioritization and population monitoring, in addition to restoring current and future suitable habitat for climate-sensitive species are the most effective tools of conservation currently at our disposal. The Tuolumne watershed may lose species and gain species, but its status as a future climate refugia positions it as an important area for climate-sensitive species that necessitates protection and investment on the part of wildlife management.

1522/1500 words

Literature

1. Beedy EC and Pandolfino ER. Recent Trends in Sierra Bird Populations and Ranges. In: *Birds of the Sierra Nevada: Their Natural History, Status, and Distribution*, pp. 28-36. University of California Press: Berkeley, CA. 2013.
2. BR – Park Ranger/Resources Management and Science Liaison. 2013. *Lyell Glacier*. Retrieved May 19, 2018 from https://www.nps.gov/yose/blogs/lyell-glacier.htm.
3. Ferreira Dos Santos MJ, Thorne J, and Moritz C (2015). Synchronicity in elevation range shifts among small mammal and vegetation over the last century is stronger for omnivores. *Ecography*, 37: 1-13.
4. Langham GM, Scheutz JG, Distler T, Soykan CU, Wilsey C (2015). Conservation Status of North American Birds in the Face of Future Climate Change. *PLoS ONE*, 10(9): e0135350.
5. Loffland HL, Siegel RB, and Wilkerson RL. 2011. *Pre-restoration bird surveys on meadows of Stanislaus National Forest and Yosemite National Park*. International Institute for Bird Populations. Point Reyes, CA. http://birdpop.net/docs/bird_meadows_2010report_yose_stani.pdf.
6. National Parks Service (2018). *Birds and Climate Change: Yosemite National Park*. [PDF]. Retrieved from https://www.nps.gov/subjects/climatechange/upload/YOSE_2018_Birds_-_CC_508Compliant.pdf.
7. Purcell KL. 2002. Abundance and Productivity of Birds Over an Elevational Gradient. In: Verner, Jared, tech. editor. Proceedings of a Symposium on the Kings River Sustainable Forest Ecosystem Project: Progress and Current Status. Gen. Tech. Rep. PSW-GTR-183, Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture: 121-132. https://www.fs.fed.us/psw/publications/documents/psw_gtr183/psw_gtr183_014_purcell.pdf.
8. Siegel RB, Pyle P, Thorne JH, Holguin AJ, Howell CA, Stock S, and Tingley MW (2014). Vulnerability of birds to climate change in California's Sierra Nevada. *Avian Conservation and Ecology*, 9(1): 7. http://dx.doi.org/10.5751/ACE-00658-090107.

9. Tingley MW, Monahan WB, Beissinger SR, and Moritz C (2009). Birds track their Grinnellian niche through a century of climate change. *Proceedings of the National Academy of Sciences*, 106(Supplement 2): 19637-19643. https://doi.org/10.1073/pnas.0901562106.
10. Tingley MW, Koo MS, Moritz C, Rush AC, and Beissinger SR (2012). The push and pull of climate change causes heterogeneous shifts in avian elevational ranges. *Global Change Biology*, 18(11). https://doi.org/10.1111/j.1365-2486.2012.02784.x.
11. Tingley MW and Beissinger SB (2013). Cryptic loss of montane avian richness and high community turnover over 100 years. *Ecology*, 94(3). https://doi.org/10.1890/12-0928.1.
12. Tingley MW, Ruiz-Gutiérrez V, Wilkerson RL, Howell CA, and Siegel RB (2016). Pyrodiversity promotes avian diversity over the decade following forest fire. *Proceedings of the Royal Society B*, 284(1840).
13. Wu JX, Wilsey CB, Taylor L, and Schuurman GW (2018). Projected avifaunal responses to climate change across the U.S. National Park System. PLoS ONE 13(3): e0190557.