

Application for the *Earth Scholar Award*

Title: Mechanisms underlying the interactive effect of temperature spikes and land cover on nesting birds

Applicant: Katherine Lauck, kslauck@ucdavis.edu

Program and position: Graduate Group in Ecology PhD candidate, 4th year

Major advisor: Daniel Karp, dkarp@ucdavis.edu

The interactive effects of climate change and habitat conversion to agriculture constitute the primary threats to terrestrial wildlife (1, 2). Efforts to increase biodiversity in agriculture, such as planting polycultures, may allow more species to thrive in human-dominated landscapes.(3) However, as climate change progresses, human-dominated landscapes may expose birds to more severe temperature extremes because converting forested land to agriculture removes trees that insulate the understory from ambient temperature (4, 5). Thus, climate change may compromise our ability to sustain species in human-dominated landscapes in the future.

In bird species with altricial young, nestlings are ectothermic, so both low and high temperatures divert energy from growth to thermoregulation (6). Especially in hot ecosystems, climate change-driven temperature spikes induce nest failure and can even cause population collapse (7). Our results from an analysis of Cornell University's NestWatch database (N=152,863 nesting attempts across 58 species) show that, across North America, unusually high temperatures lower nesting success in agriculture but increase it in forests (8). This suggests that maintaining a shaded canopy may be essential for weathering temperature extremes. Importantly, nestlings can survive heat waves by using more energy to thermoregulate, but this may increase stress, decrease growth, and lead to lower survival (9). Furthermore, heat waves may reduce food provisioning to nestlings, either by forcing adults to spend more energy thermoregulating or by reducing prey availability (10). My work investigates the relative contributions of thermoregulation challenge and food provisioning to nestling growth under temperature spikes across four land covers: natural open canopy (grassland), natural closed canopy (riparian forest), agricultural open canopy (row crop), and agricultural closed canopy (orchard). We are testing four hypotheses:

Hypothesis 1. Forests (and to a lesser extent, orchards) insulate the understory (and associated bird nests) against high temperatures. Therefore, internal temperatures of nests in forest will be coolest, followed by orchards, then grasslands, and finally row crops.

Hypothesis 2. Lack of thermal buffering in open-canopied land covers may leave nestlings more vulnerable to hyperthermia, which can elevate stress hormones (i.e., cortisol) in nestlings.

Hypothesis 3. Lack of thermal buffering in open-canopied land covers may force parents to decrease foraging time to meet thermoregulatory demands when temperatures spike.

Furthermore, in human-dominated land covers (i.e. orchard and row crop), lack of natural vegetation and pest management practices may reduce overall insect availability. Thus, declines in food provisioning (in response to temperature spikes) will be most severe in agriculture.

Hypothesis 4. Because nestling cortisol concentrations will be highest and provisioning rates will be lowest in row crop agriculture when temperatures spike, nestling growth and survival will also be most sensitive to temperature spikes in agriculture.

Methods: To address these questions, I am monitoring Tree Swallow and Western Bluebird nest boxes in four land cover treatments: row crops, orchards, grasslands, and high canopy cover riparian forests. Both species nest in nest boxes in all four studied land covers. Birds in this area

regularly experience temperatures over 40°C, making this system ideal for studying whether closed canopies can buffer nesting birds from temperature spikes. We collaborated with the Museum of Fish and Wildlife Biology at UC Davis (MFWB) to set up at least 10 nest boxes in four sites of each of four land cover types (16 total sites; $n = 230$ nest boxes total).

In April-August 2021, we selected ~20 active nests per habitat type for monitoring (~20 boxes/habitat * 4 habitats; $N = 71$ boxes monitored). We placed temperature loggers inside and outside each nest to record temperature every 5 min from egg-laying to fledging. To track nestling growth and survival, we measured weight, wing chord, tarsus length, and bill length weekly. From these intensively monitored nests, we selected 2-3 per site to quantify food provisioning rates ($N = 19$ nest attempts monitored for food provisioning). To do so, we affixed a Raspberry Pi-based motion-activated camera (Phillips et al., in press) to boxes and will quantify hourly food provisioning via an image recognition algorithm to identify adult arrivals.

In 2022, we repeated this study design, this time monitoring 161 nests. In addition, to quantify nestling stress physiology, we collected blood samples from each nestling in intensively monitored nests twice during the nesting period ($N = 263$). We also captured females during the incubation period using flap-traps and collected a small blood sample to account for maternal effects on hormone levels. At each sampling occasion, we collected two blood samples, one from each wing, to compare baseline and elevated stress levels. The first sample (baseline) was collected within 2 minutes of handling each nestling. Then, we held birds in cloth bags for 30 minutes until a second blood sample (elevated) is collected. Looking forward, we will use ELISA assay kits to quantify blood cortisol concentration.

In 2023, I plan to repeat this study design because we need to increase our sample size of camera-monitored nests for sufficient statistical power to distinguish land use effects. Specifically, I will only monitor as many nests concurrently as cameras ($N = 24$), so I expect to monitor no more than 60 nests over the nesting season. I expect to collect 600 blood samples ($60 \text{ nests} * 3 \text{ individuals/nest} * 2 \text{ samples/visit}$, plus 2 sampling rounds for $60 * 2$ nestlings), requiring an additional 15 ELISA assay plates ($600 \text{ blood samples} / 40 \text{ samples/plate}$).

I will apply generalized multilevel path models to differentiate among multiple mechanisms by which temperature and habitat types may affect avian fitness. Specifically, I will build models to determine whether the effects of temperature spikes vary by land-use type, and ultimately affect nestling growth/survival via changes in nestling physiology or changes in nestling food provisioning rates. Importantly, path models can be constructed to accommodate various error distributions of continuous, count, and binary responses (*e.g.*, food provisioning rates, nestling growth, survival; 11, 12). They can also account for spatiotemporal autocorrelation via modified error structures or random effects.

Significance: The findings of this study will advance our knowledge of the ecology of working landscapes by clarifying the mechanisms by which land cover and temperature spikes affect avian fitness. Understanding the relative contributions of thermoregulation challenge and reduced food provisioning to reproductive success under temperature spikes in agriculture and other land covers will provide concrete avenues through which working landscapes could be modified to better accommodate birds. If the direct effects of heat are more important than food-mediated effects, then planting or maintaining microclimate refugia (*e.g.* shade trees) in agriculture may buffer temperature. Nest boxes could be also modified to reduce their internal temperature (*e.g.* by painting them with white or reflective paint). Alternatively, if food-mediated effects predominate, then maintaining patches of non-crop habitats in working landscapes to support food resources and provide thermal refuges for parents may be more effective (13).

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