**Selma Herr Fund for Ornithological Research – Proposal**

**Project Title: Mechanisms underlying the interactive effect of temperature spikes and land cover on nesting birds**
**Applicant (WFCB PI Status): Daniel Karp**
**Participants (degree objective if student): Katherine S. Lauck (PhD)**
**Total Request:** $3,699.00 **New/Continuing Funding Request (circle one)**

The interactive effects of climate change and habitat conversion to agriculture constitute the primary threat 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 nests * 3 individuals/nest * 2 samples/visit, plus 2 sampling rounds for 60 * 2 nestlings), requiring an additional 15 ELISA assay plates (600 blood samples / 40 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, nesting 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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**Budget**

| Item | Quantity | Price | Total | Grant |
|---|---|---|---|---|
| 1. ELISA kits | 15 | $246.60 | $3,699.00 | Requesting from Selma Herr |

**TOTAL:** Grand total requested – $3,699.00

**Justification:**

1. ELISAs: As noted in the proposal, we will quantify physiological stress by assaying blood cortisol. We have already obtained all the necessary equipment and supplies for collecting blood. However, we still need to acquire ELISA kits to process samples. The

cost of an ELISA kit is $246.60 and it contains sufficient reagents to quantify stress hormones for 40 samples (including necessary controls). We plan to monitor 60 nests (N=24 cameras, 2.5 sampling rounds) and estimate an average of 3 birds per nest (including the mother). Thus, in total, we plan to sample 180 individuals. Each individual will be bled twice at each sampling occasion and nestlings will be bled twice over the nest period, for a total of two blood samples per adult and four per nestling. In total, we will need to assay 600 samples, and therefore require 15 96-well plate ELISA kits.

Daniel Karp
Faculty, Dept. WFCB
1073 Academic Surge
UC Davis

Dear Selma Herr family,

I, Dr. Daniel Karp, affirm and agree that:

1. All funds awarded will be expended by 1 March 2024;
2. A thank-you letter addressed to the Selma Herr family and explaining the project's results and value will be submitted to the Endowment Committee Chair by 1 March 2024; and
3. A project summary, including an accounting of funds expended, will be submitted to the Endowment Committee Chair by 1 March 2024.

Sincerely,

Dr. Daniel Karp

Katherine Lauck
PhD Candidate, Dept. WFCB
1071 Academic Surge
UC Davis

Dear Selma Herr family,

The research funded by your generous gift is the central experimental chapter of my dissertation. In this chapter, I will explore the mechanisms underlying why nest success of birds during heat waves is lowest in agriculture. Our analysis is in the beginning stages, but so far, we have demonstrated that nests in more open land covers (such as grassland and row crops) have higher internal temperatures than those in more closed land covers. These results will point to concrete conservation interventions that may increase resilience of bird populations living in multi-functional landscapes such as working landscapes.

In addition, the scientific infrastructure funded by your support is benefiting not just my own research, but the research of other young scientists involved in Dr. Karp's lab at UC Davis, including two undergraduate students this year. They will receive mentoring in proposal writing, analysis, and bird handling that will help prepare them for a career in wildlife research.
Thank you very much for your continued support.

Sincerely,

Katherine Lauck
kslauck@ucdavis.edu

**Progress report: Mechanisms underlying the interactive effect of temperature spikes and habitat conversion on nesting birds**

## 1 Background and significance of project

Habitat conversion to agriculture and ongoing climate change will determine the fate of biodiversity in the Anthropocene. Many forms of habitat conversion (e.g., agricultural expansion, urbanization) remove insulating tree canopies, thereby reducing local thermal buffering and exposing organisms to extreme heat. Temperatures on farms are often >10°C hotter than nearby natural sites. Both increased heat and less vegetation cover may accelerate evaporation, reducing water available to organisms for use in thermoregulation, and further exacerbating the effects of heat. Alternatively, irrigation on agricultural lands might compensate for water lost to evaporation. We might thus expect the effects of climate change on species living in natural and anthropogenic ecosystems to differ, given the vastly different thermal and water regimes present in each habitat. Physiological heat effects (i.e., overheating of nestlings) and food supply reductions are two main mechanisms through which heat might decrease the growth and survival of birds. Furthermore, we expect that irrigation and other sources of water will increase growth and survival of nestlings during hot periods.

## 2 Summer 2021-2022 activities

Our study leverages a large network of songbird nest boxes in California's Central Valley, established by the UC Davis Museum of Wildlife and Fish Biology (MWFB) in 2000 (i.e., the Putah Creek Nestbox Highway). Our focus is on the two most common nest box species: Tree Swallow and Western Bluebird, both of which nest in nest boxes in all four studied land uses. Birds in this area experience extreme temperatures while nesting, with temperatures regularly soaring over 40 degrees Celsius. The system is therefore ideal to study whether closed canopies buffer nesting birds from temperature spikes. Furthermore, the system stretches across a mosaic of natural and agricultural lands, allowing for the exploration of the role of irrigation and water availability in mediating the effects of heat.

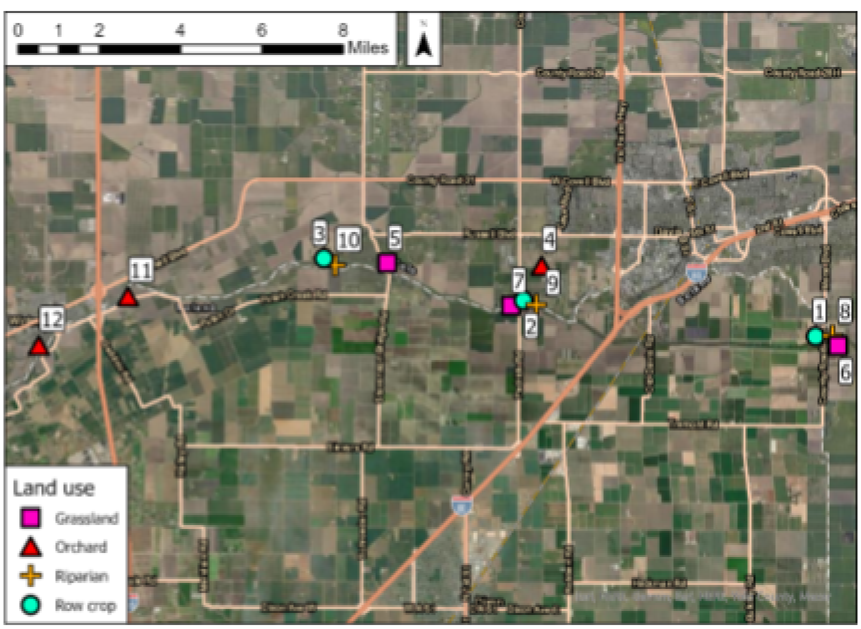


*Figure 1. Locations of sites. Each site encompasses at least 10 nest boxes, with some as many as 30.*

The MWFB maintains 165 boxes across 8 sites along Putah Creek. Most boxes are in riparian forest habitat, but two sites, with 10 boxes each, are in orchards. In 2021, we supplemented this main network with two existing grassland sites (~30 boxes each) located on City of Davis and Putah Creek Riparian Reserve (PCRR) land, both of which have been monitored for multiple years by members of the Patricelli lab at UC Davis. We also obtained permission from PCRR, UC Davis Foundation Plant Services, Russell Ranch, and the UCD-H.M. Clause Innovation Center to supplement the Nestbox Highway with five sites of ten boxes each: three sites in row crops, one in orchard, and one in grassland. In 2022, we added four sites of 10 boxes each with permission from Full Belly Farms.

In April-August 2021 and 2022, we visited all boxes weekly and recorded the contents of each box (nest status, contents, species, etc). From the occupied boxes, we selected ~20 active nests per habitat type for monitoring (N= 80 boxes; 20 boxes/habitat * 4 habitats; at end of season 2021, 71 boxes monitored; in 2022, 161 boxes monitored). We used a fisheye lens to take a standardized picture of the canopy cover at each box and placed temperature loggers inside and outside each nest to record temperature every 5 min from egg-laying to fledging. We also placed one relative humidity sensor per site to track water availability. To quantify nestling growth and survival, we visited active nests each week, hand-captured nestlings, and collected morphometric growth data (nestling weight, wing chord, tarsus length, and bill length). We tracked each individual nestling's growth by painting its nails with colored nail polish. One to two weeks prior to fledging, we affixed a small metal leg band to the nestling's leg. In 2022, we collected a small blood sample to quantify nestling stress. During Fall 2022/Winter 2023, we will quantify the amount of corticosterone (a stress hormone) in each sample. From these intensively monitored nests, we selected two to three per site to quantify food provisioning rates (at end of 2021 season, N = 19 nest attempts monitored for food provisioning: 5 in orchard, 6 in row crops, 3 in forest, and 5 in grassland; in 2022, N = 29). To do so, we affixed a Raspberry Pi-based motion-activated camera to the side or top of the box that saved videos 30 seconds before and after each motion activation. We will quantify hourly provisioning rate by using an image recognition algorithm to identify adult arrivals.

## 3 Significance

Understanding when and where physiological stress and reduced food supply contribute to decrease reproductive success under temperature spikes in agriculture and other land uses 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, providing shade trees in agriculture may buffer temperature spikes to some extent, or nest boxes could be modified to reduce their internal temperature (e.g. by painting them with white or reflective paint). 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. Furthermore, understanding the role that irrigation may play in mediating the effects of heat on wild birds living in agriculture could inform co-management of water resources for both wildlife and people. Finally, the findings of this study will advance our knowledge of the ecology of working landscapes by clarifying the mechanistic underpinnings of the fitness consequences of heat in working landscapes.

## 4 Expenses

| Category | Spending |
|---:|---:|
| Corticosterone assays | 3699 |
| Assay supplies | 195.35 |
| Bird bands | 322.5 |

## 5 Pictures

*One of the nestboxes we put up in early 2021.*

*A nestling peeks out of a nest box placed in agriculture. On the bottom of the box is one of the loggers used to record temperature and humidity.*