Firefly Conservation in Colorado: Citizen-Science and Artificial-Intelligence

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Fireflies are among our most cherished insects. Found on every continent except Antarctica, these bioluminescent beetles have captured the human imagination for centuries [1, 2]. Importantly, fireflies are thought to be a "canary in the coal mine" species, as they could be used as early warning signs for global biodiversity collapse [3]. And yet, in many places, they are declining. As is true for many invertebrates, fireflies have been largely neglected in global conservation efforts. While relatively few monitoring programs currently exist, a growing number of reports, backed by expert opinion, suggest that global firefly populations are indeed in trouble due to climate change and light pollution [4]. Fireflies have just recently been added to the International Union for Conservation of Nature (IUCN) red-list of threatened species[1]. Their recent report highlights the need to collect more information, especially for Data-Deficient fireflies in the western USA, and Colorado in particular. Current monitoring methods for firefly populations are manual and subjective, conducted by direct human observations using a stopwatch, roughly identifying their species, and estimating their densities. In contrast, we will use high-throughput techniques to automate the acquisition of firefly population surveys and species identification. Our novel strategy for recording flashing displays is accurate, simple, inexpensive, and appropriate for large-scale monitoring

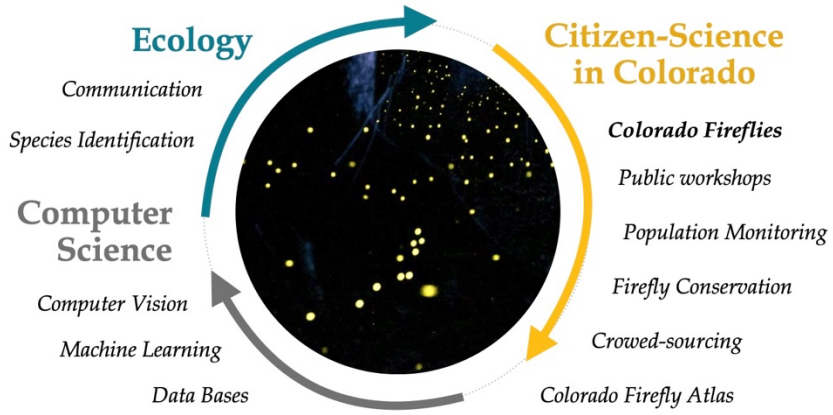

Figure 1: Proposal overview. An interdisciplinary team, bridging ecology, animal behavior, environmental conservation, and computer science to bring firefly conservation into the modern age and empower the next generation of researchers. Colorado, which is home to several endangered firefly species will be at the fore of our efforts.

programs [5-7]. By basing our firefly conservation citizen-science work in Colorado - which is home to several at-risk species - and illuminating the threats and evaluating the conservation status of firefly species, we seek the preservation of the magical lights of fireflies for future generations.

To automate the acquisition of firefly population surveys, we built an interdisciplinary team, bridging ecology, animal behavior, environmental conservation, computer science, and physics. Our team developed and tested a novel method for recording flashing displays that uses an optimization algorithm to estimate the cameras' relative positions, removing camera calibration requirements [8]. This new technology not only makes data gathering easier; it also allows us to crowdsource data acquisition. It will enable citizen scientists to use smartphones, GoPros, and other common camera devices to collect complex real-life data on firefly signal dynamics. Our tool allows us to track individual fireflies in 3D and concatenate individual flashes into trajectories, providing the exact flash pattern produced by individual fireflies. A high-throughput Machine Learning (ML) tool then analyzes the flash patterns to identify and monitor firefly populations. Since each firefly species has its unique species-specific flash pattern, we can

[1] Latest update to the IUCN Red List includes first global assessments for fireflies, with a spotlight on North America: https://www.xerces.org/blog/iucn-red-list-assess-fireflies

directly infer the species from its recorded flashes [1]. Citizen science is an essential vehicle for democratizing science and promoting the goal of universal and equitable access to scientific data and information. Indeed, data generated by citizen science groups have become an increasingly important source for scientists, especially in Biology and Ecology [9-12]. Our citizen science project will engage people of all ages in conservation efforts, bring more attention, conservation, and community awareness surrounding these species, and eventually lead to a bigger impact.

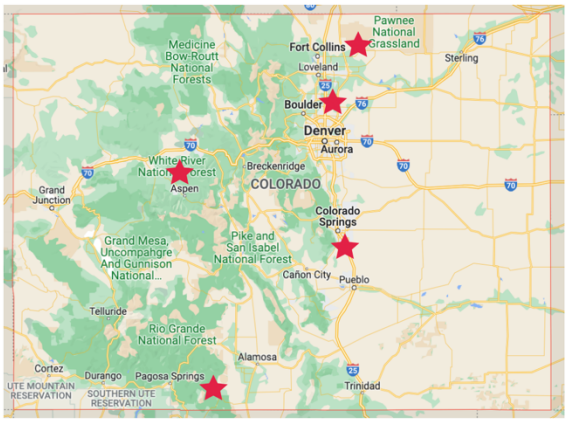

Figure 2: Colorado fireflies; Locations indicated by red star on the Colorado map.

The support of the Timmerhaus Fund will allow us to engage Colorado citizen-scientists in monitoring Colorado firefly species such as *Pyractomena dispersa*, *Photuris sp.,* and *Photinus pyralis* (Figure 2). To complement the crowdsourced data, my lab members and I will acquire recordings of these species (at least three nights per species) to train our ML species recognition system. By streamlining data acquisition with citizen scientists, we hope to record numerous firefly populations at multiple locations (an order of magnitude more than we could by ourselves) and eventually correlate local climate fluctuations and light pollution to the population levels of the recorded fireflies. In addition, engaging citizen-scientists with these firefly species, which have been observed across Colorado (as noted in [13] and by personal observations by the PI), could help illuminate the falsified myth that fireflies do not exist in Colorado and bring more awareness for the Colorado fireflies. Such crowdsourced information, vetted against our team's data, will serve as a ground–truth about firefly densities in natural habitats.

How citizen scientists will be recruited and selected. We will advertise our activities on three main fronts: (1) We will host local public lectures on firefly behavior and conservation, during which we will present the call for volunteers. (2) We will advertise at existing firefly conservation programs through our partnership with conservation organizations. And (3), we will make use of the many existing web tools to recruit citizen-scientists: from USA-wide organizations (e.g., Citizen-Science[2], SciStarter[3], and CitSci[4]), to Colorado-based mailing lists and organizations (e.g., Rocky Mountain Wild[5], Boulder Open Space Science at OSMP[6]). To select our volunteers, we will follow best practices from the literature on citizen-scientists [9-12], prioritize volunteers with accessibility to firefly populations in Colorado, and basic knowledge in camera operation.

What exactly will the citizen scientists do. In early spring (April-May), the citizen scientists will undergo standardized training with a detailed written protocol facilitated by short videos illustrating key aspects of the experimental procedure. In parallel, we will send the citizen scientists a kit (two cameras, tripods, and a hard drive), to allow them to practice the recording at home. Next, the citizen scientists will record local Colorado firefly flashes in their vicinity and upload the data to the hard drive. The firefly density measurement technique is inherently versatile and easy to deploy in the field. At the end of the firefly season (September), the citizen scientists will send us back the kit (using pre-paid postage), including the

[2] Citizen-Science is an official government website for citizen science across the U.S. https://www.citizenscience.gov
[3] SciStarter is an NSF funded organization that recruits, trains, and equips citizen scientists https://scistarter.org/
[4] CitSci is a global citizen science support platform https://www.citsci.org/
[5] Community Science Projects, Rocky Mountain Wild https://rockymountainwild.org/community_science
[6] Community Science Projects, Boulder CO https://bouldercolorado.gov/science-osmp

hard drive with their recorded data. My lab members and I will then process the recording using the software we developed and compile all data into a substantial database relating monitored firefly populations to environmental stressors in Colorado.

How many people will be affected by this funding, and for how long. Our crowdsourcing distributed approach for firefly conservation will provide ample opportunities to train a diverse next generation of scientists and engage people of all ages in conservation efforts. In the short term, this work will directly affect our volunteers (at least 15 volunteers enabled by this grant) and their families and friends. In the long term, this work could affect millions of people. Establishing a program for Colorado-specific and US firefly monitoring can serve as a successful example of firefly conservation in other states and countries that could apply the same methods. As fireflies are among our most loved insects, their conservation efforts could also ignite interest in the biodiversity of other insects and organisms worldwide. If the dozens of nights that we have spent recording firefly displays have taught us anything, it is that fireflies are a topic of universal fascination among both children and adults. We will hold open events to present our work, take questions from the community at some of our experimental sites, and introduce groups of elementary school-aged children from rural communities to the wonders of fireflies. By revealing the details of firefly behavior, we hope to open a whole new world of questions and reflections and enhance the firefly experience for the broader public, bring firefly conservation into the modern age and empower the next generation of researchers.

Connection to the Timmerhaus Ambassadors program. This proposal emphasizes public outreach in Colorado through citizen-science engagement and public lectures. In addition to the strong engineering flavor of the work, finding and recording fireflies in their natural habitat aligns well with Timmerhaus's passion for outdoor activities ("running, skiing, and later race walking") [14]. The PI, a teacher-scholar at heart[7], has a strong public outreach record. She will create an engaging program accessible to the layperson in Colorado and beyond.

Budget. We request a total of $49,754 for the following: $19,754 for a part-time lab assistant (25 hours per week) to analyze the data and create an online free database (for the crowdsourced data); $5K for organizing at least two workshops to recruit and educate citizen scientists (funds requested for space reservation, advertisements, and light refreshments); $15K for purchasing 15 firefly flashes recording kits (each kit has two cameras, tripods, and a hard drive); $10K for fieldwork (building a ground truth database for firefly species-specific behavior); Please see a more detailed budget spreadsheet attached, for more specific information about salaries and fringe benefits.

References

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