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CONTRIBUTIONS TO ENTOMOLOGY

SENCKENBERG

Methods

The Caddisfly Collective: Methods of assessing Trichoptera diversity on a continental scale with community scientists*

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Abstract

Amidst a global biodiversity crisis, collecting data at large spatial scales can illuminate patterns. Community science can be an avenue to reduce costs, broaden the scope of sampling, and, most importantly, connect with members of the public who are interested in and impacted by long-term ecological change. In 2021, we formulated a community science project – The Caddisfly Collective. Our goal was to study the regional influences on the responses of stream caddisfly (Trichoptera) communities to urbanization in the United States and Canada. Community scientists helped us achieve this goal by collecting caddisflies across a wider geographic scale than we could have reached on our own. To build The Caddisfly Collective, we recruited participants through social media and other online forums. We mailed collecting kits with a USB-powered ultraviolet LED light, a collecting container, bottles of preservative, data sheets, and collection labels to each participant; participants mailed back specimens and completed data sheets. There was a 79.7% rate of follow-through from sign-up to collection. During the project, 63 participants set up light-traps near urban and non-urban streams in seven different North American geographic regions, collecting adult caddisflies at 141 sites across the United States and Canada. Most sites were in the Midwest region, while the fewest sites were in the Far North region. Urban areas, classified by land cover data, comprised ~29% of total sites. We hope the details of our project can help other interested scientists implement similar projects in the future, especially focused on ecologically important caddisfly communities.

Key Words

aquatic entomology, citizen science, community ecology, community science, public participation in scientific research, urban ecology

Introduction

Reports of insect declines around the world (Wagner et al. 2021) have spurned both public concern and desire to contribute to solutions (Felgentreff et al. 2023). Community science is a large area of research in which members of the public participate in scientific activities, and a wide range of projects have benefitted from this model (Shirk et al. 2012; Bonney et al. 2016). There is a spectrum of ways in which non-professionals can be involved in research projects, from data collection, to project design, to the interpretation of results (Danielsen et al. 2021). Community science can give researchers the opportunity to connect with groups of people with a vested interest in their local environment and empower participants (Danielsen et al. 2021; Vance-Chalcraft and Jelks 2023). In many cases, the first-person experience of ecological change can be a very valuable addition to scientific research (Tengö et al. 2021). To clarify, "community science" is becoming the preferred, more inclusive term over the previous, commonly used moniker, "citizen science" (Ellwood et al. 2023).

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There are many types of ecological projects to which community science is well-suited. For example, water quality monitoring is typically of great interest to local communities concerned about their environment (e.g., Vance-Chalcraft and Jelks 2023). Indeed, Poisson et al. (2020) reported that the majority of long-term monitoring of lakes in some parts of the United States is the result of efforts by community scientists. Additionally, in the growing field of urban ecology, community science has yielded insights into diverse subjects such as the abundance of native lady beetles (Gardiner et al. 2021), diversity of native and exotic ant species (Lucky et al. 2014), predation and parasitism in lizard populations (Putman et al. 2021), and the frequency of human-coyote encounters (Mowry et al. 2021) in cities.

Some researchers may avoid implementing community science projects due to concerns about data quality or to avoid this criticism from colleagues and reviewers (Riesch and Potter 2014; Elliott and Rosenberg 2019). This can be a valid concern; when it comes to species identification and documentation in the field, professionals will likely have higher accuracy rates (Crall et al. 2011), and non-professionals may be more likely to record larger, more charismatic individuals (Gardiner and Roy 2022). However, with thorough consideration of data, identification of biases, and careful study design, these issues can be accounted for (Crall et al. 2011). Even more important to consider may be that all humans, including scientists, can exhibit biases (Haraway 1988). For example, Ward□Fear et al. (2019) showed that in a collaborative research project in Australia, Indigenous Rangers were more adept at finding and recording lizards in cryptic conditions than their wildlife biologist counterparts.

Entomological research may be viewed as a challenge to adapt to community science methods because of the high diversity of insect species relative to other animal groups and the taxonomic expertise needed to distinguish them. However, this issue can be resolved by either conducting trainings or having community scientists collect and submit specimens to be identified by a taxonomist (or a combination of these methods). These approaches have been implemented with success by the School of Ants Project by Lucky et al. (2014) and the Buckeye Lady Beetle Blitz by Gardiner et al. (2021). These and other methods have resulted in a rich body of entomological work contributed by community science (e.g., Gardiner and Didham 2020; Gardiner and Roy 2022; Giannetti et al. 2023). Especially as insect declines continue to be reported (Sánchez-Bayo and Wyckhuys 2019; Hallmann et al. 2020; Wagner 2020), community science efforts can be a significant source of urgently needed data (Gardiner and Roy 2022).

Here, we describe the implementation of a contributory community science project studying Trichoptera diversity in rivers of the United States and Canada: The Caddisfly Collective. We were ultimately interested in how regional contexts can influence differences in Trichoptera community structure in urban and non-urban environments, which would require a wide geographic scale of sampling. However, because research travel was restricted during the first two years of the COVID-19 pandemic, we decided to explore the capacity of community science to address our question. The goal of our broader project is to contribute to our understanding of the importance of the region-specific context in attempts to mitigate detrimental effects of urbanization and preserve the integrity of freshwater ecosystems, though we do not present these results here; however, because we believe the details of the implementation of our community science project also may be useful to caddisfly (or other aquatic insect) researchers looking to both increase sampling area and incorporate public participation in their projects, we focus here on our experience recruiting participants, methods for creating and distributing collecting equipment, combining data from participants and public data repositories, and results of participation by the community scientists of The Caddisfly Collective.

Methods

Recruitment

To recruit participants for The Caddisfly Collective, we concentrated on social media (Twitter, Instagram, and Facebook) as a method to spread word of the project to interested people. We used email listservs to a small degree, especially to attract participation in particular underrepresented regions. We also asked those who saw our post to share it, so that even if they were unable to participate, they could help the project reach interested acquaintances. To attract attention, we developed a logo (Fig. 1), twitter page (@caddis_project), and website (https://caddisflycollective.com/). Our website included information about the project's background and goals, an introduction to the collecting procedures, links to relevant information on caddisflies and insect collecting, and a form to contact us or express interest in the project. The website included preliminary context for participating, such as the fact that collecting would be done in evening hours and need to be situated near a stream or river.

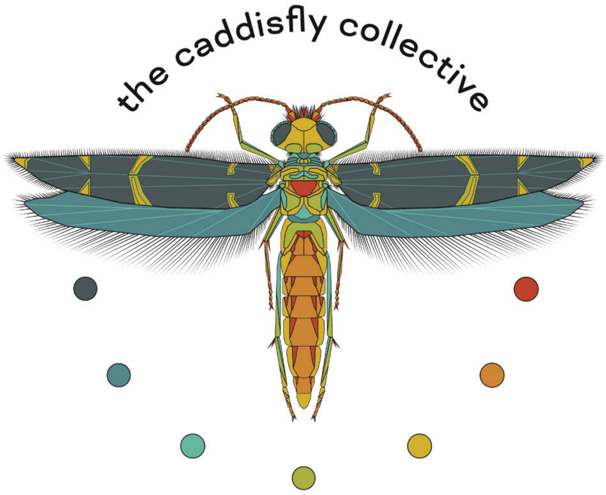

Figure 1. Logo designed for The Caddisfly Collective project, which was used on websites and social media to advertise the project and on stickers distributed to participants.

The process of signing up to participate in the project was completed in two parts. First, those interested filled out a form on our website to submit their email address for future communication, their general location (e.g., city or state/province), and their level of interest—for example, whether they were certain they would be able and willing to participate in the project, or if they were presently unsure but still interested. This allowed us to begin estimating the scope of the project and the amount of equipment needed. We responded to each submission and answered any initial questions about the project and procedures. Next, we asked all those who signed up initially to fill out a second form to submit the following information: 1) their mailing address for a collecting kit, and 2) the number of sites (between one and four) at which they planned to collect. To participate, we also asked prospective participants to read and agree to our project Terms and Conditions (Table 1).

Table 1. List of terms and conditions to which participants agreed prior to receiving their kit materials in the mail.

1.	Participants are volunteers and are not entitled to monetary compensation.
2.	At least one member of a participating group is over the age of 18 and agrees to be responsible for any children involved in collecting activities.
3.	Participants are responsible for their own safety. The Caddisfly Collective or any associated individuals or institutions are not responsible for any injury or damage that may be incurred while collecting data for this project.
4.	Participants agree to follow local, state/provincial, and/or federal laws and regulations, including (but not limited to) abstaining from trespassing on private or public land. Participants agree to check relevant guidelines in their area regarding the collection of insect specimens before collecting occurs.
5.	Participants' names, locations, and contact information will not be published or sold. Participants' names will not be publicly associated with locality data, though names or initials will be published in acknowledgements sections of academic papers and presentations, unless omission is requested by the participant.
6.	All taxonomic, specimen count, locality, and environmental data will be publicly available on an online repository following appropriate processing and will be associated with any publications resulting from this project.
7.	All photographs submitted to The Caddisfly Collective by participants may be published online, in academic papers, and in presentations.

Collecting

We categorized states and provinces of the United States and Canada into seven regions, generally following typical geographic designations: Far North, Midwest, Northeast, North Plains, Pacific West, Southeast, and Southwest (Fig. 2). For site selection, we requested that Caddisfly Collective participants select a spot adjacent to running water to collect adult caddisflies. We also requested that any participants collecting at two or more sites try to target one "urban" site and one "non-urban" site if possible. We maintained a flexible definition of urbanization, and we ultimately left site selection up to participants' judgement since the characteristics of urbanization can be relative

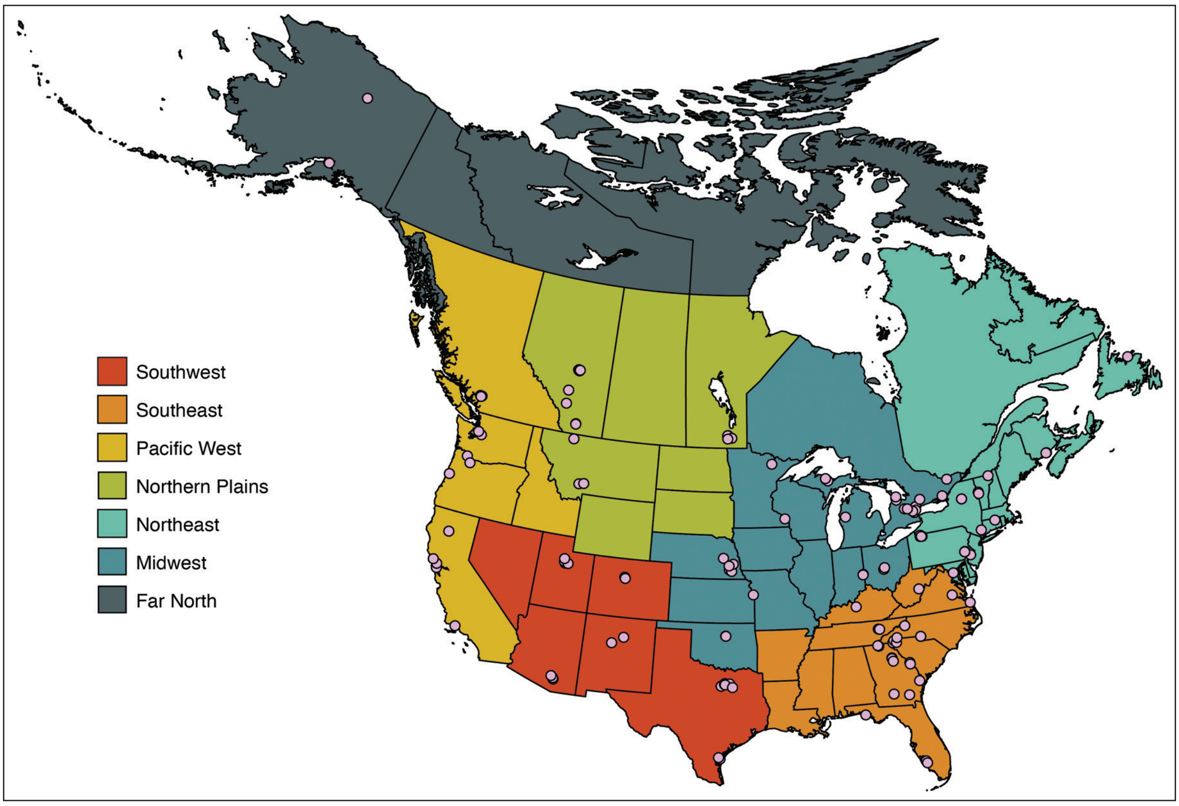

Figure 2. Regions of the US and Canada (n = 7) and sites (n = 141) where collections were completed by community scientists participating in the Caddisfly Collective in the summer and fall of 2021.

depending upon city size and geography. We also allowed for flexibility in timing; most participants collected in June, July, or August of 2021, but a few (such as those in warmer climates) collected into September and October due to better rain and temperature conditions in their local area.

Each participant who filled out the second information form was mailed a caddisfly collecting kit with supplies (Table 2). We constructed an ultraviolet (UV) light tube for each kit by wrapping a 12-watt, 5-volt UV LED light strip (e.g., White et al. 2016) around 1.25 cm wide PVC pipes at 30 cm lengths. The light strips had a waterproof coating, an adhesive backing, and a USB cord, which made it easy to use in the field with a mobile power bank. We asked participants if they already owned a USB power bank, and if not, we supplied one. We also included a 4.4 L plastic food storage bin as a container to capture caddisflies. Depending upon the number of sites each participant reported wanting to visit, we included 500 mL plastic bottles filled with propylene glycol sufficient to have one per collection site. We chose food-grade propylene glycol as a preservative because of its relative safety and reported efficacy in insect preservation for a variety of uses, including DNA extraction (Thomas 2008; Nakamura et al. 2020). Kits also included print outs of instructions for procedures before, during, and after collecting, data sheets (Suppl. material 1), data labels, a pencil, stickers with the caddisfly collective logo, and pre-paid and pre-addressed envelopes. The average cost per kit, including shipping costs within the United States, was $63.01 USD (Table 2).

Table 2. Price per collecting kit of all materials sent to participants of The Caddisfly Collective. The listed shipping fee is the average price for each domestically shipped kit.

Item	Price (USD)
LED light strip	15.00
PVC pipe	0.30
USB power bank	10.00
Propylene glycol	3.75
Sample bottle	2.67
Pencil	0.11
Pre-stamped envelope	8.55
Collecting bin	1.99
Shipping box	1.58
Cardstock paper	0.58
Shipping fee	18.48
Total	**63.01**

Participants were instructed to set up the light trap as close to a river as possible by placing the plastic bin on a flat surface, emptying a bottle of propylene glycol into the bin, and laying the UV light tube across the top of the bin. Once it got dark, participants could plug the light in and wait for adult caddisflies to fly into the preservative. After 30 to 60 minutes, participants could turn off the light and return the contents of the bin back to the plastic bottle. We suggested that participants could cut off the top of plastic drink bottle to use as a funnel on this step. No sorting of insects was necessary; all bycatch was retained along with any caddisflies.

The data sheets we asked participants to fill out included fields for the date, name of collectors, bottle number, location (waterbody, city, state/province, country), GPS coordinates, comments about weather, estimated temperature, the time light turned on and off, wildlife and plant life observations at the site, general comments about the experience of collecting, observations of the river or site, and thoughts about any potential ecological changes or pressures in the area (Suppl. material 1). Data labels with fields for date, location, GPS coordinates, and collectors were included to be placed in each bottle along with the preserved caddisflies. Once samples were collected, participants mailed the specimen bottles and data sheets to the provided address. Specimens were only mailed domestically (either within Canada or within the United States), so no permits for specimens crossing country borders were required on behalf of the community scientists.

Data processing

Once we received the bottles and data sheets back from participants, we transferred specimens into 95% ethanol for long-term storage; non-Trichopteran bycatch was also preserved. We used the community scientists' records of GPS coordinates to map sites and quantify levels of urbanization. We classified sites as either "urban" or "non-urban" using the Moderate Resolution Imaging Spectroradiometer (MODIS) Land Cover Type Product (MCD12Q1) Version 6 (Friedl and Sulla-Menashe 2019; Hufkens 2022). Urban sites were defined as having 30% or greater impervious surface cover in a 1 km radius around the collecting site. Any other landcover designation was grouped as "non-urban" (Suppl. material 2).

Results

Participation in The Caddisfly Collective was higher than we initially expected. Seventy-eight people signed up through our website. Social media was the primary point of first contact that drove potential participants to our site, responsible for 62.8% of sign-ups; 28.2% of individuals reported that they were directed to the site by friends or family, 6.4% came from an email listserv, and 2.6% reported "other" as the reason they found the site. In the two-step sign-up process, 88.9% of people followed up by filling out the second form wherein we solicited their mailing address to send the kits. We also recruited additional participants through direct communication with friends and colleagues in addition to the website.

We distributed 79 caddisfly collecting kits, which included a total of 197 sample bottles, based on the number of sites each participant indicated they wanted to visit. Ultimately, 63 distinct groups of participants completed the collections and returned bottles of specimens, a rate of 79.7% (Fig. 3). In total, 141 samples were collected

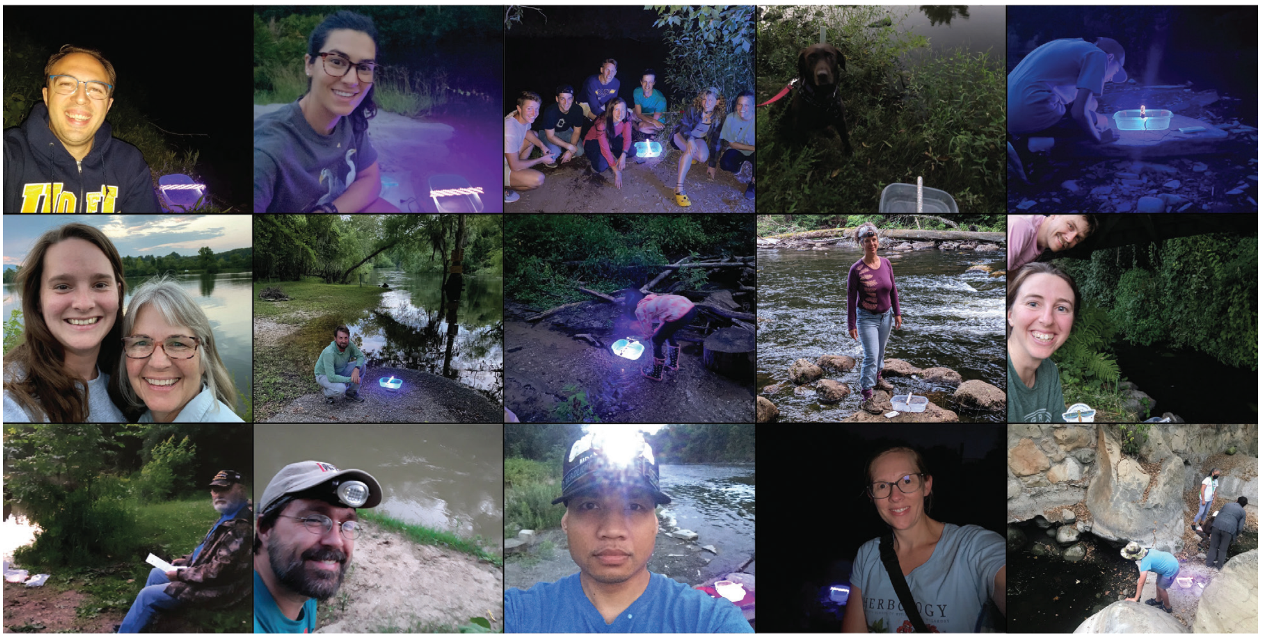

Figure 3. Photos submitted by Caddisfly Collective participants taken while collecting at various sites in the United States and Canada, frequently featuring the UV light trap kit.

(Fig. 2), meaning 71.6% of the distributed bottles were returned with specimens. The median number of sites visited per participant was two. Submitted caddisfly specimens were overall intact, identifiable, well-preserved, and made up the vast majority of insects collected.

All seven geographic regions of the US and Canada were represented in the community scientists' collections (Fig. 4), though to differing degrees (Fig. 5). The largest proportion of sites were located in the Midwest (29.1%), followed by the Southeast (19.1%), then the Southwest (14.9%), the Northeast (12.8%), the North Plains (12.1%), and the Pacific West (9.9%). The Far North had the fewest sites (2.1%), with three samples collected in Alaska. A total of 41 sites that community scientists visited were classified as "urban" by MODIS landcover (Friedl and Sulla-Menashe 2019), versus 100 sites classified as "non-urban." Figure 6 illustrates the visual differences between sites classified as urban and non-urban within different regions. The average representation of urban sites within a region was 29.3% (Fig. 5). The Midwest region had the largest proportion of urban sites (39%); urban sites were least represented by collections in the Southeast (11.1%).

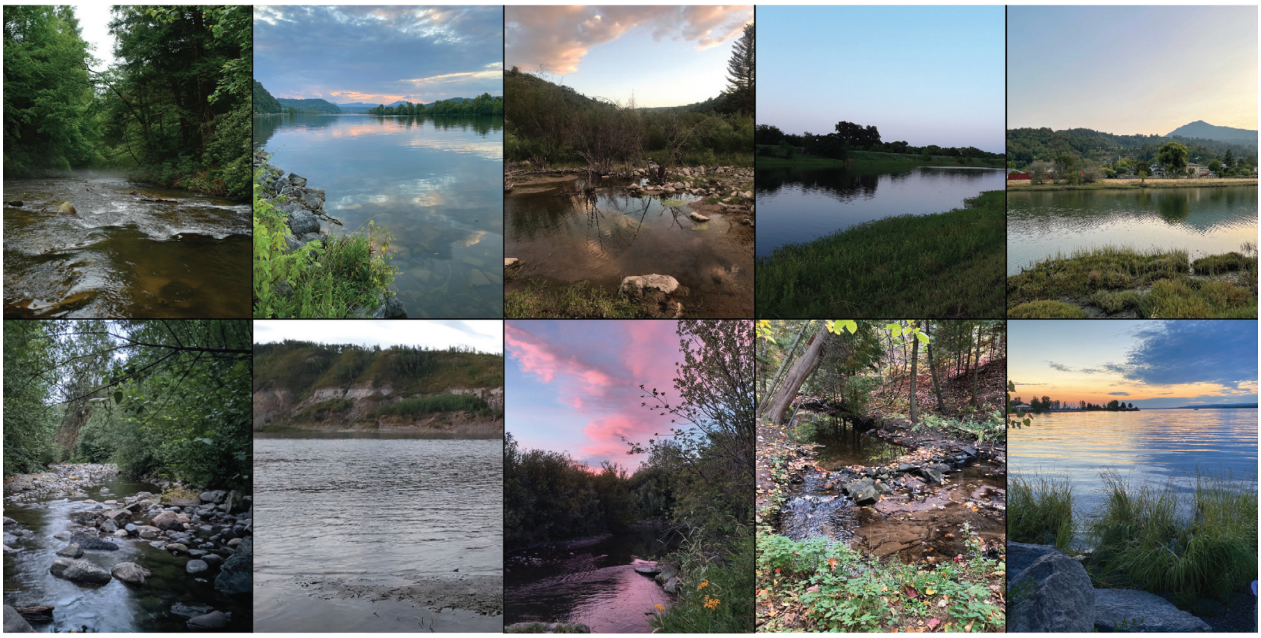

Figure 4. Photos of collecting sites taken by Caddisfly Collective participants. Top row, left to right: Georgia, Tennessee, Utah, Texas, California. Bottom row, left to right: Washington, Alberta, Montana, Michigan, Ontario. Photo credits: K. Murray-Stoker, S. Racey, A. Eichert, T. Byrs, J. Murray & D. Kim, L. Watkins, A. Hunter, H. Stratton, K. Teeter, G. Dmitriew.

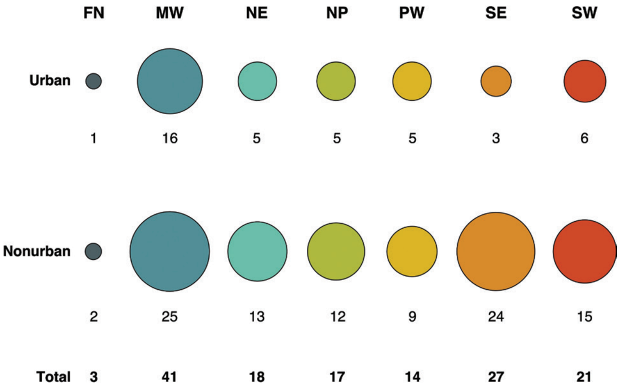

Figure 5. Number of collection sites by region and urbanization designation. Sites were classified using MODIS land cover (Friedl and Sulla-Menashe 2019). FN = Far North, MW = Midwest, NE = Northeast, NP = North Plains, PW = Pacific West, SE = Southeast, SW = Southwest.

Discussion

Here, we present a method of conducting entomological community science, allowing participants to contribute robust data and specimens without necessitating prior scientific training or access to scientific equipment. This is exciting with respect to Trichoptera, a highly ecologically important aquatic insect order (Morse et al. 2019), yet one that often goes unnoticed by the public due to the typically drab coloration and crepuscular activity of the terrestrial adult stage. We hope the results of The Caddisfly Collective will encourage Trichoptera researchers to explore the possibilities of community science to when addressing large-scale research questions.

Our project focused on collecting adult caddisflies rather than larvae for a few reasons. We expected it would be safer in general for The Caddisfly Collective members to remain on the riverbank rather than entering the water (especially since many participants expressed wanting to involve their children). Additionally, collecting adult caddisflies is much easier to standardize, with less of the outcome depending on individual collecting effort and technique. We also wanted to make this project accessible to those without prior entomological knowledge, so we did not require any preliminary identification or sorting by participants. Sending all the insect specimens collected also has the benefit of bycatch available to museums and other researchers. Finally, many North American Trichoptera species cannot be reliably identified to species in the larval stage, so collecting adults confers more taxonomic information, and in turn, potentially more ecological information (Resh and Unzicker 1975).

An ultraviolet light near a body of water is a very effective method of passive collection for adult Trichoptera, though traditional entomological research equipment can be expensive and difficult transport: a fluorescent UV light with a rechargeable 12-volt battery can cost approximately $200 USD. By contrast, the UV LED lights and USB battery packs that we used cost about $25 USD together. LED lights have been shown to be a cheaper, less power-demanding alternative to traditional fluorescent lights (Price and Baker 2016; White et al. 2016), and tests comparing the efficacy showed little difference in the abundance of Trichoptera individuals attracted to LED versus fluorescent UV light sources (Green et al. 2012; Zemel and Houghton 2017). We did notice incidentally that the LED light strips have a shorter total life span than the fluorescent lights, so this may be something to consider if researchers are planning for long periods of repeated collections. However, for our project where participants collected a maximum of four different times, this was not an issue.

Figure 6. Aerial images of paired sites showing differences in region and urbanization. **A.** Urban site, Tucson, Arizona; **B.** Non-urban site, Tucson, Arizona (MODIS classification: Open Shrublands); **C.** Non-urban site, Whistler, British Columbia (MODIS classification: Evergreen Needleleaf Forests); **D.** Urban site, Whistler, British Columbia. Scale bar: 100 m. Imagery © 2023 Google / CNES / Airbus Maxar Technologies. Map data © 2023 Google.

There are also scientific limitations to consider with the choice of adult collection with UV light. Not all caddisfly species will be attracted to lights and wavelengths in an equal manner, and there may be differences in attractivity between male and female caddisflies (Larsson et al. 2020; Szanyi et al. 2022). Additionally, it is still not fully clear what distance caddisflies will fly to reach a light source, which would be inversely related to how reflective a light trap's specimens is of the immediate environment. Caddisflies are generally thought to be relatively weak fliers, typically dispersing less than 100 m laterally from a stream (Collier and Smith 1998; Petersen et al. 1999), though evidence of longer flight events has been presented, depending on taxon (Kovats et al. 1996). Ultimately, we believe the 1 km radius used to designate land cover urbanization at a site is sufficient to represent habitat of any caddisflies coming to the light, even if from different waterbodies.

As in any research project, using a community science project requires a balance of specificity of data collected and feasibility of methods for participants. We prioritized flexibility with our project, especially in allowing The Caddisfly Collective members to choose their sampling dates and site locations. We believed this would maximize the probability of collection completion, and our goal was for community scientists to sample as many sites in different regions as possible, with representation of both urban and non-urban areas. Convenience can be an important factor, but participation in community science projects can also be driven by a strong attachment to a sense of place (Haywood 2014). For our research purposes, we were satisfied with the representation of sites. Non-urban sites were more highly represented than urban sites in each region, though this will hopefully allow us to capture a wider range of the "natural" variation in caddisfly community diversity within a geographic region. Additionally, the geographic range and number of sites sampled by the community scientists far exceeded what our academic research team would have been able to accomplish in a single field season; the cost of travel alone to each site would have been much higher than kit expenses.

While the results of the caddisfly collections in terms of diversity are not included here, the samples collected by the community scientists will allow us to measure a variety of metrics, including taxonomic richness and community structure. Because the area of the light trap collecting bin and the light source were standardized, and participants recorded the length of time the light was turned on, we can also calculate abundance using a catch per unit effort method. Some data points will have to be excluded due to missing information, but this was not an issue for most of the returned data sheets. Researchers implementing community science projects should expect tradeoffs with flexibility when planning and budgeting, which may include data loss or a lack of follow-through by a few participants. This is understandable, as community scientists are volunteers and even with good intentions, priorities can shift with changing life circumstances. Alternative options for community science studies of Trichoptera and other insect biodiversity include photo-based smart phone applications such as iNaturalist (https://www.inaturalist.org/) and ObsIdentify (https://observation.org/apps/obsidentify/, Molls 2021), which allow for greater flexibility on the part of the participants and little to no financial commitment on the part of researchers.

Ultimately, we found the implementation of The Caddisfly Collective to be extremely successful and rewarding; many community scientists expressed their enjoyment in participating, and asked to be informed if there were more science projects to which they could contribute. We will share all data and results of future analyses with The Caddisfly Collective so that participants can be aware of the fauna they collected in their local areas and how their samples fit into the entire landscape of data. We did not collect data on the public impact of our project, such as on any change in feelings about scientific research, ecology, or entomology; individuals who choose to participate community science projects are often already more engaged with science than average (Trumbull et al. 2000). However, for scientists interested in increasing public engagement with aquatic ecology or entomology, a community science project provides an ideal opportunity: as a result of this project, we were contacted to speak to two different university classes and appear on a podcast (Snowhite 2021). If public outreach is a goal for researchers, dedicated steps can be taken to use community science to meaningfully engage with members of the public in many forums (Lucky et al. 2014; Vitone et al. 2016; Vance-Chalcraft and Jelks 2023).

Conclusion

Long-term ecological change has been a persistent hallmark of human impact on the environment, manifesting in trends such as biodiversity loss and habitat alteration within freshwaters (Reid et al. 2019; Rumschlag et al. 2023) and insect declines (Hallmann et al. 2017; Sánchez-Bayo and Wyckhuys 2019; Wagner 2020; Wagner et al. 2021). However, insect diversity data needed to assess changes are still lacking; for example, over 65% of Canada's caddisfly species could not be given a conservation ranking in the most recent government report, due to a lack of information (Canadian Endangered Species Conservation Council 2022). Additionally, regions of the world outside of Europe and North America need more representation in the insect decline literature, especially regarding aquatic insects and urban environments (Gál et al. 2019; Ferzoco et al. 2023). Implementing community science initiatives could be a way to increase the scope of projects in order to collect more much-needed species occurrence data, while simultaneously raising awareness of the ecological importance of aquatic insects; we hope this report on The Caddisfly Collective can help enable researchers to do so.

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The authors declare that no competing interests exist.

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Supplementary material 1

Instructions and data sheets distributed to participants of The Caddisfly Collective

Authors: Kelly M. Murray-Stoker, Shannon J. McCauley
Data type: docx

Link: https://doi.org/10.3897/contrib.entomol.73.e109951.suppl1

Supplementary material 2

Land cover and region designations for sites sampled by The Caddisfly Collective

Authors: Kelly M. Murray-Stoker, Shannon J. McCauley
Data type: csv

Link: https://doi.org/10.3897/contrib.entomol.73.e109951.suppl2