The role of community science in orthopteran research

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Abstract

Orthopterans are commonly encountered in rural, suburban, and urban landscapes and have charismatic songs that attract the public's attention. These are ideal organisms for connecting the public with science and critical concepts in ecology and evolution, such as habitat conservation and climate change. In this review, we provide an overview of community science and review community science in orthopterans. Best practices for orthopteran community science are provided, with a focus on audio recordings and highlighting new ways in which scientists who study orthopterans can engage in community science.

Before the modern era, scientific discovery was commonly made by people who were not scientists by profession (Brenna 2011, Miller-Rushing et al. 2012). This began to change in the middle of the nineteenth century when science became highly academic, with greater "gatekeeping" of knowledge, and data collection became increasingly expensive. As a result, much of the knowledge gained during that time has been effectively withheld from non-scientists in difficult-to-obtain scientific journals, and there were few opportunities for the public to directly engage with scientific research. In recent years, there has been a concerted effort from the scientific community to change the way we engage with the public. These "citizen" or "community" science projects are filling gaps in the modern approach to scientific inquiry (Jordan et al. 2012, Toomey and Domroese 2013, Johnson et al. 2014). Here, we provide an overview of community science and highlight the exciting and unique role that community science can play in orthopteran research. We focus on how acoustic surveys can be used to study orthopteran biodiversity, provide best practices for orthopteran community science, and suggest future avenues for research.

Keywords

acoustic monitoring, best practices, citizen science, community science, crickets, grasshoppers

The importance of community science

Community science refers to the participation of people who are not professional scientists in scientific inquiry through the collection, analysis, and interpretation of scientific data (Jordan et al. 2012, Toomey and Domroese 2013, Johnson et al. 2014). There are typically two main avenues for community science, which we will refer to as "guided" and "open." In guided community science studies, scientists lead the data collection, usually using an established protocol, with varying degrees of input from local volunteers and organizations. In these studies, community scientists work directly with researchers or in tandem with them on web platforms such as Zooniverse (https://www.zooniverse.org/). In open community science studies, data are generated largely by individuals working independently and are then recorded and shared through social media or apps such as iNaturalist (https://www.inaturalist.org/; Paiero et al. 2020, Skejo et al. 2020b, Kasalo et al. 2021a, 2021b, Trewick 2021). These internet-based forums provide anyone with a smartphone or computer the ability to add to a collective database that is accessible by scientists and nonscientists everywhere.

Community science is changing the way scientists can collect data, increasing both their resources and reach (Silvertown 2009, Jordan et al. 2015). Although community science initiatives usually provide fine-scale data at a local level, they can cover large regions collectively (Theobald et al. 2015). This allows community science projects to gather much more data than a small group of scientists would alone (Pocock et al. 2015, Kaláb et al. 2021). For example, organized initiatives led by passionate amateur scientists are valuable in tracking changes in populations over time (Pocock et al. 2015). Locals have the ability to record data year-round, which would be

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difficult and costly for scientists who are based far from their study sites (Kaláb et al. 2021). Moreover, local knowledge of an area can be invaluable to scientists conducting fieldwork (Penone et al. 2013, Medin and Bang 2014). The geographic scale and depth of community science surveys are particularly valuable in the context of anthropogenic change—the scale and speed at which humans are impacting biodiversity require the collection of as much data as possible as quickly as possible (Theobald et al. 2015). Community science initiatives have been successful in monitoring conservation efforts (Barlow et al. 2015, Kallimanis et al. 2017), sighting species thought to be extinct (Woller and Hill 2015, Buzzetti et al. 2021), discovering new species (Kasalo et al. 2021b, Trewick 2021), locating occurrences of range expansion (Beckmann 2017, Paiero et al. 2020, Kaláb et al. 2021), and invasive species (Okayasu et al. 2020, Ahnelt et al. 2021, Kasalo et al. 2021a). In some taxa, most newly discovered species are first described by people who are not professional scientists (Fontaine et al. 2021).

Community science is equally important for promoting public engagement with science. Community science provides people with a way to have meaningful scientific experiences that translate into significant and lasting learning. Moreover, community science makes the scientific experience more accessible to members of historically marginalized groups (Skejo et al. 2020b) and in underserved classrooms (Fiske et al. 2019, Roche et al. 2020). A focus on justice, equity, diversity, and inclusion in community science can also bring added value to the research. For example, involving indigenous peoples in research based on their native lands brings immense value to the quality of the research through the provision of differing perspectives and contexts (Kimmerer 2002, 2013) and to the consideration and preservation of indigenous cultures (Medin and Bang 2014).

Community science in orthopteran research

Orthopterans are familiar occupants of rural and suburban backyards as well as urban parks and vacant lots, providing an acoustic backdrop to summer. These are the ideal organisms to connect the public to science and to critical concepts in ecology and evolution, such as habitat conservation and climate change. Insects make up one of the largest shares of the Earth's biodiversity, but recent reports on severe insect declines are alarming (Sánchez-Bayo and Wyckhuys 2019). Because of their short life cycles and, in some species, specialization in habitat, food source, and egg-laying, insects are excellent indicators of climate change (Riede 1998, Jeliazkov et al. 2016, Beckmann 2017). For most insects, we still have too little information about extant biodiversity to understand the causes and consequences of population declines (Saunders et al. 2019). Due to their ubiquity and sensitivity to climate change, orthopterans are particularly important organisms for climate change research (Fartmann et al. 2012, Löffler et al. 2019). Continuous monitoring through organized citizen science can contribute to long-term datasets that will help to track changes in biodiversity, while providing the public with meaningful science experiences (Basset and Lamarre 2019). Currently, there are 1,128,486 records on iNaturalist that are accompanied by photographs and observation localities for 5,732 orthopteran species (iNaturalist, available from https://www.inaturalist.org. Accessed July 14, 2022).

Because many male orthopterans sing to attract mates, community science studies quantifying species richness, abundance, and emergence times in Orthoptera are relatively simple. Species can be identified by their acoustic profiles, and acoustic survey data can be recorded from trails and roadsides (Fischer et al. 1997, Riede 1998, Penone et al. 2013, Jeliazkov et al. 2016, McNeil and Grozinger 2020, Paiero et al. 2020, Kaláb et al. 2021). This is particularly useful in fragile habitats or for threatened species, where scientists must balance effective monitoring with reducing disruption in conservation spaces (Moran et al. 2014, McNeil and Grozinger 2020). New technologies in acoustic monitoring allow for large-scale monitoring of singing insects, which provides an easier, less time-consuming means of estimating metrics such as species abundance and richness. Community scientists can sustainably crowdsource this vital information in a way that scientists are not able to do using a traditional approach or photographs alone.

Nearly 85% of the world's population owns a smartphone (Turner 2018). Every smartphone has audio and video recording, GPS, and internet capabilities, placing these tools for data collection, storage, and transmission at the fingertips of most people on the planet. Highly accurate new tools, such as TADARIDA (a Toolbox for Animal Detection in Acoustic Recordings Integrating Discriminant Analysis) and AI, make using the vast quantities of acoustic and photographic data generated by community scientists useful on a massive scale (Bas 2016, Kasalo et al. 2021b). In the case of acoustic monitoring, data for many different species across taxa can be captured and analyzed from a single recording, a practice that could further utilize existing recordings, increase the rate of new data collection, decrease costs, and encourage collaboration (Jeliazkov et al. 2016, Newson et al. 2017). Smartphone technology also allows us to easily record data that is outside the normal human sensory range, which provides a means to detect species that might otherwise go unnoticed (Moran et al. 2014). Community science acoustic monitoring is currently being used at a nationwide scale in some locations and taxa (e.g., FrogID (Rowley et al. 2019, Rowley and Callaghan 2020); North American Breeding Bird Survey, USGS Patuxent Wildlife Research Center and Environment Canada's Canadian Wildlife Survey).

We reviewed 14 studies that used community science in orthopteran research (Table 1) and found examples of both guided (43%) and open (50%) community science, with the remaining 7% unclear. Research spanned orthopteran taxa with most major groups being represented, including grasshoppers, crickets, katydids, and wetas; however, taxonomic diversity within each of those groups is relatively limited to new or invasive species (Table 1). For guided studies, the number of participants was small, with groups of less than 15 people. In open community science studies, the number of non-professionals who participated was typically not included. In most studies, participants helped collect photographic and/or acoustic data. Acoustic monitoring orthopteran community science initiatives are still underutilized. Only four of the studies we found used community-collected acoustic data (Penone et al. 2013, Jeliazkov et al. 2016, Newson et al. 2017, Kaláb et al. 2021), while the other 10 primarily used photographs, social media, field collection, or a combination of methods to achieve their aims. All 14 studies we surveyed addressed questions of species richness, species abundance, novel/threatened species identification, range changes/expansion, invasive species, and environmental factors impacting species.

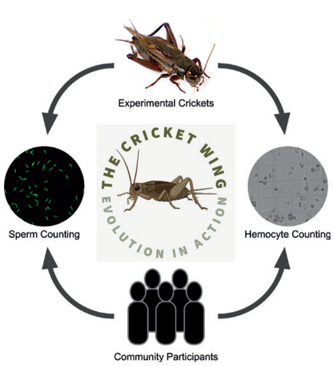
We wanted to highlight one ongoing orthoptera research project that addresses experimental evolution questions using community-analyzed data. The Cricket Wing (https://www.zooniverse.org/projects/marywestwood/the-cricket-wing, Box 1) uses an online platform to host a large dataset of images that are analyzed by the public. This type of online, large-scale data analysis community science provides an alternative to field collection projects and another exciting avenue to expand research participation and speed up scientific discovery.

Table 1. Published research on orthopterans that has included a community science element.

Type	Country	Organism	Number of participants	Involvement type	Question type(s)	Authors
Guided	France	11 species of bush crickets (Tettigoniidae family)	10 individuals	Roadside acoustic data collection	Species richness; species abundance; environmental factors	(Penone et al. 2013, Jeliazkov et al. 2016)
Guided	Germany	Oak bush-cricket (Meconematinae family)	~8 individuals	Photograph collection; social media	Range expansion	(Ahnelt et al. 2021)
Guided	United Kingdom	Bush Crickets (Tettigoniidae family)	Not reported	Placement of static acoustic sensors	Species richness	(Newson et al. 2017)
Guided	Japan	Pink-winged grasshopper (Pyrgomorphidae family)	Not reported	Field specimen collection	Invasive species	(Okayasu et al. 2020)
Guided	United States	Camel crickets (Rhaphidophoridae family)	Not reported	Photograph collection; specimen collection; social media; survey	Invasive species	(Epps et al. 2014)
Guided	United States	Grasshopper (Acrididae family)	Not reported	Transcription of field journals	Rare species record	(Woller and Hill 2015)
Open	Australia	Pygmy grasshoppers (Tetrigidae family)	8 individuals	Photograph collection; social media	Rare species record	(Skejo et al. 2020b)
Open	Canada	Red-headed bush cricket and restless bush cricket (Gryllidae family)	~15 individuals	Photograph collection; social media	Range expansion	(Paiero et al. 2020)
Open	United Kingdom	*Conocephalus* discolor and *Metrioptera roeselii*	2000+ people	Photograph collection	Range expansion; environmental factors	(Beckmann 2017)
Open	United States	Acrididae and Romaleidae families	Not reported	Photograph collection; social media	Species richness; species abundance	(Harman et al. 2022)
Open	United States	Japanese burrowing cricket (Gryllidae family)	Not reported	Photograph collection; social media	Invasive species; range expansion	(Bowles 2018)
Open	New Zealand	Ground weta (Anostostomatidae family)	Not reported	Photograph collection; social media	New species identification	(Trewick 2021)
Open	Madagascar	Southern Devils pygmy grasshopper (Tetrigidae family)	4 individuals	Photograph collection; social media	New species identification	(Skejo et al. 2020a)
Not reported	Czech Republic	Bush crickets (Tettigoniidae family)	Not reported	Photograph and acoustic collection; social media	Range expansion	(Kaláb et al. 2021)

Box 1. Orthopteran Community Science in Action: The Cricket Wing.

The Cricket Wing is an ongoing community science initiative and delves into how noise pollution impacts cricket physiology. Because singing and hearing are essential for cricket, and more broadly, orthopteran reproduction, noise pollution can have negative impacts on these organisms. Very little is currently known about how noise pollution impacts orthopterans, especially with regards to their physiology. Specifically, the research underlying The Cricket Wing aims to understand how traffic noise affects immune and reproductive traits.



To date, the lab group running The Cricket Wing has generated two datasets: (i) 12,304 images of live and dead sperm cells to measure reproductive traits; and (ii) 1917 images of immune cells (hemocytes) to measure immune traits. The Cricket Wing, via the Zooniverse platform, engages participants from the community to count live and dead sperm and hemocytes in their respective images. To control for biases and error, each image is "classified" ten different times by participants before final numbers for each image are recorded. Guides and tutorials are provided to community participants for the different tasks carried out on the site. An open chat forum ("The Cricket Wing Talk") is available for participants, scientists, and developers of the site to troubleshoot issues and discuss the broader science behind the project. Since it launched on May 10, 2022, The Cricket Wing has registered 700 participants who completed a total of 38,497 classifications (37,356 sperm and 1141 hemocyte counts) to date (Accessed July 14, 2022).

The Cricket Wing is an excellent, real-time example of how community participants can engage in orthopteran research, as well as in broad evolutionary questions. It uses a guided community science approach and follows many of the best practices that we have outlined in the main text. The Cricket Wing is a way to engage the community in novel research, educate a broader, non-scientific audience about evolutionary theory, and demonstrate how scientific data collection works. Currently, The Cricket Wing is being extended and utilized in outreach at the high school level. The developers and collaborators also plan to extend the scope to other evolutionary questions, such as rapid adaptation through song analysis and machine learning. The Cricket Wing is led by Dr. Robin Tinghitella's lab group (including Dr. Tinghitella, Dr. Mary Westwood, Gabrielle Welsh, and Sophia Anner) at the University of Denver and Dr. Sarah Reece's lab group (including Dr. Reece and Dr. Aidan O'Donnell) at the University of Edinburgh. To learn more about The Cricket Wing, visit https://www.zooniverse.org/projects/marywestwood/the-cricket-wing.

Best practices for community science in orthoptera research

Despite the opportunities for community science in orthopteran research, there are very few organized, long-term community science programs that focus on these organisms (Burton 2003, Fartmann et al. 2012, Newson et al. 2017, Löffler et al. 2019). With this in mind, we propose some best practices for creating effective community science programs in Orthopteran research. This is not meant to be an exhaustive list but rather a starting point to increase awareness, accuracy, and utility.

1. **Develop guided community science projects.** In general, we recommend guided studies for most avenues of research. Guided studies have been shown to be better suited for some research questions, such as evaluating species abundance (Penone et al. 2013). We also recommend a guided approach because it can be the best way to actively engage with community scientists and provide a more meaningful research experience.

2. **Develop clear and concise protocols.** Studies have shown that clear, concise protocols are critical for guided studies (Matteson et al. 2012, Penone et al. 2013). Below, we outline some suggestions for information that should be included in the protocol.

    2.1. **Plan how community scientists will access study organisms.** Locals, naturalists, and professional scientists have concerns regarding the damage that numerous untrained visitors can do to fragile ecosystems (Moran et al. 2014). Community science protocols should account for the frequency and manner in which community scientists will access a research area. Protocols should also include guides for how and where to find the study species.

    2.2. **Include details of how data should be recorded and stored.** For acoustics, this would entail including instructions on how to record sound, recommended recording distance, and length of time of recording. This would also include detailing any and all notes, such as locality information, date and time of observation, and general notes on habitat. A plan would also be included for how data might be backed up or shared in a repository such as Google Drive or Dropbox, website submission, or an app like iNaturalist.

    2.3. **Use automated processes to record data when possible.** Automating data collection using a smartphone app can reduce recording errors. Zilli et al. (2014) designed and deployed a smartphone app that uses acoustic data to identify specific species in real time. When designing apps for use by non-scientists, mimicking the design of existing popular apps (i.e., Shazam) can increase user uptake and engagement (Moran et al. 2014).

3. **Provide instructional resources.** In guided studies, workshops, online tutorials, fieldnotes, and/or video demonstrations should be used to provide training to volunteers (Barlow et al. 2015). In the case of collecting acoustic data, example audio recordings of the subject specie(s) are helpful to participants. In studies that require volunteers to make identifications, it is helpful to include an "unsure" column to reduce guessing when participants are uncertain (Barlow et al. 2015).

4. **Engage with community scientists and the general public.** Engaging with community scientists and the general public is of paramount importance when conducting community science initiatives and provides a more meaningful learning experience to the research project. This can be done during and after community science initiatives and can take the form of websites, discussion forums, organized "walks" to identify species, and public talks in which results are disseminated to community participants in the project. Ultimately, community science is great for collecting and processing large amounts of data, but professional scientists should also keep the goal of contributing to public scientific literacy at the forefront.

5. **Provide opportunities for practice.** The extent, duration, and mode of participant training all have effects on the quality of community science data (Galloway et al. 2006, Delaney et al. 2008, Fitzpatrick et al. 2009, Jiguet 2009, Schmeller et al. 2009). Conducting practice data collection with groups of participants or tutorials that outline methods for data collection can improve the quality of the data being generated.

6. **Build replication into data collection.** Error and bias due to variations in observer quality, along with differing approaches to data collection, can impact the validity of community science data and subsequent analysis. Several studies have shown how different approaches to the same community science datasets can yield different results and lead scientists to variable conclusions (Bas 2016, Kasalo et al. 2021b). Specifically with respect to the acoustic monitoring of frogs, researchers have found broad inter-observer variation in species identification and have suggested that this should be controlled for in either the sample design or during data analysis (de Solla et al. 2005, Weir et al. 2005, Lotz and Allen 2007, Pierce and Gutzwiller 2007). To mitigate these biases in studies that use community science data, it may be helpful to collect data based on two or more independent observers. For example, for acoustic surveying, have more than one person survey/cover a specific location/area or, in cases where measurements are being taken via a web platform, have several people measure the same thing to add replication to the measurement.

7. **Plan for sampling bias.** Sampling biases due to the temporal and spatial heterogeneity of the data collection can also be issues within community science-generated datasets. Both types of sampling biases can add their own set of issues to downstream analyses, as can trying to correct or account for these biases either before and/or after data collection (Harris and Haskell 2007, Niemuth et al. 2007, Dunn and Weston 2008, Dickinson et al. 2010). Researchers using community science data are recognizing that, like working with laboratory or scientifically generated data, there is a learning curve to working with community science-generated datasets and that issues of bias and error within the data must be addressed in a question-specific manner. Ultimately, finding and achieving the most appropriate balance between analytical techniques, community science-generated/analyzed datasets, and a given research question is a very active area of research.

Conclusions

Community science projects are quickly increasing in number but are drastically underutilized in scientific literature (Theobald et al. 2015). In Orthoptera, projects using acoustic data recorded by community scientists can help answer questions related to species abundance, species richness, emergence time, and changes in range and distribution due to anthropogenic change (Penone et al. 2013); however we were only able to locate 14 published studies that specifically mentioned the use of community science in their methods and only four of which used acoustic monitoring. Community science is growing in popularity and provides many benefits, including increasing scientific knowledge and engaging the general public, enhancing conservation, and providing much-needed work hours to advance research goals. However, these benefits can be outweighed by damage to fragile ecosystems and threatened wildlife if participants are not properly trained. Thus, it appears that community science, as with the natural world it surveys, requires balance to be sustainable. Because they are easily identified through mating song, Orthoptera species provide excellent study systems for achieving all of these goals from distances that can help protect vulnerable habitats.

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