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BRIEF REPORT

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TreeSnap: A citizen science app connecting tree enthusiasts and forest scientists

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Societal Impact Statement

The scientists that study and work to improve forest health need information on where pests and diseases are spreading, as well as where healthy, resilient trees remain. TreeSnap is a citizen science project and mobile app created to meet this need by enabling citizens to easily submit global positioning system (GPS) locations, photos, and observational information about trees of interest to scientists. The app was designed and built to ensure that the data being collected directly helps scientists engaged in a number of forest health research activities, including studying the genetic diversity of tree species, breeding trees, and monitoring tree health.

KEYWORDS
citizen science, forest health, chestnut, treesnap, mobile app, restoration breeding

1 | INTRODUCTION

Citizen science engages non-professional scientists in scientific research (Bonney et al., 2009; Conrad & Hilchey, 2011; Dickinson et al., 2012; Dickinson, Zuckerberg, & Bonter, 2010; McKinley et al., 2017). For researchers, citizen science offers exciting opportunities to expand the range and scope of data collected and involve a broader and more diverse group of observers and data contributors (Pocock, Tweddle, Savage, Robinson, & Roy, 2017). By incorporating a large number of interested people working in parallel, citizen science has the potential to accelerate the pace or expand the scope of research projects. In today's world of constrained research funding, communicating the value of scientific research to the public is increasingly important yet avenues for sharing scientific research with general audiences are few and researchers typically have little institutional support for education and outreach activities, despite outreach

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being a requirement of many grant funding agencies. Citizen science directly connects scientists to the public and shares the importance of their work (Sauermann & Franzoni, 2015).

Citizen science is not a new idea. From early naturalists to long standing species range surveys that rely on contributions from members of the public (Miller-Rushing, Primack, & Bonney, 2012; Silvertown, 2009), engaging non-professionals in scientific research has repeatedly demonstrated great value for researchers and participants alike. The increasing ubiquity of the internet and mobile phones has rapidly expanded the reach and potential of non-professionals collaborating in scientific research or conducting their own research (Bonney et al., 2014; Graham, Henderson, & Schloss, 2011; Land-Zandstra, Devilee, Snik, Buurmeijer, & Broek, 2016; Newman et al., 2012). For example, while ornithological research has a long history of utilizing citizen scientists, newer online community platforms for birders, like eBird from Cornell's Lab of Ornithology, have greatly enhanced the ease with which citizen scientists can contribute data, increasing the amount of data collected, with more than 7.5 million bird observations reported to the eBird website on average each month (Sullivan et al., 2014).

While citizen science holds great potential for professional scientists and participants alike, there are also inherent challenges such as ensuring that the quality of data collected is sufficiently rigorous for incorporation into research (Dickinson et al., 2010). Without careful consideration, projects that engage non-professional scientists in research run the risk of collecting data that cannot be directly applied to ongoing research or having low public participation. This is especially true in the world of mobile applications. For example, while there are many plant-related mobile apps available, few have a primary goal of contributing to ongoing scientific research. Instead, most serve as identification aides and/or act as repositories of educational information already publicly available, such as Forest Tree Identification (Discovery Green Lab, 2019), PictureThis - Plant Identifier (Glority LLC, 2019), About My Woods (Innovative Natural Resource Solutions LLC, 2019), and SEEDN (Bugwood, 2019). These types of apps are useful, but none focuses on facilitating scientifically meaningful collaborations between non-professional and professional researchers.

With this is mind, we created the TreeSnap mobile app (https://treesnap.org/) to meet a specific research need: to connect citizen scientists to restoration tree breeders seeking new tree breeding material and forest pest/pathogen sightings (Box 1). We work directly with restoration tree breeders across different tree species killed by invasive pests and pathogens: for example, ashes (*Fraxinus* spp.) and the emerald ash borer (*Agrilus planipennis*), or the American elm (*Ulmus americana*) and Dutch elm disease (*Ophiostoma ulmi*, *Ophiostoma himal-ulmi*, *Ophiostoma novo-ulmi*). Partners are looking for new trees in natural settings to add to their breeding programs. Many restoration tree breeders have ongoing collaborations with highly trained volunteers to find and report these trees but it has historically been difficult to collect and curate submitted data. In some cases the organizations had established protocols for accepting citizen reports, but these were with physical forms or webforms that required manually entering coordinates and associated tree data. The creation of a mobile phone app better facilitates this ongoing work by standardizing data collection, prompting users through additional useful data collection questions, adding the ability to take photos associated with the record, automating GPS reporting, and aggregating all data in a single easy to use online interface. To ensure the app features met the scientific needs, TreeSnap was designed and implemented focusing on a small number of specific tree species of interest where scientific partners were actively seeking data. However, data on other species can also be collected and new focal species can be added. As more scientists have learned about TreeSnap, the app's focus has widened to include more diverse partnerships and more trees.

2 | HOW TREESNAP WORKS

The TreeSnap mobile app is freely available on both iOS and Android. After downloading the app and creating an account, a user is presented with a list of tree species with active research partnerships (Figure 1a). This list is automatically filtered by the app to present native species of interest in their current location, for example, a user in the eastern

BOX 1 Best Practices

TreeSnap follows a range of best practices proposed to improve how citizen science is conducted (Budde et al., 2017; Sachs, Super, & Prysby, 2008). For example:

- **Accessibility:** The app is freely available on the majority of mobile platforms. Source code for the mobile (https://github.com/statonlab/Treesnap-mobile) and web app (https://github.com/statonlab/Treesnap-website) is open source and freely available under a GPL-3.0 license.
- **Consistent Protocol:** The TreeSnap submission form ensures a common-structured and partner-specified set of questions are answered by each participant for each focal tree species. The plain language, pop-up help diagrams, and background information guide less experienced users and help create a positive learning experience.
- **Real Research:** Our policy requires that partners will actively use data collected in TreeSnap for meaningful research that generates new knowledge of trees with real-world outcomes.
- **Data Security:** Personal user data are not shared with anyone, including scientists. Exact location of observed trees are also protected and limited to scientific partners to minimize risk of timber theft and vandalism.

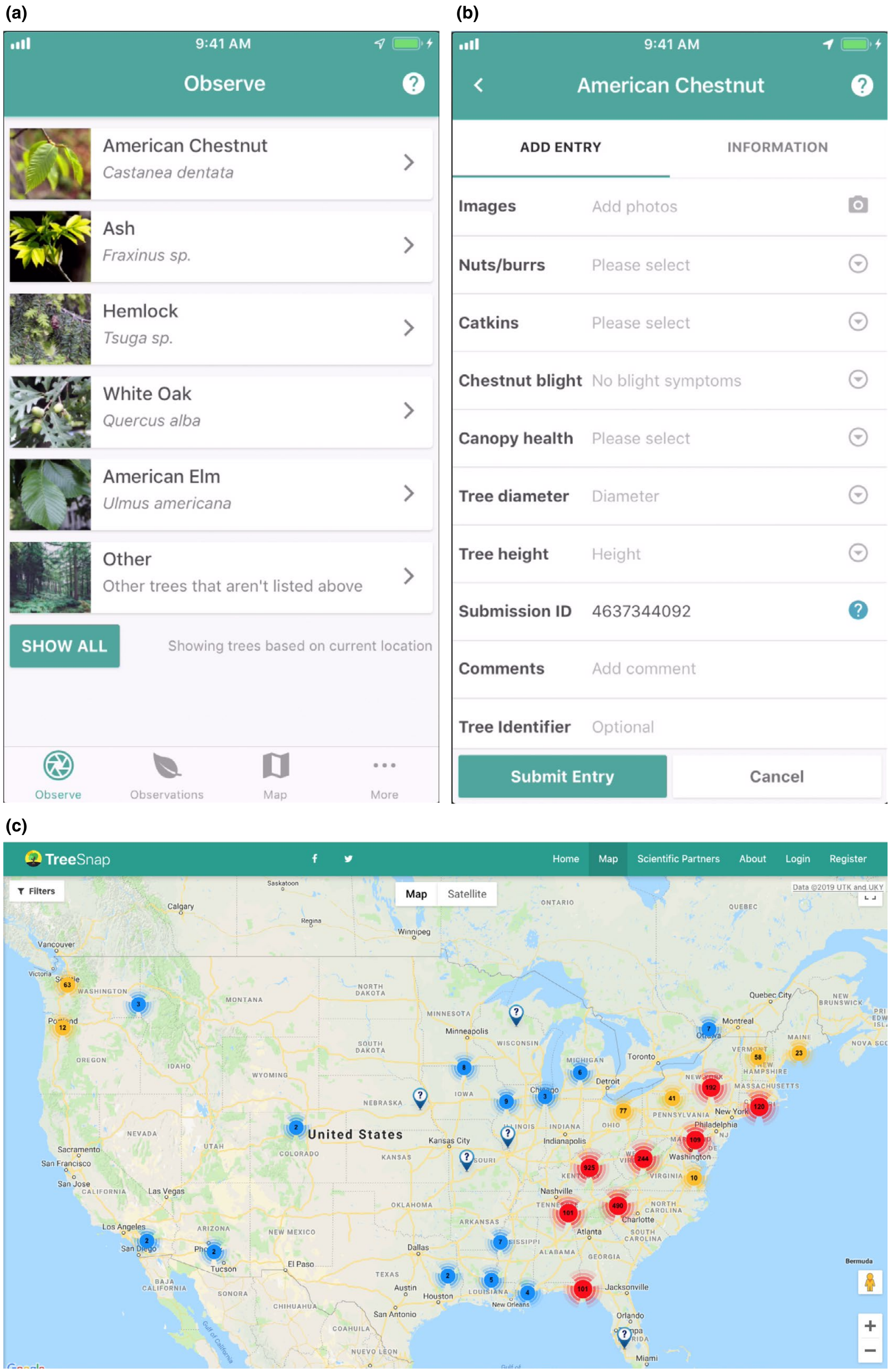

FIGURE 1 When opening the TreeSnap mobile app, users see a list of trees of interest to scientists (a). After selecting a tree, the app presents a set of questions customized for that tree by scientists. The questions prompt users to take pictures, look for signs of disease or pests, evaluate if the tree is healthy, etc. (b). On the TreeSnap website, users and scientists can explore a map of tree records; visualization presented is based on records of 28 January 2019, in the contiguous 48 U.S. states (c)

United States would see American chestnut (*Castanea dentata*) but not Pacific madrone (*Arbutus menziesii*). Tapping on each tree species will allow the user to not only submit data, but get more information about the trees, pests or pathogens, and the scientific partners (Figure 1b). The user answers the questions posed by the research partners, takes relevant photos, and the app collects the GPS coordinates. The entire user experience is designed to take less than one minute to record a given tree, with questions using as little technical terminology as possible. Figures and diagrams are present to guide users in collecting data. The app does not require an internet connection to function, meaning users can access this documentation and create observations while in the deep woods. The data are saved locally on their phone and when the user is back in wifi or cellular service, they can upload them to the TreeSnap web-server by pressing a button.

In addition to the mobile app, the TreeSnap website provides an online interface to explore observations via a map (https://treesnap.org/map/), with options to filter and search (Figure 1c). For security, users can always opt to be anonymous and GPS coordinates for individual trees are shifted up to 5 miles. To facilitate transfer of these data to the scientific partners, a password-protected scientist portal is included with numerous custom tools for discovering, sorting, curating, and downloading the data. Scientists can set up filters and alerts based on the questions associated with each record to only show certain trees meeting certain criteria (i.e., tree health, height, or location). They can create teams (referred to as groups in the app) to easily share observations and can contact users within the website to ask follow-up questions or get permission to visit the tree's location.

The TreeSnap mobile app was developed using React Native, allowing a single codebase to be used for both the iOS and Android versions. The website is built using the PHP framework Laravel with React for the user interface. The site was designed to enable relatively easy maintenance and the ability to easily add new tree types as TreeSnap continues to grow.

3 | THE AMERICAN CHESTNUT FOUNDATION AND TREESNAP

One of TreeSnap's most successful partnerships has been with The American Chestnut Foundation (TACF). TACF members are precisely the type of users that TreeSnap aims to reach: knowledgeable individuals (i.e., they can identify American chestnut trees) who are passionate about restoring and preserving an iconic tree species.

In the first year and a half of the app's release (June 2017–January 2019), users submitted 1,197 potential American chestnut observations to TACF scientists via TreeSnap, an impressive number given the relative rarity of the species due to its historic decimation by the chestnut blight fungus, *Cryphonectria parasitica* (Anagnostakis, 1987). This success is due to TACF's incorporation of TreeSnap into their research and promoting the app to their supporters at outreach events and membership meetings.

Initially, TACF saw TreeSnap's integration as a simple way to facilitate the submission of new, healthy American chestnut trees and a significant improvement on their previous strategy of a mailed paper submission system. TACF scientists now use TreeSnap's website data curation resources to monitor new observations and correspond with citizen scientists who have submitted observations to get more information about particular trees or letting people know their tree is or is not an American chestnut. However, we quickly found that professional scientists within TACF also wanted to use the app to monitor plantings of trees from their breeding programs, many of which were established in collaboration with public partners. TACF scientists also use TreeSnap to aid in scouting and collection of leaf tissue for DNA extraction to perform a species-wide genomic analysis of American chestnut.

By creating a tool that meets the needs of both the professional researchers and citizen scientists working with TACF, TreeSnap is more scientifically meaningful than if it only engaged either group independently.

4 | CURRENT USE

As of 28 January 2019, the TreeSnap database contains 2,684 submissions from 1684 registered users. While most of these observations have come from the eastern United States, where TreeSnap was developed and several scientific partners have been most active, observations have been uploaded from across the world including the Peruvian Amazon. TreeSnap users are passionately engaged with particular research programs or non-profits and use the app for their own purposes (e.g., keeping track of the locations of trees of interest to them) as well as scientific applications. The app is upgradable and designed to add new focal tree species. We are and will continue to add new scientific partners, now including those with research questions aside from restoration breeding. TreeSnap has recently expanded from five focal tree species to nine: American chestnut, North American ashes, North American hemlocks (*Tsuga* spp.), white oak (*Quercus alba*), American elm, Florida torreya (*Torreya taxifolia*), Eastern larch (*Larix laricina*), Pacific madrone, and tanoak (*Notholithocarpus densiflorus*).

5 | CONCLUSIONS

Through the process of creating TreeSnap, we found that there is a great need for and interest in better technology to facilitate scientific data collection by both citizen scientists and professional scientists. Professional researchers want to engage citizen scientists in their work but lack the infrastructure to do so effectively (Bonney et al., 2014). At the same time, many of the same scientists want better tools to facilitate their own data collection, curation, and long-term management (Kosmala, Wiggins, Swanson, & Simmons, 2016; Newman et al., 2012). While such tools do exist, our experience searching for open source software solutions for this project revealed that they are seldom free, easily accessible, up-to-date, or custom-tailored to individual research needs. While TreeSnap was created as a citizen science app, the most active users are highly engaged non-specialist participants or professional researchers, underscoring the demand among scientists for more user friendly mobile apps for data collection. Collaboration among citizen scientists, scientist partners, and TreeSnap's development team (a mix of web and app development/database specialists, outreach specialists, and tree geneticists) resulted in an advanced suite of data curation and management abilities that would likely not have been the focus of private sector app developers.

At the same time, given the somewhat specialized user base for TreeSnap (for example, users must be able to identify specific tree species) this experience has demonstrated that it is essential for the scientists leading projects to actively include the public in their work to develop meaningful tools for engaging citizen scientists. It is not enough for scientists to have a project on TreeSnap or some other citizen science platform; scientists must also put effort into personal relationships with the citizen participants. This more invested relationship with the public drives continued citizen interest in a project, by incorporating this specialized public in the totality of the research process, from planning, data collection, and analysis to sharing of results.

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AUTHORS' CONTRIBUTIONS

E.C., B.C., A.A., C.D.N., A.G.A., D.M., and M.S. planned and designed the research. B.C. and A.A. built the software. E.C. led outreach and education efforts. B.J. led outreach and education efforts with the American Chestnut Foundation. E.C. and B.C. wrote the manuscript. B.J., C.D.N., A.G.A., and M.S. edited the manuscript.

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