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Exploring Community Initiatives that Produce High Quality Volunteers: Citizen Science and Master Naturalist Programs in the United States

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Abstract
Citizen science, which has contributed greatly to scientific understanding, works through partnerships between non-governmental and governmental organizations, academia, and most importantly, volunteers. In the United States, Master Naturalist training programs prepare adults as knowledgeable environmental stewards. Once certified, Master Naturalists are encouraged to log annual volunteer activity hours involving scientific research and education. Compared to untrained volunteers, individuals who have completed Master Naturalist training (or similar programs) exhibit greater project involvement and efficiency at collecting data. These traits align well with the goals of citizen science and point to a symbiotic relationship between citizen science and Master Naturalist programs. Here, we convey how Master Naturalist programs benefit citizen science and provide guidelines for individuals who wish to pursue citizen science projects or programming to produce high quality citizen scientists.

Keywords: Public outreach, volunteer opportunities, research projects, environmental education, biodiversity, natural history

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Introduction to Master Naturalist Programs

Master Naturalist Programs are organized efforts to recruit and prepare knowledgeable volunteers to engage in natural science research and education. They focus on wildlife, habitat, and conservation efforts in a specific state or region. These programs connect people to nature through education, (such as providing online and in-person courses on local geology, species diversity, and natural history) facilitated outdoor experiences (such as species identification workshops, biodiversity surveys, and organized nature hikes) and mentorship provided by natural resource experts (wherein participants engage with experienced volunteers and university, agency professionals). In addition to high-quality naturalist training, Master Naturalist programs offer social community for participants by connecting them with like-minded people through local events and fostering involvement with active email listservs and online resource hubs. For instance, the Nebraska Master Naturalist program holds an annual conference and has its own website (www.nemasternaturalist.org) and social media page (www.facebook.com/masternaturalist). In this, Master Naturalist Programs unite people from varying backgrounds and encourage them to go beyond their shared interest in nature to become active participants in conservation (Larese-Casanvova and Prysby 2018).

Master Naturalist Programs exist in 44 of the 50 United States (Ecosystem Gardner 2018). There is a national alliance that currently includes 29 Master Naturalist programs, the Alliance of Natural Resource Outreach and Service Programs (ANROSP). ANROSP provides resources and leadership in support of Master Naturalist and similar programs (ANROSP 2016). The individual programs, however, are generally managed independent of each other (Larese-Casnova and Prysby 2018). As a result, program content varies state-by-state, but generally involves multi-day training, structured curricula and an expectation of subsequent continuing education and volunteer hours. For example, the Nebraska Master Naturalist program training schedule in July, 2018 included the following topics taught in two to four hour workshops: interpretation and environmental education; geology of Nebraska; grasslands and plants of Nebraska; animal stress and adaptations; spatial ecology; insects of Nebraska; insect backlighting diversity survey; aquatic systems; human dimensions; conservation biology; mammals of Nebraska; small mammal trapping; birds of Nebraska; kayaking a Nebraska lake; and amphibians, reptiles, and turtles of Nebraska. Purposefully, these curricula include studies of regional flora, fauna, habitats, ecology, geology and preparation for public outreach. After successfully completing the program training, participants become Certified Master Naturalists. Subsequent volunteer hours can involve assisting with land stewardship, educational outreach events, and/or citizen science projects through programs organized by the Master Naturalist Program or associated partner agencies. Master Naturalists manage current certifications by meeting the required number of annual volunteer and continuing education hours (20 hours annually in Nebraska, but this varies by state).

Funding for the Master Naturalist Programs also varies by state, but generally relies on federal grants, state grants, and support from partner organizations. These programs and partners have a mutually beneficial relationship in that partner organizations provide funding and training opportunities and the Master Naturalist program returns partner support via provision of knowledgeable volunteers. Volunteer time in the United States, valued at $25.43 per hour, proves an undeniable benefit to partner organizations (Independent Sector 2019).

Contributions of Citizen Science to Public Understanding

Citizen science, also known as community science, provides purpose and infrastructure for amateur scientists to conduct research and promotes public education through this community engagement. Importantly, the term amateur scientist does not reflect a lack of knowledge or expertise, but rather indicates the subject is not their profession. Amateur scientists have made many important scientific discoveries. The father of genetics, Gregor Mendell, was an amateur scientist (Moore 2001). Another amateur scientist, Michael Faraday, inventor of our system of oxidation numbers, also discovered benzene and advanced the study of electromagnetism (Berman 1975). In fact, Charles Darwin was the amateur scientist who developed the theory of evolution by natural selection (Stix, 2009).

Indeed, amateurs around the globe have been involved in scientific pursuits for thousands of years (Miller-Rushing *et al*. 2012). In China, citizens and officials have documented locust outbreaks for 3,500 years (Tian *et al*. 2011). Court diarists in Japan have documented cherry blossom festivals for 1,200 years (Primack *et al*. 2009). Winegrowers in France have documented dates of their grape harvests for over 640 years (Chuine *et al*. 2004). Scientific collections, such as those in museums and herbaria, have benefited greatly from contributions of amateur scientists. These collections provide indispensable foundations for studies of taxonomy and evolutionary relationships between plant and animal species. They are also useful for examining historical distribution and abundance of species, providing insight into actual and potential effects of anthropogenic environmental change (Araujo and Rahbek 2006; Feeley and Silman 2011). The benefits of museum and herbaria collections are many, ranging from niche modeling to food safety to medicine (Funk 2003; Funk 2018). As amateur scientists collect data they provide invaluable resources for professionals to further analyze, and some of the amateur scientists become experts or professionals themselves.

Current examples of citizen science initiatives in the United States that provide purpose and infrastructure for amateur scientists and promote community education include the annual Christmas Bird Count and the MainE-to-GeorgiA (MEGA) transect project. The annual Christmas Bird Count conducted by the National Audubon Society began in 1900 and now boasts participation by approximately 80,000 volunteers (Cohn, 2008) all educating themselves through community engagement. These data provide considerable history on geography and abundance of birds in North America. The Christmas Bird Count database (National Audubon Society, 2020) has provided data for over 300 peer-reviewed articles (e.g. Wing and Millard 1939; Hampton 2012; reviewed in LaBaron, 2020). The MEGA transect project is another largely successful citizen science project which monitors ecological changes along the Appalachian Trail (Dufour and Crisfield, 2008). The MEGA transect project has provided infrastructure for over 40,000 active participants to conduct research and has been able to collect data on plant phenology, pollinator activity, presence of migrating birds, and water quality (Cohn 2008). These projects confirm citizen science continues to contribute to world-wide scientific understanding.

Strengths and Weaknesses of Citizen Science

Citizen science enables large and small scale projects to increase public interest in science and educate the public. By its very nature, citizen science allows for the collection of larger data sets. With enough participants, two years of data collection may result in sample sizes that previously took 10 years to collect by a research team alone (Zapponi *et al*. 2017). Because citizen science can involve many observers in many different places, it lends itself well to geographically extensive (large scale) projects (Zapponi *et al*. 2017; Miller-Rushing *et al*. 2012; Dickinson *et al*. 2010; Dickinson and Bonney 2012). For the same reason it has been successful in documenting rare or invasive species (Pocock *et al*. 2017; Losey *et al*. 2007; Gallo and Waitt 2011) and tracking movements of species, including diseases (Dhondt *et al*. 1998; reviewed in Dickinson *et al*. 2012).

Citizen science supports studies that scientists might not otherwise be able to conduct due to funding and publication limitations. Importantly, local projects have been successful in examining ecological topics of interest including pollution, wildlife deaths, and pest outbreaks (Miller-Rushing *et al*. 2012). A small citizen science project might also focus on gathering pilot data to enable a funded grant application.

Citizen science engages the public and increases interest and scientific literacy (Lowman *et al*. 2009; Bonney *et al*. 2009). When citizen science projects are developed with the audience in mind, they help to bridge the engaging of audiences that may not otherwise have access or interest in the study. Tiered-engagement projects (designed to support multiple levels of engagement) allow participants to be involved in varying ways (as per their comfort level or personal restrictions). Tiered engagement projects can also focus on different types of data. In this, low-commitment participants might provide simple, presence/absence data (and need little training) and high-commitment participants (with more training and time) could complete transect surveys and collect more robust data. Importantly, presence/absence data can help inform where and when transect surveys should take place. Thus, both levels of data are significant and useful.

In terms of weaknesses, some question the quality of citizen science data. Data quality concerns include limited (a) attention to detail with regard to study design (Newmen *et al*. 2003; Krasny and Bonney 2005), (b) participant training (Conrad and Hilchey 2011), and (c) standardization or verification methods (Cohn 2008; Dickinson *et al*. 2010; Bonter and Cooper 2012). It is possible that poor study designs introduce sampling biases which can affect data quality (Galloway *et al*. 2006; Delaney *et al*. 2008; Dickinson *et al*. 2010) and be difficult to assess without much metadata on methodology (reviewed in Burgess *et al*. 2016). Additionally, species identification can be difficult when projects involve many species, as in the case of a Bioblitz (inventory of plant and animal species within a local area) when the goal is to survey all species encountered. In all, verification of data (e.g. species identification or measurements) requires specific training for the task at hand. Thus, large citizen science projects may encounter difficulty in gathering enough trained volunteers to head research groups over large spans of time and space.

Though citizen science affords opportunity for effectively engaging diverse audiences, citizen science participation does not align with United States demographics, with minority groups generally underrepresented (Bonneau *et al.* 2009; Pandya 2012; Burgess *et al.* 2017). This lack of diversity effectively erodes project quality by excluding knowledge-bases (e.g. native, ethnic, and/or local expertise) that could provide valuable insight (e.g. Blake *et al.* 2020). Limiting factors to broader demographic participation can be resource driven, such as lacking the time and/or money to engage in such activity, or socially driven factors, such as potential participants not seeing themselves reflected in the current project participants (Evans et al 2005; Levine *et al.* 2009; Pandya 2012; Blake *et al.* 2020). Diverse participation and perspectives, however, can round out and solidify background knowledge and methods, especially with respect to local areas (Blake *et al.* 2020).

How Master Naturalist Programs Strengthen Citizen Science

Master Naturalist programs can increase the strengths of citizen science by enabling projects, engaging the public, and increasing interest and scientific literacy. They can also help eliminate the weaknesses associated with data quality and participation. Master Naturalist programs can serve as a resource for citizen science projects by providing a physical hub for meetings, storage, and workspace. Different chapters across the State can organize around local issues and facilitate projects, such as the many successful projects conducted by chapters of the Texas Master Naturalist (TMN) program. The TMN projects include land management programs, localized herbarium collections, lizard DNA collection studies, and amphibian monitoring projects (Texas Master Naturalist 2009). Master Naturalists' training prepares adults as knowledgeable volunteers, allowing them to become valuable members of research teams and potentially strong project facilitators themselves. For instance, participants of TMN training experienced a 15% increase in their ecological knowledge and 82% participated in volunteer activities within eight months after training (Bonneau *et al.* 2009). Individuals that are part of groups such as Master Naturalist programs are generally involved in citizen science, more efficient at collecting data, and develop increasing project investment over time (Crimmins *et al*. 2015; Merenlender *et al*. 2016). For example, the Nebraska Master Naturalists program reports citizen science as the second most active area of volunteer service (behind education), with over 17,000 hours logged since 2010 (Matt Jones, personal communication, October 29, 2020). This makes up 20% of all hours logged by Master Naturalists in Nebraska. The public is often engaged by the sense of community that occurs when actively involved with like-minded individuals. Participant quotes, for instance, include "I like to volunteer with people of a like mind concerning our environment"; "It enables me to learn more about the things I love most and to share that knowledge with people with the same interests"; "I'm with people who think like I do and nobody cares what you're wearing"; "I found a community of people that have the same interests" (Texas Master Naturalist 2009).

Master Naturalist programs occur in most States with their associated training and low cost of participation increasing access to citizen science, including to a diverse set of cultural and socioeconomic participants. When asked about the relationship between Master Naturalists and citizen science, Matt Jones, the State Director of the Nebraska Master Naturalists program stated, "Nebraska Master Naturalists have been a valued asset... by offering their time and talents in their effort to fill information needs and data gaps through citizen science and monitoring projects. Citizen Science projects (in turn) have provided Master Naturalists with diversified training and education opportunities, as well as an avenue to get in on the ground floor and be valued members of research teams." (personal communication, October 29, 2020).

Resources and Best Practices for Master Naturalists as Citizen Scientists

Master Naturalists might initiate their own citizen science project or find an established project of personal interest. When initiating a project, it is generally best to understand what the target audience finds rewarding so participant interest and commitment will be peaked (reviewed in Dickinson *et al*. 2012). Larger projects across time and locations require substantial initial preparation and organization to be successful. The general considerations and steps involved (**Table 1**; reviewed in detail by Newman *et al*. 2012 and Bonney *et al*. 2009) include 1) gathering teams, resources, and partners, 2) defining research questions, 3) collecting and managing data, 4) analyzing and interpreting data, 5) disseminating results, and 6) evaluating program success and participant outcomes.

Project topics that work well at the local level include studies on water quality, species presence and/or abundance and abiotic environmental data at certain times of the year, specimens for local collections, comparative or manipulative experiments, and biodiversity (at both community and population levels). Local venues provide opportunity for outreach and workshops. Resources (e.g. binoculars, field guides, etc.) for citizen science projects may be provided by local state agencies or Master Naturalist chapters.

General guidelines for initiating and managing citizen science projects revolve around communication (Dickinson *et al*. 2012). For instance, communications with stakeholders (especially during the conception and development of a project) help establish the project relevancy, partners' investment, project scope, and scientific methods. Communication strategies might include relevant outlets such as press releases, blogs, social media, newsletters, listservs, and personal/professional networks. For longer-term projects, communications can be boosted by incentive-based interactions such as earning certificates/giveaways or participating in contests (e.g. best photo, best illustration, most identifications; Dickinson *et al*. 2012).

Attention to the human dimensions can help to ensure the quality and sustainability of a project for years to come. It can also help to increase the diversity and number of participants. Efforts to engage relevant communities while developing and maintaining local projects can be vital to instilling a sense of ownership in participants (Pandya 2012) and gathering new insights to project design and methods. The incorporation of multiple levels and kinds of knowledge can also be important for engaging different audience types (Pandya 2012). This can include different age ranges, as well as ethnic and cultural backgrounds. Keys to diverse participation include eliminating place-based and financial hurdles and using inclusive marketing and training materials (Long *et al.* 2001; Liboiron 2019; Blake *et al.* 2020; Chesser *et al.* 2020). As such, it is important to consider locations of projects with regard to participant travel restrictions. For instance, potential inner-city participants may have the interest but not the ability to reach distant or rural localities. It is also important to keep costs of participation low or free and possibly even

Table 1. Aspects to consider when joining or initiating a citizen science project.

Considerations
• General interests • The research question(s) • Potential partners • Time commitment • Prior knowledge or training required • Organized event or flexible schedule • Location(s) convenient, localized or dispersed • Quality of data needed • Data collection methods (app, data sheet, pictures, etc.) • Resources necessary to complete data collection • Lines of communication between the researcher and the data collector(s)

provide financial incentives for those that successfully collect data (Liboiron 2019; Chesser *et al.* 2020). Training and marketing materials should focus on inclusivity by actively countering stereotypes about who can conduct scientific research (Long *et al.* 2001; Blake *et al.* 2020).

New technology tools have spawned important ways Master Naturalists can play a vital role in the further success of citizen science (Newman *et al*. 2012). For example, listservs communicate volunteer opportunities associated with regional, national, or global opportunities. Web platforms (i.e. Scistarter, CitsSci, and Zooniverse) provide searchable databases of citizen science opportunities and many phone/tablet applications can connect individuals to ongoing efforts that span broad geographic options (**Table 2**). Technology access, along with promotion of stories about Master Naturalists' integral involvement in citizen science projects (related to efforts such as water quality management, ecological restoration, or biodiversity surveys) can spur Master Naturalists' participation in citizen science initiatives (Merenlender *et al*. 2016) that help us better understand our world and strengthen citizen science as a discipline.

As previously noted, citizen science can be utilized with a focus on science education or science research but, in reality, citizen science generally blends the two experiences. In the case of science education, citizen science efforts encourage lifelong learning, and can engage participants of different ages, backgrounds, and knowledge levels. In schools, citizen science can guide lesson plans (for young and old alike) on biodiversity of local environments, conservation of local species, or monitoring of ecological processes. Some larger citizen science projects lend instructional support for real-world science inquiry in K-12 schools (Trautmann *et al*. 2012). The iNaturalist Teacher's Guide (Iwane 2018) is an example that provides well-detailed pre and post-Bioblitz lessons (aligned with Next Generation Science and National Geography standards) for high school and college instruction.

In the case of science research, citizen science data may be too imprecise for rigorous analyses (Cohn 2008; Mackenzie *et al*. 2017). As project organizers, Master Naturalists can minimize weaknesses (i.e. data verification, communication, and project organization) by following three simple guidelines:

1. Be specific about what data needs to be collected (given that data collection is the primary goal).
2. Determine and maintain data reliability by including trained staff to oversee and compare data collected by volunteers (Cohn 2008).
3. Employ technology such as smartphone applications and data repositories (e.g. iNaturalist) to allow multiple confirmations of individual identifications. These confirmations can significantly increase data confidence (e.g. Bonter and Cooper 2012) and allow data to be more easily collected.

Table 2. Citizen science web platforms and phone/tablet applications that allow the user to find projects and identify and/or collect data on plants, wildlife, and abiotic factors. Most applications are found on both Android and iPhone, but some are limited to one or the other.

Platform/Application	Focus	Website
Project Noah	General	http://www.projectnoah.org/
iNaturalist	General	https://www.inaturalist.org/pages/getting+started
Zooniverse	General	https://www.zooniverse.org/
CitSci	General	https://www.citsci.org/
Scistarter	General	https://scistarter.com/
Journy North	Wildlife migration	https://www.learner.org/jnorth/
eBird	Birds	https://ebird.org/
HerpMapper	Reptiles and Amphibians	https://www.herpmapper.org/
Leafsnap	Trees	http://leafsnap.com/
Project Budburst	Plants	http://budburst.org/projects/nativars-research-project
I See Change	Plant phenology	https://www.iseechange.org/
iAngler	Fish	http://snookfoundation.org/news/research/561-iangler.html
Splatter Spotter	Roadkill	https://roadkill.csuci.edu/
Marine Debris Tracker	Floating debris	http://www.marinedebris.engr.uga.edu/
Secchi	Phytoplankton	http://www.secchidisk.org/
NoiseTube	Noise pollution	http://www.noisetube.net/#&panel1-1

Conclusions

The goals of citizen science are many. Citizen science largely focuses on collecting large amounts of data that would not be possible without many interested and active volunteers, but it also includes smaller, local projects and education. Regardless of scale, citizen science inspires the public to participate in hands-on scientific research. At its core, citizen science is about nurturing individual scientific literacy and can be a powerful tool to inspire appreciation of the natural world and to educate the public about conservation and restoration of wild places. As research suggests, citizen science participants often exhibit an increase in conservation advocacy (Forrester *et al*. 2017; Lewandowski and Oberhauser 2017) and improve their scientific and environmental literacy.

Master Naturalist programs assist and promote citizen science for the dual purpose of public education and scientific discovery. They provide high-quality training for volunteers, resulting in data quality, commitment to projects, and diversity in the sciences – all of which are fundamental to the future success of citizen science as a discipline. Master Naturalists are part of a growing network, and with the proper guidance, they can become a major driving force in the expansion of citizen science programming throughout the United States, both as participants and facilitators.

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