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Monitoring Young Tree Survival with Citizen Scientists: The Evolving Tree Checkers Program in Philadelphia, PA

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Abstract. Citizen science programs are not static; they change over time in response to new program priorities and emerging technologies, as well as to improve work flow for program staff and volunteers. In this article, the authors present a case study of an evolving urban forestry citizen science program at the Pennsylvania Horticultural Society, a nonprofit organization in Philadelphia, Pennsylvania, U.S. The Tree Checkers program involves tree stewards recording data each summer about recently planted tree survival, growth, crown vigor, and maintenance, while also engaging their neighbors to encourage proper tree care. The program began in 2011, but changed in 2016 to use a new online data collection tool that was integrated into a larger tree data management system. Tree Checkers has also shifted to be more focused on rigorous data to report program performance and share information with researchers, whereas the earlier years of Tree Checkers were centered on enabling and encouraging neighborhood tree stewards to plan for tree care. A recent data quality evaluation showed that volunteer data was reasonably consistent with data reported by more experienced interns for tree survival, vigor, and trunk measurements, but stewardship variables were not interpreted and recorded consistently. By making rigorous data more central to Tree Checkers, program staff also sought to institutionalize monitoring within the organization, allowing for direct comparisons of outcomes year-to-year. The authors close with lessons learned that are relevant to other organizations seeking to create or enhance outcomes monitoring programs with citizen scientists.

Key Words. Adaptive Management; Citizen Science; Data Quality; Tree Mortality; Tree Survival; Urban Environmental Stewardship; Urban Forestry; Volunteer Monitoring.

Volunteer stewardship is integral to urban forest management, with volunteer roles associated with duties such as tree planting, maintenance, and data collection (Silva and Krasny 2014; Fisher et al. 2015; Hauer et al. 2018). Citizen science, in particular, has been gaining steam in urban forestry, with municipal agencies and nonprofit organizations engaging volunteers in monitoring and inventories (Roman et al. 2013; Roman et al. 2017; Bancks et al. 2018; Crown et al. 2018; Roman et al. 2018). In the ecological and environmental sciences, a citizen scientist is "a volunteer who collects and/or processes data as part of a scientific enquiry" (Silvertown 2009) and citizen science programs are "partnerships between scientists and non-scientists in which authentic data are collected, shared, and analyzed" (Jordan et al. 2012). While these definitions imply formal scientific uses of volunteer-generated data, citizen science is also widely used by natural resource managers for adaptive management, with applications beyond peer-reviewed publications (McKinley et al. 2012; McKinley et al. 2015). Whether citizen science programs serve primarily scientific or resource management objectives, they can change over time, adapting to shifting goals and new technologies (Sullivan et al. 2009; Newman et al. 2012; Tulloch et al. 2013).

In this article, the authors present a case study of a citizen science street tree monitoring program, Tree Checkers, at the Pennsylvania Horticultural Society (PHS) in Philadelphia, Pennsylvania, U.S. More specifically, Tree Checkers is an example of community-based outcomes monitoring to sup-

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port urban natural resource stewardship (Silva and Krasny 2014). The study begins with a review of the program's origins, purpose, and operations, and a background on research collaborations. Next, the authors discuss recent efforts to enhance the program through mobile data collection and data quality assessments. The case study concludes with lessons learned to provide guidance to other urban forestry practitioners and researchers considering starting or enhancing a citizen science program. These findings are also relevant to practitioner-driven citizen science projects more broadly, particularly with respect to adapting data collection systems, promoting data quality, and fostering partnerships.

BACKGROUND

Street Tree Programs at PHS

PHS is a nonprofit organization, founded in 1827, with a mission to "[connect] people with horticulture and together we create beautiful, healthy, and sustainable communities." PHS is based in Philadelphia, PA, and works in that city and the surrounding counties. Tree Tenders, founded in 1993, is a volunteer urban tree planting and stewardship program and is a centerpiece of PHS's community engagement. Out of 122 current staff, 3 full-time staff work on Tree Tenders, with occasional part-time interns. PHS personnel educate residents about the importance of increasing urban tree canopy, and teach them how to plant, prune, water, and otherwise maintain trees. Residents who have taken a nine-hour course (over two or three sessions) on these topics are considered official PHS Tree Tenders. Over 5,000 people in the Philadelphia area have graduated from the program over the past 25 years.

Tree Tenders has a decentralized structure, working with neighborhood groups to plant trees. Residents serve as Tree Tenders group leaders and run their groups semi-autonomously. Within Philadelphia, there are currently 32 Tree Tenders groups. In advance of each autumn and spring planting season, Tree Tenders group leaders submit lists of potential tree planting locations to PHS staff; these locations are produced through neighborhood-level outreach from each group. PHS then distributes trees to Tree Tenders groups, who plant the trees with their neighbors. Over the past three years, 800–1,000 trees have been planted annually in Philadelphia. Most (roughly 90%) of these are street trees. In 2000, Tree Tenders switched to bare-root trees, instead of balled-and-burlapped stock, because of lower per-tree costs as well as less bodily strain for volunteer planters and PHS staff. In addition, research shows that bare root planting stock can have similar post-planting survival and growth to balled-and-burlapped trees (Buckstrup and Bassuk 2003; Jack-Scott 2012).

The Tree Checkers program was launched in 2011 to further engage Tree Tenders in the summer months, encourage ongoing stewardship and community engagement, and produce lists of dead trees that need to be replaced. Tree Checkers is a citizen science program in which volunteers collect data on recently planted tree survival, growth, crown vigor, and stewardship. Tree Checkers was based on a similar volunteer young tree monitoring program run by Friends of Trees (Portland, Oregon, U.S.), as presented at the 2010 Partners in Community Forestry conference in Philadelphia. The emergence of Tree Checkers is therefore an example of knowledge transfer through urban forestry communities of practice (Campbell et al. 2016). Another example of urban forestry professionals adopting and modifying programs from peer organizations is the spread of yard tree giveaway programs in the northeastern United States (Nguyen et al. 2017).

In addition to data collection, individuals are expected to engage with their neighbors to promote stewardship. The Tree Checkers program is structured so that the citizen scientists operate within their Tree Tenders group turf—that is, within their own neighborhoods—to monitor the trees their group planted. Promoting stewardship through community engagement was considered the highest priority for Tree Checkers during early years of the program; less emphasis was placed on data collection to report program outcomes. For the property adjacent to every tree, participants were asked to talk to the resident about proper techniques for watering, mulching, staking, weeding, and other tree and site care concerns. If nobody answered the door, volunteers left a "Tree Check-Up Report" with notes as to how the tree was faring and suggestions for improved maintenance. Specifically, this "report card" had two check boxes for each of several essential maintenance tasks: water, weed and clean, expose root flare, and mulch. One check box for each task thanks the resident for doing proper tree care, and the other reminds the resident of what actions to take. For example, with water, the Tree Checkers participant selected either "Thank you for adequately watering your newly planted tree" or "Water is crucial to your tree's survival, especially for the first year after planting," followed by detailed watering directions. A notes section on the "report card" provided space for additional handwritten encouragement. The engagement process was based on two assumptions from PHS staff that are supported in the scholarly literature. First, social norms and neighbor pressure can effectively encourage landscape management behaviors (Larson and Brumand 2014; Sisser et al. 2016). Second, proper maintenance is essential for urban tree survival and growth during post-planting establishment (Koeser et al. 2014; Roman et al. 2015; Vogt et al. 2015).

In recent years, PHS Tree Tenders staff sought to enhance the Tree Checkers program to produce more robust data to analyze and understand tree performance. Two specific areas for improvement were identified and are discussed in this paper: 1) adding a mobile data collection system as part of a larger effort to improve data management, and (2) ensuring that Tree Checkers produces reliable tree performance metrics (survival and vigor), in terms of both sampling design and volunteer observation errors. These shifts reflect new priorities among staff to produce high-quality data. Indeed, these two areas—data management and data reliability—are intricately linked, as data quality is a multidimensional issue encompassing accuracy, accessibility, believability, completeness, and unbiasedness (Pipino et al. 2002; Kosmala et al. 2016).

Research Collaborations

Recent changes to the Tree Checkers program occurred in the context of ongoing and prior research collaborations. PHS staff members were spurred to enhance Tree Checkers to leverage the close partnership between PHS and the United States Department of Agriculture Forest Service Philadelphia Field Station, which opened in 2012 and is hosted by PHS. PHS staff also sought to emulate productive research in other PHS program areas. The PHS senior director of planning and sustainable communities, who supervises Tree Tenders staff, had seen examples of rigorous research on another PHS program, LandCare, which "cleans and greens" vacant lots. LandCare has been extensively studied by scientists from the Forest Service Philadelphia Field Station and the University of Pennsylvania, with findings that demonstrate the program's impact on crime and human health (Branas et al. 2011; South et al. 2015; Branas et al. 2016; South et al. 2018). Such analyses were made possible by high-quality program records and advanced planning for research studies.

In enhancing the Tree Checkers program, the objective of PHS tree team staff was to produce reliable data for both internal program assessment and research collaborations through improved data quality and data management and in the Tree Tenders program. As stated in an evaluation of knowledge co-production in urban forestry, "relationships between individuals are at the heart of effective partnerships" (Campbell et al. 2016). Consequently, PHS staff began collaborating with a research ecologist at the Philadelphia Field Station (and lead author on this article) who specializes in urban tree mortality and monitoring (Roman et al. 2016), with recent research on citizen science data quality (Roman et al. 2017). The current set of Tree Checkers variables (Table 1) was based on this scientist's work toward a minimum data set for monitoring (Roman et al. 2013; Campbell et al. 2016; Roman et al. 2017). Studying tree mortality of PHS street trees was also the topic of that scientist's master's research at the University of Pennsylvania (Roman and Scatena 2011). There was therefore a history of personal relationships to undergird the PHS-Forest Service partnership to enhance Tree Checkers.

Across three previous monitoring studies of PHS trees led by graduate students (Roman and Scatena 2011; Jack-Scott 2012; Widney et al. 2016), there were divergent outcomes, with annual tree survival ranging from 87%–96% (Table 2). PHS staff found it difficult to make meaning of these outcomes given the different methods used in each study. In particular, while Roman and Scatena (2011) and Widney et al. (2016) followed typical convention for urban forestry studies in defining mortality as a combination of trees observed standing dead and those removed/missing (e.g., Roman et al. 2014a), Jack-Scott et al. (2012) reported mortality as only standing dead trees. Additionally, the Roman and Scatena (2011) study was limited to only one species and had a smaller sample size than the other two studies. The lowest reported survival comes from Widney et al. (2016), but PHS staff have concerns that this low survival could potentially be due to one or more abnormalities (e.g., an unusually cold winter, poor quality nursery stock, messy planting records). These suspicions are untested yet they point to the larger challenges of explaining survival outcomes across different studies, even within the same program. The enhanced Tree Checkers program is meant to institutionalize young tree monitoring within PHS, using consistent methods, to produce results that can be directly compared year-to-year. In other words, PHS staff wanted to produce data perceived internally as reliable—a common goal for many citizen science programs (Kosmala et al. 2016).

Table 1. Monitoring data collected by Tree Checkers on recently planted street trees. Methods based on the Urban Tree Monitoring Field Guide pilot test (Roman et al. 2017) with vigor following Pontius and Hallett (2014).

Variable	Description
Mortality status	Whether the tree is alive, standing dead, removed, stump, or never planted
Crown vigor class	A holistic assessment of overall crown health, ranging from class 1 (healthy with little fine twig dieback and no major branch loss) to class 5 (dead)
Trunk circumference	Circumference of the trunk generally recorded at 1.37 m (4.5 ft) depending on tree form; multi-stemmed trees recorded below the fork; exact height used is also recorded
Mulch	Assessment of mulch based on PHS recommended practices (good, poorly done / too much, too little, none)
Weeds/trash	Presence/absence of weeds and trash in the soil pit
Inadequate water	Presence/absence of insufficient water, based on field crew feeling for soil moisture
Bark damage	Presence/absence of damaged bark
Broken branches	Presence/absence of broken branches
Suckers/sprouts	Presence/absence of root suckers / basal sprouts
Root flare buried	Presence/absence of root flare above the soil line; buried root flare indicates tree was planted too deep
Tree photo	Photograph of the whole tree in the context of its immediate surroundings

Table 2. Tree survival findings from previously published studies of PHS street trees.

Study objective	Survival outcome	Years since planting	Sample size	Notes on methods	Citation
Determine annual survival rate	95.5% annual survival	2–10	151	Limited to *Acer campestre*; mortality rate includes both missing and standing dead	Roman & Scatena (2011)
Evaluate survival and growth of bare root versus balled-and-burlapped planting stock	95% cumulative survival for bare root, 96% for balled-and-burlapped	2.6 average	1,411	Limited to commonly planted species, randomly blocked by year; missing trees were not included in mortality rate	Jack-Scott (2012)
Evaluate survival and growth to estimate future benefits	59% cumulative survival; 87% annual survival	3–5	1,742	All species included; sampling based on neighborhood groups; mortality rate includes both missing and standing dead	Widney et al. (2016)

ENHANCING TREE CHECKERS

Mobile and Online Data Collection

Prior to 2016, PHS records for tree planting and monitoring were managed through a complex series of steps involving manually entered paper records and emailed spreadsheets (Boyer et al. 2016). With the decentralized structure of the Tree Tenders program, this data management system required PHS staff to clean and compile dozens of spreadsheets from the group leaders for both planting requests and monitoring data. PHS staff were concerned that this process was too time-consuming and prone to error. When PHS staff began their search for a software solution to their data management challenges, there was no off-the-shelf option, as proprietary software for urban forestry did not include monitoring features (Boyer et al. 2016). To address data management concerns, PHS switched to a new data management and collection system in 2015, called the PHS Urban Forest Cloud, a customization of the Tree Plotter software from the firm Plan-It Geo (Hanou 2016). The Urban Forest Cloud system "features a collection of all data gathered for individual trees and projects and enables multiple user groups to update and manage tree information that is stored in a central database and map" (Hanou 2016). Within the Urban Forest Cloud, the Tree Checkers component is a web-based data collection system that enables volunteers to enter data via mobile devices, such as smartphones or tablets. During the summer of 2017, half of the tree data came through mobile data collection, while data from Tree Checkers who preferred paper was entered later via computer.

With two summers of Tree Checkers data collection using the Urban Forest Cloud (2016–2017), PHS staff have identified several benefits of the system. First, although there was an initial financial and staff time investment in the software and re-training of volunteers, the data entry burden for PHS staff and Tree Tenders has declined. Second, by eliminating the data entry and spreadsheet compilation steps, PHS staff can more quickly produce summary statistics about tree-planting performance. Third, based on informal conversations between PHS staff and volunteers, Tree Tenders have appreciated using the online map for routing data collection and visualizing data. Fourth, using mobile data collection has enabled groups to seamlessly integrate tree photos, which should help with reliable re-location of trees in the future (Roman et al. 2017). A key remaining challenge is that a subset of the monitoring data is still submitted via manually transcribed spreadsheets. PHS staff would prefer to have all data submitted via the Urban Forest Cloud, to eliminate the staff time needed to incorporate those spreadsheets back into the cloud. However, PHS staff continue allowing paper data entry, so as not to discourage volunteers who are not comfortable with or do not own mobile devices. Indeed, while citizen science programs more broadly have embraced mobile data collection (Graham et al. 2011; Newman et al. 2012), such technologies can risk excluding certain populations, such as retirees and low-income individuals lacking smartphones (Roman et al. 2013; Klimova et al. 2018).

Data Quality Evaluation

Following in the semi-autonomous nature of Tree Tenders, PHS strongly encourages but does not strictly require (or enforce) participation in Tree Checkers. Therefore, Tree Checkers data is essentially a convenience sample, which may yield biased results due to patterns in non-participation. In some earlier years, only half of the trees planted in the prior two seasons were monitored. In addition to potential sampling bias, volunteers may also have observation errors (Roman et al. 2017). To investigate these data quality issues, PHS and Forest Service scientists designed a supplementary sample for summer 2017. In addition to the volunteer-generated convenience sample, paid interns monitored a random sample. The volunteer sample and the intern sample were collected independently. These interns had additional supervision and training. The primary objective of comparing the volunteers and intern samples was to determine whether overall findings as well as tree-by-tree observations—especially survival—were comparable between the two samples.

Out of the 797 trees planted in autumn 2016 and spring 2017, interns recorded data for 198 (25%) trees and volunteers recorded data for 707 (89%) trees, with 178 recorded by both crews. Volunteers collected data June–August 2017, and interns August 2017. The proportion of trees recorded by volunteers was considerably higher than in prior years (66% in 2015, 71% in 2016). More people may be participating as they learn to use the Urban Forest Cloud, and as Tree Checkers becomes an expected activity for every Tree Tenders group (i.e., staff have pushed for participation more strongly in recent years). The overall 2017 survival was the same for both intern and volunteer data (91%), and interns and volunteers agreed on mortality status for 96% of trees recorded in common (Table 3). For crown vigor, both crews reported that the vast majority of trees were in vigor classes 1 and 2, and volunteer-reported vigor was within one class of intern-reported vigor for 90% of trees recorded in common. Trunk circumference from volunteers was within 2.54 cm of intern values for 62% of trees recorded in common; different circumference values were generally attributable to different heights used. Data consistency levels needed for urban forest management are not necessarily as high as data consistency needs for scientific research (Roman et al. 2013; Bancks et al. 2018). For instance, in this case, mortality and vigor class agreed for the vast majority of trees, and trunk circumference agreed generally within 2.54 cm, but not at the level of inter-field crew agreement required for scientific research with the Forest Service's Forest Inventory and Analysis program (U.S. Forest Service 2016b). These findings suggest that volunteer and intern data quality for vigor and trunk circumference are adequate for PHS needs, but perhaps not sufficient for rigorous research. For instance, the volunteer-produced data should not be used for regression models of factors that predict stem growth, but could be used for rough reporting of typical tree size the first summer after planting. Volunteer mortality observations would be more suitable for research applications, particularly if consistency levels can be raised closer to 99% (the acceptability threshold for mortality consistency in Urban Forest Inventory and Analysis, U.S. Forest Service 2016b). The mortality consistency rates for volunteers in Roman et al. (2017) was 99.9%; those citizen scientists had more training hours compared to Tree Checkers but also encountered fewer dead trees. Additional time devoted to training, or different training techniques, could potentially produce higher consistency levels (Starr et al. 2014; Bancks et al. 2018). Future trainings will emphasize that standing dead trees should have completely dead crowns (i.e., a nearly-dead tree with only a few leaves would be classified alive), and discuss how to treat situations in which the main stem is dead but living suckers have emerged at the base.

Mulch classification was reported to be the same category for 55% of trees recorded by both interns and volunteers, the lowest consistency level reported in Table 3. Consistency levels for other stewardship variables (presence/absence of weeds/trash, inadequate water, bark damage, broken branches, suckers/sprouts, and buried root flare) are not reported here because of concerns regarding how those variables were interpreted and recorded by field crews. We suggest several possible explanations for challenges with recording stewardship variables: 1) with subjectivity involved in most of these observations, some crews may be rating trees more harshly; 2) some volunteers may have recorded the circumstances as they left the tree (i.e., after doing maintenance) rather than how they found the tree (as instructed during training), and may have been more focused on doing maintenance than recording it; 3) some of the stewardship variables are inherently ephemeral, so recording this information on different days could produce different observations; and 4) inconsistent notation (e.g., yes/no, blank/check mark) by volunteers using paper data entry. Overall, it is apparent that improved training is needed to produce consistent results with the stewardship variables, and the authors have not reported findings for most stewardship variables because the interpretations are unclear. Learning from these

Table 3. Monitoring findings comparing overall volunteer-collected data (n = 707, convenience sample) to intern-collected data (n = 198, random sample), and tree-by-tree consistency for the trees observed by both field crews (n = 178). Blank entries were omitted from all summary data.

Variable	Volunteer result	Intern result	Tree-by-tree consistency
Survival	91%	91%	96% agreement
Crown vigor	74% in classes 1 & 2	84% in classes 1 & 2	volunteer vigor within 1 vigor class of interns for 90% of trees
Trunk circumference	n/a	n/a	62% within 2.54 cm
Mulch	40% good	34% good	55% agreement

challenges, PHS and Forest Service personnel have stressed during training that crews should record tree stewardship variables as observed when they found the tree, and should always mark yes/no for binary variables (i.e., never leave a data field blank). Trainings in future years will also emphasize thresholds for stewardship variables with real-world examples, for instance, using photos from prior years to illustrate how much weeds and trash need to be present in a planting pit to warrant a "yes" finding.

Notably, Tree Checkers volunteers did not need to identify species of the planted trees, as this information was pre-populated into the mobile data collection system and printed data collection sheet. Prior studies about urban tree species identification accuracy by volunteers have suggested that volunteers perform fairly well for common genera (consistency ~86%–91%), with results varying across species (Roman et al. 2013; Bancks et al. 2018; Crown et al. 2018). Indeed, monitoring recently planted trees for survival may be particularly well-suited to amateur volunteers because species identification skills are not necessary.

Importantly, volunteers noted two trees as mortality status "not planted." These trees were improperly included in the planting records. One tree was not actually delivered to a neighborhood Tree Tenders group on planting day, and the other was given to a Tree Tenders group but could not be planted. These trees were included in both the volunteer and intern samples, but only the volunteers correctly categorized the two trees because they had situational knowledge about planting events. These two trees represent 0.3% of the trees observed by volunteers, and 1.0% of the trees observed by interns. While these are low overall proportions, every percent (or even tenth of a percent) matters for mortality rate calculations, particularly for studies such as Widney et al. (2016) that model tree population growth over time using mortality rates calculated from establishment phase monitoring. Therefore, when such errors in the baseline planting data are not caught, they can lead to inflated mortality rates, and the inappropriate mortality rate can be compound in projection models. This phenomena speaks to the importance of high-quality baseline data that lists only trees that have been confirmed planted (Vogt et al. 2015). Ultimately, in the mortality rates reported in this study, the authors excluded these two trees from the calculations. It is possible that similar circumstances arose in previous monitoring studies of PHS trees (Table 2), but external researchers (and their field interns) may not have been able to catch the issue. The concern of tree distribution records that include trees never planted has been discussed for yard tree giveaway programs (Roman et al. 2014b), yet the extent of the failure to plant phenomenon is not well understood for street tree program records.

While PHS staff and Forest Service researchers cannot be certain of the underlying causes of every data quality issue discussed above, they have identified a few changes moving forward that will hopefully improve baseline and monitoring needs. First, PHS staff will pay close attention to trees not planted, ensuring that the baseline data given to Tree Checkers does not contain such trees. Second, stewardship variables will have their definitions adjusted and training improved to promote clarity and consistency. Third, when PHS staff present findings of stewardship variables, the outcomes will be framed with a grain of salt because of the subjective and ephemeral nature of evaluating maintenance. Furthermore, it must be reiterated that the Tree Checkers stewardship variables were not originally intended to be used for data analysis, per se. Finally, regarding sampling, if Tree Checkers continue to report data on the vast majority of trees, PHS may consider recruiting additional volunteers (e.g., local college students) to monitor the remaining trees each August or September. Such a hybrid system would retain the original resident-to-resident focus of Tree Checkers, while also producing data on all planted trees.

LESSONS LEARNED

In reviewing the evolution of the Tree Checkers program at PHS, staff and researchers have identified the following lessons learned that may be helpful to others involved with citizen science in urban forestry.

Citizen science programs are not static. These programs evolve to address changing priorities, improve workflows, adapt to new technologies, and enhance engagement opportunities. With outcomes monitoring as part of adaptive management, the adaptive component is sometimes taken to refer to shifts in management strategies in response to outcomes observed (McKinley et al. 2015). Yet the monitoring program itself can and should also adapt to meet new needs and opportunities (Lindenmayer and Likens 2009). Tree Checkers, as it exists today, has the same core elements that it had when it launched in 2011—namely, volunteers monitoring recently planted trees in their neighborhoods—yet the particulars of how the program operates, and even the PHS staff's goals for the program, have shifted. Crown et al. (2018) likewise describe how a citizen science street tree inventory program in New York City, New York, U.S., has changed over time.

Objectives for monitoring urban trees—and the data quality needs for those objectives—vary across programs. Over the past few years, the Tree Checkers program has prioritized the collection of rigorous, consistent data for outcomes monitoring to produce results that can be meaningfully compared year-to-year and shared with researchers. This shift means that the goal of producing high-quality data becomes paramount. In the earlier years, Tree Checkers was more focused on encouraging proper tree stewardship through neighbor-to-neighbor pressure. That objective uses data collection as a catalyst for stewardship, rather than data collection as a vehicle to evaluate program performance. It is imperative that data quality needs be matched to monitoring objectives (Kosmala et al. 2016). The data consistency observed for the Tree Checkers program does not meet the high standards for the Forest Inventory & Analysis program. Yet that is not necessarily a large concern for internal program reports because management-oriented monitoring does not require the extremely high data consistency levels needed for scientific research (Roman et al. 2013; Bancks et al. 2018). While the trunk measurements do not show consistency levels that would enable analysis of stem growth, volunteer mortality observations may be suitable for research applications, particularly if consistency levels (currently 96%) could be pushed slightly higher through additional training.

Accurate at-planting data is critical to monitor urban tree planting programs. Any monitoring program relies on accurate baseline data; to track urban trees during establishment, this baseline is at-planting data (Vogt et al. 2015). When these records contain errors or have incomplete information, monitoring becomes challenging or even infeasible. While at-planting data for Tree Checkers are generally clean with the new Urban Forest Cloud, there are still rare instances of trees incorrectly listed as planted, as well as occasional locational confusion. Although these issues apply only to a tiny fraction of the database, they could potentially inflate mortality rates: a tree that was never planted or that was planted at a different property could mistakenly be recorded as "removed." The use of local Tree Tenders to collect data offers a validation check for at-planting data, as these tree stewards were present on planting day and can catch errors in the records. Older planting records at PHS seem to have more gaps and other issues that cause problems for monitoring studies.

Research-practice partnerships can lead to knowledge co-production, but institutionalized monitoring by managers creates continuity. While the findings of various past monitoring studies provided some useful information for PHS staff, these studies had varying methods, meaning that their findings cannot be directly compared. Enhancing the Tree Checkers program will create continuity over time for PHS to evaluate their tree planting efforts year-by-year. When natural resource managers seek to track outcomes from their own programs, practitioner-initiated and programmatically institutionalized monitoring, as opposed to researcher-originated projects, can appropriately serve local management needs (Silva and Krasny 2014).

There is much more to learn about Tree Checkers and other citizen science monitoring efforts in urban forestry, including what motivates volunteer participation, what volunteers learn by participating, how resident maintenance activity responds to conversations and "report cards," and how planted trees fare over the long-term. By enhancing their data management system and focusing on data quality, PHS staff aim to enable such investigations through future research-practice partnerships.

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Résumé. Les programmes de science citoyenne ne sont pas immuables; ils évoluent au fil du temps en réaction à de nouvelles priorités et à l'émergence de nouvelles technologies, mais également afin d'améliorer l'efficacité du travail pour le personnel de soutien et les bénévoles. Dans cet article, nous présentons une étude de cas d'un programme de science citoyenne évolutif de foresterie urbaine à la Pennsylvania Horticultural Society, un organisme à but non lucratif de Philadelphie, PA. Le programme Tree Checkers regroupe des membres qui enregistrent chaque été des données sur la survie d'arbres récemment plantés, leur croissance, la vigueur de leur houppier et leur entretien et ce, tout en encourageant les voisins riverains à s'impliquer dans l'entretien approprié des arbres. Le programme débuta en 2011 mais fut modifié en 2016 afin d'utiliser un nouvel outil de collecte des données en ligne qui était lui-même intégré à un système de gestion de données plus vaste. Tree Checkers a également changé afin d'être mieux ciblé vers l'obtention de données rigoureuses pour rendre compte de la performance du programme et partager l'information avec les chercheurs, alors que dans les premières années, l'accent était davantage porté sur l'encouragement et la prise en charge par le voisinage de la planification en vue de l'entretien des arbres. Une évaluation récente de la qualité des données montra que les données des bénévoles étaient raisonnablement cohérentes avec celles relevées par les employés davantage expérimentés en ce qui a trait à la survie, à la vigueur et au diamètre mesuré des arbres, alors que les paramètres de gestion n'étaient pas interprétés et relevées de manière constante. En priorisant l'obtention de données plus rigoureuses, le personne de soutien du programme Tree Checkers cherchait à avoir un suivi institutionnalisé au sein de l'organisation, permettant ainsi des résultats comparatifs d'une année à l'autre. Nous concluons avec des enseignements tirés qui sont pertinents à d'autres organisations cherchant à créer ou à améliorer les résultats de programmes de surveillance avec des citoyens scientifiques.

Zusammenfassung. Wissenschaftliche Programme für Bürger sind nicht statisch, sie verändern sich über die Zeit in Reaktion auf neue Programmprioritäten und sich verändernder Technologie, genauso wie sich der Work-flow für Programmmitarbeiter und Freiwillige verbessert. In diesem Artikel präsentieren wir eine Fallstudie eine sich entwickelnden wissenschaftlichen Bürgerbeteiligung an der Pennsylvania Horticultural Society, einer Nonprofit-Organisation in Philadelphia, PA. Die Baumchecker Programme involvieren Baumpaten zur Aufzeichnung von Daten in jedem Sommer über die kürzlich gepflanzten Bäume, deren Überleben, Wachstum, Kronenvitalität und Pflege, während ebenso die Nachbarn zu richtigen Pflege von Bäumen ermutigt werden. Das Programm begann in 2011, aber wechselte in 2016, um ein neues online Datenerfassungswerkzeug, welches in ein größeres Baumkatastersystem integriert ist, zu verwenden. Baumchecker hat sich auch verändert hin zu größerem Fokus auf rigorose Daten zur Leistung der Programmberichte und dem Informationsaustausch mit Forschern, wo in den früheren Jahren von Baumchecker der Fokus auf Ermöglichen und Ermutigen von nachbarschaftlichen Baumpatenschaften zur Planung von Baumpflege lag. Eine kürzliche Evaluation der Datenqualität zeigte, dass die Daten der Freiwilligen einigermaßen konsistent waren mit den Daten, die von mehr Erfahrenen für Überleben, Vitalität und Stammmessung berichtet wurden, aber die Patenschaftvariablen wurden nicht konsistent interpretiert und berichtet. Indem die rigorosen Daten in Baumchecker eine größere zentrale Rolle bekamen, versucht das Programmpersonal auch eine Überwachung innerhalb der Organisation zu institutionalisieren, um direkte Vergleiche der Ergebnisse von Jahr zu Jahr zu gewähren. Wir schließen mit gelernten Lektionen, die relevant sind für andere Organisationen, die versuchen, ein Auskommen mit der Kreation oder Verbesserung von Überwachungen wissenschaftlicher Programme mit Bürgerbeteiligung zu erzielen.

Resumen. Los programas de ciencia sociales no son estáticos; cambian con el tiempo en respuesta a las nuevas prioridades y las tecnologías emergentes, así como para mejorar el flujo de trabajo para el personal del programa y los voluntarios. En este artículo, presentamos un estudio de caso de un programa de silvicultura urbana en evolución en la Pennsylvania Horticultural Society, una organización sin fines de lucro en Filadelfia, PA. El programa Tree Checkers involucra a los administradores de árboles que registran datos cada verano sobre la supervivencia, el crecimiento, el vigor de la corona y el mantenimiento de los árboles recientemente plantados, al mismo tiempo que se involucran con sus vecinos para fomentar el mantenimiento adecuado de los árboles. El programa comenzó en 2011, pero cambió en 2016 para utilizar una nueva herramienta de recopilación de datos en línea que está integrada dentro de un gran árbol de gestión de datos. Tree Checkers también se ha centrado más en datos rigurosos para informar sobre el desempeño del programa y compartir información con los investigadores, mientras que los años anteriores de Tree Checkers se centraron en habilitar y alentar a los administradores de los árboles del vecindario a planificar el cuidado de los árboles. Una evaluación reciente de la calidad de los datos mostró que los datos de los voluntarios eran razonablemente consistentes con los datos reportados por pasantes más experimentados para la supervivencia, el vigor y las mediciones del tronco, pero las variables de administración no se interpretaron y registraron de manera consistente. Al hacer que los datos rigurosos sean más importantes para los verificadores de árboles, el personal del programa también intenta institucionalizar el monitoreo dentro de la organización, lo que permite realizar comparaciones directas de los resultados año con año. Cerramos con lecciones aprendidas que son relevantes para otras organizaciones que buscan crear o mejorar los programas de monitoreo de resultados con científicos ciudadanos.