Urban Forestry & Urban Greening 14 (2015) 1174–1182

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Original article

Stewardship matters: Case studies in establishment success of urban trees

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ARTICLE INFO

Article history:
Received 2 June 2015
Received in revised form 23 October 2015
Accepted 1 November 2015
Available online 3 November 2015

Keywords:
DBH growth
Forest monitoring
Mortality
Street tree
Survival
Survivorship

ABSTRACT

Urban tree planting initiatives aim to provide ecosystem services that materialize decades after planting, therefore understanding tree survival and growth is essential to evaluating planting program performance. Tree mortality is relatively high during the establishment phase, the first few years after planting. Qualitative assessments of programs with particularly high establishment survival can indicate best management practices for other programs to emulate. We present two case studies of high survival for young urban trees, from planting projects in East Palo Alto, CA and Philadelphia, PA, with the nonprofit organizations Canopy and University City Green, respectively. The Philadelphia case consists of two neighborhood planting projects: Kingsessing and Powelton. These trees were located mostly in streetside soil strips and sidewalk cut-outs. We used longitudinal tree survival and growth data, combined with detailed information about planting project characteristics and tree care practices, to make inferences about the underlying causes of establishment success. Annual survival during approximately six years after planting was 99.4% in East Palo Alto, 98.4% in the Kingsessing and 95.4% in Powelton. The East Palo Alto and Kingsessing outcomes are among the highest establishment survival ever reported. Our results indicate that planting and maintenance practices, program management and site characteristics contributed to establishment success. Stewardship was essential, both in terms of specific tree care activities and program processes to support those activities. These planting projects were implemented by small nonprofits which enhanced their staffing capacity through intensive volunteer and youth internship programs. Experienced volunteers, including professional arborists and landscape architects, served as leaders and trainers for other volunteers and interns. Climate-appropriate species selection and site conditions may have also played a role in East Palo Alto's exceptionally high survival. The survival and growth observed in these planting projects can be considered best case scenarios for neighborhood tree planting.

Introduction

City tree planting initiatives aim to provide ecosystem services—the environmental, socioeconomic and human health benefits that have been attributed to urban forests (Nowak and Dwyer, 2007). Many of the anticipated benefits materialize decades after planting, as trees reach mature size (Maco and McPherson, 2003), therefore it is critical to understand tree survival and growth in urban landscapes. Empirical monitoring data from planting initiatives indicate that assumed survival scenarios have been overly optimistic (Roman et al., in press). While reporting the number of trees planted has been a major focus in the public messaging of planting initiatives, especially the "million tree" campaigns (Young and McPherson, 2013), urban forest practitioners and researchers also recognize tree survival, growth and longevity as key metrics of success (Roman et al., 2013; Koeser et al., 2014; Vogt et al., 2015).

Tree losses during the establishment phase – the first several years after planting (Richards, 1979) – can be particularly high. Indeed, young street tree losses may drive population cycles and the need for replanting (Richards, 1979; Roman et al., 2014a). Urban

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http://dx.doi.org/10.1016/j.ufug.2015.11.001
1618-8667/

environments pose many challenges for urban trees, especially in constrained sidewalk spaces. Young street tree survival, growth and health can be reduced by compacted and contaminated soil (Craul, 1999), construction damage (Hauer et al., 1994), poor nursery stock (Harris and Gilman, 1993), vandalism (Nowak et al., 1990; Jones et al., 1996; Pauliet et al., 2002), lack of community involvement (Sklar and Ames, 1985), and insufficient maintenance practices (Gilman et al., 1998; Boyce, 2010). Researchers have recently begun to identify the most significant factors affecting urban tree survival and growth using multivariate analyses for planting cohorts, from among many biophysical, socioeconomic and stewardship factors (Jack-Scott et al., 2013; Koeser et al., 2014; Roman et al., 2014b; Vogt et al., 2015). These analyses indicate that some of the most important factors in predicting higher mortality are younger age, constrained site characteristics, inappropriate maintenance practices, planting by organizations with less experience and longevity, unstable homeownership, and possibly neighborhood socioeconomic characteristics. As researchers and practitioners collaborate to produce more urban tree monitoring data across cities (Roman et al., 2013; Vogt and Fischer, 2014), there can be further testing of quantitative models of survival and growth outcomes. Complementing this approach, we can also learn from qualitative case study investigations of specific programs to document suspected causal mechanisms of tree performance outcomes.

Identifying common features of planting programs with relatively high or low survival can indicate best management practices for other planting initiatives to replicate. This requires first understanding the range of typical survival and mortality rates. Based on a meta-analysis of reported street tree survivorship, typical annual survival is 94.9–96.5% with a corresponding annual mortality of 3.5–5.1% (Roman and Scatena, 2011). This estimate assumed constant annual mortality to combine survival data from many studies; since mortality is considered higher in the establishment phase, typical young street tree annual mortality is likely higher than 3.5–5.1% (Richards, 1979; Roman et al., in press). The programs reporting the two lowest survival rates in the Roman and Scatena (2011) review had catastrophic establishment losses. In Beijing, China, only 25.1% of trees survived to three months (Yang and McBride, 2003). These trees came from unusual planting stock in which branches and root systems were severely cut back. The radical technique enabled higher planting volumes at lower costs, but also violated arborist norms in terms of quality planting stock. In another example, for disadvantaged communities of Oakland, CA, trees planted through neighborhood block parties and ceremonial plantings had 60–70% survivorship five years after planting, while trees planted without community participation had <1% survivorship (Sklar and Ames, 1985). In a case of high establishment survival, small towns in PA and MD had 94–100% street tree survivorship at three years after planting (Gerhold et al., 1994). These were *Malus* sp. cultivars planted experimentally with the cooperation of municipal foresters to design plantings, select sites, and monitor for survival, health and growth. In towns across FL, with various street and lawn site types included, 93.6% of trees survived two to five years after planting, although this also included some replacement trees from the first year (Koeser et al., 2014). The FL trees followed strict nursery stock and planting procedure guidelines, and irrigation was important to survival and growth models. These examples indicate the critical role of arboricultural expertise with planting design and stock selection, as well as tree care after planting by professionals and communities.

Given the range in planting program survival outcomes, and the importance of survival and growth to the realization of benefits, it is essential to investigate high-performing programs more deeply. In this article, we present two cases of relatively high establishment survival of urban trees. Our objective was to assess program operations and circumstances that appear to have contributed to high survival and derive lessons learned for urban tree establishment. We used longitudinal tree growth and survival data, combined with detailed information about planting project characteristics, to make inferences about the underlying causes of establishment success.

Methods

Case study approach

We employed a case study approach to assess two urban tree planting programs with high rates of establishment survival. Examining cases of failure in resource management can illuminate institutional and management issues related to sustainability (Acheson, 2006); likewise, our cases of high survival suggest possible mechanisms supporting high performance. Case studies investigate contemporary phenomena in-depth and within the real-world context, and build upon existing theory (Buroway, 1998; Yin, 2009). Such detailed and holistic qualitative analyses are appropriate to study how phenomena actually occur in a situated context (Creswell, 2013). Our in-depth case studies complement multivariate modeling approaches employed in other mortality studies (e.g., Roman et al., 2014b; Koeser et al., 2014; Vogt et al., 2015) by providing a more thorough accounting of potential causal mechanisms and situational details. We used mixed methods, with demographic calculations of empirical survival data and qualitative descriptions of program operations.

Overview of case study organizations

The two cases presented here are planting projects from local urban greening organizations. These organizations had survival monitoring underway for several years to document performance (as many other local organizations have done, see Roman et al., 2013) when we realized that survival rates were unusually high. Subsequently, the two programs were examined in more depth to evaluate potential reasons for that success. Pertinent details are summarized below regarding each organization's history, mission, local human community and climate to aid in results interpretation and cross-city comparisons.

The nonprofit Canopy is based in Palo Alto, CA. Canopy was created in 1996 as a spin-off of Palo Alto's Tree Task Force, and became an independent nonprofit in 2002. The organization's mission is "to bring the life-giving benefits of trees to the schools, neighborhoods, and public spaces of the San Francisco Mid-Peninsula" (www.canopy.org). Canopy has had two-three full-time staff during the study period. The specific planting project we monitored is located in East Palo Alto, a separate municipality from the more affluent Palo Alto, with a population that has relatively lower income and educational attainment, and more Latinos (Table 1). East Palo Alto is located between San Francisco and San Jose, covers 6.8 km^2, and has a Mediterranean climate with cool, wet winters and mild, dry summers.

The nonprofit University City Green (UC Green) operates in the West Philadelphia area of Philadelphia, PA. UC Green was established in 1998 by the University of Pennsylvania's Facilities and Real Estate Services and became an independent nonprofit in 2004. UC Green's mission statement is "through partnerships and education we empower volunteer environmental stewardship in University City and its surrounding communities" (www.ucgreen.org). UC Green has two full-time staff. The UC Green service area comprises the University City District (UCD) footprint, which covers 8.5 km^2. This area has several universities and residential neighborhoods of varying socioeconomic status. The UCD has a plurality black population (Table 1) and is very racially diverse relative to

Table 1
Socioeconomic characteristics of East Palo Alto, CA and UC Green service area of Philadelphia, PA, from 2011 American Community Survey (ACS) 5-year estimates (U.S. Census Bureau, 2014). Note that ACS provides a multi-year average based on a survey sample, as opposed to the complete Census from 2010; the latter data was used in the UCD report (University City District (UCD), 2014).

	East Palo Alto, CA	UC Green service area, Philadelphia, PA[1]
Median household income[2]	$50,137	$12,892–48,144
Vacant housing units	9.4%	18.1%
Race[3]		
White	7.3%	35.2%
Black	17.3%	46.7%
Hispanic or Latino	62.1%	3.8%
Bachelor's degree or higher	15.8%	37.1%

[1] UC Green estimates are from aggregated values across census tracts that are mostly conterminous with UC Green service area. For example, with percent vacant housing across the service area, we averaged using total housing units for each tract. With median household income, we can only offer the range across these census tracts. Note that median income was lowest in tracts with college students.
[2] Median income is in 2011 inflation-adjusted US dollars.
[3] Percent white and black are non-Hispanic or Latino, and are presented for that race alone. Percent Hispanic or Latino includes individuals of any race.

the rest of Philadelphia (University City District (UCD), 2014). The UCD has a smaller proportion of the population with bachelor's degrees compared to Philadelphia as a whole. Within the UCD, rates of educational attainment and racial diversity are highest near the universities (University City District (UCD), 2014). The two neighborhoods where our planting projects were located, Kingsessing and Powelton, are lower-to-middle income areas with majority black populations. Philadelphia is at the northern edge of the humid subtropical zone, and has hot and muggy summers, with cold winters and mild spring and fall.

Data collection

Planting performance

To determine survival and growth, we monitored tree cohorts from specific planting projects. Observation interval times varied between the two cases due to local staffing capacity, and we report time intervals in years based on the exact number of days between observations.

In East Palo Alto, 568 containerized trees were planted Feb. 2007 in a soil strip adjacent to the sound wall of highway US101. These roadside trees were planted next to a busy local street (with no sidewalk or pedestrian traffic), across from residents and businesses (which do have sidewalks and pedestrian traffic). Survival outcomes were observed at 9–19 month intervals between 2008 and 2012. Final survival observations were taken 5.92 years after planting. Diameter at breast height (DBH, measured at 1.37 m on the trunk) and total tree height were measured in 2010, 4.67 years after planting.

In Philadelphia, we assessed two planting projects: 150 trees planted in and around the city-operated Kingsessing Recreation Center in Mar. 2006 and 94 trees planted in the Powelton neighborhood in Oct. 2005. In Kingsessing, most were street trees, with 71% in soil strips along the sidewalk and 29% in lawns in the park interior. Nearly all of the Powelton trees were street trees: 96% were in sidewalk cut-outs, 2% were in sidewalk planting strips, and 2% in public park lawns. Powelton trees were mostly (52%) adjacent to row homes – attached single family residential structures common in Philadelphia – with some trees adjacent to commercial/industrial (19%), park (15%) and other institutional (14%) land uses. Powelton trees were also scattered throughout the neighborhood (e.g., a given city block could have several trees from this planting project, or none). Survival and growth (DBH and total height) were recorded one month after each cohort was planted and again May–Jun. 2012.

Table 2
Species planted in East Palo Alto, CA ($n = 568$). *Tristiania laurina* was 49% straight species and 51% 'Elegans' cultivar. *Olea europaea* cultivars included 'Mission', 'Manzanillo', and a fruitless cultivar.

	% of planted trees
Arbutus 'Marina'	7.7
Arbutus unedo	24.3
Laegerstroemia 'Tuscoroa'	4.2
Lagunaria pattersonii	3.7
Melaleuca linarifolia	4.9
Olea africana	3.0
Olea europaea	8.1
Pinus sylvestris	9.5
Quercus agrifolia	3.2
Quercus arizonica	1.1
Quercus englemannii	3.2
Quercus rugosa	3.5
Quercus suber	6.9
Quercus tomentella	0.4
Quercus virginiana	2.3
Tipuana tipu	0.5
Tristania laurina	13.6

Final survival observations were taken 6.25 years after planting for Kingsessing and 6.58 years for Powelton, with growth intervals one month shorter for each neighborhood cohort.

Species composition for each planting project is given in Tables 2 and 3. In both cities, DBH was not measured for some species due to growth form (e.g., multi-stem shrubby habit).

Program operations and local context

Information about planting program operations, including records of volunteer hours and stewardship activities, was provided by nonprofit program staff (who are co-authors on this manuscript). While stewardship has a variety of definitions in the literature and among urban natural resource managers (Romolini et al., 2012), we use stewardship to refer to community tree care practices and associated program operations. Interpretations regarding causes of high survival raised in the discussion reflect conversations among the co-authors, all of whom spent numerous hours at the study sites, from project design through planting, maintenance and monitoring. We are therefore embedded within these systems and have situated experiences that reflexively shaped the framing of our findings (Haraway, 1991; Mansvelt and Berg, 2005).

Table 3
Species planted in University City, Philadelphia, PA, in the Kingsessing ($n = 150$) and Powelton ($n = 94$) neighborhoods. *A. rubrum* cultivars included 'Franks Red Sunset' and 'Burgundy Bell'; *A. saccharum* included 'Bloodgood' and 'Legacy', *Malus* spp. included 'Donald Wyman', 'Red Jewel', 'Snowdrift' and 'Prariefire'; and *P. acerifolia* included 'Bloodgood'.

	% of planted trees	
	Kingsessing	Powelton
Acer campestre 'Evelyn'	–	4.3
Acer griseum	–	1.1
Acer rubrum	29.3	7.4
Acer saccharum	–	5.3
Amalanchier × *grandiflora* 'Autumn Brilliance'	–	8.5
Betula nigra	2.1	2.7
Carpinus betulus 'Fastigiata'	5.3	–
Cercis canadensis	0.7	5.3
Crataegus viridis 'Winter King'	–	3.2
Fraxinus pennsylvanica 'Patmore'	–	10.6
Gleditsia triacanthos 'Halka'	–	10.6
Malus spp.	1.3	28.7
Platanus × *acerifolia*	8.7	7.4
Quercus bicolor	23.3	–
Quercus palustris	24.0	–
Styrax japonicus	4.7	–
Ulmus 'Frontier'	–	5.3

Survival and growth analysis

Survivorship, annual survival and annual mortality calculations followed Roman et al. (in press), which adapted demographic vital rates to urban trees. Specifically, survivorship l_x is the proportion of a planting cohort that survived to time x, where K_0 and K_x are the trees alive at the beginning and end of the time period x, respectively.

$$l_x = \frac{K_x}{K_0} \quad (1)$$

Assuming constant mortality, annual survival p_{annual} and mortality q_{annual} were calculated by:

$$q_{\text{annual}} = 1 - l_x^{(1/x)} \quad (2)$$

$$p_{\text{annual}} = 1 - q_{\text{annual}} \quad (3)$$

For Philadelphia trees, survivorship follows Eq. (1). For East Palo Alto, because survival monitoring was done on a near-annual basis, we constructed a cohort life table (Roman et al., in press). This included some trees with partial survival information for the last years of the study, when field notes by high school interns were incomplete. These cases of right censored data were treated according to standard life table calculations, with the assumption that censoring times were uniformly distributed, and that causes of mortality and censoring are independent (Klein and Moeschberger, 1997). The overall survivorship number reported for East Palo Alto compensates for censoring with the following calculations. W_x is the number of individuals right censored, Y_x is the number of individuals at risk of death during the interval x to $x+1$, D_x is the number of deaths during the interval x to $x+1$, and q_x is the interval mortality rate. As with the simpler example for UC Green, $p_x = 1 - q_x$.

$$Y_x = K_x - \left(\frac{W_x}{2}\right) \quad (4)$$

$$q_x = \frac{D_x}{Y_x} \quad (5)$$

$$l_x = (l_x - 1)(p_x - 1) \quad (6)$$

We report overall survival rates for all trees in each program, as well as survival and growth results for the most common species. Tree growth is reported in two ways: (1) DBH and height attained at the last observation for each project, and (2) annual radial and height growth based on re-measurement interval. Annual growth rates are reported only for Philadelphia trees, where exact height of DBH growth was recorded shortly after planting, with re-measurement at that same point. This is a more precise manner of reporting radial growth utilized in forest ecology research, compared to estimates of urban tree growth whereby initial size is assumed based on planting stock caliper or years since planting (e.g., Jack-Scott et al., 2013; Vogt et al., 2015).

Results

Survival and growth outcomes

Cumulative survivorship in East Palo Alto was 96.3% at 5.92 years after planting, which corresponds to an annual mortality rate of 0.6% (Tables 4 and 5). With frequent visits to the site by program staff and experienced volunteers, direct causes of death were known or suspected in many cases. All tree deaths in the first three field seasons were due to car accidents on the busy road adjacent to the highway soundwall. Later deaths were mostly attributed to site conditions, particularly excessive sun exposure after irrigation was turned off. At 4.67 years after planting many species were 3 m or taller in height (Table 6).

Table 4
Summary of trees planted and survival results for Canopy in East Palo Alto, CA and UC Green in Philadelphia, PA, for all species.

	Canopy: East Palo Alto, CA	UC Green: Philadelphia, PA	
		Kingsessing	Powelton
No. trees planted	568	150	94
No. species planted	17	9	13
No. years post-planting	5.92	6.25	6.58
Survivorship, l_x	96.3%	90.7%	73.4%
Annual survival, p_{annual}	99.4%	98.4%	95.4%
Annual mortality, q_{annual}	0.6%	1.6%	4.6%

In Philadelphia, survivorship was higher for the Kingsessing planting cohort (90.7% at 6.25 years) compared to Powelton (73.4% at 6.58 years), which corresponds to annual mortality of 1.6% and 4.6%, respectively (Table 4). Direct causes of death were not always observed, but some known and suspected causes of death include inadequate watering, strong storms, car accidents and removal due to construction. Additionally, five *Ulmus* as well as two *Crataegus viridis* were suspected to be lost as a result of being received from the nursery in poor condition. In terms of growth outcomes, several species were 7 m or taller in height at the last field observation (Table 7). Annual DBH growth was often above 1 cm and annual height growth often above 0.5 m (Table 7).

Program operations

East Palo Alto

A board certified master arborist was contracted to design the East Palo Alto planting site. Tree species were selected to be appropriate for current and future climate conditions, especially drought tolerance (Table 2). The planting palette was therefore restricted to species native to Mediterranean climates and species shown to be strong performers in Mediterranean regions. Planting stock consisted of mostly No. 15 containerized trees (approximately 13–20 L), with *Arbutus unedo* in No. 5 containers (approximately 45–61 L). Where possible, nursery stock met or exceeded horticultural standards (American Horticulture Industry Association, 2014). However, since there was a strong emphasis on utilizing drought-adapted species, this severely constrained the numbers of trees available. Root systems were carefully examined by a board certified master arborist prior to purchase, which guided subsequent root mitigation on planting day. Tree planting was carried out over several weeks by contractors, with each tree root ball pruned by volunteers under close supervision of program staff and volunteer arborists (Table 8). Detailed planting instructions were provided by program staff. Trees were numbered with metal tags.

Volunteers and paid interns contributed thousands of hours to the planting and maintenance of these trees (Table 8). This included substantial time donated from several experienced Canopy volunteers as well as the arborist who was contracted to design the planting (volunteering beyond contractual obligations). Canopy Teen Urban Foresters were responsible for some of the post-planting maintenance, under the supervision of Canopy program staff and experienced volunteers. This paid youth summer internship program recruits students from public high schools in East Palo Alto as a green jobs initiative for underserved youth. These interns are trained in urban forestry techniques including planting, pruning, irrigation repair, and data collection; once trained, the interns also assisted in leading volunteers and advocate for urban trees in the community. General planting volunteers received 1 h of training, and planting leaders and pruning volunteers received approximately 10 h of training on each topic. Canopy Teen Urban Foresters received all of the aforementioned trainings as well as supplemental trainings throughout the summer.

Table 5
Cohort life table for roadside trees in East Palo Alto, CA (see Roman et al. (in press) for a more detailed explanation of urban tree life tables). The terms q_x and p_x here are not interpreted as annual mortality and survival because observation intervals were not consistently 12 months apart.

Observation (yr)	Yrs since planting (x)	No. alive at beginning of interval (K_x)	No. deaths in interval (D_x)	No. censored (W_x)	No. at risk (Y_x)	Interval mortality (q_x) (%)	Interval survival (p_x) (%)	Survivorship, l_x (%)
2006	–	568	2	0	568	0.4	99.6	100.0
2007	1.58	566	0	0	566	0.0	100.0	99.6
2008	2.33	566	8	0	566	1.4	98.6	99.6
2009	3.75	558	5	1	557.5	0.9	99.1	98.2
2010	4.67	552	6	3	550.5	1.1	98.9	97.4
2012	5.92	543	n/a	n/a	n/a	n/a	n/a	96.3

Table 6
Tree survival and size achieved in East Palo Alto, CA for species with ten or more individuals measured. Survival was calculated per species with the cohort life table approach (see Table 3). Survivorship is reported at 5.92 years and size achieved 4.67 years after planting. Size is given as mean (standard deviation). Due to multi-stem shrubby growth form, DBH was not taken for *A. unedo* and *P. sylvestris*.

			Size achieved	
	Survivorship, l_x (%)	Annual survival, p_{annual} (%)	DBH (cm)	Height (m)
Arbutus 'Marina'	100.0	100.0	4.8 (1.2)	3.2 (0.4)
Arbutus unedo	97.1	99.5	–	1.7 (0.4)
Laegerstroemia 'Tuscoroa'	100.0	100.0	5.3 (1.2)	4.1 (0.7)
Lagunaria pattersonii	95.2	99.2	5.4 (1.8)	3.7 (1.4)
Melaleuca linarifolia	92.9	98.8	6.0 (2.9)	3.4 (0.6)
Olea africana	100.0	100.0	9.1 (1.9)	5.2 (0.8)
Olea europaea	97.8	99.6	7.6 (2.0)	4.9 (0.6)
Pinus sylvestris	96.3	99.4	–	1.7 (0.5)
Quercus agrifolia	100.0	100.0	6.3 (1.7)	4.0 (1.0)
Quercus englemannii	100.0	100.0	5.9 (2.0)	4.8 (1.3)
Quercus rugosa	95.0	99.1	5.2 (2.4)	3.6 (1.2)
Quercus suber	94.9	99.1	6.5 (2.6)	4.3 (1.1)
Quercus virginiana	100.0	100.0	5.1 (2.7)	3.2 (0.7)
Tristania laurina	98.7	99.8	3.6 (1.0)	2.9 (0.6)

Table 7
Tree survival, size achieved and growth in Philadelphia, PA for species with ten or more individuals measured, for neighborhoods Kingsessing (a) and Powelton (b). Survivorship and size achieved are given at 6.25 years after planting for Kingsessing and 6.58 years for Powelton. Size and growth are given as mean (standard deviation).

(a)				Size achieved		Annual growth rate	
	No. planted	Survivorship, l_x (%)	Annual survival, p_{annual} (%)	DBH (cm)	Height (m)	DBH (cm)	Height (m)
Acer rubrum	44	88.6	98.1	9.6 (1.8)	5.8 (0.7)	1.1 (0.4)	0.4 (0.13)
Platanus × *acerifolia*	13	100.0	100.0	14.4 (3.2)	7.8 (0.4)	1.6 (0.5)	0.6 (0.1)
Quercus bicolor	35	97.1	99.5	13.9 (2.1)	7.0 (0.7)	1.4 (0.3)	0.5 (0.1)
Quercus palustris	36	97.2	99.6	16.5 (3.7)	7.7 (0.9)	1.9 (0.6)	0.5 (0.2)
(b)							
Fraxinus pennsylvanica	10	100.0	100.0	12.4 (2.2)	6.5 (0.8)	1.3 (0.4)	0.6 (0.2)
Gleditsia triacanthos	10	100.0	100.0	11.5 (3.2)	5.6 (1.3)	1.2 (0.5)	0.5 (0.3)
Malus spp.	27	77.8	96.3	7.8 (1.3)	4.2 (0.5)	0.7 (0.2)	0.4 (0.1)

Table 8
Stewardship program activities of Canopy and UC Green for the planting cohorts studied.

	Canopy: East Palo Alto, CA	UC Green: Philadelphia, PA	
		Kingsessing	Powelton
Est. volunteer hours			
Planting	233 volunteers gave 943 h	530 volunteers gave 1382 h	364 volunteers gave 1160 h
maintenance (2007–2011)	597 volunteers gave 2393 h	88 volunteers gave 224 h	88 volunteers gave 214 h
Est. youth intern hours			
Maintenance (2007–2011)	23 interns gave 634 h	43 interns gave 128 h	43 interns gave 183 h
Stewardship actions			
Planting	Contractors & volunteers supervised by arborists & program staff; containerized stock (mostly No. 15)	Volunteers supervised by program staff & experienced volunteers; balled & burlap stock (5.1 cm caliper)	
Watering	Program staff; automated irrigation every 3 days for first 3 years and as-needed in later years	Youth interns, volunteers & residents; buckets, hoses & gator bags; variable frequency	
Mulching & site care	Youth interns & volunteers; weeds & vines removed, mulch applied	Youth interns & volunteers; pits weeded, mulched & aerated	
Staking	Youth interns & volunteers supervised by program staff & volunteer arborists	Staking fixed as needed by youth interns & volunteer pruning club	
Pruning	Youth interns & volunteers supervised by program staff & arborists	Pruned as needed by youth interns & pruning club	

Maintenance (Table 8) included regular watering with a drip irrigation system. Trees were watered approximately every three days, approximately 18.9 L per watering event, during the dry season (May–Oct.) for the first year following planting, with adjustments to irrigation frequency as needed based on weather and site conditions. In years two and three, watering amount increased to 37.9–56.8 L, but frequency was reduced to once per week in year two and once per two weeks in year three. The irrigation system was used roughly monthly during dry months in year four and was turned off in year five, but after this, irrigation was still occasionally and selectively used during periods of drought. The irrigation system was checked and maintained routinely to ensure proper functioning. Volunteers carried out site care as needed, typically through large volunteer days, including reapplying mulch, removing weeds, cutting back vines from the sound wall, and picking up trash. Young tree pruning and reapplication of stakes were done as needed by youth interns and volunteers, led by Canopy staff and volunteer arborists. Public Works maintenance crews from the City of East Palo Alto also contributed to pruning. Tree care training for all of these contributors was provided by the master arborist. Program staff and lead volunteers walked the entire length of the site at least once per summer during the establishment phase to note specific trees in need of maintenance.

Funding for the East Palo Alto planting project was provided primarily by the California Department of Forestry and Fire Protection. Although the grant required three years of maintenance, the project budget actually did not allocate for maintenance. Sources of funds for tree stewardship and the youth intern program included local foundations and individual donors.

Philadelphia

The Kingsessing and Powelton planting projects were designed collaboratively UC Green staff, two expert volunteers (a certified landscape architect and an experienced landscape designer), and a municipal arborist with the City of Philadelphia. Planting locations were scouted by the expert volunteers and approved by the city. The city's street tree inspector recommended appropriate species for each site from Philadelphia's approved street tree list. UC Green's expert volunteers then sourced the trees from local nurseries. Trees were 5.1 cm caliper balled and burlap stock. Tree planting was carried out in a single day (2.5–3 h total) at each project site, by hundreds of volunteers under close supervision of program staff and expert volunteers (Table 8). Volunteers worked in groups of 6–8 and were supervised by experienced "tree leaders" who were responsible for ensuring that trees were planted properly. Volunteers received a handout about proper tree planting technique, and were trained by tree leaders for approximately 10–15 min. After digging holes, volunteers needed approval from the tree leaders to make sure trees were planted at the appropriate depth. Trees were numbered with plastic tags.

Post-planting tree care was conducted by a volunteer Pruning Club, a seasonal crew of paid youth interns referred to as the UC Green Corps, and a few additional neighbors who volunteered their time. Participants in the Pruning Club and other neighborhood volunteers included an arborist and a landscape architect. The Green Corps program began in 2006 as a green jobs program for students recruited from high schools in West Philadelphia. These interns are trained by UC Green staff as well as staff from the Pennsylvania Horticultural Society's Tree Tenders program to carry out pit care (including reapplication of mulch and manual soil aeration) and tree care (including reapplication of stakes and pruning). This intern training included 9 h of classroom time with the Tree Tenders program and 20 h of additional hands-on training over the month of June, prior to when interns began working. Approximately 6–13 interns were employed seasonally each summer. The Pruning Club was also primarily active in the summer, though they did occasionally check on trees in the winter months. Irrigation was done by hand with buckets and hoses, often utilizing nearby fire hydrants, and gator bags were installed on most trees for the first two years after planting (removed in winter). Powelton residents who received trees in front of their properties committed to watering and maintaining those trees, but in addition to this, some blocks in that planting cohort were regularly (weekly to bi-weekly) watered, pruned, weeded, and mulched by the Green Corps for the first two summers after planting. Other trees in the cohort were cared for by residents only, thus for these trees watering amounts and frequencies may have been quite variable. The Green Corps and Pruning Club volunteers continued to prune, weed, and mulch trees in the planting cohort as needed after the second year, roughly monthly. In Kingsessing, volunteers and the Green Corps worked together to water all 150 trees weekly the first summer after they were planted. Volunteers pruned, mulched, and weeded the trees as needed over the winter. The second year after planting, the Kingsessing trees were watered weekly to bi-weekly by the Green Corps, as well as regularly weeded, mulched, and pruned. Trees that were watered by the Green Corps received approximately 113.6 L per watering event using gator bags as well as hoses.

Funding for tree planting in Kingsessing and Powelton was provided by TreeVitalize, a public–private partnership to restore tree cover that was launched by the PA Department of Conservation and Natural Resources. Funding for post-planting care was provided by a variety of local to regional private foundations, often directly supporting the youth internship program and the volunteer coordinator's position.

Discussion

We observed high establishment survival for the East Palo Alto and Philadelphia planting projects. In particular, the annual survival of 99.4% for the East Palo Alto project (Table 4) was extraordinarily high. For Philadelphia, annual survival was higher in the Kingsessing (98.4%) neighborhood compared to Powelton (95.4%). Overall, compared to young urban tree survival in other cities and programs (see reviews in Roman and Scatena, 2011; Koeser et al., 2014), these outcomes provide empirical evidence of establishment success, with the East Palo Alto and Kingsessing examples among the highest ever reported. These results are also noteworthy because the study neighborhoods were lower-to-middle income areas, and lower socioeconomic status has been associated with lower tree survival (Nowak et al., 1990).

Comparisons with growth achieved through other tree planting programs are limited due to lack of empirical data (McHale et al., 2009; Troxel et al., 2013), especially re-measurement data for planting cohorts and young trees. For East Palo Alto, final DBH attained at five years can be compared to DBH observed 4–5 years after planting in Los Angeles, CA (McPherson, 2014). Both *Lagerstroemia* and *Olea europaea* were slightly larger in East Palo Alto. For Philadelphia, tree size attained at six years can be compared to predicted growth at five years for street trees in New Haven, CT (Troxel et al., 2013). Some of our Philadelphia trees were considerably larger than predicted by the New Haven models (*Gleditsia triacanthos*, *Quercus* spp.) while others were slightly smaller (*Acer* spp., *Malus* spp.). However, the New Haven study was constrained to trees in good or fair condition, whereas our study had no such restrictions. Additionally, that study lumped many species together within the same genera, and other studies of growth attainment have grouped trees by mature size class and presumed growth rate (e.g., Ko et al., 2015). More species-specific growth data is needed. However, because the survival rates we observed were relatively high in relation to other published studies, the establishment growth we reported could be considered best case scenarios for neighborhood tree plantings in the study cities.

As more empirical cohort tree growth data becomes available for urban environments, researchers and practitioners will be better able to determine whether growth achievements are performing at, above or below expectations. Such monitoring data, for both growth and mortality, is particularly important for population projections to estimate ecosystem services of planted urban trees over time (McPherson, 2014; Ko et al., 2015).

Based on detailed case study assessments of each planting project, several factors were critical to high establishment survival: planting and maintenance activities, program management and site characteristics. Rigorous and consistent young tree care was a common theme across both Canopy in East Palo Alto and UC Green in Philadelphia. Each of these planting projects had detailed planting plans, closely supervised planting events, and frequent maintenance post-planting. The local youth interns and volunteers operated with the support of professionals donating their time. In addition to the certified professionals who volunteered, other experienced volunteers contributed substantially to maintenance and youth intern training. Our assertion that stewardship actions played a key role in establishment success is consistent with previous studies that documented statistical associations between maintenance, stewardship and survival (Boyce, 2010; Jack-Scott et al., 2013; Roman et al., 2014b; Vogt et al., 2015), and with arboricultural best practices for young tree care (Harris et al., 2004).

These tree care actions reflect programmatic best practices with the nonprofit organizations. Although these nonprofits were quite small, with only 2–3 staff each, they enhanced their organizational capacity through dedicated volunteers and seasonal youth interns. The hundreds of volunteers included a range of experience levels, and those with extensive prior experience and/or formal credentials served as trainers and crew leaders. Additionally, the youth internship programs in both cities function not only to carry out necessary tree maintenance tasks, but also to provide green job opportunities for underserved students. These strategies for carrying out the time-intensive work of tree maintenance enabled the nonprofits to continue the vital tree care work for several years, even though their original sources of funding for the planting projects did not allocate resources for post-planting activities.

Another aspect of program management common to the two case studies is that they operate in relatively small geographic areas, with close ties to local governments and institutions. Indeed, both nonprofits were founded through those relationships. In this way, these small nonprofits with extensive neighborhood-based volunteer networks are also well-positioned with regards to local partnerships. For example, in East Palo Alto, city crews worked alongside program staff and interns to carry out pruning, and in Philadelphia, university students were among the many volunteers at the planting events.

Planting site characteristics may have also played a role in establishment success. First, the relatively small geographic area for each planting project seemed to facilitate efficient maintenance work. The East Palo Alto and Kingsessing cohorts were rows of trees all planted through the same initiative, which reduced transportation time and enabled maintenance crews to maximize their workflow. For East Palo Alto, the fact that trees were in continuous soil strips enabled an automated irrigation system to be installed; this technique is not feasible for street trees in sidewalk cut-outs scattered across the landscape. Notably, the planting cohort in Powelton, where we observed the lowest establishment survival, had such scattered planting locations. Additionally, the street tree sites in Powelton were mostly sidewalk cut-outs adjacent to private residents. Those residents were partially responsible for tree care and watering, but may not have been as consistent as needed. Variation in residential implementation of recommended maintenance practices – with many not following recommended guidelines – has been reported for a yard tree program in CA (Roman et al., 2014a). The Kingsessing and East Palo Alto sites were next to parks and a highway soundwall, respectively, and not tied to individual residences. Additionally, approximately one-third of the Kingsessing trees were interior park trees. With planting strip and lawn site types, the planting cohorts in Kingsessing and East Palo Alto were not limited by the constricted growing environment of sidewalk cut-outs, such as compacted soil, which presumably affected the street trees in Powelton. Lastly, the site characteristics in East Palo Alto – roadside trees without a sidewalk, and therefore lacking direct pedestrian encounters – may have minimized the possibility for vandalism, which has been cited as a cause of health problems and death for young street trees (Nowak et al., 1990; Jones et al., 1996; Pauliet et al., 2002).

Several other distinguishing features of the East Palo Alto planting initiative may have contributed to the exceptionally high levels of survival there. The species planted were specifically chosen for drought tolerance suitable to the San Francisco Bay region. Although temperate to subtropical species can grow in that region with appropriate watering (Costello and Jones, 2014), this planting project was designed to support climate-appropriate trees, especially those that can tolerate the warmer and drier conditions predicted with climate change (Cloern et al., 2011). This issue is especially important considering water management challenges in CA (Delta Stewardship Council, 2013). Additionally, the planting stock was hand-picked by the master arborist, who also designed the planting plan as a paid consultant. Lastly, with containerized trees prone to root problems, the root pruning supervised by arborists likely helped these trees grow after transplanting (Gilman, 1990). Therefore, while tree care by novice volunteers and interns still appears important to explaining the success of the East Palo Alto planting project, the contribution of knowledge and skills from professionals was also significant.

Conclusions

In conclusion, we have presented two planting initiatives with relatively high urban tree survival during the establishment period, and we inferred that stewardship played a vital role in both cases. The time invested by staff and volunteers to planting and maintenance activities served as a manifestation of the sense of responsibility for these trees, and indicates the interconnectedness of multiple meanings of stewardship described by Romolini et al. (2012). We documented specific tree care practices, and propose that these activities were intricately linked to program processes at these nonprofit organizations, and ultimately, to a broader sense of motivation and ownership toward urban forests.

Because establishment losses are a major concern for urban tree planting initiatives, it is critical to document high survival cases that can indicate best management practices for other urban forestry programs. Based on our case study assessments in East Palo Alto and Philadelphia, we offer the following lessons learned.

Some urban tree losses are inevitable, even in the most optimal circumstances

Complete survival of a planting cohort is rarely, if ever, feasible. In both cities, for example, a few street trees were killed by cars; these mortality events occurred independent of the quality of planting stock and level of tree care.

Neighborhood-scale operations are well-suited to stewardship

These nonprofits are operating in relatively small geographic areas, with deep ties to neighborhoods and local institutions. The limited geographic scope of operations seems to have made navigating the logistics of maintenance and volunteer coordination simpler—relatively simpler of course, as the tremendous investment of time and effort demonstrated by these nonprofits was no small feat. Nonetheless, the activities from Canopy and UC Green may not scale well to urban forestry programs across large cities.

Data management strategies facilitated monitoring

Both nonprofits had systems in place that facilitated longitudinal data collection (i.e., tracking the same individual trees over time). All trees were tagged with unique identification numbers, and the East Palo Alto and Kingsessing planting projects also had professionally drawn site maps. These systems were set up to assist with tracking trees for purposes of planting day organization, ongoing maintenance tasks and general internal programmatic record-keeping, and then became invaluable for field crews to update survival and growth records.

Planting programs prioritized substantial time for tree care

Considerable staff and volunteer time was needed to ensure consistent tree care, both during and after planting. This included both experienced and closely supervised novice volunteers. The nonprofits planned ahead for post-planting maintenance through volunteer coordination, as well as cultivating lasting relationships with expert volunteers. These nonprofits also effectively utilized youth interns for ongoing maintenance tasks. Furthermore, the program staff in both cities went above and beyond what they were originally funded to do with these planting projects in terms of post-planting tree care, and sought additional funding to specifically support youth interns. These efforts appear to have paid off in terms of establishment survival. For other tree planting initiatives seeking to replicate this success, allocating resources for young tree maintenance will be essential. With some funders beginning to require survival monitoring as a metric of success (Roman et al., 2013), urban planting programs should consider allocating resources toward young tree care to give those trees the best chances of thriving.

Acknowledgements

We thank current and former staff, board members and volunteers from Canopy and UC Green for their input and dedication to this research: M. Deggeller, M. Hawkins, G. Ornelas, J. Fine, A. Benner and M. Hardy. We also thank many student volunteers from the University of California, Berkeley and the University of Pennsylvania for assisting with field data collection, as well as high school interns from East Palo Alto. We thank K. Patel for help with tree re-measurement and J. Fristensky for assistance with data management in Philadelphia. J. Vogt, L. Campbell, D. Nowak, Y. Bordeaux and two anonymous reviewers provided valuable feedback on earlier versions of this manuscript. We thank J. Blaustein and Philadelphia Parks & Recreation for their support of this research. Field work in Philadelphia was partially funded by a fellowship from the USDA Forest Service Philadelphia Field Station to L.A. Walker. This manuscript is dedicated to the memory of F.N. Scatena, who initiated the monitoring of trees planted by UC Green, and inspired both L.A. Roman and L.A. Walker to pursue careers in urban forestry.

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