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Survival is not enough: The effects of microclimate on the growth and health of three common urban tree species in San Francisco, California

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ABSTRACT

Urban forest managers must balance social, economic, and ecological goals through tree species selection and planting location. Ornamental trees are often popular in tree planting programs for their aesthetic benefits, but studies find that they have lower survivability and growth compared to larger shade trees. To maximize ecosystem services within these aesthetic preferences, it is important to select species carefully based on their ability to grow in each particular climate. However, little locality-specific and species-specific data exist on urban trees in many regions. This study examines the growth, survival, and vigor of three common ornamental street trees in San Francisco's three different microclimate zones after over 16 years since planting. While we found over 70% survival for all three species throughout the city, there were significant differences in health and vigor among microclimates for each species, likely due to differences in drought-tolerance. While *Arbutus* had the greatest proportion of healthy trees in the Fog Belt and Sun Belt zones, *Prunus cerasifera* had the greatest proportion in the Sun Belt, and *Prunus serrulata* had the greatest proportions in the Transition and the Sun Belt zones. This species-specific and climate-specific information will better equip urban foresters to target both planting and tree-care of these popular species appropriately to maximize the benefits provided by these street trees while still maintaining a diverse canopy. Finally, we argue that simple survival calculations can mask more complex differences in the health and ability of different urban tree species to provide ecosystem services.

1. Introduction

Trees in cities improve urban livability, increase property values, reduce the urban heat island effect, regulate storm water runoff, mitigate greenhouse gases, improve air and water quality, and provide essential wildlife habitat (Mullaney et al., 2015; Nowak et al., 2013; Roy et al., 2012; TEEB, 2011; Donovan and Butry, 2010; McPherson and Simpson, 2003; Xiao and McPherson, 2002; Akbari et al., 2001; among others). For urban trees to fulfill these important ecological functions, they need to successfully survive and grow in their planted habitats. However, very little quantitative information exists on the differential survival and growth of common urban species in different climates (Roman 2014; Pataki et al., 2013). Long term studies on city tree mortality and growth are particularly lacking, and many models of ecosystem services either rely on Nowak's (1986) study of maple street trees in Syracuse or simply include a wide range of growth and mortality estimates in their models, thereby increasing the already high levels of uncertainty in estimates of canopy cover, ecosystem services, and monetary benefits and costs associated with street trees (Richardson and Moskal, 2014; Roman, 2014; McPherson et al., 2011; Morani et al., 2011). Long term monitoring of urban street trees is particularly important to enable cities and their non-profit partners to adjust their management practices based on quantified performance data rather than anecdotal evidence or data from a different climate (Ko et al., 2015; Roman et al., 2013). Some studies are beginning to address this need with analyses of tree growth and survival in Sacramento (Ko et al., 2015) or through the development of allometric equations for young urban trees in New Haven (Troxel et al., 2013), for example, but significant gaps remain considering the wide range of climates and urban tree species found across the globe (Pataki et al., 2013; Setälä et al., 2013). To continue with this work, our study examines the health and growth of three commonly planted ornamental species in San Francisco in order to provide detailed quantitative assessments that can be used to improve management and planting decisions.

Although San Francisco's urban tree canopy is relatively small compared to that of other major cities in the U.S., it performs essential ecosystem services (San Francisco Department of Planning, 2015; McPherson et al., 2011; Nowak et al., 1996). For example,

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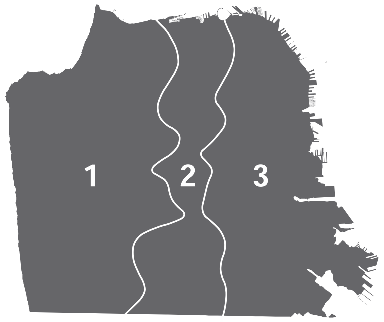

Fig. 1. Map of the three main microclimate zones in San Francisco: (1) the Coastal Zone/Fog Belt, (2) the Transition Zone, and (3) the Bay Zone/Sun Belt.

the existing urban canopy in San Francisco is estimated to provide annual economic benefits exceeding $100 million, mostly due to enhanced property values, energy savings, storm runoff regulation, and air quality control (Simpson and McPherson, 2007). San Francisco is currently conducting a feasibility study for the planting of an additional 100,00 new trees over the next 10–20 years, but at the same time is shifting responsibility for tree maintenance to property owners, most of whom lack the technical knowledge to identify maintenance concerns for their trees (Maco et al., 2003). Given this policy shift toward homeowner responsibility, it is more important than ever that the City target species selection to maximize new tree health and growth while minimizing maintenance requirements.

One important consideration in selecting appropriate tree species for urban planting is the differing microclimate conditions created by San Francisco's unique placement relative to the Pacific coast and the San Francisco Bay. These microclimate conditions have been extensively studied relative to architecture and planning projects in San Francisco, but a considerable research gap exists in the academic understanding and practical management of urban trees in San Francisco (Zacharias et al., 2004). While the City's Urban Forest Plan states that microclimate is taken into account in the selection of street tree species, few, if any, studies have actually examined differential growth and survival of street trees within these distinct microclimates (San Francisco Department of Planning, 2015). To address this gap in knowledge, we investigate the relationship between three common ornamental tree species and the unique, microclimate environmental conditions at a critical moment in the development of San Francisco's urban forest.

2. Methods

2.1. Study area

The study was located in San Francisco, CA. The city's topography and proximity to the bay and ocean create distinct microclimates marked by differences in temperature, sun, and fog, which in turn influence the type of trees and vegetation that are able to grow. The San Francisco Department of Planning delineates three general microclimate zones: (1) Coastal Zone/Fog Belt, (2) Transition Zone and (3) Bay Zone/Sun Belt (Fig. 1). The Fog Belt is characterized by cooler temperatures, dense summer fog, westerly winds, and some marine influences along the coast; the Transition Zone is characterized by cool to moderate temperatures, light fog to sun, and diminished winds; and the Sun Belt is characterized by warmer temperatures, dry and sunny skies, and light to high winds (San Francisco Public Works, Climate Zones of San Francisco). The Coastal Zone/Fog Belt (San Francisco Oceanside, CA) has a mean annual temperature of approximately 55 °C and a mean annual precipitation of approximately 19.8 in. (NOAA, 2004). In contrast, the mean annual temperature in downtown San Francisco (in the Bay Zone/Sun Belt) is 58.3 °C and the mean annual precipitation is 22.3 in. (NOAA, 2004).

2.2. Study species

We surveyed trees planted by Friends of the Urban Forest (FUF) in San Francisco between 1982 and 1997. We selected three of the most commonly planted species—*Arbutus* 'Marina' (N = 135), *Prunus cerasifera* var 'Krauter Vesuvius' (N = 136) and *Prunus serrulata* var 'Kwanzan' (N = 122)—in order to examine the relative abilities of these popular ornamentals to provide long-lasting benefits as street trees across microclimates.

Arbutus 'Marina' (Strawberry tree, Ericaceae), is believed to be a hybrid of *Arbutus unedo* and *Arbutus andrachne,* and is currently the 6th most common street tree in San Francisco with an estimated 3280 individuals (San Francisco Department of Planning, 2015). *Arbutus* 'Marina' is a medium-sized evergreen tree with a height of 25–40 ft and a crown spread of 25–40 ft (Friends of the Urban Forest, 2015). The tree is considered to be drought tolerant and moderate to slow growing, with low tree care requirements (Friends of the Urban Forest, 2015).

Prunus serrulata var 'Kwanzan' (ornamental cherry or flowering cherry, Rosaceae) is currently the 5th most common street tree in San Francisco with an estimated 3700 individuals (San Francisco Department of Planning, 2015). *P. serrulata* is deciduous tree with a height of 15–30 ft and a crown spread of 20 ft (Friends of the Urban Forest, 2015). The tree is considered to have moderate tree care requirements, including early pruning and the occasional removal of suckers, has a moderate growth rate, and is fairly disease and pest resistant (Friends of the Urban Forest, 2015).

Prunus cerasifera var 'Krauter Vesuvius' (purple leaf plum, Rosaceae) is currently the 7th most common urban tree in San Francisco with an estimated 3250 individuals (San Francisco Department of Planning, 2015). *P. cerasifera* is a small deciduous tree with a height of 12–16 ft and a crown spread of 6–12 ft (Friends of the Urban Forest, 2015). The tree is considered to be fast growing and to have medium water and tree care requirements, including early pruning and the removal of suckers (Friends of the Urban Forest, 2015).

2.3. Data collection and analysis

Sample trees were located on various land use types including residential, commercial, industrial, and vacant land, but were always street trees in the public right-of-way. For each tree we measured standing height (with a clinometer), diameter at breast height, and canopy spread (length and width). We assigned a health rating based on a qualitative assessment using the following criteria:

- Status 1: Excellent specimen. Perfect or close to perfect shape, balanced and full canopy. No sign of pest or disease, well rooted with no girdling roots, no physical injury on trunk or branches, appropriate form for species, no sign of water stress or nutrient imbalance.
- Status 2: Good specimen. Generally healthy foliage. Minimal sign of pest or disease, fairly well rooted with few or no girdling roots, minimal physical injury on trunk or branches, appropriate form for species or correctable defects in form.
- Status 3: Struggling specimen. Tree may exhibit any of the following symptoms: pest or disease problem, poor rooting with potential girdling roots, physical injury on trunk or branches, poor form for species, or defects which will require time and attention to fix. Tree will likely survive.