STREET TREE DIVERSITY AND DBH IN SOUTHERN CALIFORNIA

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Abstract. An inventory of the most common street tree species in 21 southern California cities was created. The inventory included information on tree species and diameter at breast height. The inventory indicates differences in existing species as well as differences in planting trends between coastal and inland regions. Links between the data and the potential for determining the age of the urban forest are discussed.

Street trees have long been an integral part of city and town life in the United States (1). The task of planning and maintaining these trees has been entrusted to a variety of professional municipal tree managers. These managers need to be aware of the status of the trees they care for—which trees live, which don't, when the last pruning cycle occurred, and so on. Tree inventories are often performed to clarify these issues.

Recently, the desire for an accurate picture of municipal urban forests has become more apparent. In 1992, Bernhardt and Swiecki (2) reported that at least 275 of California's municipalities had tree inventories, the majority of which were computerized. Outside consultants, often commissioned for the initial inventory, use a variety of database programs; one such program is TreeKeeper® (a tree management software package published by the Davey Resource Group, a division of the Davey Tree Expert Company). TreeKeeper records trees' vital statistics (such as height, spread, dbh, condition, and growing space) as an aid to proper management of the urban forest. While many southern California municipalities have made use of this program, the data from several individual municipalities have not been analyzed to determine regional trends.

The purpose of this study was to determine overall street tree distribution and trends in southern California, using combined data from TreeKeeper inventories of different cities.

Methods

The results of municipal inventories from 21 southern California cities (inland, U.S.D.A. zones 8 and 9; coastal, U.S.D.A. zone 10) were combined into 1 database. Only trees within a city's rights-of-way, usually 10 ft from the face of the curb, were inventoried. As a result, inventories include seedlings from native/naturalized species plus those planted by homeowners, in addition to municipally planted street trees.

Data were separated into either "inland cities" or "coastal cities" categories. Inland cities included data from Claremont, Corona, Monrovia, Pasadena, Rancho Cucamonga, Sunnyvale, Temple City, and Visalia. Coastal cities included data from Agoura Hills, Bell, Beverly Hills, Carpenteria, Huntington Park, Irvine, Laguna Niguel, Newport Beach, Orange, Redondo Beach, San Luis Obispo, Santa Ana, and Vista. Each inventory was performed by Davey personnel and took less than a year to complete. All were performed between 1988 and 1994.

The inventories were examined on a case-by-case basis for 2 categories of information: tree species and diameter at breast height (dbh). Data regarding street tree species were available from all 21 cities; data regarding street tree dbh, from 17 cities.

Results and Analysis

Species. Over 370,000 trees, representing 257 species spread across 123 genera, were ultimately recorded. *Eucalyptus* is the most widely represented genus, with 23 species present, followed by *Pinus*, 12 species; *Quercus*, 11 species; and *Prunus*, 10 species. In addition, 15 species of palm and 5 species of large shrubs (such as *Photinia*

and *Xylosma*) were recorded as street trees. Approximately 150 more species, each with an insignificant number of specimens present in each city, were not included in the analysis.

The top tree species recorded in this study are ranked by region in Table 1. Only those species that comprise more than 1% of the total number of recorded trees have been ranked (the complete list, which is too lengthy for this paper, is available upon request from the author). Approximately half of all trees planted are composed of only the top 15 species. In other words, fewer than 6% of the species make up 50% of the street trees in these 21 southern California communities.

There is a marked difference in population size of certain species between cities with a strong coastal influence (characterized by warm summers and very mild winters with an average of 10 to 14 inches of rain), versus those in inland valleys and foothills (which experience occasional winter frosts, similar annual precipitation, and hot, dry summers). Orchid tree (*Bauhinia*), which ranked number 11 overall, is one notable example of species differences; the total inland population of this species amounts to about 1% of the total coastal population. Coastal areas also seem to have a slightly greater species diversity than inland areas (223 species in coastal regions versus 192 species in inland regions), probably because the milder coastal climate is favorable to frost-sensitive species such as *Erythrina* and several tropical palms.

American sweet gum *(Liquidambar styraciflua)* is the most common street tree in southern California, as well as throughout the state as a whole (2). It accounts for about 1 of every 12 trees. It is in almost every community's top 5 most common species. Communities with high degrees of new development tend to show a higher than average percentage of *Liquidambar* than other communities—as much as 14% of all street trees (compared to the average of 8.6%).

Table 1 also reveals that only 1 species of street tree found in the top 10, Mexican fan palm (*Washingtonia robusta*), is native to California. Overall, only 28 species of street tree in southern California are endemic to the western United States, and fewer than that to California.

Size. Tree dbh was divided into the following nine classes (by inches): 0–3, 3–6, 6–12, 12–18, 18–24, 24–30, 30–36, 36–42, and over 42. In this study, such dbh classes will be referred to by the greatest size in the class: 3-inch, 6-inch, 12-inch, and so on. Data concerning street tree dbh were available from 17 cities, for a total of 162,560 trees.

A link between dbh and tree age within the urban forest involves the size of nursery-grown stock. Bernhardt and Swiecki (2) found that over 70% of new street trees throughout the state are planted as 15-gal container size, with an average dbh of .75 inches; an additional 10% to 15% are planted from 24-inch box size, which average 1.5 inches dbh. The balance of street trees are generally planted from 1- or 5-gal containers, and only rarely larger than the 24-inch box size. Therefore, given the dbh size of many newly planted municipal trees, a reasonable indicator of the proportion of young and recently planted trees might be the abundance of trees in the 0 to 3 inch dbh class.

It is difficult to determine from the data exactly how palms fit into the overall scheme of new tree planting, since they do not increase in dbh as do most shade trees. Therefore, palms have not been included in the diameter analyses.

Analysis of the distribution of tree dbh reveals the following:

1. *Many smaller trees, fewer larger trees.* In this study, "small" trees attain a maximum height of 30 ft or less, "medium" trees, 30 to 60 ft, and "large" trees, 60 ft or more. Table 2, which lists the dbh of trees by region and tree stature, indicates a large percentage of small and/or young trees (12-inch dbh class and smaller) and relatively few large trees.

There are striking similarities in the dbh distributions of both medium and large trees. Even though the majority of species being planted are "medium" in stature (Table 3), as are most existing trees in this study, the data indicate that a relatively small percentage of municipal trees have reached sizes over 12 to 18 inch dbh. Small-statured trees may also show a proportionally similar pattern at lower dbh's, but the dbh breakdown used may not be sufficient to determine whether or not this is the case.

Table 1. Comparison of the most common existing street tree species in southern California. (Percent column indicates percentage of trees in the category. Small-statured trees are in italics; medium-statured trees are in regular typeface; large-statured trees are in bold.)

Rank	Overall species	# trees	%	Coastal species	# trees	%	Inland species	# trees	%
1	Liquidambar styraciflua	31863	8.60	Liquidambar styraciflua	17506	7.85	Liquidambar styraciflua	14357	9.74
2	Magnolia grandiflora	20049	5.41	Magnolia grandiflora	12299	5.5	*Lagerstroemia indica*	7878	5.35
3	Quercus ilex	16601	4.48	Quercus ilex	10815	4.85	Magnolia grandiflora	7750	5.26
4	Washingtonia robusta	13883	3.75	Jacaranda acutifolia	8761	3.93	Cinnamomum camphora	6271	4.25
5	Jacaranda acutifolia	12566	3.39	Washingtonia robusta	7941	3.56	Washingtonia robusta	5942	4.03
6	*Lagerstroemia indica*	12047	3.25	Bauhinia purpurea (variegata)	7812	3.50	Quercus ilex	5786	3.93
7	**Platanus × acerifolia**	1101	3.00	Pinus canariensis	6907	3.10	Quercus agrifolia	5549	3.76
8	Cupaniopsis anacardioides	10316	2.78	**Platanus × acerifolia**	6679	2.99	Ulmus parvifolia	4880	2.11
9	Pinus canariensis	10076	2.72	Cupaniopsis anacardiodes	6605	2.96	**Platanus × acerifolia**	4422	3.00
1	Cinnanmomum camphora	9601	2.59	Ficus microcarpa nitida	6057	2.71	Jacaranda acutifolia	3805	2.58
11	Bauhinia purpurea (variegata)	8033	2.1	Schinus terebinthefolius	5999	2.69	Cupaniopsis anacardiodes	3711	2.52
12	Ulmus parvifolia	7799	2.10	Tristania conferta	5081	2.28	Pinus canariensis	3169	2.15
13	Ficus microcarpa nitida	7332	1.98	Arecastrum romanzoffianum	4519	2.03	**Eucalyptus globulus**	2917	1.98
14	Quercus agrifolia	7058	1.90	*Lagerstreomia indica*	4169	1.87	Washingtonia filifera	2561	1.74
15	Tristania conferta	7008	1.89	Pyrus calleryana	3892	1.74	Ceratonia siliqua	2504	1.70
16	Schinus terebinthefolius	6634	1.79	*Pyrus kawakamii*	3418	1.53	Liriodnedron tulipifera	2455	1.67
17	Arecastrum romanzoffianaum	5497	1.48	Cinnamomum camphora	3330	1.49	**Eucalyptus camaldulensis**	2236	1.52
18	Ceratonia siliqua	5330	1.44	Pistacia chinensis	3262	.46	**Alnus rhombifolia**	2159	1.46
19	Liriodendron tulipifera	4542	1.23	*Prunus cerasifera*	2964	1.33	Fraxinus uhdei	2084	1.41
20	**Eucalyptus globulus**	4478	1.21	Ulmus parvifolia	2919	1.31	**Platanus racemosa**	2035	1.38
21	Pyrus calleryana	4326	1.17	Fraxinus velutina	2840	1.27	Tristania conferta	1927	1.31
22	*Prunus cerasifera*	4295	1.16	Ceratonia siliqua	2826	1.27	Brachychiton populneus	1886	1.28
23	Pistacia chinensi	4260	1.15	Pinus radiata	2689	1.21	Phoenix canariensis	1591	1.08
24	*Pyrus kawakamii*	4203	1.13	**Eucalyptus citriodora**	2537	1.14	Eucalyptus sideroxylon	1562	1.06
25	Phoenix canariensis	4010	1.08	Phoenix canariensis	2419	1.08	Pinus halepensis	1499	1.02
26	Fraxinus uhdei	3960	1.07	Pinus halepensis	2395	1.07	Cupressus sempervirens	1405	0.95
27	Pinus halepensis	3894	1.05	*Callistemon citrinus*	2291	1.03	Pinus brutia	1360	0.92
Total trees, all species		370,526			223,136			147,390	

Table 2. Diameter breakdown of non-palm trees by region and tree stature. (Small trees are less than 30 ft; medium trees are 30 to 60 ft; large trees are more than 60 ft.)

Small trees	3"	6"	12"	18"	24"	30"	36"	42"	42"+	Total
Inland	5233	3752	1732	203	29	12	1	0	1	10963
Coast	5452	5251	4490	1030	134	15	4	0	1	16377
Medium trees	3"		6"	12"	18"	24"	30"	36"	42"	42"+
Inland	14558	6764	8851	4110	1499	623	357	123	80	36965
Coast	6761	7848	12009	5527	1325	381	135	37	26	34049
Large trees	3"	6"	12"	18"	24"	30"	36"	42"	42"+	
Inland	12609	7229	6138	3017	1776	1022	701	260	202	32954
Coast	3390	3543	6469	3395	1017	409	164	75	32	18494

Table 3. Comparison of the 10 most common recently planted street trees (0 to 3 inch dbh). Percent column indicates the percentage of species in the 0- to 3-inch dbh class. (Small-statured trees are in italics; medium-statured trees are in regular typeface; large-statured trees are in bold.)

Rank	Overall species	%	Coastal species	%	Inland species	%
1	Liquidambar styraciflua	14.27	Liquidambar styraciflua	9.68	Liquidambar styraciflua	16.53
2	*Lagerstroemia indica*	7.91	*Lagerstroemia indica*	8.48	*Lagerstroemia indica*	7.63
3	**Platanus × acerifolia**	4.86	Magnolia grandiflora	6.33	**Platanus × acerifolia**	6.24
4	Magnolia grandiflora	4.35	*Pyrus calleryana*	5.97	**Alnus rhombifolia**	4.51
5	**Alnus rhombifolia**	3.38	*Ficus benjamina*	4.76	Liriodendron tulipifera	3.85
6	Cupaniopsis anacardioides	3.35	*Prunus cerasifera*	3.69	**Eucalyptus camaldulensis**	3.74
7	Lirodendron tulipifera	2.66	Cupaniopsis anacardioides	3.10	Cupaniopsis anacardioides	3.47
8	**Eucalyptus camaldulensis**	2.58	Pinus canariensis	2.55	Magnolia grandiflora	3.38
9	*Pyrus calleryana*	2.38	Tristania conferta	2.50	Pinus brutia	2.50
10	Tristania conferta	2.31	Podocarpus gracilior	2.30	**Eucalyptus cladocalyx**	2.33

2. *Species diversity seems to be declining slightly.* A pattern similar to that of existing species populations has emerged. A small number of species seems to make up the bulk of the recently planted population. The 10 most common recently planted species comprise about half of all trees being planted (Table 3). Furthermore, *Liquidambar* is in no danger of losing its place as "all-around most common species"; in fact, its rate of increase indicates that it may soon become even more prevalent as a municipal tree. Some other species seem to be growing in popularity, as evidenced by large numbers of trees in the smallest diameter classes. For example, white alder (*Alnus rhombifolia*), which ranked number 30 in overall existing populations, is currently among the 4 species most commonly planted by inland communities.

3. *More large-statured trees are being planted in inland areas; more small-statured trees are being planted in coastal areas.* Table 3 compares the 10 most common recently planted species among 17 communities in coastal and inland areas. From this table, it appears that communities in inland areas are planting species that will eventually reach much larger sizes than trees being planted in coastal areas. For instance, crape myrtle (*Lagerstroemia indica*) is the only species of small stature among inland communities' most common recently planted species; 4 other species have the potential to exceed 60 ft in height. Coastal communities, however, have no species of large stature in their top 10; instead, 4 are of small stature, while the rest are of moderate size. Specific reasons for this difference are unclear from the data collected for this study.

Bernhardt and Swiecki (2), both in 1988 and 1992, found that more than 50% of the street trees being planted throughout the state of California were medium-statured trees, about 35% were

Table 4. Proportions of recently planted non-palm trees (0 to 3 inch dbh), by potential stature.

	Coastal		Inland		Overall	
	# trees	%	# trees	%	# trees	%
Small trees	5452	34.9	5233	16.1	10685	22.2
Medium trees	6761	43.3	14558	44.9	21219	44.4
Large trees	3390	21.7	12609	38.9	15999	33.3
Totals	15603	99.9	32400	99.9	48003	99.9

small-statured, and about 15% were large-statured. The present study, however, indicates that southern California's proportions of small-, medium-, and large-statured trees vary somewhat from results obtained statewide. Out of the 17 communities' recently planted non-palm trees (0- to 3-inch dbh class), about 44% of the trees planted are of medium stature, 33% are of large stature, and 22% are of small stature (Table 4). These proportions vary even more within specific inland or coastal regions.

Discussion

Species Diversity and Local Selection. Urban forestry managers and urban landscape designers tend to look for species that pose as few maintenance and liability problems as possible. These problems include excessive water use, surface rooting, damage to sidewalks and curbs, and heavy debris production (13). However, in a contradictory note, the top 2 existing species of street tree in this study, *Liquidambar styraciflua* and *Magnolia grandiflora*, are both notorious for producing heavy amounts of debris and causing sidewalk/curb damage through heavy surface rooting, as are at least 4 of the top 10 most commonly planted species (Table 2). Many of the most commonly planted species (such as *Liriodendron tulipifera* and *Alnus rhombifolia*) are also known for their lack of drought tolerance—a serious problem in a land for which the average annual rainfall is between 10 and 14 inches. It would seem, therefore, that to avoid future problems, many design professionals and municipal decision-makers need to become more aware of the dichotomy between what they say they want in a tree and what they actually plant.

Tree Lifespan. Some trees in the wild can live quite long. For example, the stately specimens of California's old-growth forests, such as coast redwoods and giant sequoias, are known to live 1,000 years or more. Many common species of native California oak regularly exceed 250 years in age and have an average dbh of between 24 and 48 inches, depending on the species (11). Some oaks have even attained diameters of well over 9 ft, and probably exceed 500 years in age (3,17). Municipal trees, on the other hand, have a notoriously short lifespan—often no more than 35 or 40 years (1). And while no published studies have examined long-term municipal tree growth patterns in southern California, Nowak (10), in a study in New York, indicated that medium- to large-statured maples may add an average of 0.25 to 0.50 inches dbh for every year of mature life. Urban (14) obtained similar results for a variety of species at 13 different sites in the northeastern United States.

Based upon this information, it is likely that a tree with an 18 inch dbh may be between approximately 35 and 70 years old. Using dbh as an indicator of municipal tree age, Tables 2 and 3, along with the Nowak and Urban studies, indicate that existing medium- to large-statured municipal trees do not seem to reach their full potential in size. For example, only 1 in 10 of all inland coast live oaks (*Quercus agrifolia*) in this study, and only 1 in 50 in coastal areas, have even reached a 30 to 36 inch dbh (approximately 70 to 150 years old), which is the average size of oaks in their native southern California habitats (11).

Without detailed long-term recordkeeping, such as that provided by a tree inventory database, it is ultimately difficult to determine the age and survival rate of southern California's municipal trees. Obviously, many factors influence a tree's growth rate and survival, including extremes of watering, lack of soil oxygen (12), extremes in soil pH (15), high soil temperatures (7), lack of rooting space (6,9), and compaction due to heavy equipment (4,5,8). All of these stresses have negative long-term effects that impact a tree's growth and ultimately shorten its lifespan. With this information in mind, it is not completely surprising that few trees in this study have reached appreciable dbh sizes.

It is also important to point out, especially in the context of this study, that southern California's

heaviest urbanization and tree planting have taken place in the last 50 to 75 years (16). Many trees have simply not had the time to grow to maturity; other species naturally have a relatively short lifespan. It is therefore difficult to accurately determine the degree to which the lack of mature trees in southern California is due to early tree mortality, or simply to an overwhelming abundance of "recently planted" trees. Finally, southern California's mild climate provides a much longer growing season than do other areas of the United States. Many trees in southern California may grow faster than indicated by the Nowak and Urban studies. Further research on this topic is in order.

Conclusion

Urban forestry managers in coastal and inland regions seem to follow somewhat different patterns of species planting, with coastal areas focused on small-statured species and inland areas focused on medium- to large-statured species. Forestry managers and design professionals may also need to reexamine current species selection practices to avoid future problems, such as sidewalk damage and excessive maintenance, that can give an otherwise deserving species a bad reputation.

It also appears from this study that many municipal trees have not grown to their full potential. The exact causes for this are numerous and varied, but are most likely a combination of trees that have been planted relatively recently and the municipal environments into which street trees are placed.

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Résumé. Grâce à l'emploi de *TreeKeeper*, un logiciel pour la gestion des arbres, il a été possible de produire un inventaire des espèces d'arbres de rues les plus couramment rencontrées et de leur condition générale dans le Sud et le Centre de la Californie. De l'information a aussi été recueillie sur leur diamètre pour servir comme indicateur potentiel de l'espérance de vie des arbres en milieu urbain. Dans l'ensemble, les inventaires ont indiqué une tendance certaine vers une courte espérance de vie pour les arbres.

Zussammenfassung. Bei der Anwendung von "TreeKeeper," einem Baum-mangament-Software-Paket war es möglich, eine Bestandsaufnahme der häufigsten Straßenbaumarten und ihrer allgemeinen Bedingungen im südlichen und zentralen Kalifornien zu entwickeln. Es wurden auch Informationen gesammelt über den Umfang der Bäume als potentiellen Indikator über die Lebensspanne von Stadtbäumen. Insgesamt zeigen die Bestandsaufnahmeneinen deutlichen Trend zu kürzerer Lebensspannen bei Bäumen.