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Two Hundred Years of Forest Change: Effects of Urbanization on Tree Species Composition and Structure

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Abstract. Despite their importance, the dynamics of urban floras are not well understood and quantitative historical data are rare. The current study used three data sets for trees in Indianapolis/Marion County, Indiana, U.S., to document change over 200 years to the original beech-maple forest and to examine future implications of contemporary tree planting efforts in light of these changes. Data on tree composition and size collected before significant settlement in the early 1800s are compared with recent surveys of trees in remnant natural areas and with trees found on city streets and rights-of-way. All the species recorded in historical surveys are still present in either remnant natural area forests or among city street trees, but frequencies and sizes have changed and many additional species are now present. Comparison of the composition of the original forest with current remnants shows a 95% decline of American beech (*Fagus grandifolia*), the most common species in presettlement forests. Sugar maple (*Acer saccharum*) has more than doubled in number. Silver maple (*Acer saccharinum*) is the most important street tree, with eight species of non-native broadleaf trees among the most common on city streets, along with evergreen gymnosperms that are not documented in the presettlement flora. Data for contemporary tree planting efforts in the city show a focus on native species that targets replacement of species that have declined in frequency, especially oaks, in proportions that should be sustainable. Patterns reported here are likely representative of those in many forested areas undergoing land conversion and development, so the findings apply to many cities.

Key Words. American Beech; *Acer saccharinum*; *Acer saccharum*; *Fagus grandifolia*; Indiana; Indianapolis; Presettlement Forest; Remnant Forests; Silver Maple; Sugar Maple; Urban Forest; Witness Trees.

The composition of trees in cities is determined by three major factors. The first is the historical natural vegetation in which the city developed. This composition is controlled by climate, soils, and geologic history. The second is the matrix of development of the built environment and what remnants of natural area remain. For example, a recent study documented that present day oaks, dominant species of the presettlement forest of Chicago, Illinois, U.S., are still found in sites associated with presettlement forests in the city (Fahey et al. 2012). Two hundred years of urbanization have not erased the signature of presettlement patterns of vegetation, patches of forest in a prairie matrix. The third driver of urban tree composition is based on human preference: trees planted in greenspaces and along city streets.

More than 80% of the population of the United States (U.S. Census Bureau 2015) and more than half of the global human population (UNFPA 2007) now live in cities, and so receive the benefits of urban trees. With cities expected to expand 30% in area over the next few decades (Seto et al. 2012), even more people will be affected. Trees are an important component of urban green infrastructure, providing significant ecological services. They absorb air pollution, reduce soil erosion and stormwater runoff, and decrease energy consumption by providing shade and transpiring moisture, which reduce heat island effects in cities (Nowak et al. 2010 and references therein). Urban forests provide wildlife habitat and contribute to biodiversity. The benefits of trees go beyond improvement of the physical environment. Trees make an economic impact by increasing property values. Trees contribute to sense of well-being and provide psychological value beyond utilitarian services (Dwyer et al. 1991). As urban populations swell, greenspace and green places in cities will provide for most people's contact with nature. However, despite their environmental importance and the large amounts of money spent to maintain them, there is still much that is not known (Nowak et al. 2010).

Although the urban forest composition of all cities have been shaped by these three factors, there are few cities for which data exist to allow comparison and quantification of preurban forest species composition and structure with current conditions. Having such data would allow for informed selection of trees for current planting programs that reflect species historically present—in terms of composition and relative frequency. To the extent practical, a focus on plantings that recreate historical forest have the potential to promote biodiversity across the spectrum of urban biota that rely on trees.

These data do exist for the City of Indianapolis, Indiana, in the American Midwest. Indianapolis is the thirteenth largest city in the United States and is a state capital. It was founded in a sparsely populated area in 1820, not by settlers, but by a proclamation of the U.S. Congress (Bodenhamer and Barrows 1994). The land on which the city was developed was surveyed by the federal government around the time Indianapolis was founded, as part of the opening of the Northwest Territory. Witness trees were identified to species and their sizes recorded as the land was surveyed.

This paper compares these historical records with recent data on trees collected from remnant natural areas and with inventories of street trees in the city. Objectives were to document how tree composition and size have changed over 200 years and to examine the implications of contemporary tree planting efforts in light of these changes. Patterns reported here are likely representative of those in many forested areas undergoing land conversion and development, putting numbers on trends that apply to many cities.

MATERIAL AND METHODS

Natural Region Setting and History of Indianapolis

Indianapolis is located in Marion County, Indiana, in the center of the state. The city and the county are the same governmental unit, and so occupy the same geographic space, referred to as Indianapolis in this paper. Indianapolis has an estimated 900,000 people in a total area of 105,200 hectares, a very high human population density of 3,557/km^2 by United States standards (City Data 2015).

The city is located in the Central Till Plain Section of the Central Till Plain Natural Region (Homoya et al. 1985). Topographically, there is little relief except where streams cut into unconsolidated glacial till. Historical records and soil survey records indicate Indianapolis was almost entirely forested in pre-European presettlement times (Barr et al. 2002), with remaining land cover being open water or prairie. Mesic upland forest, mostly beech-maple association (Potzger et al. 1956), covered 76% of the county, with small areas of drier upland forest on ridges. Wet-mesic depressional forests were scattered throughout the county with floodplain forests along major rivers and tributaries. These forests were reduced to 13% cover by the late 1900s (Barr et al. 2002). Remaining forest cover is found in remnant natural areas and scattered woodlots, usually along streams in areas too wet or steep for farming (Brothers 1994). Logging and grazing likely occurred on these sites.

Sources of Data

Three sources of tree data were analyzed for this study. Two are culled from previously published studies. Historical data from the 1820 General Land Office surveys for Marion County were transcribed from original records and summarized in Barr et al. (2002). Detailed individual tree size (e.g., diameter, assumed to be diameter at breast height, DBH) data were provided by the lead author of that paper for this current study; the dataset is referred to as "historical." Current street tree species and sizes are from a forest resource analysis prepared for the City of Indianapolis by Peper et al. (2008). Finally, original to this paper, current tree composition in remnant natural areas in the city is presented, based on transect sampling conducted at five sites. All three sources provide data on individual tree identities and diameters.

Forest inventory data are also available for Marion and other counties in the United States through the USDA Forest Service Forest Inventory and Analysis Program (USDA FIAP 2015). This program now uses remote sensing combined with a sample of ground-truthed field plots to evaluate forest health annually.

Data estimated include species composition and size class. Percent sample errors of >50% associated with estimates for Marion County precluded use of detailed data from the program in this paper.

Historical Data

The area that is now Indianapolis was surveyed by the General Land Office of the federal government from 1820 to 1822. Surveyors generally walked the perimeter of each square-mile section, recording the diameter and name of two or more witness trees at the intersection of each section and quarter section line. Although there is potential for bias in the choice of each tree serving as a witness tree, such as in favor of those of economic value or those whose bark is easy to mark, prior studies have not found evidence of systematic bias (Bourdo 1956; Radeloff et al. 1999). These General Land Office Survey records provide the best primary account of presettlement vegetation in Indiana (Barr et al. 2002). Although witness trees represent relatively few individual trees of the original forest, to the extent they were randomly selected they do accurately reflect percentage relationships between species present (Blewett and Potzger 1951) and provide quantitative information of species present at a particular point in time (Schulte and Mladenoff 2001; Vellend et al. 2013). Barr et al. (2002) provide a summary of transcribed survey notebooks for Marion County. They matched common names used by surveyors with currently used names. Their original transcribed data provide the historical data for the current study, 3,620 individual trees from 31 different species.

Recent – Remnant Natural Areas

Tree composition data for extant remnant natural areas in Indianapolis is based on pooled data from five sites sampled from 2003 to 2007 (Table 1). All sites are forested. Three of the five sites—Spring Pond Nature Preserve, Eagle's Crest Nature Preserve, and Woollen's Gardens—were recognized in 1994 as being the best extant examples of what presettlement forests were like (Brothers 1994). Two different sampling protocols were used. Two sites were sampled using 100 m^2 circular plots arrayed in a three × three grid of plot centers separated by 20 m for a total of nine plots per grid (= grids method) (Table 1). All trees greater than 7.5 cm DBH were identified and their diameters recorded. At an additional three locations, point-quarter method sampling was used to quantify the vegetation present (= p-q method). Every 10 m along a 100 m transect, four trees were identified and their DBH recorded. Each transect therefore yielded data on 40 trees. These studies together yielded data on a total of 1,602 individual trees and their sizes.

Table 1. Natural remnants inventoried in recent years in Indianapolis, Indiana, U.S.

Site	Year inventoried	Size (ha)	Sample method	No. transects or grids
Art and Nature Park	2005	24	p-q	5
Eagle's Crest Nature Preserve	2007	120	grids	8
Southwestways Park	2004	36	p-q	10
Spring Pond Nature Preserve	2007	18	grids	8
Woollen's Garden Park	2003	15	p-q	7

Street Trees

The City of Indianapolis maintains a database of trees on public rights-of-way. The database was compiled and analyzed as part of a 2008 cost-benefit analysis. The analysis addressed whether the accrued environmental benefits, such as energy savings and stormwater runoff reduction, and economic benefits, such as property value increase, from Indianapolis' street trees, justify the annual expenditures associated with them (e.g., tree planting, maintenance, agency administrative costs) (Peper et al. 2008). Some trees in the rights-of-way are naturally established remnants of the original forest, others have been planted. Species and DBH class data for 101,311 trees from that 2008 report comprise the street tree data in this study.

Data Analysis

Data from the three data sources were compiled to document change in tree size and composition over the last 200 years. Attention was paid to developing an analysis scheme that acknowledged the limitations associated with each data type (e.g., lack of information on density). Where trees were identified only to genus in the historical data, species were similarly lumped for the other two data sources.

Importance integrates both numbers of individuals and size to provide a measure of how relatively predominant each species is. Importance for street trees are those values reported in Peper et al. (2008), calculated as the mean of the relativized frequency, leaf area, and canopy cover estimate for each species. Leaf area and canopy cover data were not available for historical and recent natural area trees, and so importance was calculated by adding frequency and relativized mean DBH for each species and dividing by two. The two methods for calculating importance are not directly comparable but provide a measure of which trees are most predominant in terms of both number and size in each data set.

The distribution of trees among size classes for the most common species was graphed to compare forest composition through time for all three data sources. This approach, analyzing tree size based on size class ranges rather than individual tree sizes, reduces some sources of error potentially associated with individual diameter values recorded in the General Land Office Surveys (see discussion in Schulte and Mladendoff 2001). Size infers age of tree and reproductive health of populations.

RESULTS

Comparing and Historical and Recent Trees

The last 200 years have seen a change in tree composition in Indianapolis as the city has developed. Although all but five species (occurring in frequencies of less than 1%) identified during historical land surveys are still found in remnant natural areas in Indianapolis, the frequencies of some of the most common species have shifted significantly (Table 2). The most common species in presettlement forests, American beech (*Fagus grandifolia*), declined as a percentage of total trees by 95%. Two species, each representing 11% of the original forest, now have divergent patterns: sugar maple (*Acer saccharum*) has more than doubled in frequency, while white ash (*Fraxinus americana*) has declined to less than 1% of trees present. White oak (*Quercus alba*) has declined from 6% to 1%. Native elms (*Ulmus* spp.) have increased the most through time as a percentage of all trees, increasing almost five-fold from 5% of witness trees to 23% of trees in current natural areas. Boxelder (*Acer negundo*) and hickories (*Carya* spp.) changed in composition by less than 3% between the recorded periods. Twenty-two other species were present in very low numbers at both points in time.

The largest trees, based on mean DBH in the presettlement forests, were tulip popular (*Liriodendron tulipifera*), sycamore (*Platanus occidentalis*), various oak species, black walnut (*Juglans nigra*), and blue ash (*Fraxinus quadrangulata*). Tulip poplar, sycamore, and oak continue to be among the largest trees in Indianapolis' forests, while the mean size of black walnut and blue ash has declined. Cottonwood (*Populus* spp.) is the only species to nearly double in mean size (Table 2).

Street Trees

Street trees differ in composition from those in presettlement forests and in current natural areas in Indianapolis. All species recorded in historical surveys are present in street tree inventories, except one, black willow (*Salix nigra*). The difference comes with the addition of species not found in presettlement forests. Eight species of non-native broadleaf trees are among the most common in number on city streets (Table 2). Only one, tree of heaven (*Ailanthus altissima*), occurred in recent samples from natural areas. An additional group of non-native trees, evergreen gymnosperms, account for 10% of all street trees. The most common native street trees were silver maple, sugar maple, hackberry (*Celtis occidentalis*), and white ash. The most numerous non-natives were crabapple (*Malus* spp.) and white mulberry (*Morus alba*).

Similarities of Species Composition in Data Sources

Based on the species presented in Table 2 (all species in historical and recent studies and street trees present at 5% frequency or greater), Jaccard's similarity of species composition between trees recently surveyed in remnants and those from the historical record is 66%, while street trees are only 28% similar to trees from the historical record, highlighting the difference in street tree composition compared with trees historically present in Indianapolis. Trees in remnants have a similarity of 41% with street trees.

Importance

Importance values document the decline of American beech and the increase of sugar ma-

Table 2. Frequency and mean diameter at breast height (DBH) for trees in historical and recent datasets, along with street trees present at 5% frequency or greater. Frequency values of greater than five are in bold. Historical data are from Barr et al. (2002). Most common street tree data are from Peper et al. (2008).

Species	Common name	Historical		Recent remnants		Street trees
		% of trees	Mean DBH (cm)	% of trees	Mean DBH (cm)	% of trees
Acer negundo	Boxelder	**5**	25	**8**	24	1
Acer nigrum	Black maple	<1	20	3	24	<1
Acer saccharinum	Silver maple	<1	33	**5**	31	**15**
Acer saccharum	Sugar maple	**11**	38	**26**	13	6
Aesculus glabra	Ohio buckeye	<1	10	3	11	<1
Betula nigra	River birch	<1	40	-	-	<1
Carpinus caroliniana	Musclewood	1	15	<1	5	<1
Carya spp.[z]	Hickory spp.	**7**	35	4	20	1
Celtis occidentalis	Hackberry	3	38	**5**	19	6
Cornus florida	Flowering dogwood	<1	10	<1	5	2
Crataegus spp.	Hawthorne	<1	20	<1	9	1
Fagus grandifolia	American beech	**40**	38	2	33	<1
Fraxinus americana	White ash	**11**	40	<1	34	5
Fraxinus pennsylvanica	Green ash	<1	35	2	31	2
Fraxinus quadrangulata	Blue ash	<1	50	<1	10	<1
Gleditsia triacanthos	Honeylocust	<1	30	1	31	2
Juglans cinerea	Butternut	<1	25	-	-	<1
Juglans nigra	Black walnut	2	53	2	30	1
Liriodendron tulipifera	Tulip poplar	1	68	1	68	1
Ostrya virgiana	Hophornbeam	1	15	<1	24	<1
Platanus occidentalis	Sycamore	1	68	1	62	1
Populus grandidentata	Bigtooth aspen	<1	14	-	-	<1
Populus deltoides	Cottonwood	1	30	1	58	2
Quercus alba	White oak	**6**	58	1	53	<1
Quercus rubra	Red oak	1	50	1	67	2
Quercus velutina	Black oak	1	60	<1	45	<1
Quercus spp.[y]	Other oaks	<1	60	2	42	2
Salix nigra	Black willow	<1	48	-	-	-
Salix spp.	Willow	<1	18	-	-	1
Tilia americana	Basswood or linden	1	33	1	28	<1
Ulmus spp.[x]	Elm spp.	**5**	43	**23**	14	<1
Acer rubrum	Red maple	-	-	<1	15	2
Ailanthus altissima[w]	Tree of heaven	-	-	<1	13	1
Cercis canadensis	Redbud	-	-	<1	12	2
Diospyros virginiana	Persimmon	-	-	<1	30	<1
Fraxinus profunda	Pumpkin ash	-	-	<1	16	<1
Maclura pomifera[w]	Osage-orange	-	-	<1	23	<1
Morus alba[w]	White mulberry	-	-	<1	20	3
Prunus serotina	Blackcherry	-	-	2	20	2
Robinia pseudoacacia[w]	Black locust	-	-	2	37	1
Sassafras albidum	Sassafras	-	-	<1	4	<1
Ulmus pumila[w]	Siberian elm	-	-	-	-	4
Gymnosperm spp.[w]	Gymnosperms	-	-	-	-	**10**
Acer platanoides[w]	Norway maple	-	-	-	-	3
Catalpa speciosa[w]	Northern catalpa	-	-	-	-	1
Liquidambar styraciflua[w]	Sweetgum	-	-	-	-	1
Malus spp.[w]	Crabapple	-	-	-	-	4
Prunus spp.	Plum	-	-	-	-	1
Pyrus calleryana[w]	Callery pear	-	-	-	-	1

[z] *Carya cordiformis* (bitternut hickory), *C. glabra* (pignut hickory), *C. laciniosa* (shellbark hickory), and *C. ovata* (shagbark hickory).
[y] *Quercus macrocarpa* (bur oak), *Q. michauxii* (swamp white oak), *Q. muehlenbergii* (chinquapin oak), and *Q. palustris* (pin oak).
[x] *Ulmus americana* (American elm), *U. thomasii* (rock elm), and *U. rubra* (slippery elm).
[w] Not native to Indianapolis/Marion County.

ple and elm over time in extant remnants compared to historic forests in Indianapolis (Table 2). Comparing historical data with recent data from remnant forests shows American beech declined by almost 90% while sugar maple and elm almost doubled in importance. American beech, white ash, sugar maple, white oak, hickory, and elm dominated original forests. In current remnant forests, sugar maple and elm species dominate, with boxelder the only other species with an importance of five or greater. The decline in dominance of American beech with time is replaced largely by small increases in importance of many other trees.

Silver maple is the predominant street tree, with 25% importance. Sugar maple, hackberry and white ash are other species with importance values greater than five.

Size Class Distributions

Size distribution of American beech has shifted from 60% of stems being in the smallest three size classes historically to a more even distribution with no size class having over 20% of stems (Figure 1). Sugar maple has had a reverse trend, with stems in the two smallest size classes increasing 18%. Elm has similarly experienced a large increase in the percentage of trees in the smaller size classes in recent remnants, compared to historical records.

Because street trees do not have natural recruitment patterns due to growing in managed environments, shapes of size class distribution curves are not informative of reproductive success, but they do offer insight into likely future population structure. Sugar maple and elm are likely to increase in predominance while beech will decline based on size class distribution (Figure 1).

DISCUSSION

Tree species composition in Indianapolis has changed with 200 years of habitat conversion and urbanization. Although all the species recorded in historical surveys are still present in either remnant natural area forests or among city street trees, proportions and sizes have changed and many additional species are now present. There has been a large decline in American beech with an increase in sugar maple. Data in the USDA Forest Service Forest Inventory and Analysis Program (USDA FIAP 2015) for trees on forest land (land at least 10% stocked by trees, including land formerly covered by trees and naturally regenerating) and timberland (forest land that is producing or is capable of producing forest crops of industrial wood) in Indianapolis (FIDO) based on 119 plots, confirm the trends reported in this paper. For example, from 2003 to 2013, sugar maple increased as a percentage of total estimated trees from 18% to 27%, with increases concentrated among the smallest trees. The

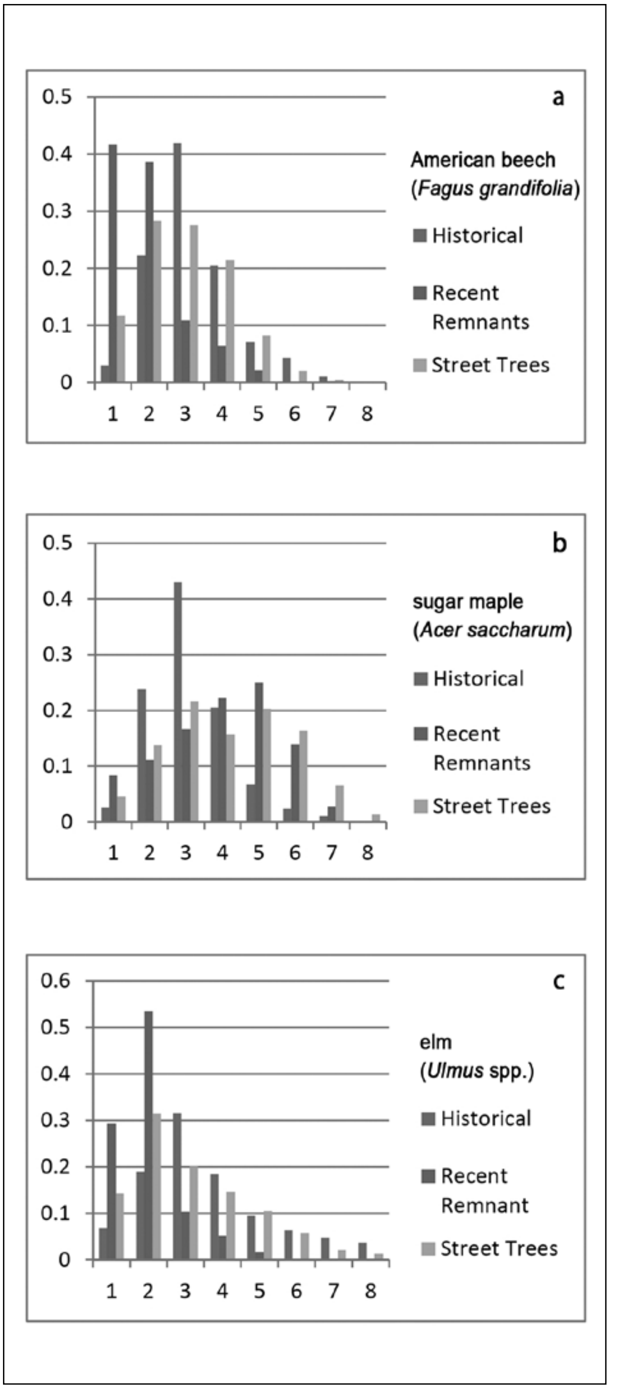

Figure 1. Frequency histogram of size distribution (DBH): a) sugar maple (*Acer saccharum*), b) American beech (*Fagus grandifolia*), and c) elm (*Ulmus* spp.) species trees from three different data sources in Indianapolis, Indiana. Size classes: 1 = 7.6–15.2 cm (3–6 inches), 2 = 15.2–30.5 cm (6–12 inches), 3 = 30.5–45.7 cm (12–18 inches), 4 = 45.7–61.0 cm (18–24 inches), 5 = 61.0–76.2 cm (24–30 inches), 6 = 76.2–91.4 cm (30–36 inches), 7 = 91.4–106.7 cm (36–42 inches), 8 = >106.7 cm (>42 inches). All size classes were scaled in inches due to street tree data only being reported in inch interval size classes in the street tree data source (Peper et al. 2008).

percentage of sugar maple in the smallest size classes (2.5 to 15 cm) increased from an estimated 22% to 33% to all trees in these classes.

The decline of American beech is likely explained in part by the loss of beech-maple forest through direct habitat destruction or conversion. Seventy-six percent of the county was covered by beech-maple forest in presettlement times (Barr et al. 2002). Upland forest was preferentially cleared for agriculture in the early part of the 19th century (Brothers 1994), which is reflected in the current estimated remaining forest cover in the county of 13% (Barr et al. 2002).

Additional factors that may have contributed to the decline of American beech in Marion County include poor tolerance of disturbance (especially disturbance to its shallow roots), compacted urban soil, low preference in the landscape industry due to its not doing well as ball-and-burlap stock, and the fact that its smooth bark is subject to vandalism in street and park settings (Carrie Tauscher, urban forester, Indiana Department of Natural Resources pers. comm.). It should also be noted that American beech frequency may have been overstated in the historical surveys. This species may have been preferentially selected for witness trees due to its smooth bark which would have been easy to blaze and mark.

The species shifts observed in Indianapolis may also be due in part to larger regional changes. Increasing presence of sugar maple and decline of American beech was noted in Indiana as early as 1977 (Abrell and Jackson 1977). The increase in sugar maple has been attributed to release from competition with American beech and alteration of natural fire regimes (USDA 2006). Decreased fire favors fire-sensitive species like sugar maple. The large proportion of small sugar maples in Indianapolis suggests the species will continue to increase in importance. As it becomes more dominant, sugar maple can have a cascading effect, further influencing forest composition through secondary effects, including altered nitrogen cycling (Lovett and Mitchell 2004).

Recent surveys also support a large increase in elm species, an increase in frequency from 5% to 23%, compared with historical records. Native elms may be any of three species, American elm (*Ulmus americana*), rock elm (*U. thomasii*), or slippery elm (*U. rubra*). Dutch elm disease, introduced in the 1950s in Indiana, killed almost all large elms. Natural populations have rebounded in some areas, but the disease still kills larger, older trees. Size of elm has decreased from a mean DBH of 43 cm to 14 cm in current remnants. Street tree elms include non-native Siberian elm (*Ulmus pumila*).

Blackcherry (*Prunus serotina*) was not reported in the historical data. This may be because of its extremely flaky bark, which is hard to mark and it might have been avoided by surveyors. It may also be that as a fast-growing tree of forest openings, it has become much more common with the forest disturbance that accompanied settlement and urbanization. Interestingly, *Sassafras*, the most common tree in urban forests in a recent statewide study (Nowak et al. 2007), and another fast-growing tree of species of forest openings, was not recorded in historical surveys and was very rarely encountered in recent surveys in natural remnant woods. Boxelder, a fast-growing disturbance-tolerant species, remained of similar low importance.

Cottonwoods, the trees with the largest increase in mean size between historical surveys and current remnants, are primarily found along streams and creeks and in floodplain forests bordering streams and creeks. Many of the remnant patches of this habitat type in Indianapolis are now protected as parks. The increase in tree size may be due to protection from disturbance.

The most striking difference between urban street tree composition and that of historical or current natural woods is the large percentage of silver maple. Its predominance has increased almost thirty times over presettlement values. In Chicago, dominance of silver maple has increased an amazing 80,000 percent over the same recorded period (Fahey et al. 2012). This species was often a street tree of choice in the 20th century because of its fast growth. It is not recommended for planting in urban forests in Indiana (IDNR 2015) because its quick growth makes it weak and susceptible to damage in wind and ice storms. The species is not among those currently being planted on city streets (Table 3).

Although all trees recorded in the historical survey records are found among Indianapolis' street trees, many other species are now planted in the city. The proportion of importance represented by other species, where species in the original forest once grew, has greatly increased. Evergreen gymnosperms, none present in presettlement Indianapolis, with the possible exception of red cedar (*Juniperus virginiana*), comprise 10% of street trees. These data show that human preference has greatly altered the tree composition of Indianapolis. Shifts in dominance from native species, such as oaks, to smaller-statured, shorter-lived non-native species have been reported for the urban forests of Chicago, with associated loss of ecosystem service over time predicted (Fahey et al. 2012).

The Future

The non-profit beautification group Keep Indianapolis Beautiful (KIB) is partnering with the city to plant 100,000 trees. The choice of species planted will be the greatest opportunity humans have to directly influence the future of Marion County's urban tree composition. Records of recent plantings show native trees are the most commonly selected, with over 20% of 12,174 trees planted since 2008 being species of oaks (Table 3).

Oaks have declined in the county since presettlement times. Species of depressional ponds and seasonally flooded wetlands, like swamp white oak (*Quercus bicolor*) and bur oak (*Q. macrocarpa*), have had their habitats drained. Oaks planted in urban spaces will replace an all but lost component of the native forest, providing wildlife with food and habitat. Oaks in the eastern United States provide significant ecological services as one of the best food sources for birds and other desirable wildlife that feed on insects (Burghardt et al. 2009).

Although slightly more than 20% of trees planted by KIB are oaks, no single species comprises more than 10% of the total. For sustainability in an urban forest, Santamour (1990) recommends no single species should be more than 10% of trees planted in a given area, and no genus more than 20%. KIB's planting list also follows the recommendation of Peper et al. (2008), for Indianapolis to plant non-maples.

Natural forces that will continue to influence forest composition on a landscape scale include additional introduced pests. The emerald ash borer (*Agrilus planipennis* Fairmaire) (EAB), a coleopteran beetle, was recently introduced and is spreading in the county (Purdue Univ. Extension 2015). Ashes have declined from approximately 12% of all trees in historical surveys, to around 3% in recent surveys, before the arrival of the EAB. It is predicted all untreated trees will die. Ashes comprise about 7% of street trees.

Streetscape tree selection is influenced by many factors, including availability, price, aesthetics, species' viability in the urban environment, and cost of maintenance. To the extent native species can be chosen while weighing these factors, urban trees can increase biodiversity of associated flora and fauna (Ikin et al. 2012) in cities while promoting regional distinctness and countering biotic homogenization. However, a caveat looking into the more distant future, is that as tree species distributions are shifted by global climate change, historical species composition may become less relevant as baseline condition data.

Table 3. Trees planted in Indianapolis by Keep Indianapolis Beautiful (2008–2011).

Species	Common name	Qty.	% total
Quercus macrocarpa	Bur oak	774	6.4
Quercus bicolor	Swamp white oak	745	6.1
Cercis canadensis	Redbud	592	4.9
Amelanchier × grandiflora	Serviceberry	520	4.3
Quercus rubra	Red oak	416	3.4
Quercus muehlenbergii	Chinquapin oak	415	3.4
Gymnocladus dioicus	Kentucky coffeetree	407	3.3
Liquidambar styraciflua	Sweetgum	387	3.2
Juniperus virginiana	Red cedar	383	3.1
Acer saccharum	Sugar maple	377	3.1
Ulmus americana	American elm	368	3.0
Nyssa sylvatica	Black gum	336	2.8
Acer rubrum	Red maple	323	2.7
Amelanchier sp.	Serviceberry species	319	2.6
Quercus sp.	Oak species	255	2.1

CONCLUDING REMARKS

With an estimated annual loss of urban tree cover, a proxy for overall urban forest resources, of 0.9% in the United States (Nowak and Greenfield 2012), threats to urban trees continue. Information on how urban forests are changing is needed to better inform policies to "protect, sustain and enhance urban forests health and benefits for future generations" (Peper et al. 2008). Although it does not include data for trees in backyards or other private property (those data do not exist for Indianapolis and likely never will due to property owners' rights), this study provides a snapshot of tree composition in Indianapolis, allowing a degree of quantification of the current fingerprint of human alteration of forests in the city. Patterns reported here are likely representative of those in many forested areas undergoing land conversion and development, so the findings apply to many cities. The quantitative data presented here provide baseline numbers to which the future urban forest of Indianapolis can be compared and which can be used for statistical comparisons with data from other cities.

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