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Tree diversity, distribution, history and change in urban parks: studies in Bangalore, India

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Abstract Urban parks constitute critical biodiversity hotspots in crowded, concrete-dominated city environments. Despite the importance, they remain little researched. This paper assesses the biodiversity and distribution of trees in urban parks in the southern Indian city of Bangalore. 127 plots were used to survey tree distribution in parks across the city. The distribution is largely dominated by a few common species. The proportion of exotic species was very high, with 77% of trees belonging to introduced species. Park history had an impact on distribution. Old parks had fewer but larger trees, and greater species diversity compared to recently established parks. Old parks also differed in species composition, having a greater proportion of large canopy trees compared to young parks. Examination of size distributions revealed that large canopied species were gradually being phased out, and replaced by narrow and medium sized tree species which are easier to maintain, but which may not provide the same environmental and ecological benefits. Greater attention requires to be paid to the selection of trees in cities, not just with a view to easy maintenance as is currently the case, but to select an appropriate mix of trees that supports biodiversity and maximizes environmental and ecosystem services.

Keywords Cities · Green spaces · India · Urban biodiversity · Urban ecology

Introduction

Cities constitute a habitat and home for an increasingly large proportion of the world's population, playing a critical role in maintaining ecological, economic and social well

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being. Unlike protected forests in distant areas, city parks constitute green spaces managed largely for recreational purposes, and form the largest proportion of publicly available green space for urban dwellers (Oleyar et al. 2008). Indeed, for many poor city residents in developing countries, urban green spaces may provide the only reference to "nature" that they will ever experience, providing important social and psychological functions that substantially improve the quality of city life (Botkin and Beveridge 1997; Long and Nair 1999; Chaudhry and Tewari 2010; Aminzadeh and Khansefid 2010).

Urban parks also provide critical habitat for urban flora and fauna (Freestone and Nichols 2004; Giuliano et al. 2004; Oleyar et al. 2008; Khera et al. 2009). They contribute multiple valuable ecosystem services, helping to provide clean air, buffer microclimatic variations and lower noise levels, and regulate water flows (Bolund and Hunhammar 1999; Chiesura 2004). Though often very small in area, they tend to be characterized by high levels of diversity and microhabitat heterogeneity, with large proportions of exotic species (Jim 2002; Khera et al. 2009), and constitute critical biodiversity hotspots (Cornelis and Hermy 2004; Jim and Chen 2009; Goddard et al. 2010). Thus, park area has been show to impact the distribution of biodiversity for multiple taxa including plants in Flanders (Cornelis and Hermy 2004), and for birds in several other cities in Europe, America, Spain and Japan (Fernández-Juricic and Jokimäki 2001; Murgiu 2009).

Despite the importance of these green spaces, they remain little researched in most parts of the world (Cornelis and Hermy 2004; Davies et al. 2008; Weifeng et al. 2006; Clarke et al. 2008), in contrast to the attention paid on parks in forested areas (Nagendra 2008). This lack of understanding of biodiversity distributions and dynamics in urban parks makes it very difficult to plan strategies for urban conservation (Alvey 2006; Weifeng et al. 2006; Jim and Chen 2009). Research on urban forestry including on urban parks has largely been conducted in north America and Europe, with comparatively few studies from other parts of the world (Fernández-Juricic and Jokimäki 2001; Cornelis and Hermy 2004). The few studies conducted in the Asia/Pacific have also largely focused on Australia, South East Asia and Russia (Jim and Liu 2001; Weifeng et al. 2006; McKinney 2008), with very little information on about urban forests and specifically on urban parks in South Asia (Nagendra and Gopal 2010; Singh et al. 2010).

This paper assesses the biodiversity and distribution of trees in urban parks in the southern Indian city of Bangalore. Once considered the garden city of India, and famous for its greenery, this city is now the second fastest growing city in India, with a population of over 7 million (Sudhira et al. 2007). The first large parks in the city were established in the 18th century, and several large publicly accessible parks were created during the 19th century. Yet, in recent times, a complex dynamic has played out in the city, with many green spaces being encroached on for developmental activities, amongst vociferous protests by local citizens, while at the same time a number of smaller neighborhood parks have been created in a number of locations (Nair 2005; Sudhira et al. 2007). As with other South Asian cities (Nagendra and Gopal 2010; Singh et al. 2010), little is known about the distribution of these green spaces within Bangalore, or about the biodiversity they harbor. Such information is essential in order to properly evaluate the contribution of parks and urban forests to the ecological integrity and health of Bangalore (Sudha and Ravindranath 2000).

Our specific objectives are to provide baseline surveys of park tree diversity in the city of Bangalore; to evaluate the impact of the history of park establishment on biodiversity and distribution; and to assess changes in planting preferences over time using tree size as a proxy for age. This study will thus provide important information on the biodiversity of parks in this little researched, yet critical South Asian city. This investigation forms part of a larger project on urban biodiversity in Bangalore, encompassing research on biodiversity on city streets and in home gardens as well as in parks, and studies of patterns in urbanization and its impact on ecological networks and ecosystem services in the city. The results of this analysis will eventually be disseminated through a freely accessible, spatially explicit database which will be useful for city planners, researchers, educators, students, urban activists and the interested public (Nagendra and Gopal 2010).

Methods

The Outer Ring Road, a large road which circumscribes the majority of the city's parks within the administrative boundary of greater Bangalore, was used to define the limits of the area within which sampling was conducted. Within this, parks were identified with reference to a 1:50,000 scale 2002 Guide Map of Bangalore from the Survey of India, and a 2002 Eicher map of the city. Field studies of biodiversity in these parks were carried out between January and April 2008. Data was collected with the assistance of students from St. Josephs College of Arts and Science, one of the city's oldest undergraduate colleges.

Within a park, sample plots of 25 by 25 m were used to record information on biodiversity. Parks with dimensions less than 25 m on any side were consequently excluded from analysis. For all remaining parks, a number of plots were randomly located within a park in proportion to its total area, taking care to ensure that a minimum distance of 200 m was maintained between sample plots. Since most of the cities' parks are small in size, most parks were sampled using between 1 and 3 plots. The city's two largest and oldest parks—the Lalbagh Botanical Garden, established in the 18th century, and Cubbon Park, established in the 19th century, were sampled using a larger number of plots (between 8 and 12). A total of 127 plots were surveyed across the city, and their location identified using a Global Positioning System (Fig. 1).

Within a plot, all trees were identified to the species level, and their diameter at breast height (DBH) and height were recorded. Canopy cover was recorded by visual observation and assigned into one of six categories—0–5%, 5–25%, 25–50%, 50–75%, 75–90%, and 90–100%. A number of measures of density, distribution and diversity were also calculated. The number of trees was used as an indication of density. Distribution was assessed using average DBH (diameter at breast height) and average height of all trees within a plot. The origin of tree species, whether introduced or native, was assessed with reference to a 19th century gazetteer of Bangalore (Rice 1897) as well as with reference to other books on the flora of Bangalore (Issar 1994; Neginhal 2006). Diversity was assessed based on species richness (the number of tree species per plot) and the Shannon index of diversity at the species level per plot. The Shannon index of diversity or SHDI is one of the most popular indices used in community ecology to quantify biodiversity, and is defined as

$$SHDI = -\sum_{i=1}^{N} p_i \times \ln p_i$$

where N is the total number of species and p_i, the proportional abundance of the *i*th species. This index, ranging in theory from 0 to infinity, combines aspects of species richness and evenness, increasing under conditions where the number of species increases, or the equitability of distribution of individuals belonging to different species increases, or both (Stohlgren 2007). The distribution of trees amongst different size classes was calculated using a measure similar to Shannon diversity. Trees were assigned to six different DBH size classes: 0–15 cm, 15–30 cm, 30–45 cm, 45–60 cm, 60–75 cm, and >75 cm. Size class

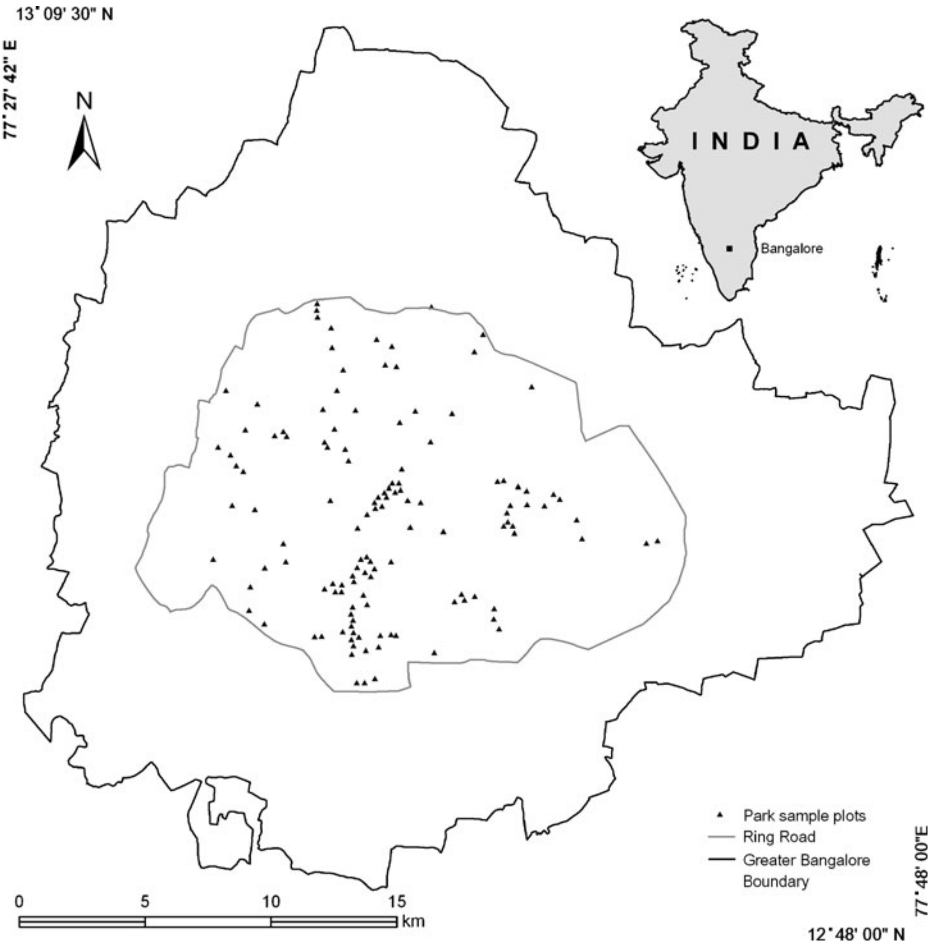


Fig. 1 Location of park sample plots in Bangalore with reference to the greater Bangalore administrative boundary, and the Outer Ring Road, which circumscribes a majority of the city's parks

diversity was calculated using the Shannon index, where N is the total number of trees in each DBH size class, and p_i is the proportional abundance of trees in the *i*th DBH size class.

Parks in Bangalore have been established at varying points of time, with different purposes in mind. The two largest and oldest parks in the city, the Lal Bagh, were established in the 18th and 19th century respectively: the Lal Bagh is a botanical garden of repute in South Asia, while the Cubbon Park constitutes a large and important lung space for the city. Several other parks were established towards the earlier part of the 20th century up until the 1960s, largely managed by British appointed foresters. These parks (constituted before the 1970s) form the first group, categorized as "old parks". A number of parks were established in the decades after Indian independence, with significant tree planting initiatives carried out during the 1980s in particular (Neginhal 2006). The second group of parks, in the intermediate age group, are defined as those constituted after 1970 but before 1990.

Finally, in the past 10 years, a large number of small parks have been established in different areas of the city, which are widely used by local residents for recreational purposes. Parks established on or after 1990 are accordingly categorized into a third group of recent parks. Although the boundaries of these groupings are somewhat arbitrary, they largely separate three phases of park creation—the first during and just after periods of British governance, the second during a phase of park creation carried out during the 1970s and 1980s, and the third during a phase of recreational park establishment, especially focused towards the development of small city parks, carried out during and after the 1990s. We hypothesized that these parks, established at different points of time with different urban interests and uses in mind, should differ in their density, diversity and species composition. Consequently, we wished to examine differences in the tree flora found in parks of different age categories.

A non-parametric Mann Whitney U test (Sokal and Rohlf 1981) was used to assess whether parks of different age categories differed significantly in measures of density, distribution and diversity. The species composition of park age categories was also investigated. For the ten most dominant species in each park age category, relative abundance (percentage of the total number of trees constituted by the species), relative dominance (percentage of total basal area constituted by the species), and importance value (sum of relative abundance and relative dominance) was also calculated, following McPherson and Rowntree (1989), and Welch (1994). Finally, in order to investigate changes in planting practices and species selections over time, size class distributions of the ten most dominant tree species were evaluated, using size as a proxy for age to determine changes over time.

Results

Aggregate distributions of trees

A total of 1,423 trees were sampled in 127 plots. The composition is overwhelmingly dominated by exotic species. Of the 80 species encountered (distributed across 27 families), 53 were introduced and only 27 were native species. In terms of abundance, 77% of the trees belonged to exotic species, while only 42% of the trees belong to native species. The distribution is largely dominated by a few commonly encountered species. The most dominant tree, *Polyalthia longifolia*, which is an evergreen species introduced from Sri Lanka, comprises almost 1/5th of the total population, while the five most common species accounted for close to half of the total population (Table 1).

The ten most common species are largely deciduous, with only three evergreen species, none of which are native to Bangalore (Table 1). They are largely ornamental. *Polyalthia longifolia* (mast tree) with its graceful drooping foliage, is commonly planted at the park periphery in densely spaced rows to provide a natural barrier that screens out the congested, noisy and dusty urban periphery. *Roystonea regia* (royal palm) is an introduced ornamental palm which has also become popular in the city in recent decades. Both these species grow quickly, and are preferred for this reason as well. There are a few large shade-providing canopy trees—*Bauhinia variegata* (orchid tree), *Peltophorum pterocarpum* (copper pod), and *Delonix regia* (gulmohar). These species, along with the other common park tree species with narrow to medium canopies—*Millingtonia hortensis* (Indian cork), *Markhamia lutea* (Nile tulip), *Tabebuia aurea* (golden bell), and *Spathodea campanulata* (Africal tulip), have been planted in the city for decades because of their strikingly beautiful flowers (Issar 1994). *Pongamia pinnata* (honge), one of the three indigenous species commonly found in parks, is also used for firewood, timber, and biofuel and has become an increasingly popular species of choice for Bangalore city in recent years (Nagendra and Gopal 2010).

Table 1 Attributes of the most frequently encountered tree species in parks, based on a sub-sample survey of the park tree population of Bangalore

Scientific name	Proportion of trees (across all parks)	Common names in India	Origin	Phenology	Canopy size	Uses
Polyalthia longifolia	19.3	Indian mast	Introduced, Sri Lanka	Evergreen	Narrow	Ornamental
Pongamia pinnata	7.5	Honge	Native to Bangalore	Deciduous	Medium	Ornamental, firewood, timber, biofuel
Roystonea regia	6.3	Royal palm	Introduced, central America and the Caribbean	Evergreen	Narrow	Ornamental
Markhamia lutea	5.3	Nile tulip	Introduced, east Africa	Evergreen	Narrow	Ornamental
Bauhinia variegata	5.0	Orchid tree	Native to Bangalore	Deciduous	Medium	Ornamental, medicinal, timber
Peltophorum pterocarpum	4.5	Copper pod	Introduced, Sri Lanka	Deciduous	Large	Ornamental, shade
Delonix regia	4.1	Gulmohar	Introduced, Madagascar	Deciduous	Large	Ornamental, shade
Tabebuia aurea	4.0	Golden bell	Introduced, South America	Deciduous	Intermediate	Ornamental
Millingtonia hortensis	3.4	Indian cork	Introduced, Myanmar	Deciduous	Narrow	Ornamental
Spathodea campanulata	3.3	African tulip	Introduced, tropical Africa	Deciduous	Medium	Ornamental

Differences across park age categories

Parks established at different points of time were compared to assess differences in species composition, canopy cover, density, diversity and biomass. Older parks had the greatest proportion of introduced species, followed by recent parks. In comparison, parks of intermediate ages appeared to have the highest proportion of indigenous species, although these were also largely dominated by exotics (Table 2). Parks intermediate in age had greater canopy cover than older and more recent parks (Table 2)—these differences were statistically significant based on a Mann-Whitney U test (Table 3). Old parks had the least number of trees compared to other categories. The size of trees (DBH and height) in older parks was however significantly greater in old parks compared to those established in more recent years (Tables 2 and 3, Figs. 2 and 3). While no significant differences in tree species richness were found amongst parks of different age categories, the Shannon diversity of tree species was highest in the older parks. The size class diversity was also significantly greater in old parks, as may be expected considering that the trees in these locations are likely to be older than in other parks, and may have been planted at multiple points in time (Figs. 2 and 3).

To assess differences in species composition across park age categories, we focused on the ten most common species identified in Table 1. Figure 4 aggregates information from relative abundance—an index which responds to differences in the proportional abundance

Table 2 Attributes of park trees—canopy cover, density, size and diversity—summarized for different park age categories, based on a sub-sample survey of the park tree population of Bangalore. Species richness refers to the number of species. Shannon diversity is an index of biodiversity, calculated as $\sum_{i=1}^{N} p_i \times \ln p_i$ where N is the total number of species and p_i is the proportional abundance of the ith species. Size class diversity is calculated similarly, based on the proportional distribution of trees in different DBH categories, as described further in the "Methods"

Park tree attributes	Old parks	Intermediate age parks	Recent parks
Number of plots	44	32	51
Percentage of trees belonging to introduced species	83%	70%	78%
Median canopy cover (%)	25–50%	50–75%	25–50%
Density per hectare—mean and standard deviation	36±18	53±35	48±29
Average DBH (cm) per plot—mean and standard deviation	44.6±17.7	33.9±17.3	30.0±12.5
Average height (m) per plot—mean and standard deviation	10.5±2.3	9.2±3.1	8.0±3.1
Species richness per plot—mean and standard deviation	4.5±2.6	4.8±3.0	3.8±2.4
Species Shannon diversity per plot—mean and standard deviation	1.1±0.3	1.1±0.7	0.9±0.6
Size class diversity per plot—mean and standard deviation	0.4±0.2	1.1±0.4	0.8±0.4

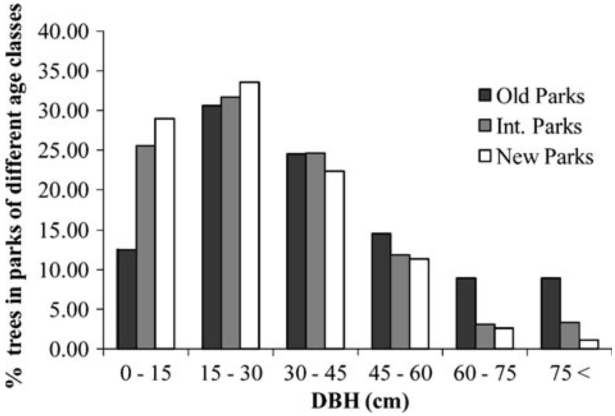
of these species—and relative dominance—an index which responds to differences in the relative biomass of these species—to describe differences in park categories based on the importance value of different species, as described further in the "Methods" section. In terms of importance value, all three park categories are dominated by mast trees, with recent parks harboring the greatest proportion of this species (Fig. 4). However, recent parks are dominated by royal palm trees (partly due to the increased frequency of this species, but also because of the shape of this palm which has a broad base but a tapering top and a narrow canopy). Old parks have a greater representation of gulmohar. Parks of intermediate age have a different distribution from that of old and recent parks, being heavily influenced by copper pod and gulmohar—the two large canopy exotic species found to predominate in parks—along with honge, an indigenous species.

Table 3 Results of a non parametric, one-tailed Mann Whitney U test assessing the statistical significance of differences in tree density, size, and diversity across parks in different age categories, based on a sub-sample survey of the park tree population of Bangalore. Species richness refers to the total number of species. Shannon diversity is an index of biodiversity, calculated as $\sum_{i=1}^{N} p_i \times \ln p_i$ where N is the total number of species and p_i is the proportional abundance of the ith species. Size class diversity is calculated similarly, based on the proportional distribution of trees in different DBH categories, as described further in the "Methods"

Park tree attributes	Old vs. recent	Old vs. intermediate age	Intermediate age vs. recent
Difference in canopy cover	Old > recent	Intermediate > old**	Intermediate > recent***
Difference in number of trees	Recent > old*	Intermediate > old**	Intermediate > recent
Difference in average DBH	Old > recent***	Old > intermediate***	Intermediate > recent
Difference in average height	Old > recent***	Old > intermediate**	Intermediate > recent*
Difference in species richness	Recent > old	Intermediate > old	Intermediate > recent
Difference in Shannon diversity—species	Old > recent**	Old > intermediate	Intermediate > recent
Difference in size class diversity	Old > recent***	Old > intermediate	Intermediate > recent**

* significant at $p<0.1$; ** significant at $p<0.05$; *** significant at $p<0.01$

Fig. 2 Proportional distribution of tree DBH across different park age categories

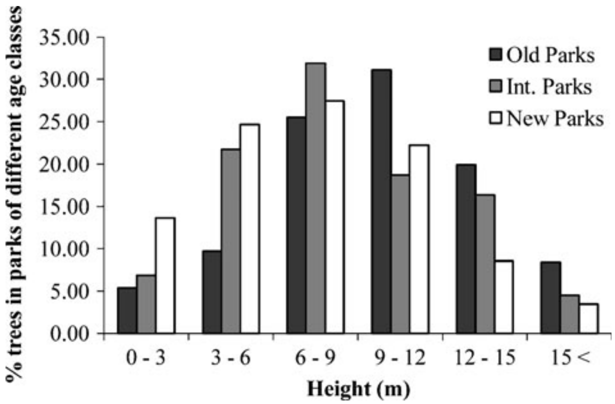


Differences in growth across species

The size class distributions of tree species can provide a fairly reliable overall indication of changes in species selection over time, although with the caveat that different species grow at different rates (Sanders 1983; Welch 1994). Thus, although data on species distributions from previous points in time are not available for Bangalore, we use size class distributions to differentiate between species which have been planted over a number of years (which should have a more evenly distributed age structure), from species which have been selected for planting recently (whose distribution should be dominated by smaller trees), or species which have been planted widely in the past and recently been discontinued (whose distribution should therefore be dominated by larger trees).

Table 4 clearly indicates differences between species age structures. Mast trees, honge and Nile tulip are dominated by individuals in the smallest size category of <15 cm DBH, and do not have any individuals in the size categories of 60–75 cm and >75 cm DBH, indicating that the majority of these trees are young, and recently planted. The oldest trees are copper pods, gulmohars, Indian corks and African tulips, which are large, flower-bearing trees that have been known to have been part of Bangalore's urban flora for centuries (Issar 1994). Yet, Indian cork and African tulip are distributed across all size classes, indicating that these species continue to be popular species of choice in the urban landscape. Gulmohar and copper pod, on the other hand, are large, spreading trees which

Fig. 3 Proportional distribution of tree heights across different park age categories



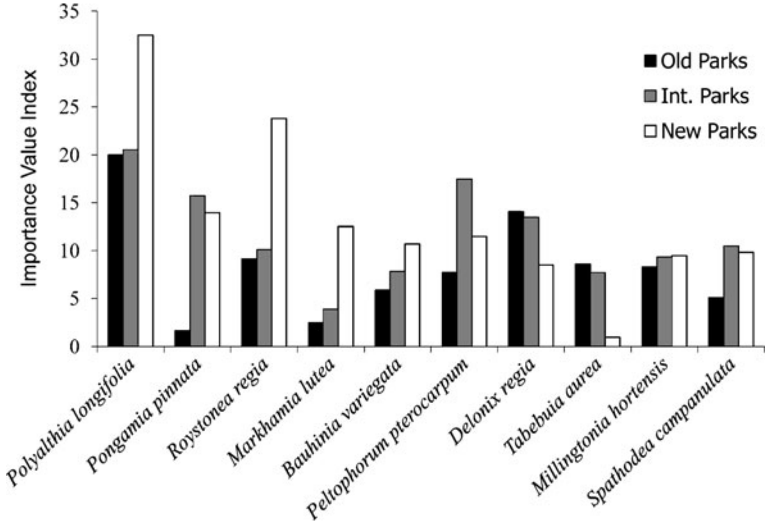


Fig. 4 Importance value distribution for the ten most dominant tree species, across different park age categories

require constant pruning, and are less stable during the rainy season, when tree falls are frequent. The fact that very few trees are found in the 1–15 cm size class appears to indicate that these species are being gradually phased out in parks. These species appear to be getting replaced by orchid trees and golden bells, both attractive flowering species which are represented to a greater extent in the smaller size classes. Royal palms are an anomaly—they appear in intermediate size classes, though not in the smallest or largest size classes. Personal observations indicate that this species is a recent entry into the Bangalore urban landscape, and has become popular over the past decade or so. It is a very rapidly growing tree, however, with a wide base and narrowing at the top, and is generally transplanted when already at a height of a few feet, and a DBH greater than 15 cm—which is the reason

Table 4 Size class distribution of the ten most dominant tree species, based on a sub-sample survey of the park tree population of Bangalore

Species	Species percentage of DBH class (cm)						Number of trees sampled
	0–15	15–30	30–45	45–60	60–75	>75	
Polyalthia longifolia	43.43	40.51	12.77	3.28	0.00	0.00	274
Pongamia pinnata	38.32	37.38	21.50	2.80	0.00	0.00	107
Roystonea regia	0.00	11.24	41.57	47.19	0.00	0.00	89
Markhamia lutea	52.63	35.53	10.53	1.32	0.00	0.00	76
Bauhinia variegata	8.45	49.30	38.03	4.23	0.00	0.00	71
Peltophorum pterocarpum	3.13	23.44	25.00	28.13	14.06	6.25	64
Delonix regia	1.64	16.39	31.15	24.59	19.67	6.56	61
Tabebuia aurea	26.32	64.91	5.26	1.75	1.75	0.00	57
Millingtonia hortensis	10.42	20.83	18.75	25.00	16.67	8.33	48
Spathodea campanulata	10.64	25.53	27.66	14.89	17.02	4.26	47

why this species is not found represented in the smallest size class. A Mann Whitney U test of size differences between trees provides corroboration, indicating that Nile tulip and mast trees tend to be the smallest in size, while Indian cork, copper pod and gulmohur contribute the largest trees. Royal palm, honge, orchid trees, golden bells and African tulips are represented across a range of sizes. Interestingly, trees belonging to introduced species are significantly larger than trees of local species (Mann Whitney U test, $p<0.05$).

Although the size class distributions reveal that the largest trees belong to exotic species, and trees from local species are smaller, the composition of Bangalore's street trees appears to be changing over time. The large sized exotic trees such as gulmohar and copper pod that dominated the landscape are gradually giving way to endemic trees such as orchid trees and honge, along with exotic species like Nile tulip, mast trees, and royal palms that continue to be planted alongside these local species. The tall, spectacular Indian cork and African tulip, popular trees in the past, are the only species which have been planted in recent years with some continuity.

Discussion

Although Bangalore is widely famed as the garden city of India, and rapidly gaining importance as a global city, little is known about Bangalore's urban environment and ecology. We find that Bangalore's parks have a high species richness, with 80 species recorded from 127 plots of 0.25 ha each, containing 1,423 trees. Yet the distribution of trees is dominated by a few species, with the top five species accounting for almost half of all trees. The percentage of exotics is very high, with introduced species accounting for 65% of the total tree flora, and constituting about 77% of trees across all parks. This is especially high when contrasted with cities such as Potsdam, where the proportion of indigenous species in parks is as high as 81% (Maurer et al. 2000), or in parks in the South Korean city of Chonju, where exotic species constitute less than 30% of the population (Zerbe et al. 2004).

The predominance of exotic species is a matter of concern. Urban forests are known to consist of a mix of introduced and native species (McKinney 2008; Garcillán et al. 2009). In Bangalore, as in many former European colonies such as Brazil, European influences dominated the selection of city tree species, with a preference for exotic species selected for their flowering and visual beauty (dos Santos et al. 2010; Issar 1994). Some authors suggest that a mix of introduced and indigenous species may actually be beneficial for some aspects of biodiversity (McIntyre and Hobbs 1999; Hunter 2007), but clearly, the presence of a large number of introduced species must alter ecosystem structure and function in a fundamental manner (McKinney 2006). Thus in some cities such as Phoenix, there appears to be a movement towards planting of native vegetation (Martin et al. 2004).

In Bangalore, the overwhelming dominance of introduced species appears to be leading to homogenization of park flora, with approximately every 4 out of 5 trees belonging to an exotic species. This is a particularly disturbing trend when coupled with findings from other research which suggests that introduced plant species have a negative impact on the distribution of other taxa, particularly of birds (Mills et al. 1989; Khera et al. 2009). Recent planting has continued along this trend, focusing on a variety of non-native species such as the royal palm, mast tree, Nile tulip and golden bell, while only two native species have been planted in significant numbers in recent years—orchid tree and honge.

Urban floristic distributions in this city are strongly impacted by development histories, as has been shown for other parts of the world (Kent et al. 1999; Maurer et al. 2000; Weifeng et al. 2006; Davies et al. 2008). Old parks have been similarly observed to have greater plant diversity in Beijing (Weifeng et al. 2006) and in the vicinity of Berlin (Maurer et al. 2000). Old parks have a long history, having been established at different points in time and cared for by a number of different park managers, providing the opportunity for more heterogeneous and diverse growth. Thus, we find that while they may have fewer trees, they harbor trees of larger sizes, and their species composition tends to be more heterogeneous compared to recent parks, which are dominated by a few small sized tree species, presumably with reduced environmental and ecological benefits.

We observe a decrease in the preference for large canopied species which bear a great deal of flowers and fruits like copper pod and gulmohar, and an increased dominance of small sized trees such as mast trees and royal palm which will not provide the same environmental and ecological benefits. This parallels changes in planting patterns observed for street trees of Bangalore (Nagendra and Gopal 2010). Similar patterns of change have also been noted in Guangzhou, China, where park managers have shifted from a preference for large, shade bearing broadleaf trees in older parks, to a mix of conifers, palms and smaller sized trees in newly established areas (Jim and Liu 2001). Large trees constitute a better habitat for other urban species such as woodland birds, sequester greater amounts of carbon, contain more above ground biomass and provide more effective removal of air particulate pollutants, greater shade and more effective cooling (McPherson and Rowntree 1989; Pauleit 2003). At a time when the initial impacts of climate change are beginning to be felt across the world, it is disturbing to note this movement away from large shade bearing broad leaf trees towards palms and other narrow canopied species.

The city unfortunately lacks a consistent, publicly available tree policy that specifies which species to plant, and towards what purposes. Greater attention requires to be paid to the selection of trees planted in city parks, not just with a view to easy maintenance as is currently the case, but with some effort to select an appropriate mix of trees that supports other biodiversity and provides environmental and ecosystem services.

Despite Bangalore's identity as a green "garden city", it is also a fast growing metropolis subject to demands on parks and green spaces for infrastructure and developmental activities. As with other cities in India and other rapidly urbanizing developing countries, green spaces are considered "land banks", and often encroached on by private as well as government interests for creating additional built space (Zérah 2007)—despite numerous citizen's protests and public interest litigations against these conversions (Nair 2005; Sudhira et al. 2007). At this contentious time of change, it is unfortunate that basic information on the city's green cover is lacking, let alone any analysis of structure and composition that would provide guidelines for future management and change. This paper reports results from a long term program aimed at monitoring ecological, environmental and land use change in the city. Future goals include the preparation of a spatial database of trees in the city, which will facilitate the monitoring of basic ecology, enable the identification and protection of large heritage trees and facilitate monitoring of changes over time. With the advent of high resolution satellite imagery such as IKONOS and GeoEye, the preparation of such spatial databases appears increasingly feasible (Nagendra and Rocchini 2008). This constitutes one of the further objectives of our urban program.

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