

Urban domestic gardens (III): Composition and diversity of lawn floras

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Abstract.

Question: How do lawn floras compare with those of semi-natural grasslands? Are the compositions of lawn floras determined by local, within-garden factors (e.g. lawn management and size) or by regional factors (e.g. climate and location)? Are lawn floras nested (like semi-natural grasslands) or not (like cultivated parts of gardens)? Are there gradients of species composition within lawns?

Location: Sheffield, UK.

Methods: We examined the composition of the floras of entire lawns and of two 1-m² lawn quadrats in 52 gardens.

Results: A total of 159 species of vascular plants was recorded, 60 of them only once. Most lawn species were forbs, but most lawn cover consisted of grasses. Lawn species were predominantly natives. Bigger lawns had more species, but richness was not closely linked to other environmental or management variables. Composition of lawn floras varied with altitude, with woodland and wetland plants more common in the higher west of the city, and weeds of waste ground in the east. The species-area curve derived from 1-m² lawn quadrats was very similar to that of semi-natural grasslands. Lawn quadrats were significantly nested, with rarer species mostly confined to more species-rich quadrats. Trampling-tolerant *Poa annua* was more abundant in the part of the lawn nearer the house.

Conclusions: In most respects, lawns behaved much more like semi-natural grasslands than like cultivated flower beds and borders. Species composition of lawns is strongly influenced by local climate. Most lawns show an internal gradient of composition, linked to a gradient of intensity of use.

Keywords: Alien plant; Climate; Urban ecology; Urban flora; Weed.

Nomenclature: Stace (1997).

Introduction

Although it is widely appreciated that England is increasingly urbanized, that much of this urban area is residential, and that much of the residential zone consists of private domestic gardens (23% of Sheffield for example, Gaston et al. unpubl.), there has been almost no attempt to describe the composition and distribution of the floras of private gardens (Thompson et al. 2003). In studies of urban floras, private gardens are very often subsumed within other land-use categories (e.g. Hope et

al. 2003). This general neglect of garden floras applies also to the ubiquitous garden lawn. Apart from the series of papers by Wilson and co-workers (Wilson et al. 1992; Wilson & Watkins 1994; Roxburgh & Wilson 2000), which are more concerned with community assembly rules and stability, ecologists have paid very little attention to domestic lawns.

We have sought answers to the following questions for a sample of lawns in private gardens in Sheffield, UK: 1. How do lawn floras compare, in terms of composition, origin and local and total richness, with the floras of semi-natural grasslands? 2. Are the compositions of lawn floras determined by purely local, within-garden factors (e.g. lawn management and size) or are they also influenced by regional factors (e.g. climate, distance from the edge of the city)? 3. Are lawn floras nested (like those of semi-natural grasslands) or not (like those of the cultivated parts of gardens)? 4. Are there gradients of species composition within lawns? Although the study applies specifically to the UK, we expect our findings to be of more general relevance to urban gardens throughout the temperate northern hemisphere.

This study constitutes part of a broader investigation (the Biodiversity of Urban Gardens in Sheffield [BUGS] project) of the resource that domestic gardens provide for biodiversity and ecosystem functioning, the factors that influence the levels of biodiversity associated with different gardens, and ways in which features of gardens can be manipulated to enhance native biodiversity (Thompson et al. 2003; Gaston et al. in press).

Methods

Study site

The city of Sheffield, South Yorkshire, UK (53°23' N, 1°28' W; OS grid reference SK 38) lies in the centre of England and is largely surrounded by agricultural land, except where the urban area merges with Rotherham to the northeast. The administrative boundaries of the city enclose an area of more than 360 km², including farmland and a portion of the Peak District National Park. The

BUGS study was carried out in the rear gardens (hereafter called 'gardens') of 61 private, owner-occupied houses in the predominantly urbanized region of the city (ca. 143 km², defined as those 1 km × 1 km cells having more than 25% coverage by residential or industrial zones, as judged by eye from Ordnance Survey 1:25000 scale maps). The study focused on rear gardens because they form the major garden component of most properties: front gardens are frequently absent from terraced housing, and semi-detached and detached properties, especially younger ones, tend to have access and parking space for vehicles at the front of the plot.

We used a selection of 61 gardens from a pool of 161 householders derived from contacts among ancillary, clerical and academic staff at the University of Sheffield, and from members of the public at lectures or displays. This approach was chosen owing to the great difficulty of recruiting householders at random who were both sympathetic to research being conducted in their gardens, and able to offer daytime access. Our method also enabled us to maximize variation in the environmental axes of interest e.g. house age, garden size, and location across the urban area. Housing type was characterized as terraced (two or more adjoining dwellings), semi-detached (one adjoining dwelling), and detached (no adjoining dwellings); these comprised 16%, 56%, and 28% of the sample respectively (compared to 50%, 44%, and 6% occurring in a random sample ($n = 218$) of Sheffield gardens, Gaston et al. unpubl.). Rear gardens ranged from 32-940 m² in area and their associated properties ranged from 5 - 165 yr in age.

Although there were 61 gardens in the study, only 52 had a lawn. Although we defined a lawn as an area of grass managed by mowing not less than once per month during the growing season, a single lawn was apparently unmanaged at the time of sampling. Accordingly, the rest of this account is confined to these 52 gardens.

Recording lawn floras

All 52 lawns were visited during June 2001, with the exception of a single lawn that was visited during the same month in 2002. The largest lawn was 507 m², the smallest only 9 m². The mean lawn area was 82 m² and the median 46 m². Two 1-m² quadrats were placed on each lawn. One was placed in the half of the lawn nearer to the house, the other in the half of the lawn further from the house, although quadrats were placed randomly within each half. In each quadrat, rooted frequency of all vascular plant species was assessed on a 1-10 scale, i.e. any species rooted in 5% ($\pm 5\%$) of the quadrat was scored 1, any species rooted in 15% ($\pm 5\%$) was scored 2, and so on. Although some lawn plants may be subspecies or cultivars, we did not attempt to classify plants below the species

level. For example, we did not distinguish *Festuca rubra* ssp. *rubra* from the commonly-sown *F. rubra* ssp. *commutata*. Percentage cover of all bryophyte species was also assessed in each quadrat. An inventory was then made of all vascular plants and bryophytes in the whole lawn, and the percentage cover of each estimated.

Recording garden characteristics

Rear gardens were surveyed between July and September 2000. Principal dimensions were measured to the nearest 0.5 m, and a scale plan was drawn of each garden; this included the side portion on properties occupying corner plots. Distance to the centre of the nearest 1 km × 1 km grid cell having less than 25% coverage by residential or industrial zones (as judged by eye from Ordnance Survey 1 : 25000 scale maps) was measured. Information on garden management was gathered from garden owners using a questionnaire. The only important aspect of lawn management that we were able to determine for most lawns was frequency of mowing, which varied from twice per week to once per month. It was not possible to obtain reliable information on use of lawn herbicides.

Recording other garden vegetation

A complete list was made of all vascular plant taxa (excluding those in lawns) during the garden survey, and each taxon was allocated to alien or native categories. Some plants were allocated to the native taxon (e.g. *Primula vulgaris*, *Aquilegia vulgaris*), even though many garden plants are of hybrid origin. Cultivars were not considered as separate taxa. Although the timing of the survey meant that some strict vernalis (e.g. *Anemone blanda*) were missed, the remains of *Hyacinthoides*, *Narcissus* and *Tulipa* spp. were still visible. The number of trees taller than 2 m was also recorded.

Data analysis

With lawn vascular plant richness as dependent variable, we conducted a stepwise multiple regression (entry $P = 0.05$, removal $P = 0.10$) with the following independent variables: lawn area, garden area, total garden species richness (excluding species only in the lawn), position in Sheffield (east and north National Grid coordinates), distance to the city edge, house age, altitude, number of trees and frequency of mowing. Lawn area, garden area, house age and number of trees were log transformed to homogenize variances. To discover any systematic variation in species composition between lawns, we conducted a Principal Components Analysis of the whole-lawn vascular plant data. Both analyses were conducted using SPSS 11.5.

We examined the ‘nestedness’ of our quadrat data using software available from the Field Museum, Chicago, USA (http://www.fnmh.org/research_collections/zoology/nested.htm), which calculates the ‘temperature’ (signal to noise) of nestedness order within a species presence-absence matrix (Atmar & Patterson 1993). In a perfectly nested data set, once the quadrats have been ranked in terms of species richness, the set of species in any quadrat will be a perfect subset of all the species in the quadrats that precede it in the matrix. In other words, rare species will be found only in the species-rich quadrats, and species-poor quadrats will consist only of common species. Such a data set will have a ‘temperature’ of zero. Theoretically, a completely disordered matrix will have a temperature of 100°, but in practice, depending on matrix size, occupancy and rectangularity, the temperature of a random matrix is often much less than this. To test if our data were significantly different from random, a Monte Carlo test was conducted, in which each matrix was randomized 50 × and the temperature of the random data compared with that of the original matrix. Nestedness was examined for quadrat (rather than whole lawn) data, so that the results could be compared with quadrat data for other plant communities.

We also calculated the average species-accumulation curve for the lawn quadrats, based on 50 randomly shuffled runs (Software used: Species conservation and richness, PISCES Conservation Ltd.), thus removing the effect of sample order and producing a smoothed curve. We then compared this curve with quadrats from the cultivated parts of the same gardens and also from two different types of semi-natural grasslands (Thompson et al. 2003).

Results

A total of 159 species of vascular plants was recorded in all 52 lawns, 60 of them only once; 14 species occurred in at least half of all lawns, while *Poa trivialis* was the only species found in every lawn. The 25 most frequent species were all natives, and in fact lawns consisted overwhelmingly of native species. As a percentage of all lawn species, natives averaged 94% and never accounted for less than 83%. Indeed, lawns made a major contribution to the native vascular plant richness of gardens; species unique to lawns accounted for up to 69% of the total native richness of our gardens, and 35% on average. The most frequent alien species, found in 14 lawns, was *Epilobium ciliatum*. Individual lawns contained 12 - 42 vascular plants, with a mean of 24. The number of grass species per lawn varied from 5 - 12 (mean 9), while numbers of forbs varied from 4 - 32 (mean 15). Therefore no lawn consisted only of grasses. Amongst the 14

bryophytes recorded, *Eurhynchium praelongum* was much the most frequent (43 lawns), followed by *Brachythecium rutabulum* (29 lawns). Bryophyte and vascular plant richness were scarcely related ($r^2 = 0.023$, $n = 52$, NS). Vascular plant species richness of individual quadrats varied widely, from 4 to 20 (mean 11), split about equally between grasses (mean 6) and forbs (mean 5). Lawn and quadrat vascular plant richness were significantly correlated, but lawn richness explained only a small fraction of quadrat richness ($r^2 = 0.09$, $n = 104$, $P < 0.01$).

Although lawns were dominated by forbs in terms of species richness (only 20 grass species out of 159), cover was dominated by a few grass species. As a proportion of total vascular plant cover, grasses averaged 84%, with just three commonly-sown grasses (*Agrostis capillaris*, *Festuca rubra* and *Lolium perenne*) making up over half of total cover. Five of the next six most abundant species were also grasses: *A. stolonifera*, *Holcus lanatus*, *Poa trivialis*, *P. pratensis* and *P. annua*. The forb with highest average cover was *Trifolium repens*, followed by *Bellis perennis*, *Ranunculus repens* and *Taraxacum* agg. Although frequency of occurrence was correlated with cover where present, the relationship was not close ($r^2 = 0.38$, $n = 159$, $P < 0.001$, cover arcsine transformed). A few species occurred only rarely, but were locally abundant, e.g. *Fallopia japonica*, *Lotus corniculatus* and *Potentilla × mixta*, each of which was abundant in a single lawn. At the opposite extreme, a number of species were frequent but rarely (if ever) attained high cover, e.g. *Taraxacum* agg., *Senecio jacobaea*, *Epilobium montanum*, *E. ciliatum* and *Cardamine hirsuta*. Woody species were generally uncommon, but a few were moderately frequent, e.g. *Fraxinus excelsior* and *Rubus fruticosus*.

The pattern of species occupancy by vascular plants is shown in Fig. 1. Lawns show a pattern typical of many semi-natural plant communities, with a minority of common species and a long tail of uncommon species (Grime 1998). The plot of quadrat occupancy (not shown) is extremely similar, although the tail is somewhat shorter, since only 96 vascular plant species were recorded in quadrats.

The analysis of nestedness showed that lawn data had a temperature of 10.09°, while random data had a

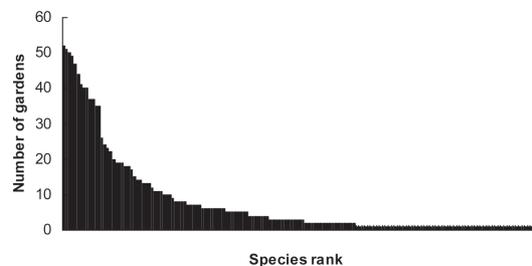


Fig. 1. Pattern of species occupancy by vascular plants of 52 Sheffield, UK lawns; 60 species occurred only once.

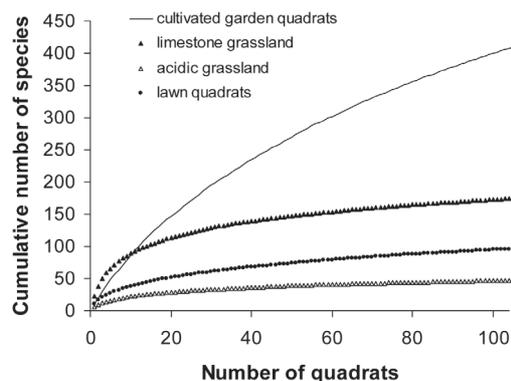


Fig. 2. Vascular plant species accumulation curves for 104 1-m² quadrats in the lawns and cultivated beds of 52 private gardens in Sheffield, UK, plus 1-m² quadrat data for two types of semi-natural UK grasslands. Curves are based on 50 randomly shuffled runs (Species conservation and richness, PISCES Conservation Ltd.).

temperature of $44.07^{\circ} \pm 1.29$ (mean \pm SD), indicating that lawn species are significantly nested. In this respect they are similar to the floras of semi-natural grasslands and derelict urban land, and unlike the floras of the cultivated parts of gardens, which are not nested (Thompson et al. 2003). The species-area curve for lawns is very similar to those from semi-natural grasslands, and quite different from that for cultivated garden quadrats (Fig. 2).

Vascular plant species richness was clearly positively related to lawn area, but the relationship is not linear. At low areas, species richness increased very rapidly with increasing lawn area, but the rate of increase then declined with further increase in area. As a result, species richness appears to be correlated linearly with log of lawn area (Fig. 3). Lawn area is thus a major determinant of lawn species richness, but we tested whether any other variables contributed to lawn richness (Table 1). The regression explained just over half of the variation in lawn richness, with the great majority of this explained by lawn area. Distance to the edge of the city and location in the city both made small positive contributions to the regression; lawns that were further from the edge of the city and further north were slightly more species-rich.

The first three axes of a Principal Components Analysis of the whole-lawn vascular plant data explained nearly

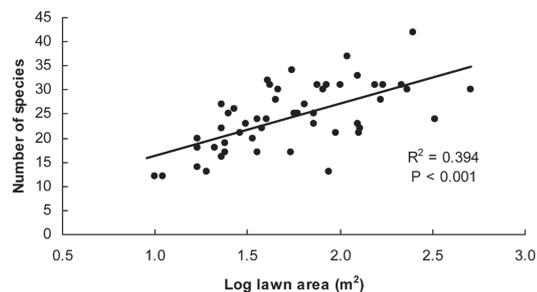


Fig. 3. Relationship between lawn area and number of vascular plant species in 52 private garden lawns in Sheffield, UK.

75% of the variation in the data, with the first axis alone accounting for 41.7%. Pearson correlations with environmental variables revealed that the first two PCA axes were both strongly related to location within the city. Axis 1 was negatively correlated with distance east ($r = -0.44$, $P < 0.01$) and positively with altitude ($r = 0.37$, $P = 0.01$), while axis 2 was positively correlated with distance east ($r = 0.57$; $P < 0.001$) and negatively with altitude ($r = -0.56$; $P < 0.001$). Axis 3 was not significantly correlated with distance east or north, altitude, distance from the city edge, house age, house type or mowing frequency. Neither of the first two PCA axes was significantly correlated with house age, distance to the edge of the city or mowing frequency.

A number of species showed a trend in abundance and/or frequency across the city from east (lowland) to west (upland): *Viola riviniana*, *Cardamine pratensis*, *Rumex sanguineus* and *Anthoxanthum odoratum* were commoner in the western half of the city, while *Rumex obtusifolius*, *Poa pratensis*, *Epilobium obscurum* and *Galium aparine* were more common in the east. Two common species of *Agrostis*, *A. capillaris* and *A. stolonifera*, showed contrasted behaviour. While both species are widespread, the former is characteristic of 'short turf in upland pastures' (Grime et al. 1988), while the latter is 'common in an exceptionally wide range of fertile habitats... especially in lowland districts' (Grime et al. 1988). In Fig. 4. we plot the abundance of both species against distance east. While there was considerable overlap in the distribution of the two species, *A. capillaris* was either absent or present in only trace amounts in the eleven most easterly lawns. Similarly, *A. stolonifera* was absent from seven of the nine most

Table 1. Results of a stepwise multiple regression (entry $P = 0.05$, removal $P = 0.1$) with lawn vascular plant species richness as dependent variable. Only three predictor variables contributed significantly to the regression, of which lawn area was much the most important. The analysis was conducted using SPSS 11.5.

Predictor variables	Adjusted r^2	F change	df	Significance F change
Lawn area	0.383	29.518	1, 45	< 0.001
Lawn area + distance to city edge	0.460	7.463	1, 44	< 0.01
Lawn area + distance to city edge + grid north coordinate	0.508	5.258	1, 43	< 0.05

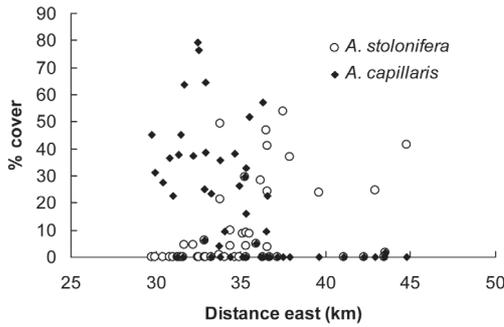


Fig. 4. Cover of *Agrostis capillaris* and *A. stolonifera* in 52 lawns across a west-east gradient in Sheffield, UK.

westerly lawns and had a cover of < 1% in the other two.

There may also be gradients in species composition within individual lawns. In particular, the parts of lawns nearest the house may be more heavily used than those more distant from the house. To test this hypothesis, we examined the distribution of *Poa annua*, a species that is both frequent in our lawns and also a sensitive indicator of trampling intensity ('the most common species on paths within the Sheffield region', Grime et al. 1988). We plotted abundance of *P. annua* in the quadrat nearer the house against abundance in the quadrat more distant from the house (Fig. 5). While the two cover values were significantly correlated, the slope of the regression was significantly less than 1 (upper 95% confidence limit of slope = 0.67). In a few lawns, the differences between the two quadrats were very large. In four lawns, *P. annua* exceeded 20% cover in the quadrat near the house, yet was absent from the more distant quadrat.

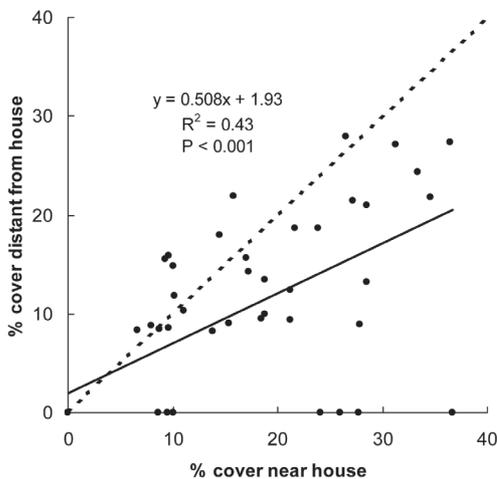


Fig. 5. Cover of *Poa annua* in quadrats near to the house plotted against cover in quadrats more distant from the house in the lawns of 52 gardens in Sheffield, UK. Cover is arcsine transformed. Dashed line is 1:1 relationship.

Discussion

Our results showed a clear tendency for lawns to accumulate species, either by seed or by clonal expansion. Species with effective clonal growth were clearly able to form large patches once established, especially traditional lawn 'weeds' such as *Trifolium repens* and *Ranunculus repens*. A number of species were frequent but rarely (if ever) attained high cover, behaviour associated with abundant seed production and effective seed dispersal, e.g. *Taraxacum* agg., *Senecio jacobaea* and *Epilobium* spp. Even some woody species were able to invade lawns by effective seed dispersal (e.g. *Fraxinus excelsior*) or by a combination of seed and vegetative expansion (e.g. *Rubus fruticosus*). Many species found in lawns, particularly the less frequent species, are clearly not permanent members of the community, in the sense that they are very unlikely ever to attain reproductive maturity in a lawn. Among the 60 species that occurred only once, very few (e.g. *Pilosella officinarum*, *Trifolium micranthum*) are genuinely plants of short turf; the great majority are tall herbs or woody plants that owe their presence to continual invasion vegetatively (e.g. *Syringa vulgaris*, *Convallaria majalis*, *Gaultheria shallon*, *Fragaria ananassa*) or by seed (e.g. *Buddleja davidii*, *Laburnum anagyroides*, *Dipsacus fullonum*).

It seems clear that the natural condition of lawns is relatively diverse, intermediate between semi-natural grasslands on limestone and acid soils (Fig. 2). The few unusually low-diversity lawns in our sample were probably maintained only with the aid of herbicides, and although we had no information on use of selective herbicides in lawns, the near-ubiquity of *Taraxacum* suggests that they are not commonly or frequently used. Other purely local factors, such as mowing frequency, seem to have rather little influence on lawn diversity. Lawn area was the major determinant of species richness, with a small contribution from location within the city. It is not clear why lawns distant from the city edge and towards the north of the city were richer in species. Possibly this part of the city has a larger species pool.

Explanations for the diversity and composition of most plant communities are usually sought in terms of traditional ecological processes of colonization, extinction and competition. In the planted and intensively cultivated parts of gardens, such influences are substantially modified (or completely overwhelmed) by human decisions about what to grow and where to grow it (Thompson et al. 2003). In this continuum between 'natural' and completely man-made, lawns occupy an interesting intermediate position. Individual lawns differ in their origins – from turf, seed or sometimes from natural colonization, modified by the effects of frequent mowing. They also vary enormously in the extent to which garden owners

attempt to control their composition, by chemical or cultural means.

To some extent, our results show the continuing influence of attempts to control the composition of lawns, at least at the outset. The three species that are normally found in lawn seed mixtures (*Agrostis capillaris*, *Festuca rubra* and *Lolium perenne*) make up the bulk of the cover of most lawns. Nevertheless, only half a dozen lawns were clearly either ryegrass lawns (> 80% *L. perenne*) or traditional 'fine' lawns (> 80% combined cover of *F. rubra* and *A. capillaris*). Most lawns contained substantial quantities of all three species, often together with *Holcus lanatus*, *A. stolonifera*, *P. annua* and *P. trivialis*, and sometimes also definitely unsuitable lawn grasses such as *Arrhenatherum elatius*, *Dactylis glomerata* and *Deschampsia cespitosa*. None of these latter seven grasses is included in lawn seed mixtures, so they presumably either colonized naturally or were contaminants of poor-quality turf.

In two important respects, lawns behaved much more like semi-natural vegetation than like cultivated flower beds and borders. Like semi-natural grasslands, but unlike cultivated borders, the floras of lawn quadrats were significantly nested. Similarly, the species-accumulation curve was much closer to those of semi-natural grasslands than to that of cultivated borders. In other words, lawns seem to consist of a relatively well-defined plant community, with a species pool comparable in size to that of semi-natural grasslands. The cultivated parts of gardens, on the other hand, contain only a small sample of an extremely large potential pool of species.

At the large scale, local climate appears to be the major influence on species composition of lawns in Sheffield. Sheffield has a strong east-west gradient of altitude, from 40 m a.s.l. in the Don Valley to 280 m a.s.l. on the edge of the Pennines, and this clearly has a strong influence on lawn composition. Despite being one of the main sown species, *A. capillaris* appeared to be unable to maintain itself in the drier and warmer east of the city, where it was replaced by *A. stolonifera*. Some other species showed a similar trend: generally speaking, plants of woodland or damp habitats were more common in the west, while weeds of waste ground were more common in the east. However, not all species followed this predictable pattern: *P. trivialis*, a characteristic species of damp grassland, was present in mostly small amounts in every lawn, but the few lawns in which it was abundant (> 5% cover) were scattered across the city. Perhaps the ability of *P. trivialis* to grow in the cooler and damper spring months allows it to persist even in the drier parts of the city. Many lawns show a clear internal trend of intensity of use, with the most intensively-used part closest to the house.

In conclusion, lawns are a zone of considerable ten-

sion between the desire of gardeners to control the composition of their gardens and the natural processes of colonization and succession. Many species in lawns, and all the abundant ones, are typical 'lawn' species, well-adapted to frequent mowing by virtue of a creeping habit, basal leaves or basal meristems. Nevertheless, lawns contain an abundance of 'transients' (Grime 1998), including tall herbs, trees and shrubs, which could rapidly transform the appearance and biomass of the typical lawn if management were relaxed.

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