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Research Paper

Ecological outcomes of civic and expert-led urban greening projects using indigenous plant species in Cape Town, South Africa

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HIGHLIGHTS

- Measures of plant and insect diversity show the role of civic-led greening in linking conservation to the 'good and just city'.
- Civic-led interventions can contribute towards urban conservation agendas with the acknowledged exclusion of fire.
- How to integrate civic-led interventions into urban biodiversity planning remains an open question.

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ABSTRACT

Parks and private and public gardens do not exist in isolation, but form part of the urban fabric, contributing to ecological functioning. There is growing interest in how civil society shapes urban ecologies and vegetation patterns. This paper explores the ecological outcomes of a series of indigenous plant greening interventions in Cape Town. The six different sites were sampled: two civic-led intervention sites, one expert-led rehabilitation site, two conservation sites and one abandoned site. These sites are compared in terms of their plant and insect diversity and then discussed in relation to their contingent management arrangements and in relation to conservation and abandoned land. Plant and insect diversity measured at the civic-led greening intervention sites suggest these sites are similar to adjacent conservation sites, while floristic composition differs. The inclusion of a vacant lot with poor species and growth form diversity shows the significant role of intervention in the ecological reformation of urban green space. By emphasizing the ecological outcomes, this study highlights the importance of civil society in linking conservation goals to more broad-based notions of quality of life and the 'good and just city'. Our results indicate that civic-led efforts warrant attention in keeping with those of experts, both in relation to meeting indigenous conservation targets, as well as supporting functional groups and wider ecological processes, with the acknowledged exception of fire. How to integrate such civic-led interventions into urban biodiversity management planning is still an open question.

1. Introduction

1.1. Forging urban ecologies

Urban ecology is neither natural nor social, but rather a "recombinant ecology" (Barker, 2000). It has arisen from historical climatic and vegetation conditions and shaped by multifaceted urbanization processes of housing, transport, energy and telecommunication infrastructure, but also the allocation of 'green spaces' (Niemelä et al., 2011). Among the many heterogeneous urban land uses that support ecological functions, the broad category of 'green spaces' are crucial in several ways. For example, urban forests, park areas, sports fields, and water bodies and wetlands, have the capacity to support biodiversity often restricted to these areas, mitigate climate extremes, sequester carbon, provide educational opportunities, and facilitate the infiltration of storm water (Cadenasso & Pickett, 2008; O'Farrell, Anderson, Le Maitre, & Holmes, 2012). Studies have shown how such green spaces support critical functions and services, in particular when services cannot be acquired

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or bought from outside the city, but must be delivered in situ (Bolund & Hunhammar, 1999; O'Farrell et al., 2012; Tratalos, Fuller, Warren, Davies, & Gaston, 2007) and of particular significance is the high degree of social interventions and engagement in such spaces (Breuste, Niemela, & Snep, 2008; Ernstson, 2013a).

There is a growing interest to study how civil society groups play a part in shaping and forming urban ecologies and vegetation patterns through their capacity to support management and protect green spaces and habitats (Ernstson, 2013a; Ernstson, Barthel, Andersson, & Borgström, 2010; Ernstson & Sörlin, 2009; Tidball & Krasny, 2011). The bulk of this literature has however focused on the social features and factors that lead to and sustain such interventions, and less on their ecological or biophysical impacts. For instance, Tidball and Krasny (2011) link civil society efforts to environmental pedagogical issues through a notion of 'civic ecology'. Colding, Lundberg, and Folke (2006) used property rights theory to demonstrate the importance of non-protected green spaces to support biodiversity and ecological functioning, and the value of 'urban green commons', while Barthel, Folke, and Colding (2010) have theorized the importance of local ecological knowledge and social-ecological memory that these groups develop and sustain. These studies point towards a multifaceted socio-ecological role played by local civic groups. They demonstrate: (i) local ecological knowledge and social cohesiveness; (ii) support for environmental management; and (iii) the production of real biophysical changes on the ground in areas where they work (Ernstson, Barthel, et al., 2010; Ernstson, van der Leeuw, et al., 2010). Researchers have mainly focused on the former two with less work on ecological outcomes, which forms the focus of this paper.

This paper aims to measure the ecological outcomes or biophysical impacts of civic-led interventions of planting and green space protection. To do this we compare ecological measurements across three types of sites: civic-led intervention sites (2), expert-led rehabilitation efforts (1), and vacant lots with no historically recorded management (1). While the former two are in focus, the latter are used as sites for comparison. Although an increasing number of studies exist in urban conservation ecology of how management, intervention and experiments leads to ecological changes, these tend to focus either on controlled experiments (Aronson & Handel, 2011), or expert-led rehabilitation efforts (McPhearson et al., 2010). One study that looked at civic groups is that of Andersson, Barthel, and Ahrné (2007). They compared the ecological outcomes between different management regime practices at allotment gardens, cemeteries and urban parks in Stockholm. Measuring the abundance and diversity of bumble bees and birds and linked management regimes to the ecological functions of pollination, seed-dispersal and pest regulation. Our study builds on such efforts, but also contributes with a study from the global south, acknowledging the value of site specific knowledge production.

In doing this study we recognize the huge complexity that urban ecologies bring. Although it is difficult to identify causal mechanisms generally in ecology, this is even more difficult in urban ecologies since they are inherently produced, altered, and modified through a range of processes that we often refer to as social, economic, political and cultural (Alberti et al., 2003; Ernstson, 2013a, 2013b; Grimm et al., 2008; Pickett et al., 1997). Thus, all of our selected sites have a unique combination of factors and historical contingencies that have played out over time to influence their biophysical features, most notably with the settlement of this area over the last 100 odd years, and the nature of the interventions that have taken place more recently. Our task here is nonetheless important as we use established methods from ecology to describe biophysical and ecological patterns that can be attributed to socially constructed interventions in urban green spaces. There has been a bias in the emergent field of social-ecological studies to theorize 'the social' and leaving out 'the ecological', which we seek to bring to the fore here.

1.2. Cities and biodiversity: the City of Cape Town's conservation agenda

The conservation agenda for the Cape Town region is recognized as of global significance (Anderson & Elmqvist, 2012; Holmes, Rebelo, Dorse, & Wood, 2012; Myers, Mittermeyer, Fonseca, & Kent, 2000). The city falls within the Cape Floristic Kingdom and hosts exceptional biodiversity with some 3350 plant species, and 19 of 220 national vegetation types, all within the 2460 km^2 city area (Rebelo, Holmes, Dorse, & Wood, 2011). Of these 19 vegetation types, 11 are threatened accounting for 52% of all threatened vegetation types in the country (Rebelo et al., 2011). The region has a Mediterrannean climate and the indigenous vegetation, broadly termed Fynbos, is short scrubby and sclerophyllous vegetation that is both fire prone and fire adapted (Cowling, 1992). This study focuses on Cape Flats Sand Fynbos, one of these critically endangered vegetation types. Historically this was one of the most prevalent vegetation types in the City of Cape Town prior to its establishment and urban growth. Today it has the highest concentration of threatened plants per area of remaining vegetation in the world (Mucina & Rutherford, 2006; Rebelo, Boucher, Helme, Mucina, & Rutherford, 2006). Only 14% of its original area is left in fragmented remnant patches scattered around the city and only 5% is deemed conservation worthy (Mucina & Rutherford, 2006). Predicted climate change for the region, with higher temperatures and significant drying, is likely to have devastating effects on remnant flora (Midgley, Hannah, Millar, Thuiller, & Booth, 2003). Additional on-going threats posed come from agriculture, urban development, mining and degradation by invasive alien plants (Holmes et al., 2012).

Concerted efforts on the part of City management to address conservation concerns have seen the formulation of a conservation plan devised on the basis of biodiversity and connectivity metrics, which forms the basis of a biodiversity network plan (Rebelo et al., 2011). However, the actualization of this into formal protected conservation areas is challenging (Rebelo et al., 2011; Holmes et al., 2012). Continual development pressure, and limited budgets for conservation, thwart efforts to secure and appropriately manage remnant patches of biodiversity in the city (Holmes et al., 2012). Despite a good legislative environment, and support for conservation as demonstrated through international signatory agreements, implementation of local policies to support these international agreements is often slow (Holmes et al., 2012). Local government, to whom this conservation task falls, feel they are not viewed as important implementation partners.

The prohibitive cost of securing conservation areas in cities (where land prices and demand for land is high) and conservation planning theory in relation to size and connectivity, both point to the significance of the greater urban matrix, which includes built up land, private gardens, and public parks, in meeting urban conservation needs (Colding et al., 2006; Goddard, Dougill, & Benton, 2010; Pauw & Louw, 2012). Evidence that small conservation areas in cities fail to conserve species through time (Colding et al., 2006; Woodroffe & Ginsberg, 1998), and suggestions that this will become more critical in light of anticipated climate change (Cartwright, Oelofse, Parnell, & Ward, 2012), further support the relevance of the greater urban fabric in supporting urban conservation. The areas between formal conservation areas, the matrix, are vital to connectivity and function (Desmet, 1999). The nature of this matrix, both its texture and form, is critical, and needs to be given greater attention in urban planning. Indeed the permeability of the matrix is generally disregarded or unknown in urban ecology.

1.3. Objectives

This study measures the biophysical changes that can be inferred to have been created by locally envisioned and driven interventions to plant indigenous vegetation in the City of Cape Town. These interventions, which range from the voluntary and civic-based, to the professional, aim, with different objectives in mind, to develop a practice to rehabilitate indigenous vegetation ecologies in spaces where they once existed. We view these interventions as case studies into how human efforts can make alterations to the urban matrix, and thus shape the functioning of particular aspects of urban ecology.

In order to understand ecological outcomes due to interventions, we added 'control sites' and studied three green spaces with the same original vegetation type, including two conservation sites (representing a more 'pristine' condition) and an abandoned lot (a more 'degraded' condition). In total we studied six sites. Three were 'intervention sites': Bottom Road Sanctuary, a small-scale civic-led initiative supported by conservation managers and public agencies that started in 2005; Princess Vlei, a civic-led initiative from 2008 that grew out of the Bottom Road project; and Tokai Park, an initiative led by expert conservation managers that started in 2005. Three were control sites: a vacant plot with no historically known management until it fell to CapeNature in 1986, but with no evidence of historical development, and two conservation sites; Rondevlei, established in 1986 on the site of a previously abandoned school, and Kenilworth Racecourse, cordoned off in 1882 without any prior development, that have had relatively long-term protection and management. In this way the intervention sites are placed on what was anticipated as a continuum of ecological functioning.

In this rapid assessment we took a set of basic ecological measures as indicators of the relative contribution to local biodiversity and ecosystem functioning. Using these measures, and in order to answer the overarching questions of whether these management interventions into rehabilitating indigenous vegetation can impact on broader urban ecological functions, enhancing general biodiversity and promoting the services biota generate towards a healthy ecosystem, and increase the possibility to meet conservation targets, we specifically answer the following questions:

(i) What is the vegetation composition and structure of local civic-led intervention sites in comparison to expert-led conservation sites and vacant lots in the same original vegetation type?
(ii) What are the morpho-species insect assemblages between these types of sites, given they had the same historical original vegetation type?

2. Materials and methods

2.1. Study area

All the study sites fall within the Cape Flats Sand Fynbos vegetation type (Fig. 1), a dense, moderately tall, ericoid shrubland with the occasional taller shrubs (Mucina & Rutherford, 2006). Typical of the Cape Fynbos, Proteoid and Restioid species are prevalent, with more Asteraceous and Ericaceous species occurring in drier and wetter areas respectively. According to Rebelo et al. (2006) approximately 108 threatened and near threatened Red List species occur on the remnants of this vegetation type. This vegetation is edaphically and climatically constrained and grows on typically acid soils that are relatively deep and tertiary in origin. The region experiences a typical Mediterranean-climate of hot, dry summers and wet winters. As an early established port city in 1652 by Dutch trade companies, Cape Town has a long recorded history with the usual marks of colonization (Anderson & O'Farrell, 2012), and in particular apartheid city planning from the 1950s to 1994 which segregated so called 'Coloured' and 'African Black' areas, generally poor to very poor, from those of so called 'Whites' and generally affluent areas (Turok, 2001). The sites selected fall in a spectrum of socio-economic neighbourhoods, ranging from middle income to lower income areas. Significantly the two gardening intervention sites fall within lower income areas with little open green space, small and few gardens and limited recreation areas.

Six sites were selected with an a priori view of examining the intervention sites in some continuum of remnant patches. The sites examined range from a vacant plot (with no engagement), through civic-led indigenous intervention efforts, larger scale professionally led restoration interventions, to longer-term conservation areas. The sites were, besides one vacant lot: Princess Vlei, Bottom Road Sanctuary, Tokai Park, Kenilworth Racecourse, and Rondevlei Nature Reserve. Each is presented in more detail in Table 1 and located in Fig. 1.

2.2. Methods deployed

At each site five, 3 m × 3 m quadrats were used to sample species composition and cover across the study sites. Quadrats were spread evenly across the sites with a view to minimizing variation in slope and aspect, and keeping a minimum avoidance distance of 3 m. On this basis, actual quadrat situations were determined randomly with the field worker taking a random walk across the site, stopping at an arbitrary point, with the centre of each quadrat selected by throwing a plastic marker over the shoulder, which then formed the central point of the quadrat. Sampling was carried out in summer, during the months of December 2010 and January 2011.

Plant and functional diversity was recorded for each quadrat and site. Structural, and in turn functional, diversity is used as a proxy for ecological functioning (Diaz & Cabido, 2001). Where species could not be identified in the field a specimen was taken for off-site, herbarium identification. Taxonomic nomenclature follows SANBI's Plants of Southern Africa database (SANBI, 2009). For functional diversity analysis, species were assigned to one of the following life history and growth form categories: annual and perennial herbs, annual and perennial grasses, geophytes, dwarf shrubs (only including perennials of less than 25 cm in height, and all perennial herbs), woody shrubs (only including woody shrubs of more than 25 cm in height), succulents and trees (Cornelissen et al., 2003).

A pan trapping method for flies, wasps, and other pollinating insects was employed, and four traps of each colour, white, blue, orange and yellow, resembling flowering plants, were left out at each site for two, 24 h periods. Traps were evenly scattered around the study site in places where they were not obscured by leafy vegetation or likely to tip over. All insect specimens caught were counted and a representative specimen of each was preserved in ethanol for identification. Sampling was carried out in summer, during the months of December 2010 and January 2011. Specimens were identified to a morpho-species level, following expert advice, allowing each specimen to represent a distinct, easily identifiable, group, termed a functional group for the purposes of this paper.

Differences and/or similarities in vegetation community structure between the three intervention sites and reference sites were described using the multivariate statistical technique of correspondence analysis. The online statistical computing software, 'R,' (http://www.r-project.org/) was used for multivariate analyses of all five quadrats sampled across each study area, and within each study site. Both plant species percentage cover and percentage cover of functional type were analyzed in this way. Non-parametric pollinator data were analyzed using a log-linear association analysis in a three-way frequency table (sites × insect type × flower

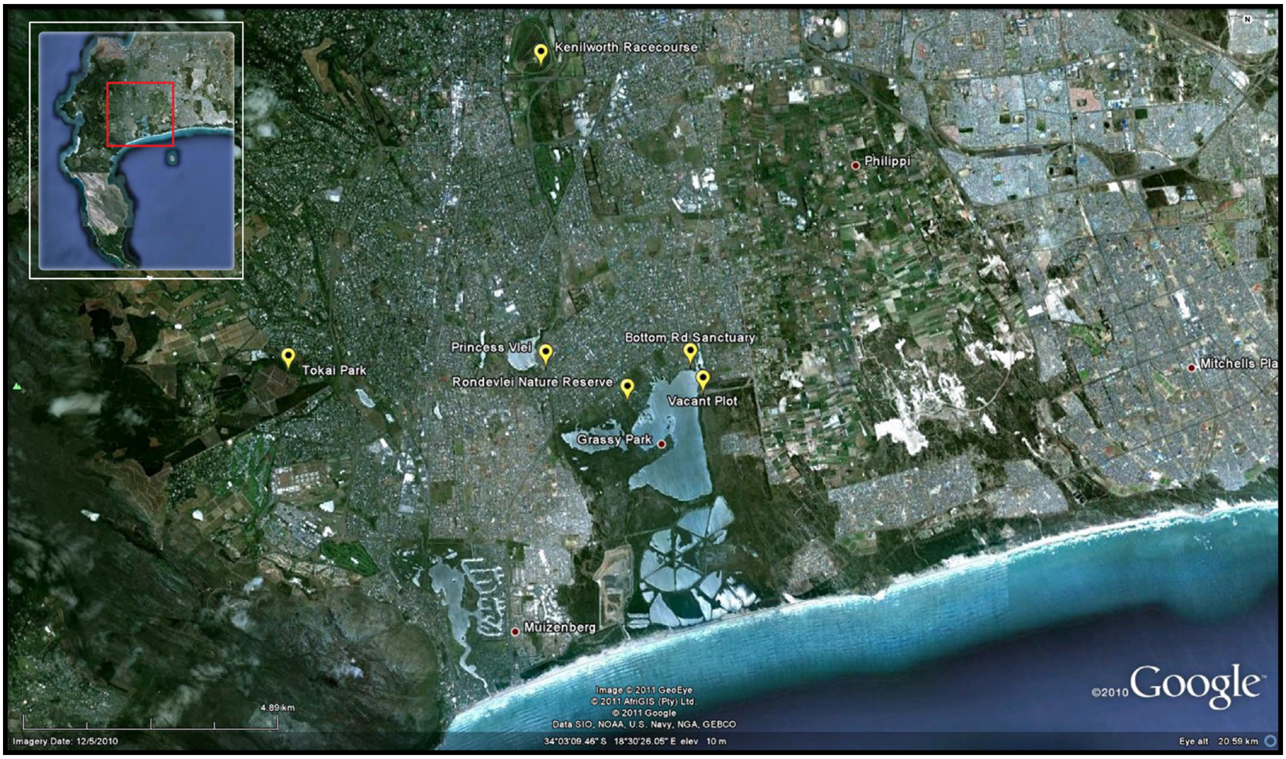

Fig. 1. Study site with the location of the sites under examination generally indicated, in the context of the Cape Peninsula, South Africa. The study sites, Bottom Road Sanctuary, Princess Vlei, Tokai Park, Rondevlei, Kenilworth Racecourse and the vacant plot are indicated with pin points. Surrounding adjacent neighbourhoods are named and marked with a single dot.

Table 1
The sites selected for the study present a social organization continuum, relevant details pertaining to temporal scales, relevant partnerships and the degree of social engagement and intervention, are presented here.

Site name *Status*	Area (ha)	Project start date	Land owner and current status	Intervention	Partners
Bottom Road Sanctuary *Civic-led intervention*	0.08	2005	False Bay Nature Reserve: Maintenance	Refuse and invasive removal, landscaping and planting of approximately 50,000 plants of 40 species of Cape Flats Sand Fynbos	Cape Flats Wetlands Forum, Rondevlei Nature Reserve, Working for Wetlands, 'Friends' group and 12 local resident households.
Princess Vlei *Civic-led intervention*	0.1	2008	City of Cape Town: On-going project (currently under threat from a proposed mall development)	Planting of 5000 species of Cape Flats Sand Fynbos, and some 200 trees some of which are not indigenous to the area	"The Dressing of the Princess" project includes: Cape Flats Wetland Forum, Department of City Parks (City of Cape Town), and South African National Biodiversity Institute (SANBI). Extended supporters: 5 local schools on an 'adopted-a-plot' basis, local social development organization LOGRA, Greater Cape Town Civic Alliance, WESSA.
Tokai Park *Expert-led intervention*	120.0	2005	Table Mountain National Park: On-going project	Felling of pine trees, invasive plant removal, burning to stimulate seed bank, some seeding and planting of individual species of Cape Flats Sand Fynbos fynbos, introduction of snakes to control rodent population	Table Mountain National Park (TMNP), South African National Biodiversity Institute (SANBI), Kirstenbosch Gardens. Extended supporters: Friends' group, WESSA and others.
Kenilworth Racecourse Conservation Area *Control*	41.96	1882	Gold Circle: managed and maintained	No formal intervention, but site upkeep is managed	Gold Circle, Western Cape Nature Conservation Board (WCNCB), City of Cape Town, WESSA, Friends' group and others.
Rondevlei Nature Reserve *Control*	290.0	1986	Cape Nature: False Bay Nature Reserve: managed and maintained	Originally an abandoned school property. Indigenous species of Cape Flats Fynbos planted	Cape Nature, South African National Biodiversity Institute (SANBI). Extended supporters: Friends' group, WESSA and others.
Vacant lot *Control*	290.0	1986	Cape Nature: False Bay Nature Reserve: managed and maintained	No intervention. Site considered a degraded Cape Flats Sand Fynbos remnant.	Cape Nature

colour). This was done by fitting a generalized linear model based on the Poisson family of analysis.

3. Results

3.1. Biotic measures

From all six study sites a total of 94 plant species were recorded. In an initial correspondence analysis, displayed in two-dimensional space, the vacant plot proved to be so compositionally different to the rest that remaining sites clustered tightly together but still distinct. By removing the first (horizontal) dimension, which can be attributed solely to this large general difference, the differences between the remaining sites could be investigated in a plot of the 2nd, 3rd and 4th dimensions (Fig. 2). Each site is still relatively unique in composition, with some degree of clustering and overlap broadly suggesting homogeneity in composition. Sites sampled at Princess Vlei and Bottom Road Sanctuary do not cluster as closely with the remaining sites, but show internal homogeneity. While compositionally similar to Princess Vlei, relatively high cover means Bottom Road clusters more tightly to the remaining sites. Generally low cover accounts for the proximity of the Princess Vlei and vacant lot sites. The remaining samples cluster together but all remain, largely, true to their site.

A closer look at cover and composition shows the marked difference between the vacant plot and the other sites is attributed to the fact that the former has lower overall vegetation ground cover, and a dominance of annual plants (Fig. 3 and Table 2). An examination of the relationship between species number and percentage cover shows Bottom Road Sanctuary and Kenilworth Racecourse to have both high vegetation cover and plant diversity. Rondevlei follows with similar cover, but slightly fewer species, while Princess Vlei has high species numbers, but low cover. Tokai Park has high vegetation cover and comparatively low diversity while the vacant plot has low vegetation cover and low plant and pollinator diversity. The two civic-led intervention sites, Princess Vlei and Bottom Road Sanctuary, have plant functional diversity in keeping with the expert-led conservation areas, while Tokai Park, which is the expert-led intervention site, has comparatively low functional diversity (Table 2). Invasive alien plant species are a problem throughout the sites, but significantly in the vacant plot and Bottom Road Sanctuary. In the expert-led conservation sites as well as the civic-led intervention sites the presence of red data listed species is unsurprisingly high. The presence and relatively high contribution to vegetation ground cover of a rare species in the vacant plot was less expected. The dominant annual vegetation of the vacant plot is mainly alien such as *Lagurus ovatus*.

3.2. Morpho-species insect diversity

A total of 80 insect individuals, comprising 26 different species, were trapped over a period of 48 h at the six study sites. An ANOVA revealed no statistically significant differences between the sites. This is likely to be a function of high variance in the data. In light of this a log-linear association analysis was adopted to explore variation between the sites. This was done by fitting a generalized linear model based on the Poisson family of analysis. This formal hypothesis test showed that there were highly significant differences between study sites with regards to insect number and that site effect as well as pan trap colour played a significant role in determining how many pollinators were trapped. The majority of insect species were trapped in yellow pan traps, followed by white and then blue. It has been suggested that different coloured pan traps differentially attract pollinator species, with specialists

Table 2
The mean values (±SD) or total values of plant variables listed for each site.

	Bottom Rd. Sanctuary	Kenilworth Racecourse	Princess Vlei	Rondevlei Nature Reserve	Tokai Park	Vacant Plot
Plant cover (%)	90 ± 16.9	80 ± 7.1	40 ± 11.9	94 ± 13.4	99 ± 1.1	42 ± 19.3
Annual plant coverage (%)	6	7	3	10	6	18
Perennial plant coverage (%)	84	73	37	84	93	24
Total number of plant functional types	8	9	7	9	6	6
Dominant functional type and (species number thereof)	Perennial shrubs (11)	Perennial shrubs (6), dwarf shrubs (7)	Perennial shrubs (9)	Perennial shrubs (7), perennial grass (2)	Perennial grass (2)	Annual grass (3)
Total species number	31	31	25	26	12	14
Dominant species (mean percent coverage)	*Elegia tectorum* (13.6%), *Ficinia nodosa* (9.8%)	*Stoebe plumose* (22%), *Passerina corymbosa* (11%)	*Eriocephalus racemosus* (7%), *Metalasia* sp. (5%), *Chrysanthemoides monolifera* (5%)	*Clifortia feruginea* (24%)	*Stenotraphrum secundatum* (60%)	*Lagurus ovatus* (8.1%)
Endangered species (mean % contribution to overall coverage)	*Erica verticillata-EW* (2%)	*Erica margaritacea-CR* (1%), *Lachnaea grandiflora-VU* (2.5%), *Serruria glomerata-VU* (1.4%)	*Lampranthus vernalis-NT* (8.5%)	*Erica verticillata-EW* (2.3%), *Leucodendron coniferum-VU* (0.5%)	*Erica verticillata-EW* (2.4%), *Serruria cyanoides-EN* (8%)	*Amphithalea imbricata-R* (12%)
Alien flora (mean %contribution to overall coverage)	*Lagurus ovatus* (1.1%), *Pennisetum clandestinum* (8.8%)	*Pennisetum clandestinum* (1.25%), *Invasive Rumex* sp. (2.2%)	*Pennisetum clandestinum* (0.25%)	*Acacia* sp. (0.9%), *Lagurus ovatus* (0.2%)	*Acacia* sp. (1%)	*Pennisetum clandestinum* (4.7%), *Lagurus ovatus* (19.3%), *Acacia* sp. (0.24%)

Notes: CR – critically endangered; EN – endangered; EW – extinct in the wild; NT – near threatened; R – rare; VU – vulnerable (POSA 2010).

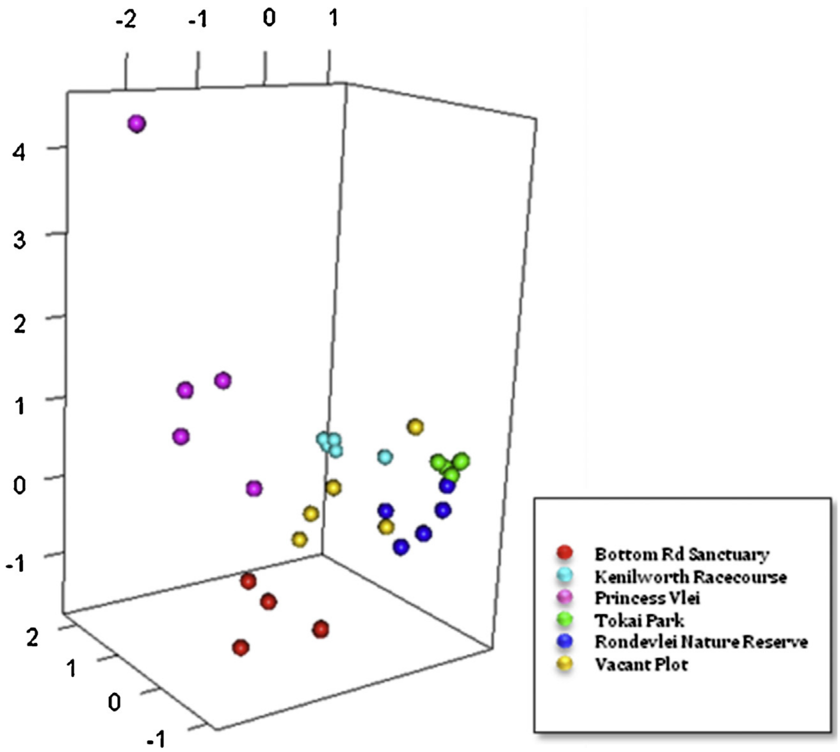

Fig. 2. Three dimensional visualization of the 2nd, 3rd, and 4th dimensions of the correspondence analysis of the sites sampled by species composition and percentage cover, accounting for 34% of the variation in the data after removal of the 1st dimension.

being attracted to blue and white; and generalists being attracted to orange and yellow traps (Kirk, 1984). In the analysis however, all insect numbers were grouped together per site, regardless of trap colour, as resources disallowed all insects from being comprehensively identified, so no conclusions could be drawn with regards to actual specialist numbers at the various sites. Results presented in Fig. 4 show Princess Vlei with relatively high pollinator activity (46 trapped pollinators of 5 species); and Kenilworth Racecourse coming in second (22 trapped pollinators of 6 species). Interestingly the vacant plot appeared to have slightly higher pollinator numbers

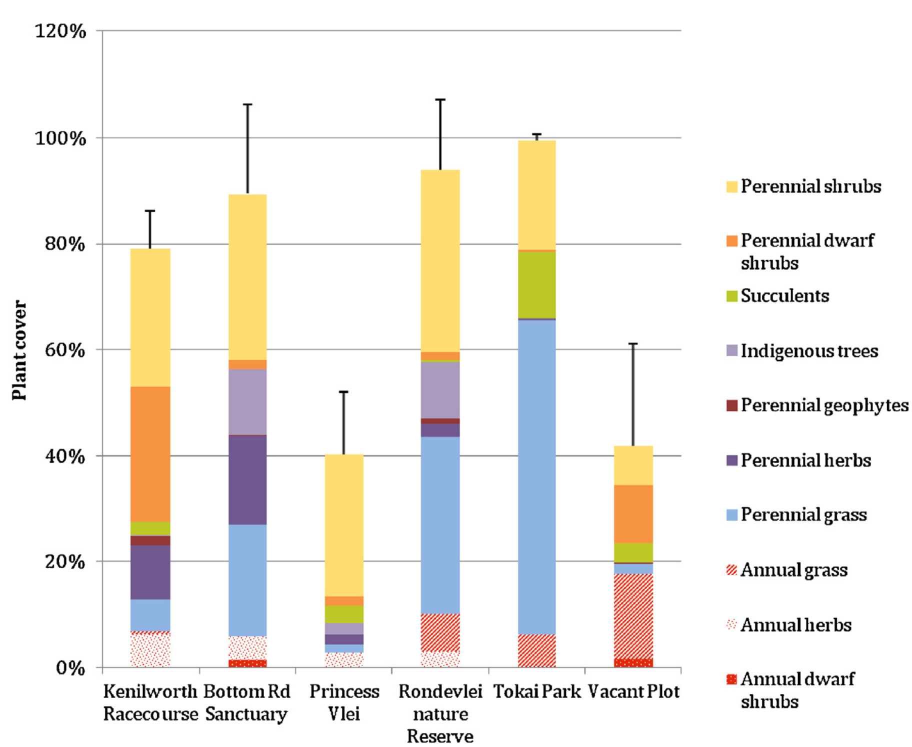

Fig. 3. Bar graph representing the proportions of plant functional type within the mean (±SD) total plant coverage (%) for each site. Red patterned series highlight annual plants, while non-patterned series denote perennial plants. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)

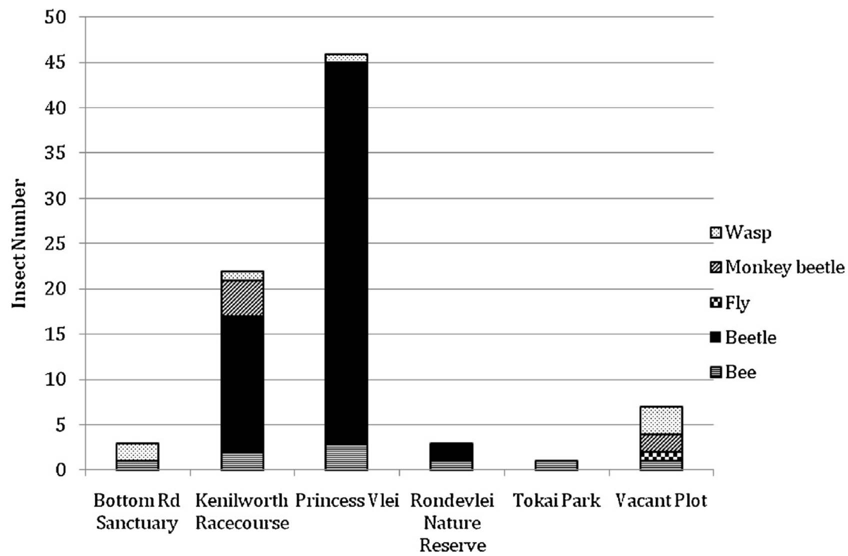

Fig. 4. Bar graph representing the total number of insect morpho-species groups collected from pan trapping.

when compared to Rondevlei, Tokai and Bottom Road and all functional groups except beetles where trapped at the vacant plot.

Tokai Park, Rondevlei Nature Reserve and Bottom Road Sanctuary's pollinator numbers all suggest relatively low pollinator activity for these sites. Contrary to the trapping results, ocular observations while conducting vegetation field studies suggested that there were in fact numerous pollinators present at these sites. Carpenter bees (*Xylocopa* sp.) where seen flying around the abundantly flowering *Erica verticillata* plants at the Tokai site. Similarly, at the Rondevlei site, numerous bees were seen hovering on *Protea repens* flowers as well as around the *Erica verticillata*, and at Bottom Road Sanctuary, there were undeniably pollinators present and flying between various flowering species, especially the Psoraleas. Notably, at the vacant plot, a large Sphecidae wasp nest was noted between the branches of an *Amphithalea imbricata* shrub; however in the results, we see only three wasp specimens accounted for at this site. Although bees and wasps were spotted, no ocular observations of beetles or monkey beetles, which were present in the pan traps. Evidently the pan trap method favoured certain morphospecies over others. Future work should include a greater diversity of methods including a more formalized observation method, and possibly longer sample times. Sample times in this study were restricted by the permitting conservation authority.

4. Discussion

4.1. Management and ecological outcomes: contextualizing interventions

Conservation areas, gardens, urban forests and parks are all human-made, while also being a product of biophysical processes beyond the control of humans. All sites studied here, while biophysically similar in being constrained to one soil type and a single climatic envelope, are nonetheless outcomes of variably scaled biophysical factors and contingent factors of how intervention and management were brought together. This makes it challenging to provide causal explanations to account for the ecological differences and similarities recorded. Nonetheless, to discuss the ecological outcomes we will contextualize the interventions to provide an interpretative frame to understand ecological outcomes.

Indigenous plant diversity recorded at Bottom Road Sanctuary is high, and in line with the Kenilworth Racecourse conservation area, although we acknowledge scaled-sampling may yield different results. Princess Vlei is not dramatically different, and given that the practice, vision and role players involved is akin to that at Bottom Road Sanctuary, it is likely to later present similar diversity. In terms of indigenous plant diversity it could be that the civic-led interventions of planting at Bottom Road and Princess Vlei may have created a trajectory, if sustained, towards a plant diversity equivalent to local conservation sites managed by professional conservation managers. The nature and scale of intervention at Tokai Park, which rely more on natural succession, probably means that the full capacity of diversity is still to be realized where here the emphasis was more on the existing in situ seed bank with more limited inputs, and these largely relating to specific, conservation-worthy, species. The variable species diversity combined with relatively similar structural and functional diversity between the sites can be attributed to high functional redundancy, a common feature of Fynbos vegetation types (Cowling, Mustart, Laurie, & Richards, 1994). The dramatically lower diversity recorded on the vacant lot provides a stark reminder of the heavy impact of urbanization on local diversity and flags the significant role of civic-led, as well as expert-led, planting interventions to remediate urban indigenous biodiversity loss. While a useful comparison where we know this to be a neglected site, the exact reasons for the particular floristic structure of this vacant lot can only be speculated at. The specific history of this site is unknown aside from the fact that it would have been grazed historically and is likely to have been bulldozed in the 1960s when the area went under housing. While dramatically lower than interventions sites, the evidence of some elements of important remnant biodiversity at the vacant site however suggests that even derelict fragments of open green space are in fact important.

The replicates sampled within each site cluster tightly with respect to composition, with evidently high levels of species turnover and prominent beta diversity between sites. This is typical of Fynbos vegetation, which is noted for its high beta diversity (Cowling, 1992). That said it is also indicative of a high degree of fragmentation, in particular in the urban context (Andrieu, Dornier, Rouifed, Schatz, & Cheptou, 2009; Fahrig, 2003). While the sites in question cannot collectively be viewed as natural remnants, these points are both relevant where degrees of isolation are evident and their origins and relevance to management and associated value warrant interpretation. What the records of diversity suggest from among the intervention sites is the critical role of decision-making in determining planting schemes and ultimately local diversity. It is important to note a limitation to the sampling design where had plots been scaled to the site in question different diversity might have been found at the larger sites. Any additional future or monitoring work will need to address this.

The expert-led intervention at Tokai Park for example adopted an approach underpinned by natural scientific understandings of succession, with discussions among experts to decide on a plan for intervention and management (Avlonitis, 2011). After felling and controlled burning of non-indigenous pines in 2005 to stimulate the natural seed bank, there was also a seeding process where the seed of appropriate species were broad cast across the site. The selection of plants was based on a 'base line' taken from a species list constructed between 1917 and 1919 by a local naturalist named William Purcell (Avlonitis, 2011). In effect, this approach has become more reliant, and its ecological outcomes more dependent on, the existing seed bank in the soil. The ideal sought was to make room for 'natural processes' to shape emergent plant and animal communities, but the approach includes close monitoring and intervention when deemed necessary, e.g. the planting of certain red listed species and caring for their survival, and the introduction of snakes to lower the numbers of seed-predating rodents (Avlonitis, 2011).

The planting from 2005 at Bottom Road Sanctuary, was in contrast less informed by rigid lists of species to be planted, and emerged more through 'learning-by-doing' on behalf of residents to demonstrate that spaces in previously disadvantaged areas could become harbours of biodiversity while serving public recreation needs (Ernstson, 2013b). Nonetheless, the selection of plants was influenced by the practical knowledge of near-by conservation managers at Rondevlei, by availability of species from nurseries, by a desire to attract bird species, and by aesthetic considerations of visual and floral display throughout the year (Avlonitis, 2011; Ernstson, 2013b). At the time of this study, some 50 000 plants on less than one hectare had been growing for five years. Managing the site on practically a daily basis, residents and a team of workers (paid by residents and governments funds) gained experiential knowledge of what plants thrived at the site. This was paired with the continuous work of removing non-indigenous plants, but also the removal of some indigenous plants to make room for higher diversity as some indigenous plants outcompeted other indigenous plants (in particular, the almost extinct *Erica vertcillata* was favoured, which historically had grown at the site) (Ernstson, 2013b). Various factors have thus influenced the ecological outcomes we measured.

After having matured at Bottom Road, the same civic-led network moved in 2008 to begin planting at the considerably larger Princess Vlei area. Informed by the experiences of Bottom Road, the Princess Vlei project increased its collaborative ties with schools, the department of City Parks, South African National Biodiversity Institute, and a number of local community associations. The aim was to 'dignify' spaces, recreate a once useful public park area, and rehabilitate wetlands and Fynbos (Ernstson & Sörlin, 2013). The species initially planted were chosen to be 'eye catching' to make passers-by aware of activity and action and to draw their attention to the site. When the City in 2009 promoted plans to allow the building of a shopping centre at Princess Vlei, the initiative quickly became the vehicle of resistance and now holds significant social and political relevance (Ernstson & Sörlin, 2013). In light of protests, this development plan has recently been dropped.

The presence of endangered species at all the sites sampled is encouraging. These populations, even though small, can be significant contribution to the broader conservation agenda of the region. These sites will serve as repositories for future use and distribution, and contribute to cross pollination and enhanced genetic vigour (Maurer, Peschel, & Schmitz, 2000). It is noteworthy that the vacant lot was also host to a listed rare and endangered species. This stands in support of the view that what are frequently termed urban wastelands can hold unexpected and significant contributions to broader city-level biodiversity (Zerbe, Maurer, Schmitz, & Sukopp, 2003). This study also suggests that smaller patches, with high levels of social engagement, can be less prone to alien invasion. Variable findings here however suggest that factors informing the degree of involvement, money available for maintenance etc. would also influence long term alien plant status. Alien invasive plant species are one of the most significant contributors to biodiversity loss in South Africa (Richardson et al., 1996) and noted as likely to increase globally in response to a shifting climate that favours opportunistic species (Goddard et al., 2010).

It is pertinent to note that smaller sites within urban built-up areas, within the urban matrix, can hardly achieve self-sufficiency and ecological succession, due to the prohibition of fire as a central ecological driver in this system (Cowling, 1992). Burning is not allowed on small areas in close proximity to houses, and even where sought for ecological purposes, such as with the Tokai Park site, burn times are often restricted to safer periods which are generally ecological suboptimal. Despite the fact that these will not be self-sustaining systems, it is evident that the civic-led intervention sites of Bottom Road and Princess Vlei studied here are making a notable contribution to the conservation agenda of the City more broadly serving as refugia for species, including rare species, serving as sites for future dissemination of species, contributing to genetic diversity, and significantly to recreational space in the city. And this apart from the 'social' factors show as urbanization increases and the threats of climate change are realized, these types of social interventions will become more important.

In relation to civic-led interventions, experimental work by Lindemann-Matthies and Bose (2007) working with visitors to a botanical garden in Switzerland shows that given the choice, people actively seek out structurally diverse and species rich gardens, suggesting that people tend to construct biodiverse green spaces. This current work supports that of others (Kendal, Williams, & Williams, 2010; Maurer et al., 2000; Zerbe et al., 2003) noting the potential to include gardeners in efforts to reach conservation goals (Colding et al., 2006). Generally gardens can make significant contributions to urban biodiversity measures (Goddard et al., 2010), though in general managed at a scale below that required for population viability, and they can also be the source of invasive alien species and fertilizers and pesticides. In the case of indigenous gardening, where small patches might link larger patches and the potential for non-indigenous escapees is removed, these considerations are less troublesome. Here we see an additional role where at Bottom Road and Princess Vlei it is the 'gardeners' and 'civics' that have mobilized the conservation managers to meet broader defined public ends to provide well-working public spaces and reconciliation in a post-apartheid city, bringing these role players into the public domain (Ernstson, 2013b; Ernstson & Sörlin, 2013).

Understanding how public, civic and conservation goals get entangled to shape the ecological outcomes of these types of civic and expert-led interventions are key for policy making and resource allocation for biodiversity protection in cities. That interventions can make big and positive differences is quite clear in our case, where the real outlier of the vacant lot, which by contrast makes all the remaining sites appear relatively uniform, highlights the dramatic compositional shift that planting and management interventions can produce.

4.2. Towards functionality and ecosystem service provision

There is agreement that the effects of diversity on ecosystem processes must be ascribed to the functional composition and the number of different plant functional types, rather than simply species number (Diaz & Cabido, 2001). Here the premise is that diversity of structure is central to ecological functioning. The restoration and recreation of system structure should then be followed by ecological process and function (Diaz & Cabido, 2001).

This study shows the importance of the role of either civic-led or expert-led intervention in constructing nature with a high degree of functional diversity in the Bottom Road Sanctuary site, akin to the conservation site of Kenilworth Racecourse. More generally, vegetation cover is a function of age and management, where the Princess Vlei site has low cover due to its recent inception and the vacant lot has low cover as nothing has been formally planted here and the predominance of annual cover which is seasonally short lived renders some areas bare for large parts of the year. It is clear that on-going social engagement at Princess Vlei will result in higher cover and likely greater structural diversity, where the neglected vacant lot may follow some successional trend but it is unlikely to shift dramatically given the competitive vigour of alien annual grass (Yelenik, Stock, & Richardson, 2004).

The ecosystem service of pollination is well described and its disruption known to reduce seed production (Bond, 1994). Loss of pollinators is recognized as a critical impact of fragmentation (Allen-Wardell et al., 1998). While relatively understudied, recent work exploring phytophagous insect species diversity in Fynbos demonstrates diversity in keeping with the high plant diversity of this biome (Proche & Cowling, 2006), and insect pollination is believed to account for pollination of some 83% of the plant species of the biome (Johnson, 1992). The findings of the insect studies can only be considered in relation to functionality where full species identifications were not possible. These results are also possibly confounded by the competitive role of actual flowers in a pan-trapping exercise. For example the high capture levels at Princess Vlei may be a function of the lack of an abundance of flowering plants. The particularly high numbers of beetles in particular both at Princess Vlei and Kenilworth Race Course are harder to explain and might be attributable to some specific local history or micro-climatic factor, but would need further investigation to establish likely cause (Botes, McGeogh, & Cown, 2007). Field observations suggest a more formalized method using observation would be useful in future studies. The findings are less conclusive when contrasted to one another, but show relevance when considered in light of other urban invertebrate studies. In keeping with the ideas around plant function diversity, Andersson et al. (2007) used functional diversity in insect groups as an indirect measure of the performance of the ecosystem service of pollination, as they determine the efficiency of the ecological function on which the ecosystem services are based. A study by Pryke and Samways (2009) across the broader City of Cape Town region of invertebrate diversity in different vegetation states, showed high richness in Cape Town's National Botanical Garden demonstrating the importance of garden sites for maintenance of diversity and for recolonization of adjacent sites. Donaldson, Nanni, Zabchariades, and Kemper (2002) showed that pollinator numbers did not decrease linearly with decreasing fragment size and relatively small fragments can in fact maintain and attract a diversity of insect pollinators. A more significant factor in reducing diversity is habitat heterogeneity (Donaldson et al., 2002) and if considered in their entirety what is evident is that all these smaller patches contribute to landscape diversity, and in turn appear to support certainly an insect functional diversity. This study demonstrates that even small urban green spaces can serve as a hub of pollinator activity and apparent morpho-species insect diversity.

4.3. Planting intervention sites as critical entry points

The civic-led planting interventions studied here are clear entry points to informing a publically envisioned and ecologically functioning urban ecology. This is part of the more general notion that urban and suburban gardens, along with public parks, form much of the urban matrix, known to make significant ecological and conservation contributions in cities (Goddard et al., 2010; Colding et al., 2006). However, there is a quite important difference it seems between private gardens and public parks and open spaces. While the decisions of the former sits at the private owner, the latter, although driven by smaller networks of committed associations and individuals needs to be negotiated in the 'eye of the public'. So while one can lament the negative role in ecological outcomes of gardens in introducing problematic exotics, this might be less of an issue for public spaces and in societies with strong urban regulation on biodiversity and indigenous plant protection. Indeed, conservation approaches, or any reworking of public land, needs to negotiate the wider institutions of society.

In relation to Bottom Road and Princess Vlei, the presence of the wider society in the selection of plants is quite obvious in that great resources in South Africa have been gathered around Fynbos, both workers and seedlings were sourced from the Working for Water/Wetlands public works programme (Ernstson, 2013b). Given that civic associations wanted to re-work their spaces, it was Fynbos that carried most resources to accomplish that. To work out these negotiations, while importantly carry out real material and ecological changes on the ground, public open spaces and gardens turns into physical spaces for 'social ecological innovation', or experimentation sites, on how to rethink conservation in the context of the hybrid character of 'recombinant' urban ecologies (Ernstson & Sörlin, 2009; Ernstson, van der Leeuw, et al., 2010; Hinchliffe & Whatmore, 2005). It is these opportunities that foster multiple ends that need to be integrated into urban planning.

5. Conclusion

Parks and private and public gardens do not exist in isolation, but form part of the urban fabric, contributing to ecological functioning. This makes research into their role in shaping urban environments difficult, but important. This paper has empirically researched the ecological outcomes of a series of indigenous planting interventions in the urban area of Cape Town, and argued that more studies that focus on ecological outcomes are needed. The six different sites, three of them being intervention sites, two civic-led and one expert-led, were compared in terms of their plant and insect diversity and then discussed in relation to their contingent management arrangements. By emphasizing the ecological outcomes, this study has not only highlighted the importance of how civil society and residents can link conservation goals to more broad-based notions of quality of life and the 'good and just city', but also provided tools to better theorize the ecological role that such interventions can bring. Cape Town in particular serves as a good starting point to think about indigenous biodiversity conservation (Maurer et al., 2000), and our results indicate, although more research of the sites in the future are needed, that civic-led efforts can do just as well as expert-led ones, both in relation to meet indigenous conservation targets, as well as supporting functional groups and wider ecological processes, with the acknowledged exception of fire. How to integrate such civic-led interventions into urban biodiversity management planning is still an open question, but will require significant collaboration between civic associations, urban planners and conservation agencies, and informed by work emerging in the realms of urban ecology by social and ecological scientists (Goddard et al., 2010; Maurer et al., 2000).

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