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Recommendations for Urban Biodiversity Conservation in the Context of Landscape Preference in Singapore

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Effective urban biodiversity conservation requires that planners facilitate public acceptance towards biodiversity and its associated habitats within urban areas. This research quantifies the biodiversity conservation potential of landscapes of varying human interference in Singapore and functions under a backdrop that the general public has an aesthetically-driven preference for manicured landscapes. Biodiversity counts for conservation-targeted species from six biodiversity categories species [seed plants, ferns and fern allies, mammals, reptiles, birds and insects (excluding Lepidoptera)] across four landscape types show that naturalistic landscapes (primary and secondary vegetation) harbored at least eight times the number of conservation-target species than manicured landscapes and urban areas. To conserve a maximum number of threatened species while keeping in line with aesthetic landscape preferences, this research offers specific suggestions at modifying existing manicured landscapes to provide better habitats for conservation-target species which have shown recent adaptations to manicured landscapes and urban areas. The percentage of these species makes up as much as 50.39% of seed plants to a lowest of 17.86% of mammals. Taking these small initial steps in urban biodiversity conservation would not only serve to enhance public experience with native nature in urban areas but improve conservation potential of these areas in tangible and feasible means.

Keywords

Urban biodiversity conservation, Landscape preference, Species richness, Policy recommendation, Tropical biodiversity

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INTRODUCTION

Conservation biology is a long-established field and has traditionally been enacted from the standpoint of treaty-level protection of target species (e.g. Convention for the regulation of Whaling 1946, Convention on the Conservation of Migratory Species of Wild Animals 1979) and the creation of nature reserves (Miller et al. 2002). However, the extent to which these initial measures have been effective at achieving conservation goals is questionable (Miller et al. 2002, McKinney 2002). This is especially in the light of findings which show that the total area set aside for conservation may be too small to adequately represent global ecosystems and are therefore ineffective in halting species extinctions (Grumbine 1990, McNeely et al. 1994, Newmark 1995). Furthermore, the total area of built environments alone, excluding land area which have been modified for anthropogenic needs, exceed the total area allocated for conservation countries such as the United States (McKinney 2002) and Singapore (Yee et al. 2011). In lieu of a continuing urbanization trend, this situation may become quickly evident in throughout the world (McKinney 2002; Dearborn and Kark 2010).

Out of a range of anthropogenic impacts, urbanization has been recognized as the factor which produces the greatest and longest-lasting habitat loss, local extinction rate and native species loss (Vale and Vale 1976, Luniak 1994, Kowarik 1995, Marzluff 2001, McKinney 2002). Urbanization in Singapore's context can be taken as a case study in an "ecological worst case scenario" (Sodhi et al. 2004). Widespread clearance of more than 90% of native habitats has caused the extinction about 34 - 87% of its butterflies, fish, birds and mammals over the last century (Brook et al. 2003, Sodhi et al. 2004). Out of a total land area of 714.3 km^2 (DOS 2012), what remains of Singapore’s primary vegetation is confined to 0.16% of the country (Yee et al. 2011).

The realization that traditional conservation methods may have limited effectiveness in the face of continued urbanization has gradually broadened the focus of conservation planning to include unprotected lands (Jongman 1995, Saunders et al. 1995) and, more recently, peri-urban and urban areas (Rosenzweig 2003; Kühn et al. 2004; Dearborn and Kark 2010). These newer practices have demonstrated that natural and human systems can no longer be thought of as separate entities in order for conservation movements to remain relevant (Miller and Hobbs 2002). As such, spearheaded by countries in Europe and the United States (McHarg 1992; Forbes et al. 1997), practices such as increasing the percentage of green-space cover (usually synonymous with manicured landscapes) in urban areas have become more commonplace throughout the globe (The Biodiversity Conservation Strategy Partnership 2008; Biodiversity Strategy Office, Tokyo 2009; Hostetler et al. 2011).

Determinants of Sustainable Urban Biodiversity Conservation in Singapore

Singapore has not been an exception to the trend of utilizing urban green-spaces for ecological service provision and biodiversity promotion (Ministry of National Development, Singapore 2013). Of "Garden City" fame, a post-1965 country-wide greening movement has resulted in 47% of the country being classified as green areas (Yee at al. 2011). However, more than 90% of these green areas are represented by manicured landscapes (Tan 2009; Yee et al. 2011), which irreversibly replace native habitats. Although manicured landscapes are more positive in bolstering urban species richness as compared to the built environment, adopting an increase in green-space cover as an across-the-board practice may not be as effective for biodiversity conservation in (for example) tropical cities as they are in temperate cities (Chong et al. 2010). Wider structural and microclimatic differences between natural areas and areas with a high level of human modification in the case of tropical cities (as compared to their temperate counterparts), could result in urban manicured landscapes of lower conservation quality within tropical cities (Chong et al. 2010, Shwartz et al. 2014). There is therefore need for studies which promote a deeper understanding of the conservation-potential of urban environments and its associated green-spaces in tropical cities such as Singapore.

The conservation potential of urban areas and its associated manicured landscapes can be gauged through quantifying existing habitat specific conservation-targeted species-richness (e.g. Bryant 2006; Shwartz et al. 2014). Conservation methods can then be better contextualized based on information on how this parameter changes across landscapes with varying levels of human disturbance (Dale et al. 2000). Such studies can be used to inform management-level decisions regarding the placement and ecological design of urban green-spaces to maximize potential species preservation effects (e.g. Blair and Launer 1997, Zerbe et al. 2002).

Previous studies focusing on species-richness change across landscapes with different levels of human disturbances were mostly centered on quantifying general species-richness (not specifically focused on conservation-targeted species) in birds, plants and butterflies within temperate countries such as Germany, France, USA and Canada (see Kowarik 1995, Clergeau et al. 1998, Blair 2011, Zerbe et al. 2002 for examples). These studies reveal an overall decrease in biodiversity from landscapes with least to most human interference with a biodiversity peak in suburban areas due to increased landscape heterogeneity (e.g. Blair and Launer 1997; McKinney 2002; Zerbe et al. 2002). However, it is current not clearly understood if conservation-targeted species in Singapore would exhibit a similar pattern.

Furthermore, in order to ensure continued policy success, garnering public support of the resultant landscapes is as essential as ensuring a robust conservation potential in urban green spaces (Briffet 1991; Leong 2000; Choo 2012). This social aspect is relevant in Singapore where landscape planning and urban biodiversity conservation has become an increasingly participatory movement with the advent of a more ecologically-literate general public (Soh and Yuen 2005). Therefore, in Singapore's context, contextualizing urban biodiversity conservation also has to be done in the light of landscape preference in order to determine the acceptable extent to which urban green spaces can be naturalized (Fischer and Young 2007; Saito 2007). A study has been conducted by Khew et al. (2014), which has found that the majority of the general public in Singapore has a preference towards the scenic aesthetics contained in manicured landscapes despite displaying significant intention towards nature preservation (which is, conversely, best achieved in naturalistic habitats). These results differ from landscape preference studies conducted in temperate and subtropical urban areas, where the general public was found to have a neutral preference with regards to naturalistic and manicured landscapes because of their structural similarity (Jim and Chen 2006; Özgüner and Kendle 2006).

Reasons why conservation intent did not translate to the right landscape choice in Singapore could be most Singaporeans having been exposed to manicured landscape as their staple "nature" after the country adopted an aggressive urbanization and urban-greening initiative after 1965. When asked about reasons driving their preference, besides citing obvious aesthetic reasons, Singaporeans also seemed to believe that these landscapes were sufficient for biodiversity conservation (Khew et al. 2014).

An aesthetic landscape preference would pose problems for policies which advocate the increase in the number of species in urban areas as a whole. These problems may range from reacting adversely to urban biodiversity due to a lack of understanding (Xu 2010) to the withdrawal of public support for greening projects. Therefore, when addressing public perceptions of nature and preferences regarding biodiversity conservation in urban areas it is necessary to consider scenic aesthetics in order for resultant policies to be socially sustainable.

This paper aims to propose specific recommendations on how to conserve biodiversity in highly urbanized Singapore while keeping in line with the prevailing aesthetic landscape preference. In order to do so, we profile the conservation potential of manicured landscapes through profiling conservation-targeted species-richness per landscape type and contextualize how this result compares with conservation potential of landscapes along a gradient of human influence. This would enable the elucidation of trends concerning how, and in which landscapes/ combination of landscapes, species-richness can be maximized. Consequently, this study would provide data which aids in the conception of socially-acceptable green spaces in Singapore as public perception of nature has been recognized as important in determining the long-term acceptability of green-space policies (Leong 2000).

DATA AND METHODS

Species-richness by Habitat Type: Selection of Habitat Types and Conservation-targeted Species

Assessment of species-richness per habitat type was carried out for conservation-targeted species in Singapore for six biodiversity categories [seed plants, ferns and fern allies, mammals, reptiles, birds and insects (excluding Lepidoptera)] was obtained from the Singapore Red Data Book (Davidson et al. 2008). These categories were chosen in lieu of data exhaustiveness, reliability and availability. The biodiversity count was limited to threatened native species in Singapore as these species are most affected by land-use change and are target species for conservation goals, even within urban areas (Davidson et al. 2008).

Occurrence records for each red-list species was then cross-checked using the aid of the following online databases with species location sighting records within Singapore:

- Raffles Museum of Biodiversity Research: Digital Nature Archive of Singapore
  (URL: http://rmbr.nus.edu.sg/dna/. Last accessed date: 2 Feb, 2013)
- The Total Vascular Flora of Singapore Online
  (URL: http://floraofsingapore.wordpress.com/. Last accessed date: 2 Feb, 2013)
- The IUCN Red List of Threatened Species
  (URL: http://www.iucnredlist.org/. Last accessed date: 2 Feb, 2013)
- Wildsingapore: Wild Fact Sheets

(URL: http://www.wildsingapore.com/wildfacts/index.html. Last accessed date: 2 Feb, 2013)

If the record for any species showed up in more than one database, occurrence records were summed. Summation of species occurrence records for the purpose of conducting a review analysis of species richness has also been conducted in other review studies on species richness in urban parks (e.g. Fernandez-Juricic and Jokimäki 2001, Hernandez et al. 2009, Nielsen et al. 2013), and general trends in the field of urban biodiversity (McKinney 2002). In lieu of the urban biodiversity conservation focus of this paper, only species which inhabit terrestrial habitats were considered. The database search also provided information which allowed exclusion of species which were either nationally extinct, data deficient or not inhabiting any of the shortlisted landscapes.

Habitats that the conservation-targeted species were found to occur in were then classified along a rural to urban gradient. Landscapes selected were short-listed to 1) primary vegetation (including old secondary vegetation); 2) secondary vegetation; 3) manicured landscapes and 4) urban areas. Shortlisted landscapes were those which were easily recognizable to the public but yet, representative of varying degrees of human interference (with primary vegetation having the least human interference and urban areas having the most human interference) (Blair 1999; Reis et al. 2012; Shwartz et al. 2008). A land-use survey completed in 2012 has recorded the total area of Singapore to be 72574.68 ha (Yee et al. 2011). The respective area covered by the selected landscapes are as follows: A) primary vegetation, including old secondary vegetation (1,113.02 ha, 1.53% of total land area), B) secondary vegetation (14,288.48 ha, 19.64% of total land area), C) manicured landscapes (19,972.96 ha, 24.75% of total land area) and D) urban areas (28,270.43 ha, 38.85% of total land area) (Yee et al. 2011). In this manuscript, abbreviations would be henceforth used to refer to each landscape category with (P) representing primary vegetation (including old secondary vegetation), (S) representing secondary vegetation, (M) representing manicured landscapes and (U) representing urban areas.

Specific Conservation Potential: Number of Species Unique to a Landscape Type

Habitat specific species-richness was quantified by quantifying conservation-targeted species, instead of habitat-type, as an independent factor. Results would elucidate the number of species unique to a landscape type, or a combination of landscape types, as no species would be double counted. For example, if a species was found to occur in a combination of primary/ old secondary vegetation and secondary vegetation, it would be considered unique to the primary/ old secondary and secondary vegetation landscape category, and not counted once in the primary/ old secondary vegetation habitat and once again in the secondary vegetation habitat.

The authors note that limitations exist with regards to compiling database results for species-occurrence data. For example, results cannot be statistically analyzed as data collection methods vary between different records. However, this method was deemed sufficient insofar as this paper aims to give an estimation of conservation-targeted species-richness in different landscape categories. The occurrence information within the databases used in this study were deemed accurate as they were either collected through peer-reviewed papers (e.g. IUCN database) or, in the case of local biodiversity databases (e.g. Wildsingapore) from observation records or surveys conducted by trained biologists. As mentioned earlier, a similar method has also been used to profile landscape-specific species-richness in other studies (e.g. Fernandez-Juricic and Jokimäki 2001, McKinney 2002, Hernandez et al. 2009, Nielsen et al. 2013)

RESULTS AND DISCUSSION

Conservation-targeted species in six biodiversity categories [seed plants, ferns and fern allies, mammals, reptiles, birds and insects (springtails, peripatus, other insects including moths)] were surveyed across four landscape types ranging from sites with least human disturbance (**P**) to sites with most human disturbance (**U**) (Blair 1999). (**S**) was taken to be sites with intermediate-low human disturbance while (**M**) was considered as a site with intermediate-high human disturbance (Blair 1999). Table 1 shows the number and percentage of species which were considered in the biodiversity survey.

Table 1 Percentage and number of species considered in this study

	Percentage				
	Total	**Extinct**	**Habitats not included in survey**	**Insufficient information**	**Remaining (Considered in biodiversity survey)**
Seed plants	100.00 (n = 1723)	34.82 (n = 600)	9.05 (n = 156)	3.83 (n = 66)	52.47 (n = 904)
Ferns	100.00 (n = 100)	15.00 (n = 15)	0.00 (n = 0)	0.00 (n = 0)	85.00 (n = 85)
Mammals	100.00 (n = 31)	0.00 (n = 0)	9.68 (n = 3)	0.00 (n = 0)	90.32 (n = 28)
Reptiles	100.00 (n = 66)	0.00 (n = 0)	24.24 (n = 16)	3.03 (n = 2)	72.73 (n = 48)
Birds	100.00 (n = 56)	0.00 (n = 0)	23.21 (n = 13)	0.00 (n = 0)	76.79 (n = 43)
Insects (excluding Lepidoptera)	100.00 (n = 49)	0.00 (n = 0)	8.16 (n = 4)	12.24 (n = 6)	79.59 (n = 39)

Consistent with previous studies conducted in temperate regions, results of the biodiversity survey conducted in this project show a general decrease of species-richness from habitats of least to most human disturbance for all six biodiversity categories (Figure 1). However the degree of biodiversity change across habitats with high levels of human influence to habitats with low levels of human influence is much more drastic in Singapore as compared to temperate environments.

Studies by Blair and Launer (1997) have found that natural habitats such as nature preserves contain about two to three times the number of bird and butterfly species as urban landscapes. However, results from this project show that the number of species in more natural landscapes (primary and secondary vegetation) was at least about eight times higher than the number of species harbored in manicured landscapes and urban areas. Results also reveal that three biodiversity categories show diversity peaks at secondary vegetation [Seed plants, birds and insects (excluding Lepidoptera)] (Figure 1).

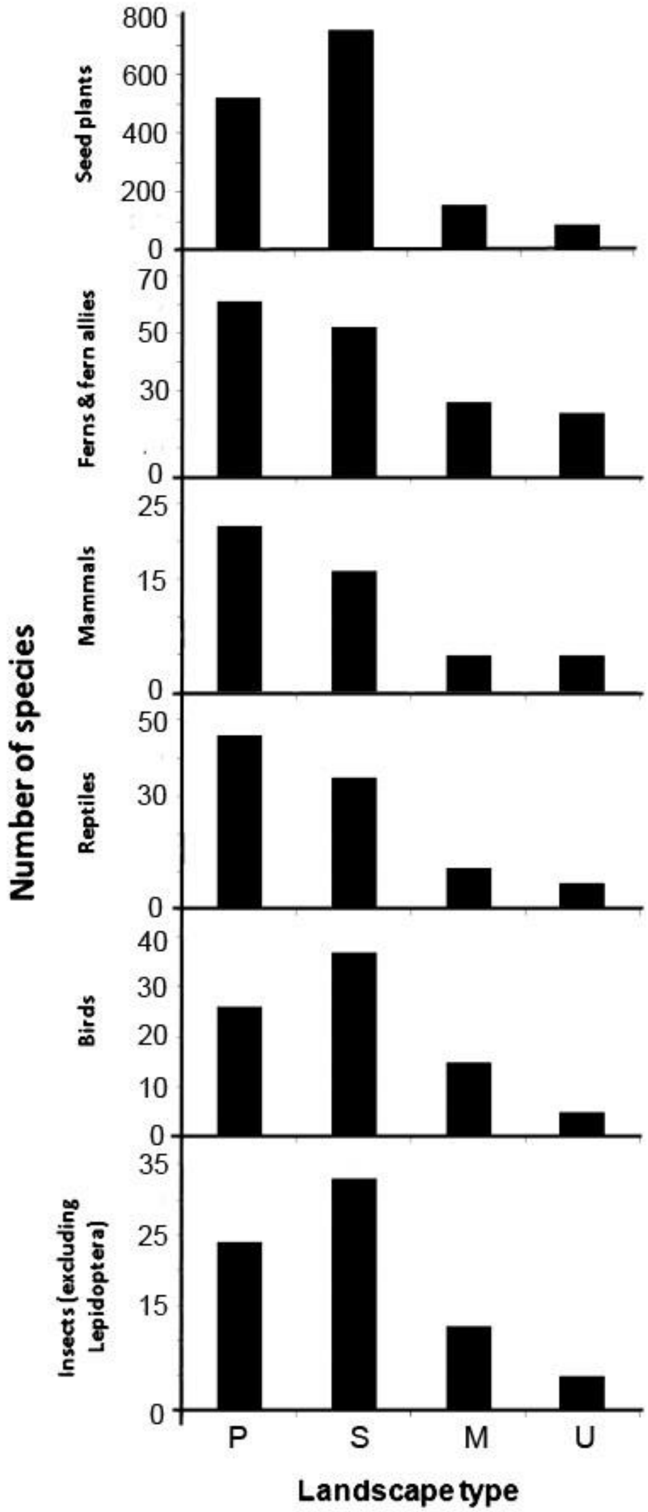

Figure 1 Graph of number of conservation-targeted species in six biodiversity categories against landscape type. P = primary vegetation (including old secondary vegetation), S = secondary vegetation, M = manicured landscape and U = urban areas

Quantifying the species-richness according to predefined landscape types may thus point to species in the three biodiversity categories of seed plants, birds and insects exhibiting a distribution pattern consistent with the intermediate disturbance hypothesis commonly found in previous studies (e.g. Blair and Launer 1997, McKinney 2002, Zerbe et al. 2002). The intermediate disturbance hypothesis hinges on the explanation that biodiversity thrives in the increased environmental heterogeneity present in suburban areas (where human impacts are also considered to be relatively low). A large proportion of land use in suburban areas is usually dedicated to housing and agricultural projects which represent matrixes within a relatively large natural landscape typified by fringing rural settings. As such, the proximity to natural systems allows more adaptable biodiversity to spread their ranges to the suburban fringe. Furthermore, suburban land-owners aid in biodiversity spread through cultivating fruit and nectar bearing plants in their gardens (Henderson et al. 1998). These plants potentially function as a food sources for birds and host plants for insects.

However in this study, diversity peak in seed plants, birds and insects can possibly be explained more through species association with landscape level features (primary forest fragments in Singapore's case) rather than through the intermediate disturbance hypothesis (Melles et al. 2003). A closer examination of habitat specific conservation potential (conducted by counting species instead of pre-fixed landscape types as independent units) shows that a large proportion of species found in secondary forests are not exclusive to habitats containing secondary vegetation (Figure 2).

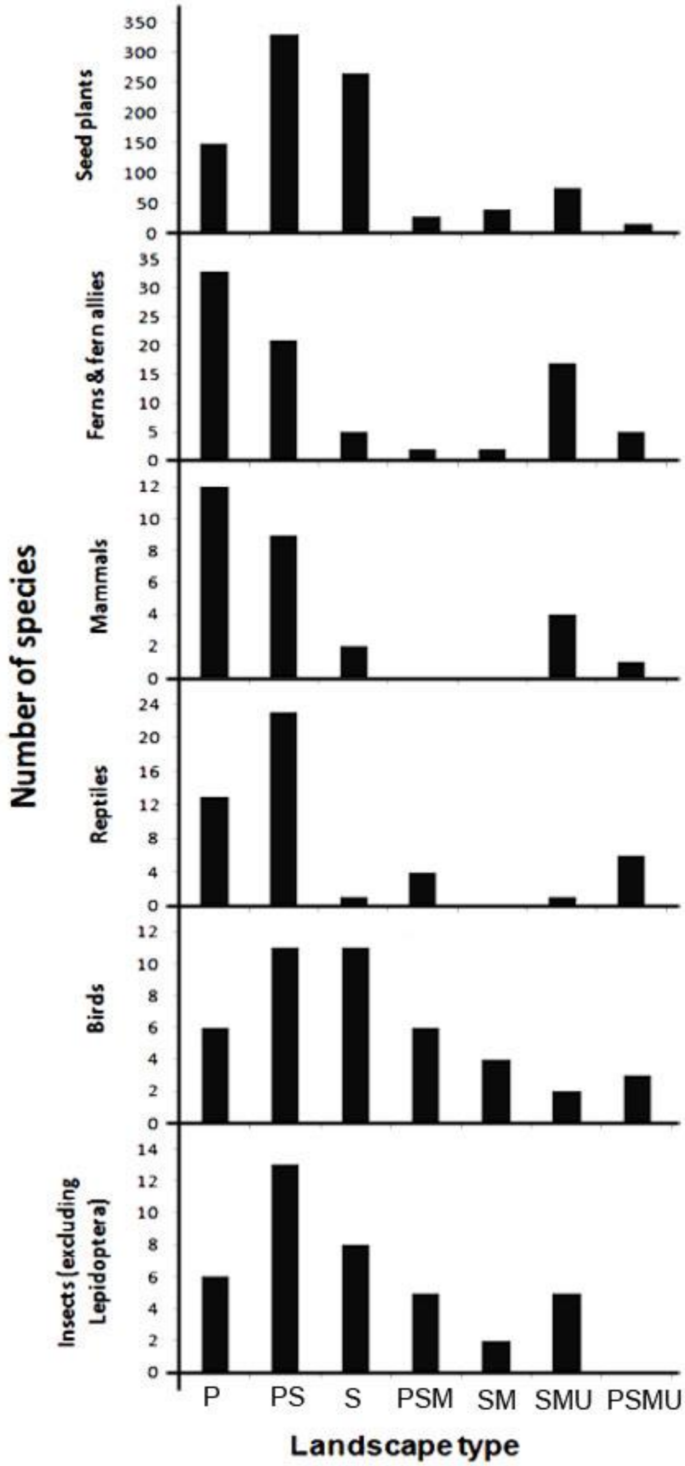

Figure 2 Habitat specific conservation potential of a landscape or a group of landscapes for six conservation-targeted biodiversity categories

Data was categorized using species as an independent factor. Species found to be least adapted to human disturbance in the landscape are confined to P (left of graph) and species found to be most adapted to human disturbance are spread across PSMU (right of graph). In this graph, P = primary vegetation (including old secondary vegetation), S = secondary vegetation, M = manicured landscape and U = urban areas.
These species are instead found in a combination of primary and secondary vegetation and may thus require a combination of both habitats for survival. In the case of seed plants, birds and insects, this proportion is greater or equal (in the case of birds) to the number of species found exclusively in secondary habitats. The species which are found in a combination of both habitats could have been dependent on primary vegetation for essential needs such as food, nesting and breeding grounds. Unlike previous studies where habitats of intermediate disturbance could promote biodiversity through provision of food sources and alternative nesting sites, the function of secondary habitats in Singapore's case could be a fringe extension of the range of some primary forest dwelling species.

The results of the review on distribution of conservation-targeted species conducted in this study have so far shown that natural landscapes, especially primary and secondary vegetation, still support the highest number of species. However this does not mean that manicured landscapes and urban areas should be written off when it comes to their potential in supporting conservation-targeted species in Singapore. It is instead rather optimistic to know that the percentage of conservation-targeted species which were found to be able to exist in manicured landscapes and urban areas ranged from 50.39% of seed plants to a lowest of 17.86% for mammals (Figure 3).

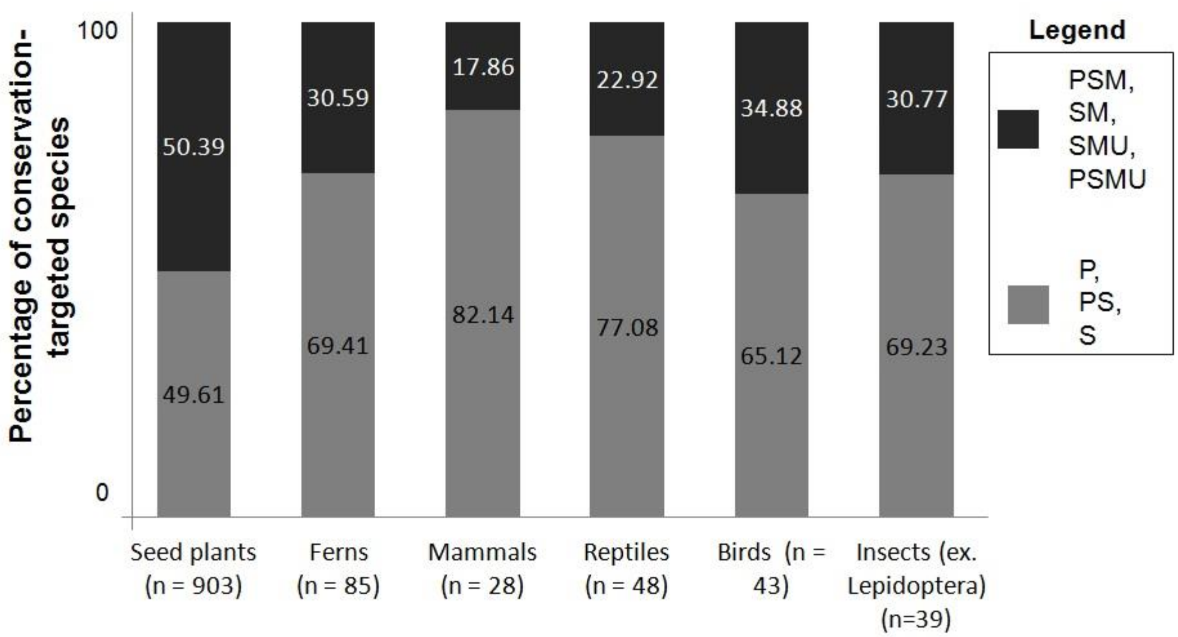

Figure 3 Percentage of conservation-targeted species which are able to exist in manicured/ urban environments (colored black in graph) as a percentage of the total number of conservation-targeted species in each biodiversity category. Habitat classifications are P = primary vegetation, S = secondary vegetation, M = manicured landscapes, U = urban areas.

However it should be noted that further studies on the autecology the individual species should be conducted in order to ascertain the degree of which these species have shown morphological, behavioral and/ or physiological adaptations (if at all) to urban environments. Certain conservation-targeted mammals such as the large Indian civet (*Viverra zibetha*) have been found to be capable of finding food in urban areas (Chua et al. 2012). Species such as the black bearded tomb bat (*Taphozous melanopogon*), on the other hand, were found to utilize urban structures for roosting but it is currently uncertain if this is a clear behavioral adaption or if these species are remnant populations from previously cleared natural vegetation. Having a relatively small, but still significant population of species in urban areas has been a finding also reported by Zerbe et al. (2003) for native birds within temporary wastelands in Berlin. Garden et al. (2006) has also found that small areas of manicured landscapes may in fact, serve to promote urban bird species-richness in urban areas in Australia due to the resultant patch not being able to support natural predators and parasites.

In lieu of the potential of urban areas to function as a stepping stone in attracting sensitive species, more consideration should be given to policies which focus on urban habitat enhancement. Preferably, in Singapore's context, this should be done in ways which would allow shortlisted species to better adapt to built environments without drastically changing existing urban landscape aesthetics.

RECOMMENDATIONS FOR URBAN BIODIVERSITY CONSERVATION IN SINGAPORE

The species-richness review conducted in this paper shows that, natural landscapes such as primary and secondary vegetation are still best for the retention of the highest number of conservation-targeted species. Therefore in the context of urban biodiversity conservation, habitat connectivity should be promoted with any adjacent patches of primary/ old-secondary forest. This should be given priority over promotion of habitat connectivity between "lower-conservation-grade” habitats like other manicured parks.

Traditional biodiversity conservation approaches in Singapore and several other tropical urban centers have been centered on adopting solutions applied to temperate regions (e.g. green corridors, increasing manicured landscape cover) (Briffet et al. 2004). However, these proposals are often vague in their intention to increase biodiversity in urban areas, and have been identified as being potentially ineffective with regards to tropical biodiversity which have different habitat requirements as well as behavior, when compared to their temperate counterparts (Chong et al. 2010).

Streamlining Current Conservation Policies

In order to more efficiently set conservation goals and encourage higher efficiency of resource use, urban biodiversity conservation should be specifically targeted at native species which currently exist in manicured landscapes/ urban areas. This would contrast with the conventional “save as many species as you can” approach. This paper provides the initial groundwork for the identification of such species. Table 3 shows a summary of the conservation-targeted biodiversity from four categories [mammals, reptiles, birds and insects (excluding Lepidoptera)] which have been found to exist in manicured landscapes and urban areas with associated suggestions on how to improve species population sizes in these areas.

All of the conservation-targeted species listed in Table 3 are non-harmful to humans, with the exception of one reptile [King cobra (*Ophiophagus hannah*)], which should not attack unless provoked. Care should be taken also in monitoring the increase of horseshoe bat populations [Greater wooly horseshoe bat (*Rhinolophus luctus*)] due to its probable link with the spread of the SARS coronavirus (Shi and Hu 2008). However, it should be noted that although a strain of SARS coronavirus which is highly similar to the SARS coronavirus found in humans has been sequenced in horseshoe bats, the study by Shi and Hu (2008) does not imply conclusive bats-to-human transmission.

Table 2 (Continued) Conservation-targeted biodiversity from four categories and accompanying suggestions on how to improve the population sizes of these species in manicured landscapes and urban areas. Conservation-targeted species were identified from Davidson et al. (2008)'s Singapore Red Data Book.

Category	Common name	Scientific name	Status	Habitat [a]	Suggestion on how to best improve population sizes in manicured landscapes/ urban areas [b]
Mammals	Black bearded tomb bat	*Taphozous melanopogon*	Endangered	PSMU	Increase structural complexity of manicured landscapes through inclusion of artificial boulders and varying vegetation height.
	Greater wooly horseshoe bat	*Rhinolophus luctus*	Critically endangered	SMU	
	Horsfield's flying squirrel	*Lomys horsfieldii*	Endangered	PSM	
	Large Indian civet	*Viverra zibetha*	Critically endangered	SMU	Increase access to water sources by including stream/ pond designs in parks. Also increase presence of food trees like fishtail palms (*Caryota* spp.) (Xu, 2010).
	Leopard cat	*Prionailurus bengalensis*	Critically endangered	SMU	
Reptiles	Dog toothed cat snake	*Boiga cynodon*	Endangered	PSMU	Increase access to water sources by including stream/ pond designs in parks. Also increase humidity and vegetation coverage in areas of parks which are at least 100 meters from visitor paths in order to provide suitable habitats with high humidity.
	Variable reed snake	*Calamaria lumbricoidea*	Endangered	PSMU	
	Common malayan racer	*Coelognathus flavolineatus*	Endangered	SMU	
	Orange bellied ringneck	*Gongylosoma baliodeirum*	Endangered	PSMU	
	Red tailed racer	*Gonyosoma oxycephalum*	Endangered	PSMU	
	King Cobra	*Ophiophagus hannah*	Endangered	PSM	

	Black bearded flying dragon	*Draco melanopogon*	Vulnerable	PSM	Increase structural complexity of manicured landscapes and provide suitable habitats through hollowing out enclaves in trees or construction of artificial shelters.
	Five banded flying dragon	*Draco quinquefasciatus*	Endangered	PSM	
	Tokay	*Gekko gecko*	Critically endangered	PSMU	
	Large forest gecko	*Gekko smithii*	Critically endangered	PSM	
Birds	Rudy breasted Cuckoo	*Cacomantis sepulcralis*	Critically endangered	PSMU	Increase access to water sources by including stream/ pond designs in parks. More research should be done on the type of food trees preferred by each species, as well as preferred nesting sites. However, more native fig species could be planted as food sources for the thick billed pigeon (*Treron curvirostra*).
	Violet Cuckoo	*Chrysococcyx xanthorhynchus*	Vulnerable	PSMU	
	Blue crowned hanging parrot	*Loriculus galgulus*	Endangered	PSM	
	SpotteWood Owl	*Strix seloputo*	Critically endangered	PSM	
	Thick billed pigeon	*Treron curvirostra*	Endangered	PSM	
	Red legged crake	*Rallina fasciata*	Vulnerable	PSM	
	Greater Painted Snipe	*Rostratula benghalensis*	Critically endangered	SMU	
	Crested Goshawk	*Accipiter trivirgatus*	Critically endangered	PSM	
	Black thighed falconet	*Microhierax fringillarius*	Critically endangered	SM	
	Magpie Robin	*Copsychus saularis*	Endangered	SMU	
	Straw-headed Bulbul	*Pycnonotus zeylanicus*	Endangered	PSMU	These bird species are found near waterbodies and mangrove forests. Therefore conservation could be more feasible in parks near such locations (e.g. Woodlands park, Pasir Ris park), through ensuring the health of the mangrove ecosystem in such areas.
	Grey headed fish eagle	*Ichthyophaga icthyaetus*	Critically endangered	SM	
	Crested serpent eagle	*Spilornis cheela*	Critically endangered	PSM	
Insects (ex. Lepidoptera	Lime shieldbug	*Rhynchocoris humeralis*	Critically endangered	PSMU	Planting of more Kalamansi host plants (*Critus microcarpa*) could aid in population increase.
		Aciagrion hisopa		SMU	These insects are associated with shallow water present in the landscape. Factoring for the design of ponds and
		Urothemis abbotti		PSM	

Tetrathemis irregularis	PSM	slow streams could help to increase population
Rhyothemis obsolescens	SMU	The biology of these insects is currently not well understood. Besides increasing vegetation density to aid in the creation of a humid habitat, more research should be done on the type of food sources and host plants utilized in the species' life cycles
Pseudothemis jorina	PSM	
Camacinia gigantea	SMU	
Brachydiplax farinosa	SMU	
Agrionoptera sexlineata	SMU	
Aethriamanta aethra	PSM	

[a] Habitat information: P – primary vegetation, S – secondary vegetation, M – manicured landscape, U – urban areas
[b] Conservation suggestions were derived from the preferred habitat conditions of the respective listed species found in the Singapore red data book (Davidson et al., 2008) unless stated otherwise.

Planting of Conservation-targeted Plants in Urban Parks

At present, much of Singapore's manicured landscapes and urban areas predominantly consist of exotic plants with ornamental value. Consideration should be given to the use of conservation-targeted ferns and vascular plants such as the hare's foot fern (*Davallia* spp.) and the ornamental *Tabernaemontana corymbosa* for landscaping purposes. With increased planting, these native plants can serve as habitat and food support for a wider variety of other native species (and possibly other conservation-targeted species).

Reasons why native plants are currently unpopular for landscaping use could be due to logistical issues such as slow growth, lack of propagation-know-how and lack of demand as opposed to popular aesthetically known exotic plant species (Kong and Yeoh 1996; Tan 2006). However, studies on how to increase propagative ability of native and especially, conservation-targeted plants should also be done in tandem in order for conservation goals to be better targeted and fulfilled.

Increasing the Habitat Complexity of Urban Parks

Maintenance of existing urban landscape aesthetics while increasing urban conservation capacity could also be achieved through ecological-design measures which modify the micro-habitat of manicured landscapes. Micro-habitat modification for biodiversity promotion is a relatively recent, but growing field of study. Previous work by Olive & Minichiello (2013) have shown an increase in bird and insect diversity with seemingly 'small' measures such as including artificial hollows in trees and increasing woody debris in parks. These modifications support urban biodiversity by providing shelter and increasing habitat complexity for more lower-tropic level species to thrive. In the context of Singapore's urban landscape, the habitat complexity of manicured landscapes can be increased with the aid of planting a variety of native/ conservation-targeted plants. As mentioned in the earlier section, conservation-targeted seed plants such as

Tabernaemontana corymbosa have ornamental value and can also function to preserve the aesthetics of urban parks.

CONCLUSION

A previous study by Khew et al. (2014) found that the general public in Singapore has a tendency towards wanting to preserve nature but this tendency was not consistent with landscape choice. Preferred landscapes were those of a manicured nature which have lower conservation potential as compared to natural landscapes (Khew et al. 2014). This paper presents findings from a biodiversity count of conservation-targeted species which show that a combination of primary (including old secondary) and secondary vegetation harbor about eight times the number of conservation-targeted species from the six biodiversity categories investigated as compared to manicured landscapes. Consequently, pre-existing preference for manicured landscapes in Singapore could possibly raise social obstacles against naturalizing parks to resemble native vegetation for biodiversity conservation as naturalization would likely lower the aesthetic quality of existing parks.

However, a sizable percentage of conservation-targeted species has been found to reside in manicured landscapes and urban areas. Therefore, there should be thought given to how manicured landscapes can be made more ecological by increasing their conservation potential without changing their aesthetic appearance. In a nutshell, recommended recommendations are:

- Promoting habitat connectivity with remnant patches of primary/ secondary vegetation.
- Re-orientating existing broad conservation policies to one which focuses specifically on increasing the population sizes of conservation-targeted biodiversity that are currently found in manicured landscapes and urban areas. This would enable more efficient goal-setting and encourage higher efficiency of resource use.
- Encourage the percentage use of native plant species and reduce the use of exotic plants.
- Encourage the increase in habitat complexity in parks through planting native plants of varying heights, or through creating artificial holes in rocks which can serve as habitats for species such as the Horsfield's flying squirrel (*Lomys horsfieldii*) and the Greater wooly horseshoe bat (*Rhinolophus luctus*).

The recommendations given through this paper suggests that argues that urban biodiversity conservation targets should be specific and done in small but feasible steps in Singapore's context, especially when public preference for manicured landscapes is taken into account.

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