



A Study of 32 Roof Gardens in Singapore

Biodiversity Oases in the Urban Jungle

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Preserving biodiversity in the urban landscape faces a multitude of challenges. The ever-increasing areas of concrete and hard surfaces encroach on remnant green areas as the demands for space from a growing population continues. This is most pressing in Asia, where the urbanisation rate exceeds that of other regions. Asia currently houses 53 percent of the world's urban population and is estimated to be 64 percent urban by 2050.¹ As we lose more and more natural habitat to urban development, the creation of new habitat for wildlife within the complex urban space may help maintain wildlife species in the “urban jungle”.

Roof gardens, or green roofs as they are sometimes referred to, are becoming increasingly popular in cities around the world as their many aesthetic, environmental, and economic benefits are realised.² A number of the ameliorating effects of roof gardens, including increasing building energy efficiency, stormwater retention, and reducing the urban heat island effect, are well documented.³ The role of roof gardens in enhancing urban biodiversity, however, is less well studied, especially in a tropical context. In Singapore, researchers are exploring roof gardens as potential oases of biodiversity.

Singapore provides an ideal platform to assess the role of roof gardens in promoting biodiversity due to the large and diverse array of roof gardens that the city supports. At present, there are 65 hectares of skyrise greenery, of varying size, height above the ground, and planting schemes.⁴ Moreover, the number of roof gardens is expected to increase with growing awareness and recognition of their varied uses. In light of this, a study between the National Parks Board and National University of Singapore was initiated to better understand the interaction of skyrise greenery with urban biodiversity, with particular focus on two charismatic wildlife groups: birds and butterflies. All the study sites were located on the fourth storey or higher, were accessible for communal use, had at least 300 square metres of softscape and at least three layers of vegetation, and were not actively managed to exclude wildlife.

The study is establishing both quantitative and photographic databases of the birds and butterflies that visit local skyrise greenery, and it is assessing which primary environmental factors influence animal diversity and abundance at those sites. By identifying the links between roof garden characteristics and wildlife visitation, the research will help formulate guidelines and recommendations for the design and management of roof gardens so as to enhance their general biodiversity values. These guidelines will be a benchmark in the emerging field of urban ecology.

Observations So Far

Research began in May 2014, with monthly surveys at 32 roof gardens across Singapore. From then till December 2014, the team recorded a total of 44 species of birds and 49 species of butterflies. Of course, the most abundant species were “the usual suspects” in urban environments: the Javan Myna (*Acridotheres javanicus*), Eurasian Tree Sparrow (*Passer montanus*), and Black-naped Oriole (*Oriolus chinensis*). However, the researchers have already met with some surprises, sighting birds thought to be more avoidant of urban areas or that are migratory in nature, such as the Asian Brown Flycatcher (*Muscicapa dauurica*), Mugimaki Flycatcher (*Ficedula mugimaki*), and Yellow-rumped Flycatcher (*Ficedula zathopygia*).

Similarly, the butterfly community has been dominated by common and highly adaptable species, such as the Painted Jezebel (*Delias hyparete metarete*) and Lemon Emigrant (*Catopsilia pomona pomona*). A few relatively rare species of butterflies have also been sighted on a number of roof gardens, including the Common Archduke (*Lexias pardalis dirteana*), Common Birdwing (*Troides helena cerberus*), Green Baron (*Euthalia adonia pinwilli*), and Scarce Silverstreak (*Iraota rochana boswelliana*).

Perhaps the most noteworthy bird sightings have been a Blue Rock Thrush (*Monticola solitarius*)—a very rare winter visitor—at the skybridge on the 50th storey of Pinnacle @ Duxton and the

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Apefly (*Spalgis epius epius*), which was recorded at the Marina Bay Sands SkyPark on the 57th storey. The unexpectedly high diversity along with some unique surprises are indications of the potential of Singapore's roof gardens to act as havens for urban biodiversity. It is interesting to note that some of the butterflies with their small wings were able to travel up into these gardens, ranging from 8 to 189 metres in height!

The research has found that these birds and butterflies do not behave much differently from what we usually see on the ground level. Most birds choose to perch in the garden and sing in the early morning. Some fly from tree to tree within the garden, perhaps looking for food such as seeds or fruits and nectar from the trees. Butterflies were observed flying around the garden and feeding on flower nectar. Both birds and butterflies have been seen to make nests or lay eggs on garden plants respectively, suggesting that roof gardens are suitable sites for their reproduction. Juvenile birds sometimes follow their adult caregiver around, demanding to be fed, or wait patiently for their parent to return. These observations build evidence that roof gardens actively support biodiversity.

Factors Influencing Garden Attractiveness to Wildlife

The study is improving our understanding of what promotes wildlife biodiversity in a roof garden. Structural features that appear to influence the visitation of birds and butterflies include the garden's height from the ground level, its floor area, and the presence of human-relevant features. Gardens on lower levels and those with a relatively larger floor area tend to attract more birds and butterflies than those on higher levels and with smaller areas. Some birds frequently use human-relevant structures like lampposts, railings, ledges, and water bodies. These structural features of the gardens may be relevant to architects and planners seeking to design buildings that exhibit a wildlife-friendly design.

Vegetative features of rooftop gardens also affect the abundance of birds and butterflies. Gardens with tall trees and

dense vegetation cover tend to support the greatest numbers of animals. Botanical features such as richness in plant species, number of trees, and tree crown cover are more likely to play roles in attracting birds and butterflies. Finally, the amount of vegetation at the ground level, and its distance from the garden, is another factor that appears to influence the roof garden's wildlife biodiversity. The data obtained so far seems to suggest that birds and butterflies tend to visit roof gardens that are more isolated from the greenery on the ground level. Think about it this way: a bird or butterfly would probably not want to venture up to a roof garden if there were plenty of food downstairs! These vegetative features are of high relevance to the building managers and those responsible for making decisions about what to plant, how to plant, and how to maintain (or prune) the rooftop garden. Generally speaking, the more a garden is like a natural habitat and provides wildlife-relevant resources, the more likely it will be to attract urban biodiversity, a concept illustrated below.

Using Plants to Attract Wildlife

One of the most direct ways to encourage animals to visit roof gardens is to selectively plant species that provide important resources to wildlife. By assessing which garden plants the animals are visiting, it is possible to pick out those with the most attractive fruits, seeds, and nectar to the greatest variety of birds and butterflies and those that contribute to the reproduction of the wildlife.

Plants that have the potential to attract the greatest number of birds and butterflies include the Singapore Rhododendron (*Melastoma malabathricum*), Fishtail Palm (*Caryota mitis*), Sea Hibiscus (*Talipariti tilliaceus*), and Sea Apple (*Syzigium grande*). Their fruits and/or nectar are highly sought after by birds such as the Scarlet-backed Flowerpecker (*Dicaeum cruentatum*), Pink-necked Green Pigeon (*Treron vernans*), Oriental White-eye (*Zosterops palpebrosus*), and Crimson Sunbird (*Aethopyga siparaja*). Butterflies such as the Centaur Oakblue (*Arhopala centaurus nakula*) and Common Mormon



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1. Yellow-rumped Flycatcher, an uncommon winter visitor in Singapore, was sighted on a roof garden.
2. Scarce Silverstreak, an uncommon butterfly, was spotted feeding on nectar of *Ixora* 'Super Pink'.
3. Apefly recorded at the Marina Bay Sands Hotel SkyPark.
4. An Olive-backed Sunbird feeding on a banana blossom.
5. A female Pink-necked Green Pigeon nesting in a bamboo bush.



(*Papilio polytes romulus*) also like to sip nectar from the Singapore Rhododendron. Fishtail Palm, Sea Hibiscus, and Sea Apple double as butterfly host plants for the Common Palmfly (*Elymnias hypermnestra agina*), Common Tit (*Hypolycaena erylus teatus*), and Centaur Oakblue respectively.⁵ These plants act as breeding grounds for butterflies to lay eggs and caterpillars to feed.

At one of the study sites, Khoo Teck Puat Hospital, special effort has been made to support the Common Birdwing butterfly. This species has gone extinct in the wild, but can still be found in managed gardens where the Dutchman's Pipe (*Aristolachia* sp.) is planted.⁶ Like most butterfly species, the Common Birdwing has a very special association with very few (and sometimes only one) species of plant—termed the “host plant”—upon which it exclusively lays its eggs. The Dutchman's Pipe has leaves that are nutritious for the Common Birdwing caterpillars. Since butterfly species differ in their host plants, building managers can focus their efforts on attracting and conservation of particular butterfly species by planting specific host plants.

As an added bonus, not only are the above plants attractive, they are also native. In this manner, planting these wildlife-friendly plants in roof gardens can help conserve Singapore's native floral diversity as well as animal diversity. The list of recommended plants for biodiversity-friendly roof gardens suggested by this study runs much longer than what is indicated here, and it is still growing with continued surveys. A rich mixture of plant species on the green roof would be able to not only attract but also support more diverse groups of wildlife in the long run.⁷

What Do People Think of Wildlife on Roof Gardens?

Positive public perception of roof gardens would likely lead to greater levels of support for conservation. Roof gardens have the potential to serve as key conservation sites in Singapore's

urban environment. Incorporating skyrise greenery on new buildings and selectively planting species that attract birds and butterflies can bring biodiversity closer to the public. But what do people think of wildlife on roof gardens? Do they welcome these beautiful winged creatures, or should roof gardens only provide for people's aesthetic pleasure and recreational needs?

A perception survey found that most people expect roof gardens to fulfil the environmental roles of air purification, heat reduction, and aesthetic improvement, with the role of enhancing urban biodiversity ranking fourth. When asked if they would support the notion of attracting wildlife onto roof gardens, a large majority of respondents were agreeable and recognised the various potential ecosystem benefits; it is encouraging to note that birds and butterflies came out top as the most desired animals on roof gardens. They also preferred naturalistic gardens with complex vegetation structures, but would also like to have seats, shelters, and other simple facilities. Correspondingly, most people want roof gardens to meet the needs of both people and wildlife—the best of both worlds!

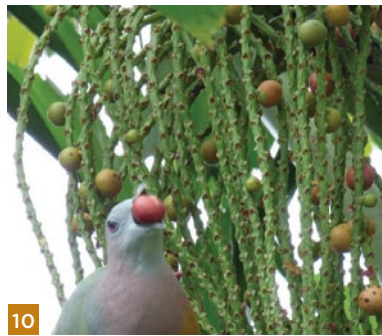
Such support for the cause, however, will only be sustained if the perceived undesirable aspects of wildlife are minimised. For example, many of the survey respondents suggested that insects such as bees and dragonflies may not be equally welcome. Even if birds and butterflies are desired, the garden managers and the visitors may not be able to effectively manage or tolerate the sight of droppings, nests, eggs, and caterpillars. Considering public perception and impressions surrounding this topic, the project results may prove to be relevant and practical to enhancing urban wildlife in ways that benefit the public.

Harmonising the Ecological and Sociological Roles of Roof Gardens

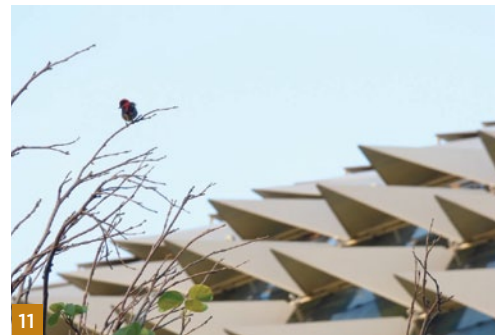
Looking ahead, as Singapore continues to add skyscrapers to its landscape, skyrise greenery that is conducive for both people and wildlife can be incorporated. Such gardens should have a




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high diversity of recommended bird and butterfly food plants in a lush natural environment that also includes simple facilities to encourage human visitation. Public education can further help to raise awareness and appreciation towards roof gardens and all forms of associated urban biodiversity. With the support of people, roof gardens have strong potential to be sustainable biodiversity oases. 

- 1 United Nations, Department of Economic and Social Affairs, Population Division, *World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352)* (United Nations, 2014), <http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf>.
- 2 Nicholas S.G. Williams, Jeremy Lundholm, and J. Scott MacIvor, "FORUM: Do green roofs help urban biodiversity conservation?," *Journal of Applied Ecology* 51 (2014): 1643-1649.
- 3 Erica Oberndorfer, Jeremy Lundholm, Brad Bass, Reid R. Coffman, Hitesh Doshi, Nigel Dunnett, Stuart Gaffin, Manfred Köhler, Karen K.R. Liu, and Bradley Rowe, "Green roofs as urban ecosystems: ecological structures, functions and services," Paper 1, *Architectural Science Publications and Research* (2007), <http://digital.library.ryerson.ca/islandora/object/RULA%3A376>.
- 4 Joelyn Oh (Manager of Skyrise Greenery & Projects at National Parks Board), email to Jessca Bramley-Alves, June 10, 2015.
- 5 Lian Pin Koh, Navjot S. Sodhi, and Barry W. Brook, "Ecological correlates of extinction proneness in tropical butterflies," *Conservation Biology* 18 (2004): 1571-1578.
- 6 Ibid.
- 7 Jeremy T. Lundholm, "Green roof plant species diversity improves ecosystem multifunctionality," *Journal of Applied Ecology* 52 (2015): 726-734.
6. A Painted Jezebel laying eggs on a mistletoe leaf.
7. A naturalistic rooftop garden at Subaru Motor Image Enterprises that allows the growth of spontaneous vegetation where minimal maintenance work is conducted. The presence of many tall trees encourages bird visitation.
8. The roof garden at Khoo Teck Puat Hospital is densely planted with flowering shrubs, making it very attractive to butterflies.
9. A Javan Munia taking a bath and sip by a pond at Pan Pacific Singapore's Japanese garden.
10. A Pink-necked Green Pigeon eating Fishtail Palm fruits.
11. A Scarlet-backed Flowerpecker perches on a tree on Esplanade's sky terrace.