CHAPTER 17

The HortPark Bee Trail: Habitat Enhancement and Education for Bees in Singapore

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Introduction

Bees play an integral role to Singapore's ecosystems. As major pollinators of native and cultivated plants, bees maintain the genetic diversity of wild plant populations and support the productivity of urban edible gardens. However, the general public in Singapore is largely unaware about native bee diversity, and the fear of bees is common among Singaporeans. This is in spite of the fact that the city-state is home to a rich diversity of about 140 bee species (Ascher *et al.*, 2022; Soh & Ascher, 2020), most of which are docile and pose little risk to people. In addition to a paucity of local outreach efforts for bees, targeted efforts to conserve bee diversity, such as habitat enhancements, are relatively novel in Southeast Asia. Our objectives for this project were thus to:

1. Develop a locally relevant, evidence-based bee planting palette for Singapore using data on bee foraging and nesting;
2. Pilot the bee planting palette together with artificial nest boxes to conserve a rich diversity of native bee species, in conjunction with providing interpretative signs and programming for public education;
3. Partner with the community to further address the knowledge gap and sustain bee conservation efforts.

Methods

Planting palettes for bees

Planting schemes to support butterflies are well documented and established in Singapore, but very little similar information is available for bees. Like butterflies, adult bees and their offspring rely almost entirely on plants for sustenance. While several species in the tropics are known to be generalists (e.g., the honey bees, *Apis* spp.), a large proportion of species exhibit foraging preferences for pollen and require suitable flowering plants to persist. In addition to food, twig-nesting small carpenter bees and reed bees (*Ceratina* spp. and *Braunsapis* spp. respectively), stingless bees (Tribe Meliponini), and leafcutter bees (*Megachile* spp.) rely on particular plants for nesting sites and/or nest-building materials (e.g., leaves, resin).

To build our planting palette, we compiled bee-plant interaction data from field surveys across parks in Singapore, published research papers (e.g., Soh & Ngiam, 2013; Ascher *et al.*, 2019), museum reference collections (e.g., the Lee Kong Chian Natural History Museum), and photographs taken by citizen scientists (e.g., nation-wide BioBlitz). Plant species with greater frequency of interactions with bees at multiple sites were scored as more effective bee-attracting plants. We also recorded plant species that were used by bees for nesting material or nesting sites, and collaborated with the National University of Singapore to document examples (Soh *et al.*, 2019). These were combined to create the first planting palette that contains forage and nesting plants, tailored to supporting native bee diversity for Singapore (see Appendix 1).

Bee hotels

Several species of solitary, cavity-renting bees of the family Megachilidae naturally nest in pre-existing cavities in the environment, such as in dead wood. However, such natural nesting sites are often scarce in urban areas and managed parks. Artificial nest boxes used to supplement the lack of nesting sites and support populations of these solitary bees are known as "bee hotels". Bee hotels have been widely implemented in farms, parks, and urban areas across North America and Europe to bolster solitary bee populations, but have not been tested widely in Southeast Asia. Solitary wasps, which play a beneficial ecological role as natural enemies to herbivorous insects, may also nest in bee hotels. Crucially, unlike the social honey bees which tend to sting when their hives are disturbed, solitary bees and wasps are docile and do not defend their nests, preferring to flee instead. Thus, from a public risk management perspective, bee hotels were assessed to be safe to be sited in areas of human activity. We therefore sought to implement bee hotels and test their effectiveness as habitat enhancement in Singapore.

HortPark Bee Trail

A hub for novel horticulture research and initiatives, HortPark was found to be an ideal site to trial the bee habitat enhancement initiatives. HortPark's bee fauna had also been very well surveyed relative to many areas in Singapore, being one of the study sites of pollinator research by Soh & Ngiam (2013). We decided to leverage HortPark's collection of garden plots by implementing the bee habitat enhancement features as a trail across three existing thematic gardens: the Native Garden, the Butterfly Garden, and the pollinator-friendly Edible Garden. The inclusion of these three gardens was an opportunity to showcase the bee-supporting flora associated with three

distinct habitat contexts in Singapore (Table 1; Fig. 1–3), and concurrently highlight the diverse roles that bees play in Singapore for broader educational value.

We reviewed the three gardens along the trail, and found that most of the existing flora was suitable for bees. The trail was enhanced further through additional plantings to enhance the density and diversity of bee-supporting plants.

Table 1. Gardens of the Bee Trail.

	Description	**Educational opportunity about bees**	**Bee-supporting flora**
Native Garden	A collection of native trees and shrubs from Southeast Asian lowland forests.	Highlights the role of bees in supporting the natural ecosystem and its native biodiversity.	▪ *Ardisia elliptica* [F] ▪ *Dendrolobium umbellatum* [F+N] ▪ *Melastoma malabathricum* [F] ▪ *Premna serratifolia* [F+N] ▪ *Pluchea indica* [F] ▪ *Leea indica* [F+N] ▪ *Leea rubra* [F+N] ▪ *Kleinhovia hospita* [F]
Butterfly Garden	A mix of introduced and native shrubs and climbers that attracts butterflies.	Highlights how bee-friendly landscaping may be conducted in parks, gardens, and urban settings, particularly alongside existing enhancements to support butterflies.	▪ *Leea indica* [F+N] ▪ *Rotheca myricoides* [F+N] ▪ *Antigonon leptopus* [F+N] ▪ *Stachytarpheta indica* [N]
Edible Garden	Plots of edible vegetable and fruit crops	Highlights the role of bees in supporting edible gardening in Singapore.	▪ *Talinum triangulare* [F] ▪ *Luffa aegyptiaca* [F] ▪ *Citrullus lanatus* [F] ▪ *Psophocarpus tetragonolobus* [F] ▪ *Solanum melongena* [F] ▪ *Capsicum anuum* [F] ▪ *Ocimum basilicum* ▪ *Clitoria ternatea* [F+N] ▪ *Moringa oleifera* [F]

[F] – Forage plants

[N] – Plants which provide nesting sites or nesting material for bees

Figs. 1. Bee-attracting flora in the Native Garden. (Photo credit: Zestin Soh)

Figs. 2. Bee-attracting flora in the Butterfly Garden. (Photo credit: Zestin Soh)

Figs. 3. Bee-attracting flora in the Edible Garden. (Photo credit: Zestin Soh)

Coupling interpretative signage with nest boxes

We designed eight frames for installing bee hotels along the trail, each with a roof to keep out the rain. The frames allowed the bee hotels to be modular, making it easy to re-orientate the blocks, and add or remove materials for maintenance if required. Each frame also doubled as educational signage, with a side featuring a poster containing pictures, text and a QR code to an online trail guide. These frames were then positioned strategically along the trail as markers to highlight interesting bee-related features in each of the three thematic gardens (Fig. 4).

Seven frames were installed with bee hotels. Inside the eighth frame, we placed a box hive of Valdez's Stingless Bees (*Tetragonula valdezi*) that had been rescued from an abandoned fridge. This harmless native species is common and naturally occurring at HortPark. We also set a disused upturned plant pot containing a hive of the same stingless bee species along the trail. Both the bee hotels and the stingless bee hives allowed visitors to safely observe bees that are lesser known and often overlooked by the public.

Fig. 4. Frame installed with bee hotel showing the interpretative sign. (Photo credit: Zestin Soh)

Monitoring

To test the effectiveness of the bee planting palette and bee hotels in supporting bees, we conducted observational surveys to record bee diversity along the HortPark Bee Trail twice a month.

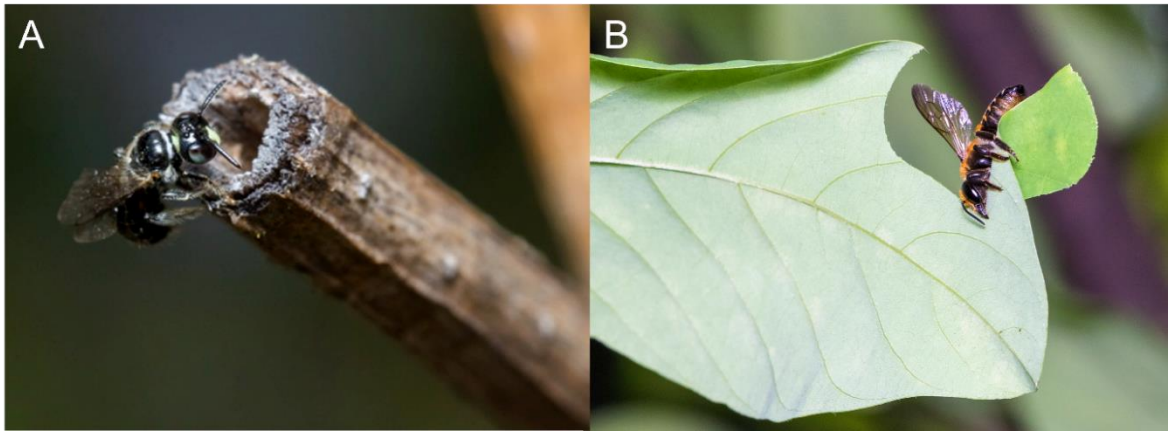
Results and discussion

Launch and public outreach

The trail was launched on 15 September 2018, and members of the public were invited to the event. Students of Jurong West Primary School were trained as station guides for the bee trail to engage the public and share with them facts about native bees and the bee-supporting plants. Over 200 visitors attended the event and walked the trail. Since then, guided walks by volunteer guides at the trail have been conducted quarterly, and the venue is used for workshops on bee species identification.

Bee diversity and newly recorded species

Over the monitoring period along the Bee Trail between 15 September 2018 to 22 September 2019, we recorded a rich diversity of 31 bee species along the trail. This included seven new bee records for the park, bringing the recorded diversity for HortPark to 40 species (see Appendix 2). For comparison, only 20 bee species were recorded over seven months in HortPark in 2012 (Soh & Ngiam, 2013). The vast majority of the species recorded was seen visiting flowers. This included the newly recorded rare *Ceylalictus communis* and *Nomia thoracica*, which were observed visiting *Pluchea indica* and *Leea rubra* respectively. We also observed *Braunsapis hewitti* nesting within *Rotheca myricoides* (Fig. 5) and *Megachile* bees cutting foliage plants along the trail, demonstrating that the nesting plants were used.



Figs. 5. Examples of bees using plants for nesting: (A) Hewitt's Reed Bee (*Braunsapis hewitti*) nesting in a pithy stem of *Rotheca myricoides*; (B) Broad-headed Leafcutter Bee (*Megachile laticeps*) gathering a piece of leaf from *Dendrolobium umbellatum*. (Photo credit: Zestin Soh)

Bee hotel occupancy

Occupants were seen in only four of the seven bee hotels along the trail over the one-year monitoring period. These active hotels were under semi-shade, whereas the three empty hotels were under full sun – a crucial learning point for future siting of bee hotels. Nonetheless, the four active bee hotels were utilised by seven species of Megachilid bee for nesting (Fig. 6), four of which are new bee records for HortPark. The most significant bee found was *Anthidiellum smithii* (Fig. 6G), a rare solitary bee species that was last recorded for Singapore in 2015 in the vicinity of Bukit Timah Nature Reserve (Soh & Soh, 2020). We also observed and documented for the first time two rare instances of cleptoparasitism by native cuckoo bees: the first instance being *Coelioxys confusus* (Fig. 6E) on *Megachile tricincta* (Fig. 6A), and second being the rare *Euaspis polynesia* (Fig. 6F) on the uncommon *Megachile fulvipennis* (Fig. 6D). These observations demonstrate that bee hotels in Singapore may not only support common species (such as *Megachile laticeps* and *Megachile disjuncta*), but rare ones as well.

Figs. 6. Bee occupants of the Bee Hotels along the HortPark Bee Trail: (A) Golden-bellied Leafcutter (*Megachile tricincta*); (B) Broad-headed Leafcutter (*Megachile laticeps*); (C) Disjunct Resin Bee (*Megachile disjuncta*); (D) Orange-winged Resin Bee (*Megachile fulvipennis*); (E) Confusing Sharp-tailed Bee (*Coelioxys confusus*); (F) Asian Chilli-tail Bee (*Euaspis polynesia*); (G) Smith's Rotund-Resin Bee (*Anthidiellum smithii*). (Photo credit: Zestin Soh)

Conclusion and future directions

The HortPark Bee Trail was developed with the intention of trialling and showcasing contextualised habitat enhancement for bees and providing a unique venue for public education on Singapore's bee diversity. Bee hotels were installed along the trail amongst bee-supporting plants, together with educational signage and a link to an online trail guide. Trail users can observe bees nesting in the bee hotels, or foraging for food among the bee-attracting plants. The trail is safe, as it only promotes flower-visitation by honey bees and nesting of solitary bees and stingless bees. Since its launch, over 30 bee species had been observed foraging and nesting along the trail.

The monitoring of the trail's bee hotels had provided insights in informing how bee hotels should be set up to maximise usage by bees. The information had been used in a new bee hotel programme for community gardens, launched by Community-in-Bloom. All participating gardens would receive a bee hotel that they could set up and monitor to provide more data on bee habitat enhancement.

Fig. 7. A bee hotel provided to community gardens. (Photo credit: Jacqueline Chua)

Data on bee-plant interactions were compiled to ensure that the planting palette was evidence-based and locally relevant. Information on these bee-supporting plants was also included in a published guidebook to the bees of Singapore (Soh & Ascher, 2020), as well as in the latest expansion of the NParks Flora & Fauna Web (FFW), an online database for plants. The database

is growing and constantly being updated with ongoing research. It is our hope that with all the available information on bee-supporting plants, landscapers will have quick and easy access to a wide selection of suitable plants to create successful pollinator-friendly gardens by habitat restoration and enhancement across Singapore.

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Appendix 1: Bee-supporting planting palette.

Highly attractive bee forage plants

Common name(s)	Scientific name	Honey Bees	Stingless Bees	Leafcutter Bees	Large Carpenter Bees	Digger Bees	Nomias	Sweat Bee	Cloak-and-Dagger Bees	Reed Bees	Small Carpenter Bees
Long-leaved Beauty Berry	*Callicarpa longifolia*	+	+			+	+			+	
Red Leea & Common Tree-vine	*Leea rubra & Leea indica*	+	+			+	+	+		+	+
Buas-buas	*Premna serratifolia*	+	+	+				+	+	+	
Senduduk, Singapore Rhododendron	*Melastoma malabathricum*				+	+	+			+	+
Spicate Eugenia	*Syzygium zeylanicum*	+	+	+	+		+	+		+	
Petai Laut	*Dendrolonium umbellatum*			+			+				
Simpoh Air	*Dillenia suffruticosa*	+	+		+	+	+			+	+
Yellow Cow Wood	*Cratoxylum cochichinense*	+	+	+	+		+				+
Seashore Ardisia	*Ardisia elliptica*		+		+	+	+				
Nipis Kulik, Blue Strawberry Flowers	*Memecylon caeruleum*			+		+	+				
Gelam	*Melaleuca cajuputi*	+	+					+			
Kemunting, Rose Myrtle	*Rhodomyrtus tomentosa*				+	+	+	+		+	
Snakeweed	*Stachytarpheta* spp.	+			+	+	+		+	+	
Hairy Beggarticks	*Bidens pilosa*	+	+	+		+	+	+	+	+	+
Blue Glory Bower	*Rotheca myricoides*		+		+		+			+	
Coral Vine, Honolulu Creeper	*Antigonon leptopus*	+	+	+	+		+			+	+
Dark-eyed Turnera	*Turnera subulata*	+	+		+	+		+		+	+
Chinese Violet	*Asystasia gangetica*	+	+	+		+	+	+	+	+	+
Golden Bells	*Tecoma stans*	+			+	+			+	+	+
Buah Cheri, Malayan Cherry	*Muntingia calabura*	+	+	+	+		+	+		+	+
String Bush	*Cordia cylindrostachya*	+		+	+		+		+		
Fiddlewood	*Citharexylum spinosum*	+			+		+			+	+
Winged Bean, Four-angled Bean	*Psophocarpus tetragonolobus*			+	+		+				
Basil	*Ocimun* spp.	+	+	+		+		+	+	+	+
Waterleaf, Surinam Purslane	*Talinum triangulare*	+	+	+		+		+		+	
Sponge Gourd	*Luffa aegyptiaca*	+	+		+		+	+			+

Note: Green: native; Blue: introduced & non-edible; Orange: introduced & edible crops.

Plants with leaves used by leafcutter bees

Common name	Scientific name
Petai Laut	*Dendrolobium umbellatum*
Yellow Cow Wood	*Cratoxylum cochinchinense*
Candlebush	*Senna alata*
Common Bauhinia	*Phanera kockiana*
Indonesian Bay Leaf	*Syzygium polyanthum*

Plants with pithy-stems suitable for twig-nesting small carpenter bees and reed bees

Common name	Scientific name
Peacock Flower	*Caesalpinia pulcherrima*
Buas-Buas	*Premna serratifolia*
Blue Glory Bower	*Rotheca myricoides*
Common Tree-vine	*Leea indica*
Coral Plant, Fountain Bush	*Russelia equisetiformis*
Pink Mussaenda	*Mussaenda erythrophylla*

Appendix 2: Bees of HortPark

Common name	**Scientific name**
Black Dwarf Honey Bee	*Apis andreniformis*
Red Dwarf Honey Bee	*Apis florea*
Asian Honey Bee	*Apis cerana*
Giant Honey Bee	*Apis dorsata*
Valdez's Stingless Bee	*Tetragonula valdezi*
Orange-legged Combed-Sweat Bee	*Lasioglossum deliense*
White Combed-Sweat Bee	*Lasioglossum albescens*
Wandering Combed-Sweat Bee	*Lasioglossum vagans*
Tooth-legged Small Carpenter	*Ceratina dentipes*
Lieftinck's Small Carpenter	*Ceratina lieftincki*
Perforatrix Small Carpenter	*Ceratina perforatrix*
Hewitt's Reed Bee	*Braunsapis hewitti*
Puang Reed Bee	*Braunsapis puangensis*
Broad-handed Carpenter	*Xylocopa latipes*
White-cheeked Carpenter	*Xylocopa aestuans*
Yellow-and-black Carpenter	*Xylocopa flavonigrescens*
Cerulean Carpenter	*Xylocopa caerulea**
Sunda Banded-Digger	*Amegilla andrewsi*
Koroton Banded-Digger	*Amegilla korotonensis*
Himalayan Cloak-and-Dagger Bee	*Thyreus himalayensis*
Thai Epaulette-Nomia	*Pseudapis siamensis*
Red-waisted Grass-Nomia	*Lipotriches ceratina*
Indomalayan Pronged-Nomia	*Nomia incerta*
Felt-topped Nomia	*Nomia thoracica**
Striped Nomia	*Nomia strigata*
Iridescent Nomia	*Nomia iridescens*
Blood Bee species	*Sphecodes* sp.

*New records for HortPark since launch of the Bee Trail

Appendix 2: Bees of HortPark *(Cont'd)*

Common name	**Scientific name**
Kuala Lumpur Steppe Bee	*Ceylalictus communis**
Smith's Rotund Resin Bee	*Anthidiellum smithii**
Asian Chilli-tail Bee	*Euaspis polynesia**
Orange-belled Leafcutter	*Megachile subrixator*
Broad-headed Leafcutter	*Megachile laticeps*
Shadow-winged Resin Bee	*Megachile umbripennis*
Golden-bellied Leafcutter	*Megachile tricincta**
Disjunct Resin Bee	*Megachile disjuncta*
Orange-winged Resin Bee	*Megachile fulvipennis**
Tuberculate Resin Bee	*Megachile tuberculata*
Confusing Sharp-tailed Bee	*Coelioxys confusus*
Woodborer Bee	*Lithurgus* sp.
Armoured Resin Bee	*Heriades othonis*

*New records for HortPark since launch of the Bee Trail