Bee harmony: an investigation into flower visitor diversity

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Forward

The question asked was if the increased presence of honey bees on North Stradbroke island interfered with the native bees? This is a difficult to answer directly, and the approach taken was to monitor the flower visitors through intervals in a year to capture their activity in each season, and overall.

Firstly, a review of the flora on the island was undertaken and possible species that would be flowering in each season identified.

A new technology was adapted from the Marine Futures Lab using Go-Pro cameras and special software for their analysis. Video analysis opened student training opportunities converting a manual system into an automated one using artificial intelligence. Whilst not reported in this project report, achieved was the detection of the entry and exit of an insect, cutting down the time observing video footage for insect activity.

The surprise of the analysis was the variety of insects visiting the flowers. Whereas this project started out as looking at the relationship between honey bees and native bees, it ended with considering all insect interactions and coming to unexpected conclusions. Evident was that there was a complexity that has not often been noted in the literature, and this may be due to the advancement in monitoring technology.

Each season showed varying insect presence and interactions. Caution on a steadfast conclusion is advised as this study only captures a single year, and a very dry year on North Stradbroke Island.

Whilst this project was looking to solve a competition question, inadvertently it did identify flora that supports native insect populations for pollination services, and this information could be useful for mine rehabilitation on the island.

Dr Liz Barbour
CEO

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Marine Futures Lab(https://meeuwig.org/) for their support for this project through their guidance setting up the equipment and analysing the data. Changing from monitoring fish to insects was an interesting challenge.

Executive Summary

Highlighted is that the flower visitor community is diverse, and honey bees are one of many species that collect resources from the flowers on North Stradbroke Island. There was an abundance of flower visitors in recordings over the year. Bees (both native and honey) accounted for only 13.9% of flower visitors, with the remaining 86.1% mainly being ants and flies. The inclusion of these other flower visitors when considering the competitive exclusion of native bees is limited to few studies.

Honey bees have resided on North Stradbroke Island for at least 50 years and impacts to native bee survival may have already occurred. There was no previous data on the island flower visitors to compare, however this study recorded a wide taxonomic diversity of native bees and in the same proportions to honey bees as recorded elsewhere in Australia (Goulson et al., 2002).

The flower visitors liked the same flowers. Overall, honey bee activity was positively correlated with the taxonomic richness, diversity and abundance of native flower visitors. Plants closer to apiary locations also had a higher abundance of native flower visitors that spent longer on flowers and arrived on flowers more often.

When looking at the activity of specific flower visitor groups: ants, beetles and butterflies and moths (with the exception of flies), there was a negative correlation with native bee activity. With ants accounting for the majority of flower visitors (42.7 ± 7%) and the highest niche overlap found between native bees and ants, it is likely that these species are more competitive with native bees than any other group. Additionally, beetles (6.6 ± 2.1% of flower visitors) and butterflies and moths (2.5 ± 0.7% of flower visitors) are also likely to be competitors with native bees.

Different insect relationships were observed across plant groups. There was no evidence of competition on Acacia and the tree plant groups (*Eucalyptus, Corymbia* and *Elaeocarpos* species). The spike plant group appears to be the most important floral resource for native bees, followed by the tree plant group, shrub plant group and the Acacia plant group. These plant groups were also a major floral resource for honey bees.

Native bee activity was the highest during the warmer months of February - May and lowest in July – December. However, our results show no obvious flowering periods to avoid with honey bees to have complete certainty of possible native bee and honey bee competition.

We have shown that honey bees and native bees share resources and made observations that are suggestive of small scale competitive exclusion, but this does not necessarily mean that competition is occurring. Moreover, what we observed could change with a climatically-influenced different flora source the next year.

A low-cost approach to test for a causative link would be to measure native bee survival, fecundity and population numbers through routine monitoring of bee 'hotels' for solitary bee species and hives for stingless bees in areas of the island with differing numbers of honey bee hives. Coupling this monitoring with artificial manipulation of honey bee hives would provide a powerful definitive test for competition between native bees and honey bees.

Alternatively, competition could be overcome, and compliment the survival of insects, through native flora resource development on North Stradbroke island. Reclaiming native landscapes provides more floral resources for both native flower visitor species and honey bees and can benefit other species in these ecosystems.

A final medium for honey bees to affect native bees is through the transmission of shared pathogens. From our observations of generally low amounts of disease in the apiaries, it is unlikely that disease spread to native bees more than from other hives already present on the island.

Introduction

The European honey bee (Apis mellifera, hereby referred to as honey bee) is an important species for Australian agriculture. Europeans brought the honey bee to Australia during the British colonial period (1820s) initially to produce honey. However, pollination services became more important as European crop species spread (Thorp, 1987). Australia is now dependent on 65 % of its (non-native) crops being pollinated by honey bees which have been valued at $14 billion (Karasinski 2018).

Australia's flora and environmental conditions allow the honey bee to collect nectar throughout the year and the species has thrived to the point where it is now regarded as feral. Their thriving is due to their reproductive swarming from managed hives and subsequent occupation of suitable cavity nesting sites, whether in buildings or in the bush. Unfortunately tree hollows are under pressure with Australia's endemic fauna as well as feral fauna (mainly birds) and honey bees (where there is a water-source) all vying for the space. Intensive logging and fire regimes are reducing the number of tree hollows creating competing demand in some regions.

It is not possible for honey bees to rely on agricultural food crops throughout the year. Many crop species, such as wheat, oats, barley and sorghum, are wind pollinated, and so do not supply nectar to attract, and therefore feed, honey bees. Nectar-producing food crops, such as canola and legumes, have annual cropping cycles. They flower for only just a few weeks a year. Modernised agricultural cropping practices in Australia have led to less fallow periods and the employment of more sophisticated targeted herbicides, biological controls and fertilisers. These practices have resulted in a decline in many of the native flowering ground flora plants and 'weed' species beekeepers rely on to support their honey bees. An example of a weed species is Salvation Jane (Echium plantagineum) which was an important food source for honey bees in spring.

Due to the seasonality of agricultural crops, honey bees must spend some period of the year feeding on native flora. The only alternative is an artificial diet of sugar solution and pollen-substitute protein source. This is an expensive option, and not economically viable for beekeepers as agriculture-food pollination services are under-valued. Consequently, Australian beekeepers rely on native flora to sustain the health and viability of the colony.
Researchers in the 1970s questioned whether honey bees were effective pollinators of the native Australian flora and their possible ability to out-compete native flower visitors for nectar and pollen arose (Paini, 2004, Paton, 1996). This question of competition was against the backdrop of reduced native floral resources and increased use of chemicals that either killed or hindered insect reproduction, a problem honey bees and native flower visitors still face today.

All bees rely on floral resources for their food, and at least some of their water needs. Nectar provides an important energy source (carbohydrate) through supplying a complex range of sugars, whilst pollen gives vital protein and fats. The quantity and digestibility of pollen can vary greatly between plant species (Frias et al 2016; Roulston and Cane 2000), and this can directly influence the welfare of the colony.

Honey bees and native bees may compete for floral resources in natural habitats (Paini, 2004). This competition is known as resource exploitation and occurs when resource use by one species depletes the amount available to another (Roubik, 1978). Australia has an estimated 2,000 species of native bees (Houston, 2018). The majority of these are solitary and are a key part of pollination guilds that service native flora (Armstrong, 1979). It has been hypothesised competition may occur where native bee populations are constrained by resource availability (Carpenter, 1979), as unlimited resources would have no deleterious effect on native bees (McQuillan and Hingston, 1999). Such non-competitive conditions occur if plants produce superfluous amounts of floral resource to compete for the attraction of pollinators (McQuillan and Hingston, 1999, Schwarz, 1997). According to Mallinger et al. (2017), 53% of studies investigating resource exploitation suggest that honey bees have the potential to have a negative impact on native bees. The inconclusiveness of these studies highlights the challenge within the scientific community to find an approach that can conclusively demonstrate whether this competition between honey bees and native bees exists.

For there to be resource exploitation between honey bees and native bees, firstly, there must be floral resource overlap where both species collect nectar and pollen from the same plant species. Secondly, resource use by honey bees must lead to reduced resource availability and/or increased foraging costs to native bees (Roubik, 1978). This reduction in foraging by native bees would only occur if floral resources are limited. The complexity and variety of possible floral sources for native bees make it difficult to conclude if floral resources are limiting and has not been a focus in previous studies (for a logical explanation of how studies can measure evidence for competition between honey bees and native bees, see reviews by Mallinger et al., 2017, Paini, 2004). In the absence of measuring whether resources are limited throughout the entire environment, we can measure the potential for competitive exclusion through observations on plants with varying levels of honey bee resource collection. Indications that depletion of resources by honey bees results in competition with native bees could be when native bee numbers visiting flowers decline (Pyke, 1978, Inouye, 1978) and foraging time is reduced (McQuillan and Hingston, 1999, Pyke, 1978, Pyke and Balzer, 1985). Thirdly, if there is an overlap in honey bee and native bee floral resources and there is evidence that resource collection by honey bees excludes or reduces the resource collection of native bees, then it is necessary to investigate the long-term survival of native bees as a definitive measure of whether honey bees and native bees are competing in the study area.

This Project examines patterns of flower-visiting insect activity (abundance on flower, time on flower and visitation frequency) at sites on North Stradbroke Island (QLD) at varying distances from apiary locations. North Stradbroke Island was chosen as the Quandamooka Yoolooburrabee Aboriginal Corporation (QYAC) were interested in understanding if there was competition between introduced honey bees to the island and the native bee population. These data were used to assess whether native bee activity is affected by the activity of honey bees with climate and floral seasonal effects taken into account. More specifically, we examined the potential for competition through identifying:

- what potential competitors are present in the flower visitor community on North Stradbroke Island and overall trends in activity of these flower visitors due to environmental factors and honey bee activity,
- if honey bees, native bees and other native flower visitors collect nectar and pollen from the same floral resources (measured through niche overlap and preferences for specific plant species),
- whether native bee resource collection is negatively correlated with honey bee resource collection and
- whether native bee resource collection is correlated with the resource collection of other potential competitors and environmental factors.

Objective

The objective of this project is to provide evidence of the effect on native bee populations with the introduction of honey bees to the traditional lands of QYAC

Key activities

- Investigate whether there is enough food for all flower visitors, or whether competition for limited resources occurs, which may force displacement of a bee species.
- Develop and test disease control measures to prevent the introduction of disease into native bee populations.

Outcomes

- Honey bee hives can be placed on Quandamooka Yoolooburrabee Aboriginal Corporation (QYAC) traditional lands with no impact on the native bee population.
- Bee diseases are not introduced to the local bee populations.

Impact

Produce honey with no threat to the native bee populations.

*Figure 1: **Apiary and recording sites on Stradbroke Island in 2018-2019.** Plant recording sites showing those that had honey bees (Apis mellifera) present (n=73) (blue dots) and those where they were absent (n=132) (pink dots) are shown. Apiary site is indicated by yellow dots. The study area is contained within the red rectangle.*

Change in experimental conditions

Apiary sites

In the original Project Agreement, the experimental design included assessing plants that provide floral resources for flower visitors in areas on the island that had no apiary sites within range, in comparison to plants that were within range of apiary sites. On arriving on the island, and inspecting sites across the island, it became evident that this experimental condition could not be met.

Honey bees have been managed on the island for at least 50 years. The Bowman family (Stradbroke Island Organic Honey) and Medibee Apiaries are the two-main beekeepers on the island. The Bowman family have managed hives on the island since the 1980s, and currently have an unknown number of hives across 19 apiary sites across the island. Records of honey bees on North Stradbroke Island are scarce, so 50 years should be regarded as a conservative estimate of the date of honey bee introduction. The result is that there has been an unknown population and distribution of managed and feral honey bee hives and apiary sites across Stradbroke Island whilst this Project was occurring.

The new experimental design included the distance from known apiary sites (Figure 1).

Pathogen monitoring

There are a number of honey bee pathogens with a documented presence in Queensland. In order of their prevalence in Queensland (according to Roberts et al., 2015), these pathogens include:

- *Nosema* which is a fungal pathogen and measured from adult honey bees. There are two forms of this pathogen, and both *Nosema ceranae* and *Nosema apis* are likely to be present in Queensland throughout the year with spring having higher levels than winter.

- Small hive beetle (SHB) (*Aethina tumida*) is a small brown-black beetle with clubbed antennae that originated from sub-Saharan Africa and is common in Queensland. Its presence has been previously documented on North Stradbroke Island (Leemon et al., 2018) so hive beetle traps added to all hives (Figure 2)

- Chalkbrood pathogen is caused by the fungus *Ascosphaera apis*. The fungus rarely kills infected colonies but can weaken it and lead to reduced honey yields and susceptibility to other bee pests and pathogens. Its incidence is generally higher when a colony is subject to temperature changes, particularly cooler weather, or other sources of stress (Figure 2).

- Wax moth has two species: the Greater wax moth (*Galleria mellonella*) and the Lesser wax moth (*Achroia grisella*). Both species eat beeswax, particularly unprocessed wax, pollen, remains of larval honey bees, honey bee cocoon silk and enclosed honey bee faeces found on walls of brood cells. The frames within the hive are regularly inspected and changed, and stored in a cool room to kill the larvae when not in use (Figure 2).

- American foulbrood (AFB) is a fatal bacterial disease of honey bee brood caused by the spore forming bacterium *Paenibacillus larvae*. It is not a stress related disease and can infect the strongest to the weakest colony in an apiary. AFB can be measured in honey and devalue the honey. As the bacterial spores can easily be spread between hives and apiaries through beekeeping practices, AFB hives are destroyed or irradiated upon detection (Figure 2).

- European Foul Brood (EFB) is a brood disease caused by the bacterium *Melissococcus plutonius*. When at uncontrollable levels in the larval gut of bees, antibiotics, which are legal in Queensland, can be used (Figure 2) to reduce the population of *M. plutonius* and enable the colony to recover.

Other important honey bee pathogens not found in Australian include:

- *Varroa destructor* and the viruses it transmits. The main concern with this parasitic mite is its ability to transmit viruses.
- Deformed wing virus (*Iflavirus DWV)*, is transmitted by *Varroa destructor* (Roberts et al., 2015)

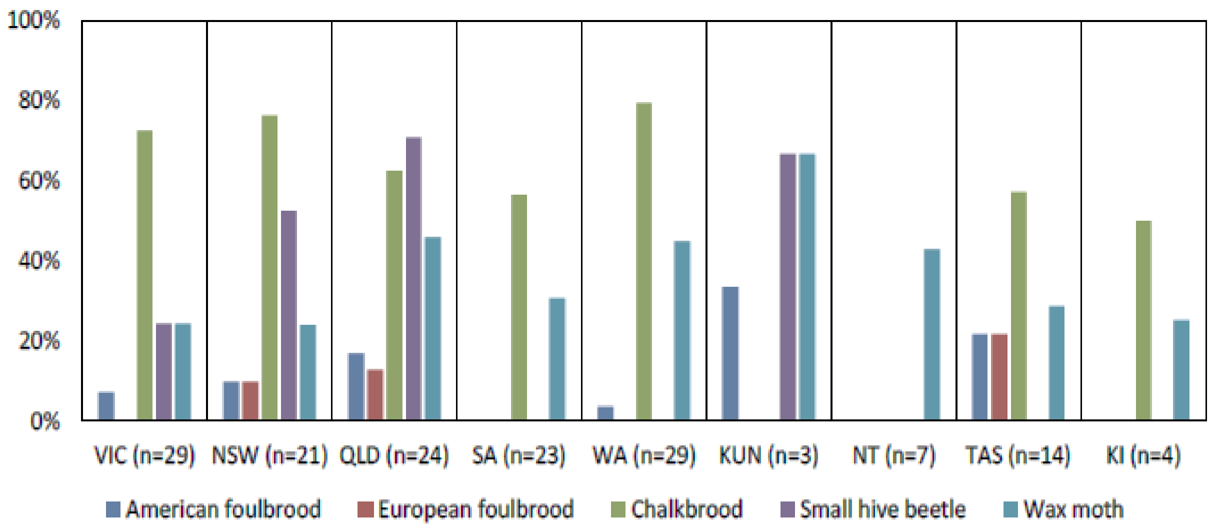

Figure 2: Percentage of hives with brood pathogens and hive pests detected during hive inspections in a national survey across Australia by Roberts et al. (2015). American Foulbrood and European Foulbrood were confirmed by Polymerase Chain Reaction. n = number of apiaries. VIC = Victoria, NSW = New South Wales, QLD = Queensland, SA = South Australia, WA = Western Australia, KUN = Kununurra, NT = Northern Territory, TAS = Tasmania and KI = Kangaroo Island.

With honey bees already present on North Stradbroke Island, the area is likely to already have a presence of AFB, EFB, chalkbrood, *Nosema*, small hive beetle and wax moth. The Project ensured that healthy hives were transferred to the island and monitored through a combination of visual hive inspections and laboratory testing for AFB and *Nosema*. The approach was taken to ensure that any hive with pathogen infestations that could not be controlled without intervention was removed from the island.

Pathogen inspections and collection of test samples were conducted by Medibee Apiary beekeepers and UWA researchers. Laboratory testing for AFB and *Nosema* was conducted by the Biosecurity Sciences Laboratory in Biosecurity Queensland Veterinary Laboratories, Department of Agriculture and Fisheries. Samples were provided to the laboratory by Medibee beekeepers.

Full visual inspections for pathogen of all 360 hives were conducted in May (29/5/2018 - 30/5/2018) and August (1/8/2018 - 2/8/2018) (Table 1). Inspections showed small hive beetle, chalkbrood and wax moth were below average levels for Queensland in the national survey by Roberts et al. (2015) (Figure 2).

Table 1: **Disease prevalence in visual inspections of honey bee hives on North Stradbroke Island**. Low = Disease detected, no detrimental effect visible. Medium = disease present, no detrimental effect visible. Heavy = disease abundant, detrimental effect visible. Note that zeros have been omitted for clarity. Neither AFB nor *Nosema* were found, and therefore are not shown in this table.

Infestation level	Number of hives			% of total hives		
	Chalk-brood	Small Hive Beetle	EFB	Chalk-brood	Small Hive Beetle	EFB
Trip 2, 28/05/2018-30/05/2018						
Any	3	12		0.8	3.3	
Low	1	6		0.3	1.7	
Medium		5			1.4	
Heavy	2	1		0.6	0.3	
Trip 3, 31/07/2018-2/08/2018						
Any	1	54	2	0.3	15.0	0.6
Low		33	2		9.2	0.6
Medium	1	21		0.3	5.8	
Heavy						

Nosema presence was tested through microscopic examination of adult bees in December 2018. Bees were collected from the entrance to hives, euthanised and stored in methylated spirits before being sent to the laboratory for examination. 50% of hives were tested with bees pooled into six tests per apiary. Each test contained equal numbers of bees from five randomly selected hives. Diagnosis of *Nosema* was not conducted to species level. *Nosema* spores were detected in all samples, indicating a prevalence of the disease throughout all apiaries. Both heavy and moderate infestations were observed in samples from Bulsey North and Bulsey South apiaries, while moderate and low infestations were observed in other apiaries (Figure 3). Compared to results from a national survey by Roberts et al. (2015), these observed levels of infestation are not unusual given the generally high averages for the whole of Australia and Queensland (Figure 4). Weather during recordings is shown in Table 4. Several recordings in April, May, December and February had rainfall, which will have made conditions humid suiting the proliferation of *Nosema*.

Small hive beetle was found in apiaries, occurring in 3.3% and 15% of all hives in May and August, respectively (Table 1). There was one account of a hive with heavy hive beetle infestation in May (with loss of bee numbers and brood) and this hive was removed and exterminated. As a precaution measure, small hive beetle traps were observed present in all hives.

Chalkbrood was rarely observed, present in 0.83% and 0.27% of all hives in May and August, respectively. In May, minor evidence of chalkbrood was observed with only a removal decision being made on two hives. As two hives (0.56%) were suspected of EFB, they were removed and exterminated in August before confirmation. Only one other hive was removed in December with a heavy wax moth presence.

AFB presence was measured through *Paenibacillus larvae* culture of honey. 100 g samples of honey were collected from five apiaries in February on North Stradbroke Island. Each sample was pooled from 10% of the hives within an apiary site, chosen at random. AFB spores were not observed in honey samples from February 2019 sampling.

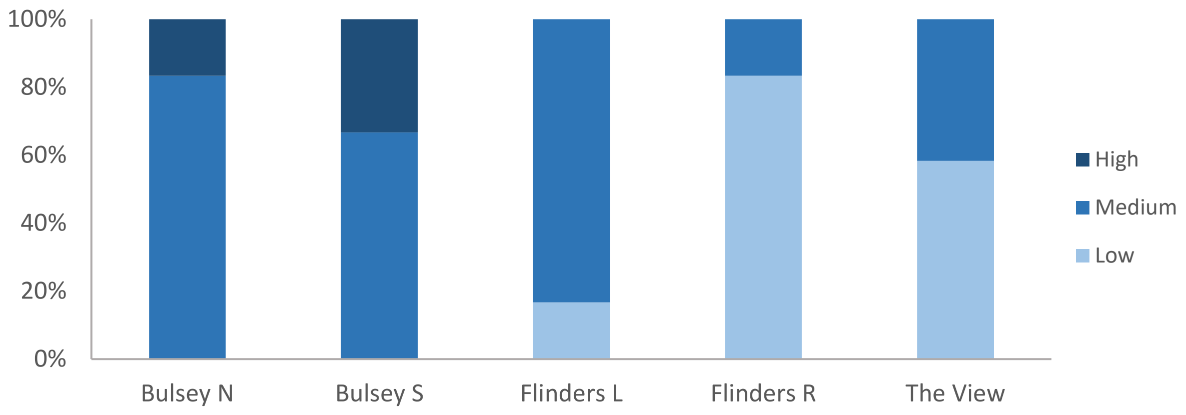

Figure 3: Percentage of samples with Nosema spore levels estimated to be high (>1000 spores), medium (>100 and <1000 spores) and low (<100 spores). Nosema spore levels were estimated from microscopic examination of adult bees in North Stradbroke Island apiaries sampled in December.

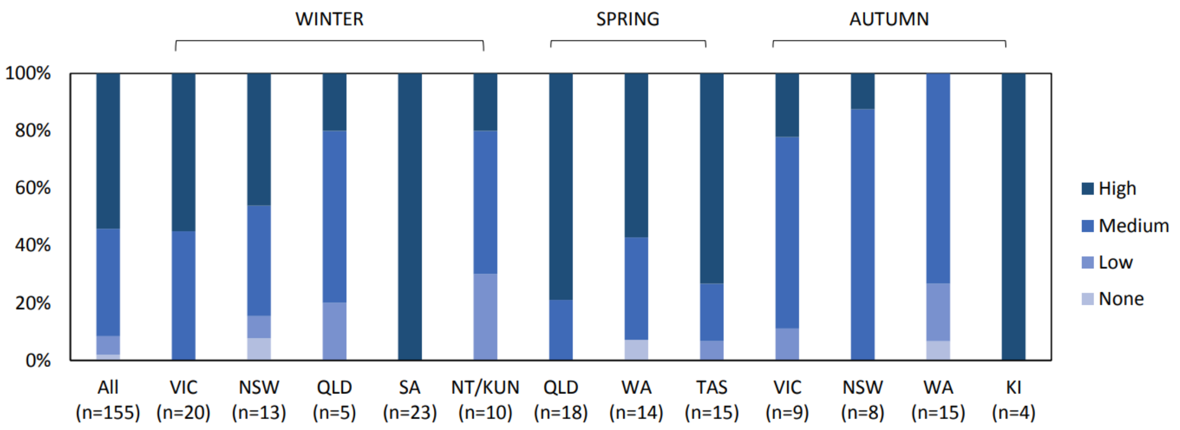

Figure 4: Percentage of samples with average Nosema spore levels estimated as high (>1000 spores), medium (>100 and <1000 spores), low (<100 spores) or none (n = sample size) from a national survey in Australia by Roberts et al. (2015). N = sample size. VIC = Victoria, NSW = New South Wales, QLD = Queensland, SA = South Australia, NT = Northern Territory, KUN = Kununurra, WA = Western Australia, TAS = Tasmania and KI = Kangaroo Island.

Flower visitor monitoring methodology

Annual cycle of flowering plants on North Stradbroke Island

The annual flowering cycle of flora on the island was collated using the available literature. From this annual flowering map, a choice of plants was identified for monitoring during each bi-monthly data collection trip.

Study site

The study site was located in the north-west region of North Stradbroke Island, Queensland (-27.4285, 153.4547) where five apiaries (360 hives) were introduced in January 2018. The region has a wide distribution of plants from heath, forest, fresh and salt-water swamps, mangrove and dune communities (Clifford et al., 1979) (Figure 1).

Camera rig design

Our camera rig design is an adaptation of the stereo baited remote underwater video systems (BRUVS) used as a non-invasive and cost-effective method of measuring fish populations (Bouchet and Meeuwig, 2015, Letessier et al., 2013). Here, we have adapted this design to monitor the activity of flower visiting species. We used these adapted BRUVS as they were well suited to the circumstances, allowing multiple plants to be recorded simultaneously in all weather conditions. Camera rigs were positioned to observe flowers of varying heights on plants of interest.

Camera rigs consist of an aluminium flat bar with a pair of GoPro Hero 5 cameras mounted in a stereo configuration. Camera housings are bolted 190 mm apart with an inward convergence angle of six degrees, allowing length measurements to be made, based on three-dimensional trigonometry (Klimley and Brown, 1983), at the minimum focusing distance of the cameras (300 mm). The rigs are mounted on tripods and are able to reach a height of 4100 mm. Cameras are set to record in medium-FOV (field of view) mode.

Video recording experimental design

The overall plan for each trip was to set cameras at four different floral sites for Day 1, 2 and 3 on two separate plant species. Distance from known apiary sites was measured and recorded. Timing depended on sunrise and sunset starting 1.5 hours after sunrise, 2 hours before sunset and the mid-point between sunrise and sunset (Table 2). The original plan was not achieved as plant selection was limited by accessibility and flowering time. The final monitoring plan is outlined in Table 3 with further pictorial description in Appendix 1.

We obtained 205 separate videos that each recorded one hour of flower visitor activity. These recordings included 72 plants from 24 plant species over the six field trips (Table 3).

Plants that were monitored were placed into similar groups based on taxonomy and structure; Acacia and Leptospermum based on genera and trees, spike plants and shrub plants based on size and inflorescence.

1. Acacia: *Acacia concurrens, Acacia longifolia*
2. Tree species: *Alphitonia excelsa, Corymbia intermedia, Elaocarpus obovatus, Eucalyptus haemastoma, Eucalyptus robusta*
3. Spike plants: *Banksia integrifolia, Banksia serrata, Melaleuca pachyphylla, Melaleauca quinquenervia, Xanthorrhoea australis*
4. *Leptospermum: L. juniperinum, L. liversidgei, L. trinervium*
5. Shrub plants*: Aotus lanigera, Astrotricha longifolia, Austromyrtus dulcis, Conospermum taxifolium, Dilwynia retorta, Lantana camara, Persoonia virgata, Ricinocarpos pinifolius, Woollsia pungens*

Four plants from one to two plant species were recorded from each day over three days per visit. At least two plants from each species were selected from the flowering plants found during initial searches. Plant selection prioritised plants of the same species that were the largest distance apart (one close and one far) from known apiary locations to increase the likelihood of a contrast in honey bee activity. Figure 1 show the recording and apiary locations.

Table 2: Showing the bee activity monitoring times for each day. Recordings were repeated for 3 days to assess 12 plants per visit. Recording times were consistent relative to sunrise and sunset within and between trips.

	Bee flora spp 1	Bee flora spp 2	Bee flora spp 3	Bee flora spp 4
1st observation	1.5 hours after sunrise for 1 hour			
2nd observation	Midpoint between sunrise and sunset for 1 hour			
3rd observation	2.0 hours before sunset for 1 hour			

Table 3: Plant species recorded during field visits in 2018-2019. The start date of each field trip is listed.

TRIP 1 9-April	TRIP 2 28-May	TRIP 3 31-Jul	TRIP 4 25-Sept	TRIP 5 4-Dec	TRIP 6 05-Feb
Alphitonia excelsa	*Melaleuca quinquenervia*	*Ricinocarpos pinifolius*	*Ricinocarpos pinifolius*	*Leptospermum juniperinum*	*Corymbia intermedia*
Lantana camara	*Banksia serrata*	*Acacia concurrens*	*Conospermum taxifolium*	*Leptospermum liversidgei*	*Persoonia virgata*
Banksia serrata	*Eucalyptus haemastoma*	*Persoonia virgata*	*Xanthorrhoea australis*	*Leptospermum trinervium*	
Eucalyptus robusta	*Woollsia pungens*	*Acacia longifolia*	*Melaleuca pachyphylla*	*Austromyrtus dulcis*	
	Banksia integrifolia	*Aotus lanigera*	*Astrotricha longifolia*	*Elaeocarpus obovatus*	
		Dillwynia retorta			

Table 4: Average weather conditions during field visits in 2018-2019. The start date of each field trip is listed. The average weather during recordings for each field visit is from Redland / Alexandra Hills BoM station 140007 (-27.5433, 153.2394). Average climate statistics (of closest month start) for years 1997-2018 are from Point Lookout BoM station 040209 (-27.4361, 153.5456).

	TRIP 1 9-April	**TRIP 2** 28-May	**TRIP 3** 31-Jul	**TRIP 4** 25-Sept	**TRIP 5** 4-Dec	**TRIP 6** 05-Feb
Redland						
Air temp (°C)	24.60	19.56	17.88	19.18	23.07	26.20
Dew point temp (°C)	17.08	15.57	5.50	12.95	17.78	20.61
Wind speed (m/sec)	3.20	2.28	2.25	2.74	4.15	3.40
Rainfall (mm)	0.03	0.07	0.00	0.00	0.24	0.29
Point Lookout						
Max temp (°C)	26.4	21.7	24.0	25.4	28.2	29.4
Min temp (°C)	19.6	14.5	16.6	18.4	21.4	22.6
AM wind speed (m/sec)	5.86	5.58	5.25	5.25	5.28	5.42
PM wind speed (m/sec)	5.89	5.28	5.89	6.08	6.03	6.06
Rainfall (mm)	169.0	167.0	56.9	96.4	115.5	146.0

Video analysis and metrics

Videos were analysed using the EventMeasure software package (SeaGIS, Pty Ltd, http://www.seagis.com.au). Analysis of all camera recordings began at the same time (to the nearest minute) by synchronisation with a stop watch and continued for 60 minutes. Individual flower visitors captured on camera were identified to the lowest taxonomic level possible, primarily to genus or family. The abundance, number of arrivals and time on flower were recorded for each identified taxa, with the exception of only recording abundance for ants (Formicidae) due to difficulties in recording other metrics with their flower visiting habit. Flower visitor abundance was estimated as MaxN, the maximum number of a given taxa observed in a single frame to avoid double counts (Cappo et al., 2004, Cappo et al., 2006). Taxonomic richness and the Shannon diversity index were calculated for each taxa and group. An assumption was made that these measures of activity directly relate to the amount of resources collected by each flower visitor group.

The advantage of using stereo was that the area of the floral source could be calculated and if one camera failed there was a back-up so the data was not lost. This data has been stored so it can be revisited for further research questions.

The area and number of flowers within a frame were measured for each plant. Area of an individual flower was defined as the circular or rectangle plane bounded by the outer tepals, petals or sepals. The area of unobscured flowers in recordings was calculated by stereo camera measurements of flower diameter where Area=πr2 and r = radius for actinomorphic flowers and with measurements of the two length dimensions of a rectangle where Area=width x length for flowers with differing symmetry. The total area of flowers for an individual plant in recordings was then calculated by multiplication of the number of flowers and average flower area.

Statistical analysis

Measures of activity of honey bees, native bees and other native flower visitors were calculated in each of the 205 video recordings. Measures of activity of flower visitors were abundance, time on flower and number of arrivals. From flower visitor identifications, both taxonomic richness and Shannon diversity (with abundance) were calculated. 12 recordings had no flower visitors and were excluded from analysis. Statistical analyses were conducted using R v. 3.4.4. (R Development Core Team, 2011).

Taxonomic richness and abundance of all native flower visitors were examined with linear mixed models. Data from other measurements of flower visitor activity failed to meet the assumptions of linear regression and were analysed with non-parametric methods (Kruskal-Wallis rank sum test, Dunn's Kruskal-Wallis Multiple Comparisons and Kendall rank correlations). Statistical tests between flower visitor groups used recordings where either flower visitor pair were present (i.e. presence only data were used).

Linear mixed models were selected by Akaike's information criterion (AIC). Effects in linear mixed models were tested by comparing nested models (fitted with maximum likelihood) with chi square tests based on log-likelihood ratios.

Taxonomic richness of all native flower visitors was Log+1 transformed and analysed using a linear mixed model (lmer function from lme4 package). The final model had log flower number and honey bee abundance as fixed effects. Abundance of all native flower visitors was also Log+1 transformed and analysed using a linear mixed model. The final model had log flower number, trip and honey bee abundance as fixed effects. Honey bee abundance was selected for simplicity, as honey bee presence, time on flower and number of arrivals could also be included in the final model. Plant species was included as a random effect in both models to account for non-independence of data.

The effects of time of day, trips (1-6) and plant group on the taxonomic richness and activity of all native flower visitors, native bees and the activity of honey bees were examined with Kruskal-Wallis rank sum tests. Significant effects were examined further with Dunn's Kruskal-Wallis Multiple Comparisons. These tests determine differences between the mean ranked positions of each factor, to assess relative effect. Relationships between the taxonomic richness, diversity and activity of all native flower visitors and the activity of honey bees and environmental factors were examined with Kendall rank correlations. Kendall rank correlations provide a measure of ordinal association between two variables, reflecting the relationship's direction and strength. The coefficient calculated, τ, varies from -1 to 0 to 1, with -1 meaning a perfect negative correlation, 1 a perfect positive correlation, and 0 no correlation at all.

To investigate the overlap in resource collection between flower visitor groups, we calculated niche overlap between honey bees, native bees and other native flower visitors using abundance measurements, following Colwell and Futuyma (1971):

where niche overlap between flower visitor groups $i \text{ and } h = 1 - 0.5 \sum |P_{ik} - P_{hk}|$

And $P_{ik} = \frac{\text{No. flower visitor group } i \text{ visiting plant species } k}{\text{Total no. flower visitor group } i}$

Niche overlap was calculated separately for each trip.

Relationships between the taxonomic richness, diversity and activity of native bees and the activity of honey bees and environmental factors were also examined with Kendall rank correlations. Correlations between native bee and honey bee activity were rerun on recordings separated into different plant groups. To investigate other potential competitors to native bees, we ran correlations on the activity of native bees with all other native flower visitors, ants (Formicidae), flies (Diptera), beetles (Coleoptera) and butterflies and moths (Lepidoptera) activity on data where each pair of flower visitor groups were present.

Flower visitor monitoring results

Potential flower visitor competitors

Variety of flower visitors

In total, 1,565 individual flower visitors were recorded at all sites, comprising 93 distinct taxa. Of these taxa, 11 were bees (Anthophila including honey bees), with the remainder consisting of 27 flies (Diptera), 14 butterflies and moths (Lepidoptera), 11 ants (Formicidae), 9 beetles (Coleoptera), 7 vespoid wasps (Vespoidea), 5 honeyeaters (Meliphagidae), 4 sphecoid wasps (Spheciformes), 3 true bugs (Hemiptera), 1 cockroach (Blattodea) and 1 unidentified taxa (Table 5). For a full list of identified flower visitors, see Appendix 2.

Of all the flower visitors only 13.9% were bees with 85.0% being other insects and 1.2% honeyeater birds. There were only rare cases where any of the other flower visitors, besides bees, harvest pollen. Most flower visitor activity involved collection of nectar resources.

Table 5: **Flower visitors recorded on North Stradbroke Island.** Number of distinct taxa, total number and percentage of individuals in each group as observed over all recordings shown. The percentage was calculated from identified individuals only. * = less than 1%

Taxon	Common name	# distinct taxa	# individuals	% Individuals
Hymenoptera				
Apis mellifera	European honey bee	1	119	8
Anthophila	Native bees	10	98	6
Spheciformes	Sphecoid wasps	4	8	1
Vespoidea	Vespoid wasps	7	29	2
Formicidae	Ants	11	741	47
Other insects				
Coleoptera	Beetles	9	87	6
Diptera	Flies	27	305	19
Hemiptera	True bugs	3	5	*
Lepidoptera	Butterflies and moths	14	32	2
Blattodea	Cockroaches	1	1	*
Vertebrates				
Meliphagidae	Honeyeaters (birds)	5	18	1
Unknown		1	122	

As native bees require nectar as a carbohydrate and liquid resource, competition for nectar resources are likely with all other 86.2% of flower visitors foraging nectar from flowers. If pollen is a limiting factor then honey bees are likely to have the largest impact on native bees as all bees require pollen (some pollen sources being a better resource than others) as a protein source for their reproductive requirements.

Table 6: **Variation in flower visitation over the year**. Metrics are taxonomic richness, Shannon diversity (diversity index), abundance (MaxN) and total time on flower (minutes). The mean ± se of metrics for all visitors, native bees, and the honey bee are shown. Dates refer to the start date of each 3-day data collection trip. Trips with the greatest amount of each measure are highlighted in **bold**. *All visitors = excludes honey bees.

Metric	9-Apr	28-May	31-Jul	25-Sept	4-Dec	5-Feb
All visitors*						
Taxonomic richness	**5.6 ± 0.5**	3.4 ± 0.4	3.1 ± 0.3	3.8 ± 0.4	3.2 ± 0.4	3.2 ± 0.3
Diversity index	**1.3 ± 0.1**	1.0 ± 0.1	1.0 ± 0.1	1.1 ± 0.1	0.9 ± 0.1	1.0 ± 0.1
Abundance	**15.8 ± 3.62**	6.1 ± 0.8	4.8 ± 0.7	6.2 ± 0.9	4.9 ± 0.6	5.2 ± 0.7
Time on flower	6.6 ± 2.96	4.2 ± 2.0	8.8 ± 3.4	**21.6 ± 7.5**	6.6 ± 2.8	1.7 ± 0.6
# arrivals	**24.0 ± 12.20**	7.3 ± 4.0	5.7 ± 1.4	6.4 ± 1.6	3.2 ± 1.2	4.4 ± 2.5
Native bees						
Taxonomic richness	**0.7 ± 0.2**	0.4 ± 0.1	0.3 ± 0.1	0.4 ± 0.1	0.1 ± 0.1	0.4 ± 0.1
Diversity index	**0.2 ± 0.1**	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Abundance	**1.0 ± 0.3**	0.4 ± 0.2	0.3 ± 0.1	0.6 ± 0.2	0.1 ± 0.1	0.5 ± 0.1
Time on flower	**4.1 ± 2.8**	0.7 ± 0.6	0.1 ± 0.1	3.7 ± 2.0	0.1 ± 0.1	0.4 ± 0.2
# arrivals	**15.3 ± 12.1**	1.4 ± 0.7	1.2 ± 0.6	1.8 ± 0.9	0.1 ± 0.0	3.1 ± 2.5
Honey bees						
Abundance	**1.2 ± 0.3**	0.3 ± 0.1	0.7 ± 0.2	0.8 ± 0.2	0.4 ± 0.1	0.2 ± 0.1
Time on flower	3.6 ± 1.6	0.6 ± 0.3	2.7 ± 0.9	**6.2 ± 2.6**	0.5 ± 0.2	0.1 ± 0.0
# arrivals	**35.8 ± 15.3**	4.3 ± 2.0	21.8 ± 6.5	19.0 ± 8.3	6.1 ± 3.2	0.6 ± 0.3
N	32	36	33	33	36	35

Trends in variety of flower visitor abundance, taxonomic richness and diversity

Monitoring over the year showed that ants accounted for the majority (42.7 ± 7%) of the total abundance on flowers, followed by flies accounting for 21.4 ± 4% (Figure 5). Other dominant groups were beetles (6.6 ± 2.1%) and butterflies and moths (2.5 ± 0.7%). Of all the flower visiting taxa, bees (both native and honey bees) accounted for just 14 ± 1.4% of flower visitors, representing a minority of flower visitors.

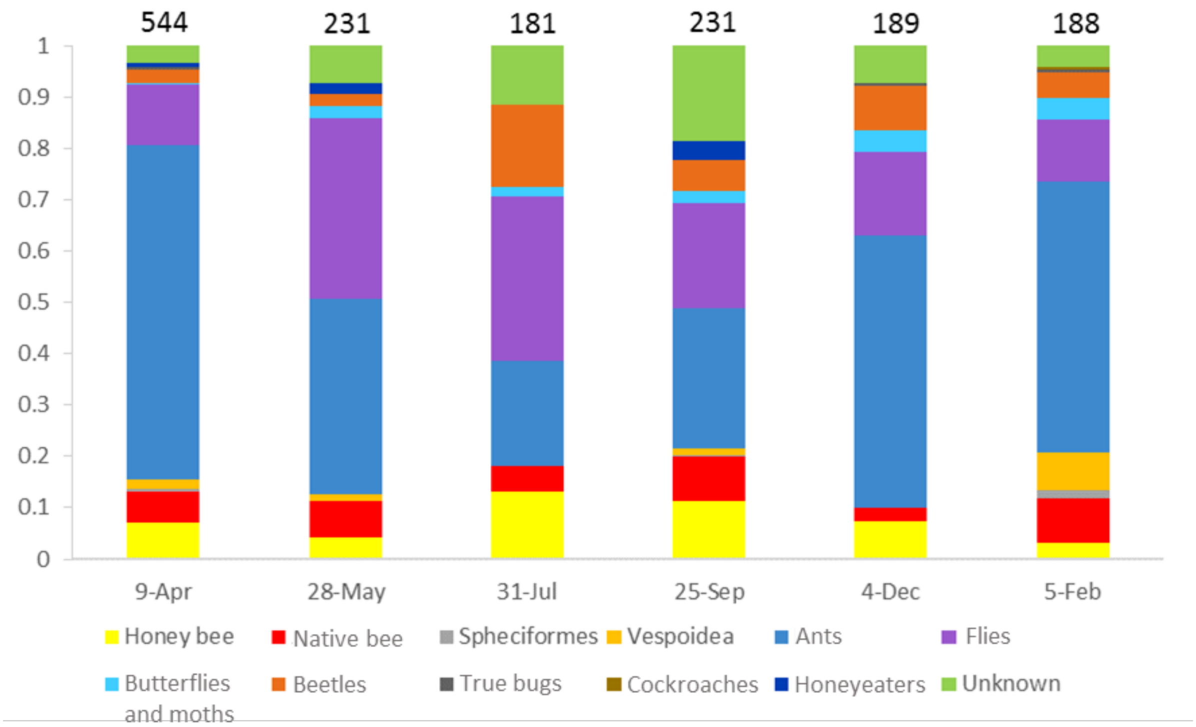

Figure 5: Proportion of total abundance of grouped flower visitors found during video recordings at different times of the year. Dates refer to the start date of each 3-day data collection trip. Total abundance of each trip is shown above bars.

The abundance of flower visitors varied with each trip (Figure 5; native flower visitors: Table 10), with abundance of native flower visitors being highest in April (Table 6). The dominance of ants was highest between December and April which coincides with the highest temperatures and precipitation during recordings (Table 4). When the ant abundance dominance declined, fly dominance increased from May to July (Figure 5). Recordings in April had the highest taxonomic richness, diversity and abundance of all native flower visitors and native bees (Table 6).

Honey bees were by far the most common bee species (55.3% in abundance measurements). Honey bees were most abundant relative to other flower visitors in recordings during July - December and April and were less dominant in May and February. They were most abundant in recordings during April, followed by September and July (Table 6). However, differences between most months failed to meet statistical significance ($p > 0.05$). Honey bee abundance was only significantly different between the highest abundance in April and lowest in February recordings (Dunn's Kruskal-Wallis Multiple Comparisons $z= 3.48$, $p= 0.00758$). Honey bee abundance varied with time of day (Kruskal-Wallis rank tests $X^2= 7.26$, df=2, $p= 0.0266$) with significantly greater abundance in midday recordings than morning recordings (Dunn's Kruskal-Wallis Multiple Comparisons $z= 2.66$, $p= 0.0235$).

Native bee abundance was significantly higher in April than December (Dunn's Kruskal-Wallis Multiple Comparisons z= 2.99, p= 0.0426). Native bee abundance did not significantly vary between other months. The abundance proportion of native bees was similar in recordings over the whole year (6.3 ± 0.9%) with particularly low dominance in recordings in December.

Trends in flower visitor time on the flower and number of arrivals

Striking is the difference between the dominance of bee abundance and dominance of bee number of arrivals (landings on flower; Figure 6) and total time on flower (Figure 7). This percentage was calculated by taking the total number of arrivals and time on flower of each flower visitor group compared to all flower visitors on each trip. Compared to other flower visitors, bees arrived on flowers the most (73.1 ± 5.7% of visitations). Honey bees made up the majority of these bee visitations, comprising 54.6 ± 10.5% of all flower visitors, while native bees comprised 18.5 ± 9.3%. Other groups that had a large number of arrivals relative to other flower visitors were flies (16.2 ± 6.5% of flower visitor arrivals) and beetles (4.0 ± 1.3% of flower visitor arrivals).

Bees also spent the longest time on flower (32.9 ± 9.3% of the total time on flower), where honey bees spent 17.3 ± 4.9% of total time on flower of all flower visitors and native bees spent 15.6 ± 5.9% (Figure 7). Other groups that made up a large proportion of the total time on flower were beetles (21.8 ± 10.2%), flies (20.7 ± 6.1%), and butterflies and moths (15.9 ± 9.9%). Note, time on flower and number of arrivals were not recorded for ants as ant arrivals and departures could not reliably be recorded with their flower visiting habit.

Similar to abundance, honey bee time on flower and number of arrivals was highest relative to other flower visitors in July – December and, in particular, April, and was lowest in May and February, with the exception of December having a lower number of arrivals of honey bees. The time on flower and number of arrivals proportion of native bees was slightly higher during February - May and lower during July - December. This could be related to availability of floral resource (Table 3) where we observed more variety in July - December.

Differences in honey bee number of arrivals and time on flower failed to meet statistical significance between most months (Dunn's Kruskal-Wallis Multiple Comparisons p > 0.05) and native bee number of arrivals and time on flower did not significantly vary with months (Table 16). Similar to abundance, honey bee number of arrivals was significantly greater in April than February (Dunn's Kruskal-Wallis Multiple Comparisons z= 3.37, p= 0.0114), but also greater in April than May (Dunn's Kruskal-Wallis Multiple Comparisons z= 2.95, p= 0.0412).

Honey bee time on flower was also significantly greater in April than February (Dunn's Kruskal-Wallis Multiple Comparisons z= 3.28, p= 0.0159) and greater in July than February (Dunn's Kruskal-Wallis Multiple Comparisons z= 2.97, p= 0.0421). There is a decline in February of the proportion of total time on flower and number of arrivals of honey bees with an increase in proportions of native bees, however this month had the least number of arrivals and time spent on flower. Periods of high time on flower and arrival activity for beetles was from May – December and for butterflies and moths was December and February.

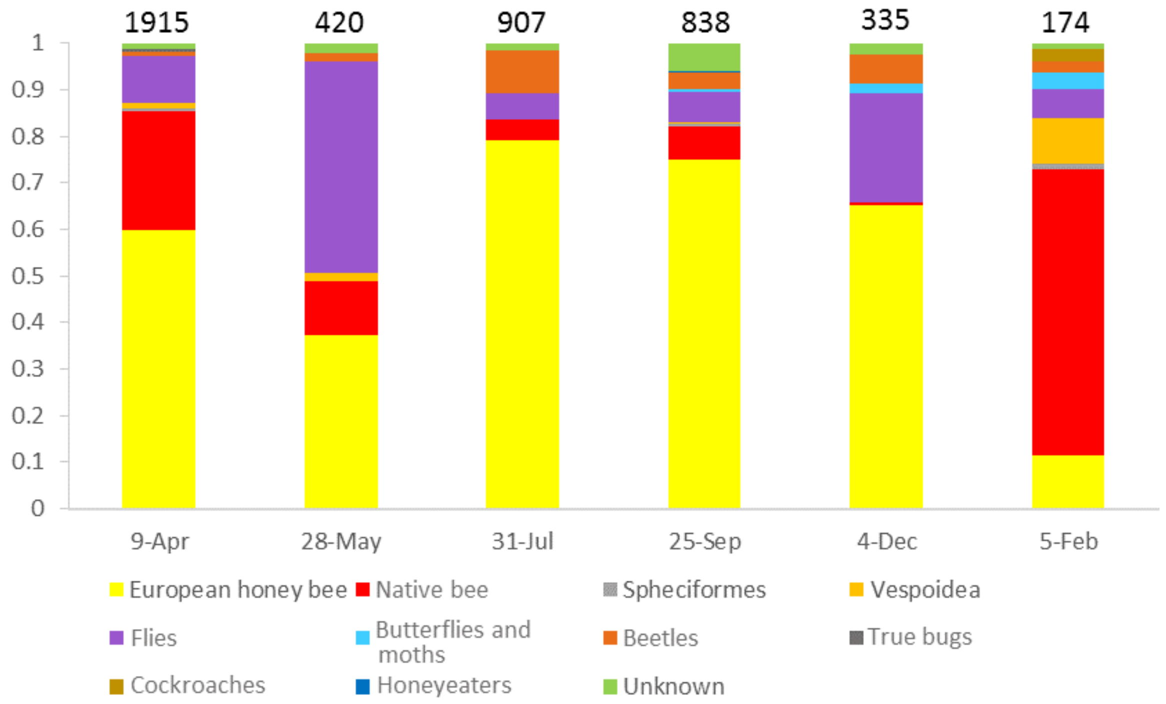

Figure 6: Proportion of total number of arrivals of grouped flower visitors found during video recordings at different times of the year. Dates refer to the start date of each 3-day data collection trip. Total number of arrivals of each trip is shown above bars.

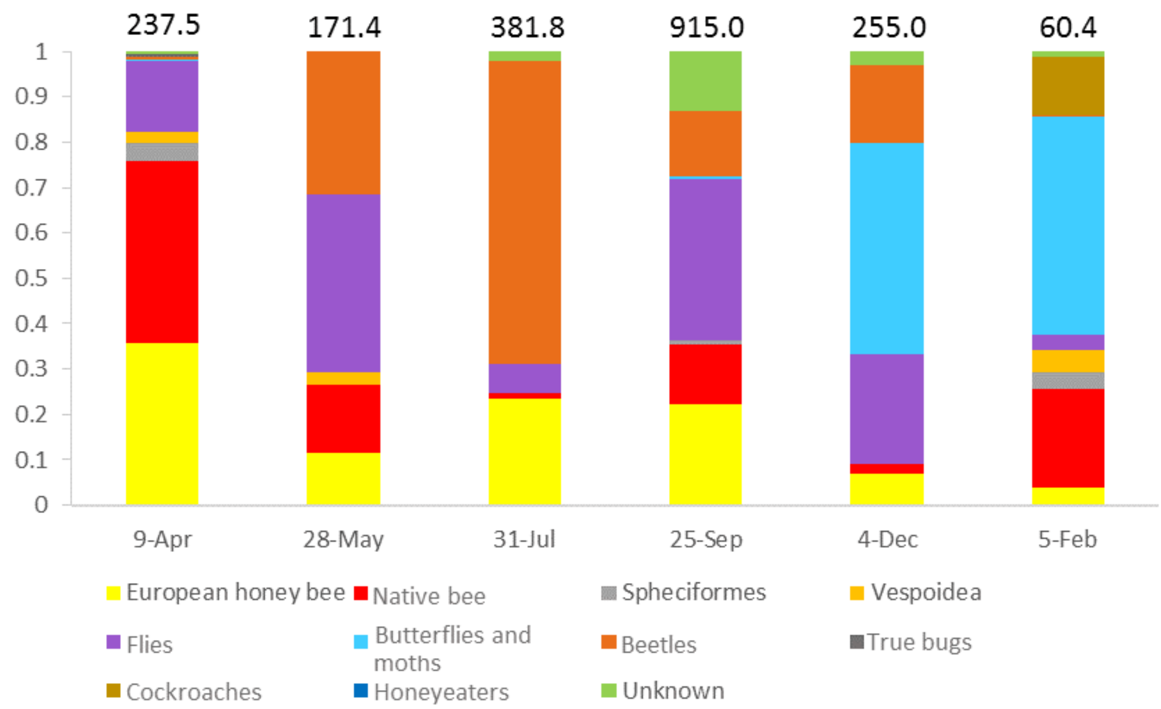

Figure 7: Proportion of total time on flower (minutes) of grouped flower visitors found during video recordings at different times of the year. Dates refer to the start date of each 3-day data collection trip. Total time on flower of each trip is shown above bars.

Niche overlap between flower visitor groups

To investigate if honey bees, native bees and other native flower visitors collect nectar and pollen from the same floral resources, the niche overlap between each flower visitor group was investigated (Table 7). A mean niche overlap equal to 1 indicates that a pair of flower visitor groups was only found on the same plant species. Total overlap was not found (Table 7); however most groups shared floral resources with other flower visitor groups. The highest overlap was between native bees and ants (0.727 ± 0.042). The overlap between honey bees and native bees over the whole year was 0.570 ± 0.081, indicating that they do share their floral resources (Table 7). These overlaps indicate that there is the potential for competition between most flower visitor groups. Niche overlaps do not take into account whether species are collecting nectar or pollen, so they should be interpreted as upper estimates.

Niche overlaps between native and honey bees were highest in recordings during July, September and April coinciding with high honey bee activity, as well as February where there was a particularly high dominance of native bee activity (Table 8).

Table 7: **Niche overlap between honey bees, native bees and other abundant native pollinators**. Overlaps shown are mean ± se for all trips sampled in which each pair of flower visitor were observed in recordings. Number of trips with overlaps is shown in brackets. Vespoid and sphecoid wasps were grouped into wasps, as each had low abundance in recordings.

	Ants	Beetles	Butterflies and moths	European honey bees	Flies	Native bees	Wasps
Ants	-						
Beetles	0.596 ± 0.052 (6)	-					
Butterflies and moths	0.524 ± 0.089 (6)	0.556 ± 0.101 (6)	-				
European honey bees	0.563 ± 0.08 (6)	0.563 ± 0.037 (6)	0.433 ± 0.045 (6)	-			
Flies	0.662 ± 0.092 (6)	0.716 ± 0.081 (6)	0.676 ± 0.054 (6)	0.619 ± 0.062 (6)	-		
Native bees	0.727 ± 0.042 (6)	0.613 ± 0.053 (6)	0.561 ± 0.084 (6)	0.570 ± 0.081 (6)	0.616 ± 0.055 (6)	-	
Wasps	0.580 ± 0.159 (4)	0.510 ± 0.166 (4)	0.645 ± 0.070 (4)	0.539 ± 0.058 (4)	0.617 ± 0.043 (4)	0.599 ± 0.186 (4)	-

*Table 8: **Niche overlap between honey bees and native bees over each trip**. Overlaps shown are for all recordings in which native bees and honey bees were observed (measured with abundance).*

Time of year	9-Apr	28-May	31-Jul	25-Sep	4-Dec	5-Feb
Niche overlap	0.534	0.400	0.681	0.746	0.286	0.771

Highlights

There is a diverse community of flower visitors that collect floral resources from plants on North Stradbroke Island. Bees (including honey bees) are a minority in regards to abundance, representing 13.9% of all visitors that we observed. The most abundant flower visitors were ants, followed by flies.

All flower visitor groups share floral resources (including native bees and honey bees), indicating there is the potential for competition between most flower visitors. Niche overlaps were found between native bees and honey bees over all trips. The highest overlap was between ants and native bees.

Trends in all native flower visitor activity

In total, 1446 flower visitors (excluding honey bees) were observed in video recordings, comprising 92 distinct taxa.

Variation with environmental factors

Taxonomic richness and abundance of all native flower visitors varied significantly with number of flowers, however these were likely due to flower visitors favouring spike plants (see section 5.3). In our categorisation system, a single spike (actually comprising several hundred flowers densely packed in a spiral around a woody axis) was categorised as a single flower. Greater flower area was weakly positively correlated with greater time on flower and number of arrivals of all native flower visitors (Table 11). Diversity was significantly lower with higher wind speed; however diversity did not vary with other environmental factors. Taxonomic richness and activity of all native flower visitors did not vary with time of day nor all other environmental factors.

Variation with honey bee activity

Relationships between honey bee activity and the activity of all native flower visitors are shown in Figure 8 and 9. Recordings with greater honey bee abundance had significantly greater taxonomic richness, diversity, abundance, time on flower and number of arrivals of all native flower visitors (Table 10 and 11). Greater honey bee number of arrivals was also significantly correlated with greater taxonomic richness, diversity, abundance, time on flower and number of arrivals of all native flower visitors. Honey bee time on flower had no discernible effect on native flower visitor abundance (Table 9), but was positively correlated with native flower visitor taxonomic richness, diversity, time on flower and number of arrivals. Honey bee presence was significantly associated with greater taxonomic richness and abundance of native flower visitors. Recordings that were closer to apiary sites had slightly greater abundance, time on flower and number of arrivals of all native flower visitors, but had no effect on taxonomic richness or diversity (Table 11).

Highlights

Greater flower area was weakly correlated with greater time on flower and number of arrivals of all native flower visitors. We did not record any significant correlation between all native flower visitor activity and environmental factors, with the exception of a weak correlation of lower diversity with greater wind speed during recordings.

Recordings with greater activity of honey bees were correlated with greater activity of all native flower visitors. Recordings closer to apiary sites were also weakly correlated with greater activity of all native flower visitors.

Table 9: Variation in flower visitation over the day. Metrics averaged over all days are taxonomic richness, Shannon diversity (diversity index), abundance (MaxN) and total time on flower (minutes). The mean ± se of metrics for all visitors, native bees, and the honey bee are shown. Times of day with the greatest amount of each metric are highlighted in bold. *All visitors = excludes honey bees

Metric	Morning	Midday	Afternoon
All visitors*			
Taxonomic richness	3.34 ± 0.27	**4.10 ± 0.30**	3.58 ± 0.28
Diversity index	0.93 ± 0.08	**1.15 ± 0.07**	1.01 ± 0.07
Abundance	**7.48 ± 1.73**	6.73 ± 0.83	6.97 ± 0.75
Time on flower	**11.1 ± 3.82**	6.63 ± 2.23	6.67 ± 1.76
Number of arrivals	9.12 ± 5.82	**10.1 ± 2.73**	5.70 ± 1.08
Native bee			
Taxonomic richness	0.28 ± 0.08	**0.48 ± 0.08**	0.36 ± 0.07
Diversity index	0.04 ± 0.02	**0.05 ± 0.02**	0.05 ± 0.02
Abundance	0.42 ± 0.14	**0.59 ± 0.11**	0.42 ± 0.09
Time on flower	**2.74 ± 1.61**	1.19 ± 0.51	0.54 ± 0.29
Number of arrivals	**6.40 ± 5.79**	3.38 ± 1.44	1.23 ± 0.44
Honey bee			
Abundance	0.33 ± 0.08	**0.81 ± 0.15**	0.59 ± 0.12
Time on flower	0.85 ± 0.36	**3.12 ± 0.95**	2.59 ± 1.17
Number of arrivals	6.40 ± 2.30	**20.9 ± 5.66**	14.7 ± 6.79
N	67	69	69

Table 10: Factors affecting the taxonomic richness and all native flower visitor abundance on North Stradbroke Island from linear mixed model analysis. Note that native flower visitor taxonomic richness and abundance measurements exclude honeybees. P-values with a confidence level of 95% are highlighted in bold. Trend direction is indicated by Tau (-1: negative, 1 positive). HB = honeybee

Term (added or subtracted from final model)	Taxonomic richness			Abundance		
	X^2	d.f	p	X^2	d.f	p
HB abundance	24.3	1	<0.001	8.43	1	0.004
HB presence *	22.4	1	<0.001	9.06	1	0.003
HB time on flower *	7.20	1	0.007	2.55	1	0.11
Honey bee # arrivals *	16.7	1	<0.001	7.73	1	0.005
Log flower area *	1.80	1	0.18	0.89	1	0.345
Log # flowers *	4.77	1	0.029	10.8	1	0.001
Trip	10.5	5	0.063	21.4	5	<0.001
Time of day	1.63	2	0.443	2.14	2	0.343
Air temperature	3.67	1	0.056	1.94	1	0.164
Dew pt temperature	1.67	1	0.197	1.24	1	0.265
Wind speed	2.32	1	0.128	2.96	1	0.086
Precipitation	1.12	1	0.291	0.12	1	0.725

* Terms added to the final model without correlated terms (i.e. honey bee abundance and log flower area). Final model for all native flower visitor taxonomic richness: Taxonomic richness ~ Honey bee abundance + Log number of flowers + (1|Plant species). Final model for all flower visitor abundance: Log abundance ~ Honey bee abundance + Trip + Log number of flowers + (1|Plant species).

Table 11: **Relationships between honey bee metrics and flower visitation rates on North Stradbroke Island**. Note distance to apiary is the nearest apiary, and the environmental factors were those measured during the observation period. Taxonomic richness and flower visitor activity measurements exclude honeybees. P-values with a confidence level of 95% are highlighted in bold. Trend direction is indicated by Tau (-1: negative, 1: positive). HB = honey bee

Explanatory factor	Taxonomic richness		Diversity index		Abundance		Time on flower		Number of arrivals	
	τ / Χ²	p	**τ / Χ²**	p	**τ / Χ²**	p	**τ / Χ²**	p	**τ / Χ²**	p
Kendall rank correlations (τ)										
HB abundance	**0.297**	**<0.001**	**0.307**	**<0.001**	**0.203**	**<0.001**	**0.231**	**<0.001**	**0.336**	**<0.001**
HB time on flower	**0.274**	**<0.001**	**0.278**	**<0.001**	**0.182**	**0.0015**	**0.234**	**<0.001**	**0.318**	**<0.001**
HB # arrivals	**0.276**	**<0.001**	**0.285**	**<0.001**	**0.180**	**0.002**	**0.237**	**<0.001**	**0.321**	**<0.001**
Apiary Distance	-0.095	0.067	-0.058	0.241	**-0.109**	**0.031**	**-0.110**	**0.030**	**-0.106**	**0.039**
Flower area	0.084	0.107	0.068	0.168	0.043	0.390	**0.131**	**0.010**	**0.102**	**0.046**
Air temperature	0.062	0.237	0.031	0.537	0.054	0.285	-0.032	0.536	-0.008	0.880
Dew pt temp	-0.003	0.960	-0.014	0.782	0.007	0.889	-0.096	0.059	-0.087	0.093
Wind speed	-0.089	0.089	**-0.107**	**0.032**	-0.054	0.289	-0.075	0.142	-0.097	0.061
Precipitation	0.019	0.754	0.018	0.754	-0.0003	0.996	-0.026	0.661	0.034	0.579
Kruskal-Wallis rank tests (Χ²)										
Time of day	3.60	0.166	3.53	0.171	4.04	0.133	1.45	0.484	3.23	0.199
Trip	**22.5**	**<0.001**	**12.3**	**0.032**	**21.1**	**0.001**	**17.8**	**0.003**	**21.3**	**0.001**

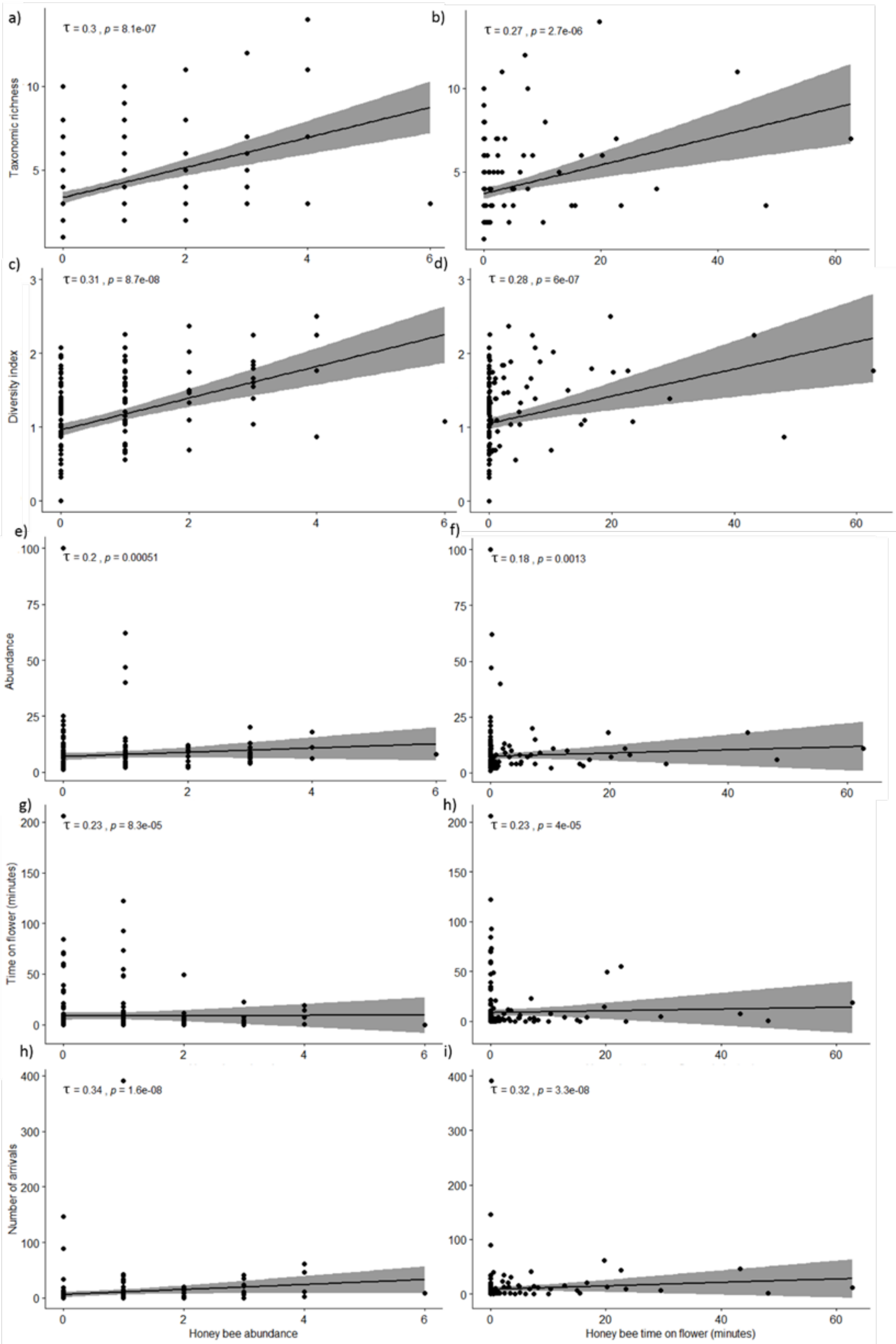

Figure 8: ***Correlations plots of all flower visitor activity in response to honey bee abundance and time on flower (minutes).*** *Correlation coefficients (Tau) and p-values for Kendall rank correlations are shown. Trend direction is indicated by Tau (-1: negative, 1: positive) and a regression line with confidence intervals is shown.*

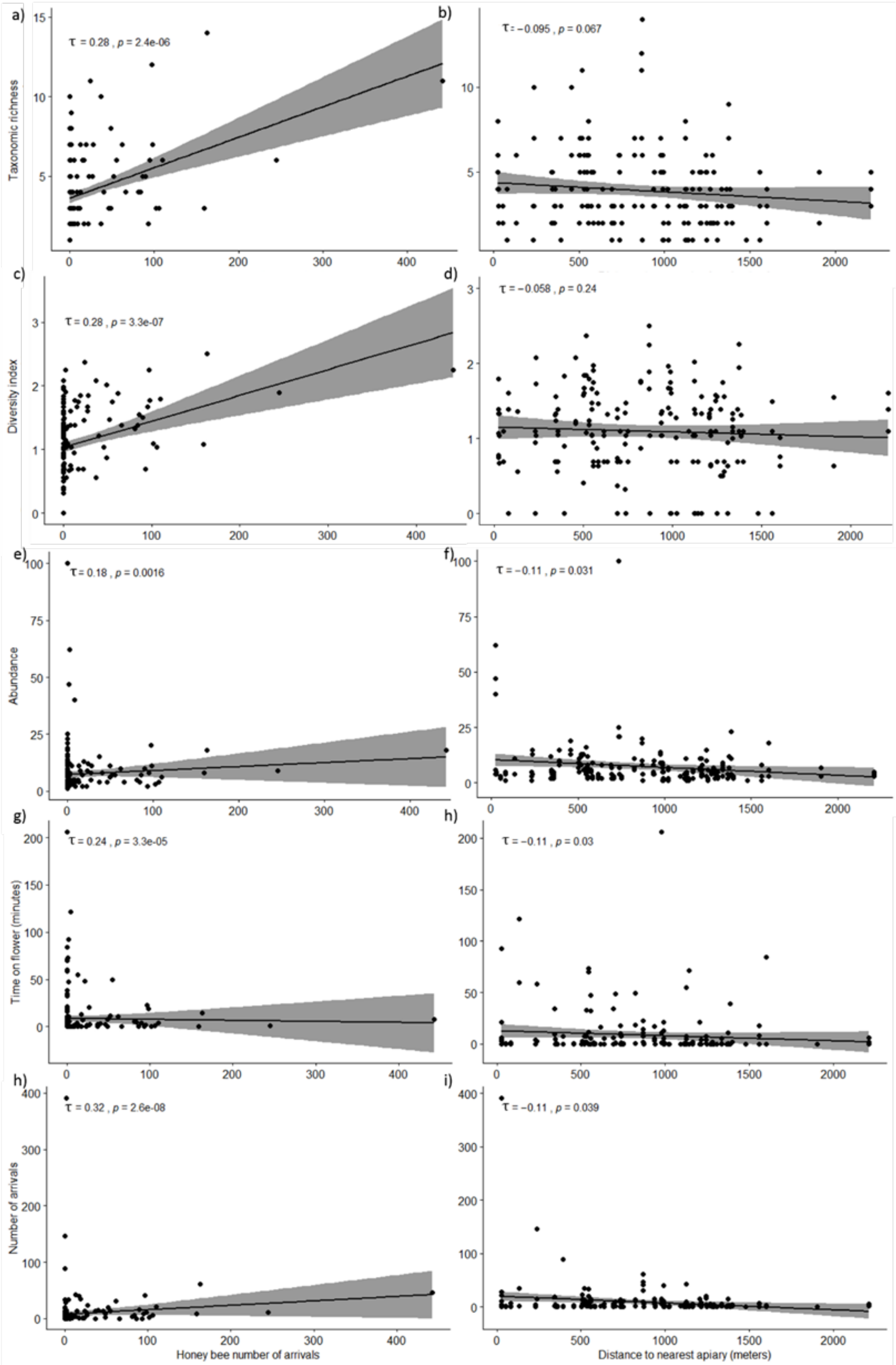

Figure 9: Correlations plots of all flower visitor activity in response to honey bee number of arrivals and distance to nearest apiary (meters). Correlation coefficients (Tau) and p-values for Kendall rank correlations are shown. Trend direction is indicated by Tau (-1: negative, 1: positive) and a regression line with confidence intervals is shown.

Bee plant preference

Plants that were monitored were placed into similar groups based on taxonomy and structure; Acacia and Leptospermum based on genera and trees, spike plants and shrub plants based on size and inflorescence.

1. Acacia: *Acacia concurrens, Acacia longifolia*
2. Tree species: *Alphitonia excelsa, Corymbia intermedia, Elaocarpus obovatus, Eucalyptus haemastoma, Eucalyptus robusta*
3. Spike plants: *Banksia integrifolia, Banksia serrata, Melaleuca pachyphylla, Melaleauca quinquenervia, Xanthorrhoea australis*
4. Leptospermum: *L. juniperinum, L. liversidgei, L. trinervium*
5. Shrub plants: *Aotus lanigera, Astrotricha longifolia, Austromyrtus dulcis, Conospermum taxifolium, Dilwynia retorta, Lantana camara, Persoonia virgata, Ricinocarpos pinifolius, Woollsia pungens*

Table 12: **Variation in flower visitation over different plant groups.** Metrics are taxonomic richness, Shannon diversity (diversity index), abundance (MaxN) and total time on flower (minutes). The mean ± se of metrics for all visitors, native bees, and the honey bee are shown. Times of day with the greatest amount of each metric are highlighted in **bold**. *All visitors = excludes honey bees.

Metric	*Acacia*	*Leptospermum*	Shrub	Spike	Tree
All visitors					
Taxonomic richness	4.08 ± 0.45	3.33 ± 0.48	2.83 ± 0.19	**4.62 ± 0.34**	4.24 ± 0.42
Diversity index	**1.25 ± 0.14**	0.95 ± 0.14	0.88 ± 0.07	1.16 ± 0.08	1.16 ± 0.09
Abundance	6.75 ± 1.35	4.75 ± 0.74	4.15 ± 0.35	**14.3 ± 2.81**	6.55 ± 0.73
Time on flower	**16.3 ± 7.66**	5.93 ± 2.62	5.82 ± 2.12	15.3 ± 5.61	4.69 ± 1.75
Number of arrivals	11.9 ± 2.91	4.21 ± 1.76	3.65 ± 1.26	**18.7 ± 9.76**	7.73 ± 1.83
Native bee					
Taxonomic richness	0.33 ± 0.14	0.17 ± 0.08	0.30 ± 0.06	**0.62 ± 0.13**	0.39 ± 0.10
Diversity index	0 ± 0	0 ± 0	0.02 ± 0.01	**0.12 ± 0.04**	0.07 ± 0.03
Abundance	0.33 ± 0.14	0.17 ± 0.08	0.34 ± 0.07	**0.98 ± 0.25**	0.45 ± 0.12
Time on flower	0.25 ± 0.21	0.21 ± 0.21	0.14 ± 0.10	**6.35 ± 2.62**	0.34 ± 0.16
Number of arrivals	1.83 ± 1.49	0.04 ± 0.04	1.78 ± 1.18	**12.7 ± 9.22**	1.12 ± 0.52
Honey bee					
Abundance	**1 ± 0.30**	0.21 ± 0.09	0.45 ± 0.09	0.64 ± 0.16	0.80 ± 0.19
Time on flower	4.14 ± 1.93	0.17 ± 0.15	0.86 ± 0.29	**4.96 ± 2.05**	2.40 ± 1.03
Number of arrivals	**30.6 ± 13.0**	1.17 ± 0.79	11.2 ± 4.03	10.5 ± 3.70	23.6 ± 9.81
N	12	24	76	42	51

Native bee and honey bee abundance varied with plant group (X24 = 11.2, p= 0.02). Native bees were found in highest abundance on spike plant groups, followed by trees, Acacia and shrubs (Table 12 and 13). Similarly, honey bees were found in highest abundance on Acacia, tree, and spike plant groups. Similar trends are seen in both time on flower (Table 14) and number of arrivals (Table 15) data. The spike plant group (Banksia, Melaleuca and Xanthorrhoea) represent a particularly important plant group for resource collection of both native bees and honey bees.

Table 13: Percentage of total abundance recordings of flower visitors on different plant groups. Abundance measurements were averaged by the number of recordings on each plant group.

Flower visitor	*Acacia*	*Leptospermum*	Shrub	Spike	Tree
Native bees	14.7	7.3	15.1	43.0	19.9
Beetles	56.3	17.1	7.7	8.4	10.4
Flies	27.9	11.4	12.2	26.0	22.6
Honey bee	32.2	6.7	14.4	20.7	25.9
Vespoid wasps	0.0	0.0	17.2	13.3	69.5
True bugs	0.0	36.7	11.6	0.0	51.8
Butterflies and moths	19.6	24.5	9.3	16.8	29.9
Honeyeaters	0.0	0.0	0.0	81.0	19.0
Sphecoid wasps	0.0	0.0	8.5	15.4	76.1
Cockroaches	0.0	0.0	0.0	0.0	100
Unknown	26.1	14.4	16.1	29.9	13.5
Ants	7.1	13.6	10.5	54.0	14.8
All	19.6	12.5	11.6	37.8	18.6

Table 14: Percentage of total time on flower of flower visitors on different plant groups. Time on flower measurements were averaged by the number of recordings on each plant group.

Flower visitor	*Acacia*	*Leptospermum*	Shrub	Spike	Tree
Native bees	3.5	2.9	1.9	87.1	4.6
Beetles	70.5	7.9	13.8	7.3	0.4
Flies	9.6	19.5	20.8	40.1	10.0
Honey bee	33.0	1.4	6.9	39.6	19.2
Vespoid wasps	0.0	0.0	8.8	0.0	91.2
True bugs	0.0	0.0	0.0	0.0	100.0
Butterflies and moths	0.0	38.1	2.2	0.0	59.7
Honeyeaters	0.0	0.0	0.0	98.7	1.3
Sphecoid wasps	0.0	0.0	0.0	37.5	62.5
Cockroaches	0.0	0.0	0.0	0.0	100
Unknown	17.9	8.9	7.2	64.5	1.5
All	33.7	10.1	11.0	33.4	11.7

Table 15: Percentage of total number of arrivals of flower visitors on different plant groups. Number of arrival measurements was averaged by the number of recordings on each plant group.

Flower visitors	*Acacia*	*Leptospermum*	Shrub	Spike	Tree
Native bees	10.5	0.2	10.2	**72.6**	6.4
Beetles	**76.8**	8.8	3.8	5.6	5.0
Flies	16.5	19.3	5.9	**30.2**	28.0
Honey bee	**39.7**	1.5	14.5	13.7	30.6
Vespoid wasps	0.0	0.0	13.4	0.0	**86.6**
True bugs	0.0	0.0	10.1	0.0	**89.9**
Butterflies and moths	14.5	29.0	11.4	4.1	**40.9**
Honeyeaters	0.0	0.0	0.0	**70.8**	29.2
Sphecoid wasps	0.0	0.0	0.0	31.8	**68.2**
Cockroaches	0.0	0.0	0.0	0.0	**100**
Unknown	**30.7**	11.2	15.0	27.9	15.1
All	**34.5**	4.4	12.0	23.7	25.4

Trends in native bee activity

98 native bees were observed in 61 recordings, comprising 10 distinct taxa.

Variation with environmental factors

Based on data from all recordings, native bee time on flower varied significantly with time of day (Table 16) with significantly lower time on flower in the morning than midday (Dunn's Kruskal-Wallis Multiple Comparisons $z= 2.48$, $p= 0.0392$). Other measures of native bee activity did not significantly vary with time of day or trip ($p > 0.05$). Native bee time on flower and number of arrivals varied significantly with plant group (Table 16), with spike plants having significantly greater time on flower (Dunn's Kruskal-Wallis Multiple Comparisons $z= -2.99$, $p= 0.028$) and number of arrivals (Dunn's Kruskal-Wallis Multiple Comparisons $z= -3.02$, $p= 0.0255$) than *Leptospermum* plants. Differences between other plant groups were not significantly different ($p > 0.05$). Native bees spent the most time on flower on *Melaleuca pachyphylla* (13.8 ± 8.31 mins), *Banksia serrata* (10.0 ± 7.37 mins) and *Xanthorrhoea australis* (6.44 ± 6.44 mins) and arrived on flowers most on *Banksia serrata* (36.3 ± 32.1), *Banksia integrifolia* (7.17 ± 3.74) and *Melaleuca pachypylla* (8.17 ± 4.08). Time on flower and number of arrivals of native bees was highly variable between recordings. Other measures of native bee activity did not significantly vary with plant group ($p > 0.05$).

Environmental variables had no discernible effect on native bee taxonomic richness, diversity and activity. There was no significant correlation with flower area and native bee taxonomic richness, diversity or activity. Number of flowers was significantly negatively correlated with native bee activity; however these were likely due to native bees favouring spike plants. In our categorisation system, a single spike (actually comprising several hundred flowers densely packed in a spiral around a woody axis) was categorised as a single flower. Thus, only flower area is included in correlations in Table 16.

Correlations with honey bees and other native flower visitors

Based on data where we observed either native bees or honey bees ($n = 97$), we did not find a significant difference in native bee taxonomic richness and activity according to honey bee time on flower and number of arrivals (Table 16). Distance to nearest apiary had no discernible effect on native bee taxonomic richness, diversity and activity. Recordings with greater honey bee abundance had significantly lower native bee taxonomic richness and abundance (Table 16; Figure 10 a and e). Correlation analyses were repeated on recordings from each plant group to identify if this negative correlation was specific to different plants (Table 17). Recordings on *Leptospermum* and shrub species had significantly lower native bee abundance and taxonomic richness with higher honey bee abundance. Recordings on spike plant groups had significantly lower native bee taxonomic richness with higher honey bee abundance, but there was no discernible effect on the abundance of native bees. Native bee abundance and taxonomic richness did not vary with honey bee abundance on *Acacia* and tree plant groups. Correlations were rerun with data excluding a possible outlier recording with a honey bee abundance of 6; however this had no effect on trend direction or significance. For recordings on shrub species, taxonomic richness of native bees increased with increasing distance from apiaries. However, on spike plants, taxonomic richness, abundance and number of arrivals of native bees was greater in recordings closer to apiary locations (possibly from more attractive spike plants in these locations overall; Table 17)

In all data, native bees had greater taxonomic richness and greater activity across all measures in recordings where other native flower visitors were more abundant (Table 16). Native bee taxonomic richness, abundance and time on flower were also significantly weakly positively correlated with the number of arrivals of other native flower visitors. There was no discernible effect of other native flower visitor number of arrivals on native bee number of arrivals, or other native flower visitor time on flower on native bee taxonomic richness or measures of activity. When looking at the activity of specific flower visitor groups (in recordings where either of the correlated flower visitor pairs were present), different patterns emerge (Table 16). Higher ant abundance was weakly correlated with lower taxonomic richness and abundance of native bees (n = 156; Figure 11). Ant abundance had no significant effect on native bee diversity, time on flower and number of arrivals. Beetle abundance, time on flower and number of arrivals was significantly negatively correlated with native bee taxonomic richness and measures of activity (n = 92; Figure 13), but had no effect on diversity. The strongest correlations for beetle activity were on native bee taxonomic richness and abundance (τ= -0.404 to -0.489). Butterfly and moth activity was also significantly negatively correlated with native bee taxonomic richness and activity (n = 77; Figure 12). Butterfly and moth abundance and number of arrivals, but not time on flower were significantly negatively correlated with native bee diversity. The strongest negative correlations for butterfly and moth activity were with native bee taxonomic richness and abundance (τ= -0.405 to -0.574). Fly activity had no discernible effect on native bee taxonomic richness, diversity or activity (n = 154; Table 16; Figure 11).

Highlights

Native bees were most active on spike plants and least active on Leptospermum plants. Native bees were more active during midday time periods than the morning.

Greater honey bee abundance was significantly correlated with lower taxonomic richness and abundance of native bees. Negative correlations with native bee activity were also found with the activity of other flower visitor groups. Ant abundance was negatively correlated with native bee taxonomic richness and abundance. Lower native bee activity was also correlated with greater beetle and butterfly and moth activity.

Table 16: Results of Kruskal-Wallis rank tests for all recordings and Kendall rank correlations on the activity of native bees with the activity of different flower visitors groups. Kendall rank correlations are on data where each pair of flower visitor groups is present. Note distance to apiary is the nearest apiary, and the environmental factors were those measured during the observation period. Taxonomic richness and flower visitor activity measurements exclude honeybees. P-values with a confidence level of 95% are highlighted in bold. Taxonomic richness, diversity index (Shannon diversity) and native flower visitor activity measurements exclude honey bees. P-values with a confidence level of 95% are highlighted in bold. Trend direction is indicated by Tau (-1: negative, 1: positive)

Explanatory factor	Taxonomic richness		Diversity index		Abundance		Time on flower		Number of arrivals	
	τ / Χ²	p	**τ / Χ²**	p	**τ / Χ²**	p	**τ / Χ²**	p	**τ / Χ²**	p
Kendall rank correlations (τ)										
HB abundance	**-0.287**	**0.001**	-0.164	0.076	**-0.244**	**0.006**	-0.001	0.994	0.015	0.866
HB time on flower	-0.144	0.085	-0.153	0.075	-0.093	0.254	0.107	0.175	0.106	0.186
HB number of arrivals	-0.154	0.067	-0.168	0.051	-0.112	0.174	0.075	0.348	0.078	0.333
Apiary distance	-0.036	0.656	-0.056	0.493	-0.036	0.649	-0.048	0.532	-0.05	0.514
Ant abundance	**-0.155**	**0.022**	-0.017	0.802	**-0.158**	**0.018**	-0.101	0.125	-0.097	0.14
Fly abundance	-0.092	0.192	0.026	0.719	-0.084	0.23	0.041	0.552	0.008	0.911
Fly time on flower	-0.03	0.67	0.068	0.335	-0.017	0.804	0.069	0.302	0.46	0.497
Fly # arrivals	-0.028	0.695	0.11	0.124	-0.019	0.788	0.057	0.4	0.037	0.592
Beetle abundance	**-0.489**	**<0.001**	-0.131	0.169	**-0.474**	**<0.001**	**-0.286**	**0.001**	**-0.336**	**<0.001**
Beetle time on flower	**-0.429**	**<0.001**	-0.167	0.073	**-0.409**	**<0.001**	**-0.304**	**<0.001**	**-0.328**	**<0.001**
Beetle # arrivals	**-0.41**	**<0.001**	-0.124	0.186	**-0.404**	**<0.001**	**-0.273**	**0.002**	**-0.313**	**<0.001**
Butterfly and moth abundance	**-0.574**	**<0.001**	**-0.235**	**0.03**	**-0.504**	**<0.001**	**-0.317**	**0.001**	**-0.32**	**0.001**
Butterfly and moth time on flower	**-0.415**	**<0.001**	-0.188	0.081	**-0.405**	**<0.001**	**-0.288**	**0.003**	**-0.273**	**0.006**
Butterfly and moth # arrivals	**-0.526**	**<0.001**	**-0.217**	**0.046**	**-0.506**	**<0.001**	**-0.34**	**<0.001**	**-0.326**	**0.001**
All other native visitor abundance	**0.199**	**<0.001**	**0.194**	**0.001**	**0.201**	**<0.001**	**0.197**	**<0.001**	**0.191**	**0.001**
All other native visitor time on flower	0.058	0.340	0.053	0.387	0.068	0.257	0.063	0.289	0.061	0.308
All other native visitor number of arrivals	**0.138**	**0.024**	**0.155**	**0.013**	**0.144**	**0.017**	**0.126**	**0.036**	0.116	0.054
Flower area	0.019	0.816	0.055	0.506	0.01	0.904	0.054	0.474	0.031	0.686
Air temperature	0.060	0.458	0.414	0.616	0.051	0.521	0.024	0.749	0.044	0.571
Dew pt temp	0.056	0.485	0.498	0.546	0.045	-0.567	-0.029	0.705	-0.027	0.73
Average wind speed	-0.002	0.984	-0.002	0.984	-0.038	0.632	-0.083	0.278	-0.078	0.314
Precipitation during recording	0.113	0.236	0.102	0.299	0.082	0.383	0.03	0.738	-0.001	0.99
Kruskal-Wallis rank tests (Χ²)										
Time of day	4.53	0.104	0.119	0.942	4.46	0.107	**6.34**	**0.042**	5.85	0.054
Trip	11.00	0.052	**14.90**	**0.011**	**11.23**	**0.047**	9.31	0.097	11.00	0.051
Plant group	5.48	0.241	**10.20**	**0.037**	6.38	0.173	**11.40**	**0.023**	**10.9**	**0.027**

Table 17: Results of Kendall rank correlations for each plant group in video recording data that contained bees on activity of native bees according to honey bee activity and distance to nearest apiary. Note distance to apiary is the nearest apiary, and the environmental factors were those measured during the observation period. Taxonomic richness and flower visitor activity measurements exclude honeybees. P-values with a confidence level of 95% are highlighted in bold. Trend direction is indicated by Tau (-1: negative, 1: positive).

Plant group	Taxonomic richness		Abundance		Time on flower		Number of arrivals	
	τ	p	τ	p	τ	p	τ	p
HB abundance								
Acacia	0	1	0	1	0.3	0.36	0.3	0.36
Leptospermum	**-0.77**	**0.04**	**-0.77**	**0.04**	0.29	0.44	0.29	0.44
Shrub	**-0.47**	**0.004**	**-0.43**	**0.0071**	-0.094	0.53	-0.16	0.3
Spike	**-0.37**	**0.042**	-0.24	0.17	-0.16	0.34	-0.1	0.56
Tree	-0.11	0.54	-0.069	0.7	0.27	0.13	0.3	0.097
HB time on flower								
Acacia	0.14	0.66	0.14	0.66	0.32	0.31	0.32	0.31
Leptospermum	-0.24	0.51	-0.24	0.51	0.45	0.21	0.45	0.21
Shrub	**-0.29**	**0.048**	-0.26	0.069	0.024	0.86	-0.086	0.53
Spike	-0.11	0.52	0.086	0.61	0.16	0.33	0.21	0.2
Tree	-0.16	0.33	-0.15	0.36	0.16	0.32	0.19	0.27
HB number of arrivals								
Acacia	0.14	0.66	0.14	0.66	0.32	0.31	0.32	0.31
Leptospermum	-0.12	0.74	-0.12	0.74	0.62	0.08	0.62	0.08
Shrub	-0.24	0.1	-0.24	0.1	-0.024	0.86	-0.092	0.51
Spike	0.052	0.76	0.052	0.76	0.17	0.31	0.2	0.23
Tree	-0.13	0.42	-0.13	0.42	0.13	0.42	0.16	0.35
Distance to nearest apiary								
Acacia	-0.41	0.24	-0.41	0.24	-0.29	0.38	-0.29	0.38
Leptospermum	-0.1	0.77	-0.1	0.77	0.54	0.12	0.54	0.12
Shrub	**0.31**	**0.033**	0.25	0.084	0.0093	0.94	0.13	0.36
Spike	**-0.52**	**0.002**	**-0.43**	**0.0085**	-0.29	0.061	**-0.42**	0.008
Tree	-0.14	0.39	-0.12	0.46	-0.089	0.59	-0.13	0.44

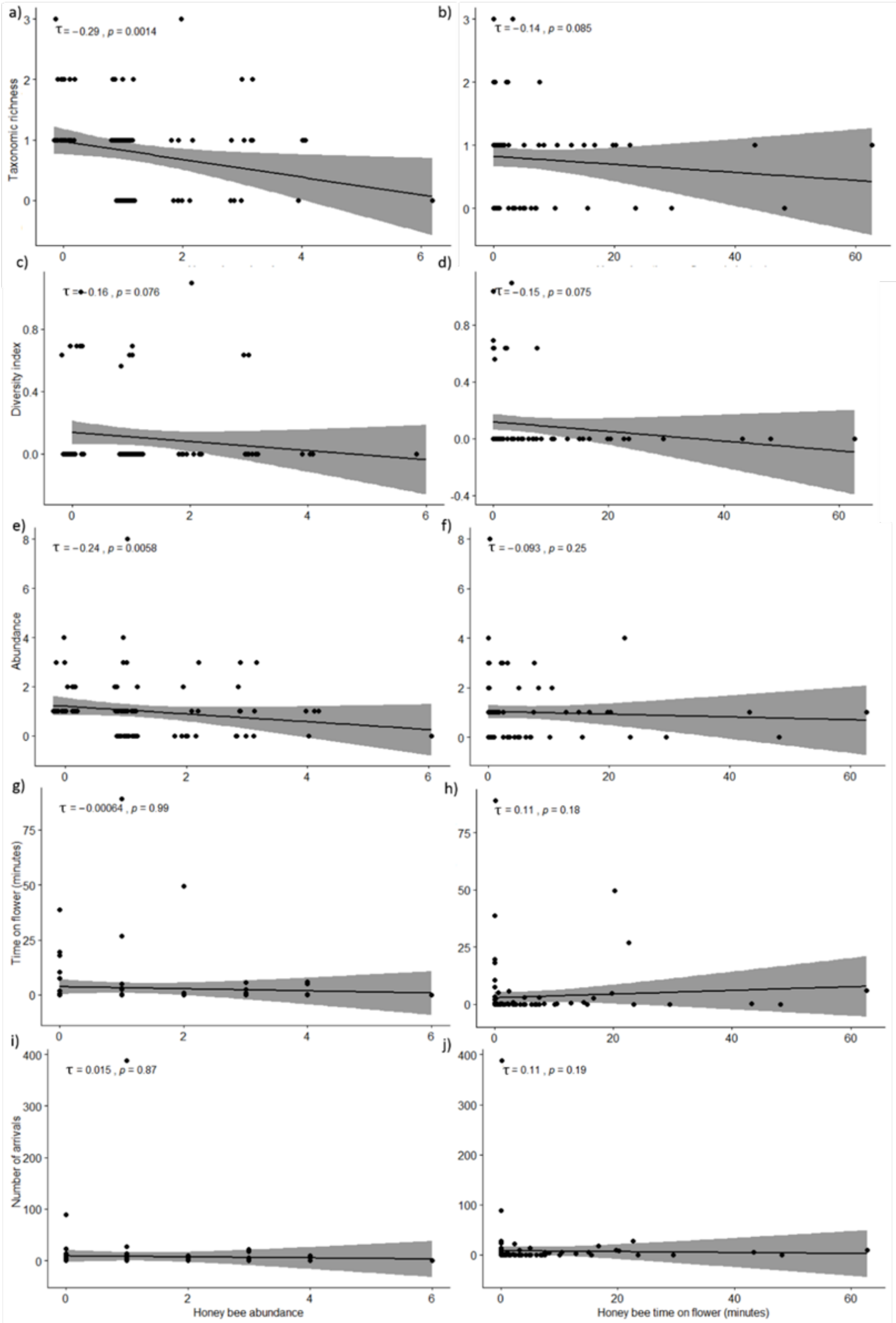

Figure 10: Correlations plots of native bee taxonomic richness, Shannon diversity (diversity index) and activity in response to honey bee abundance and time on flower (n = 97). Correlation coefficients (Tau) and p-values for Kendall rank correlations are shown. Trend direction is indicated by Tau (-1: negative, 1: positive) and a regression line with confidence intervals is shown. Plots a, c and e have added jitter along honey bee abundance axis for clarity.

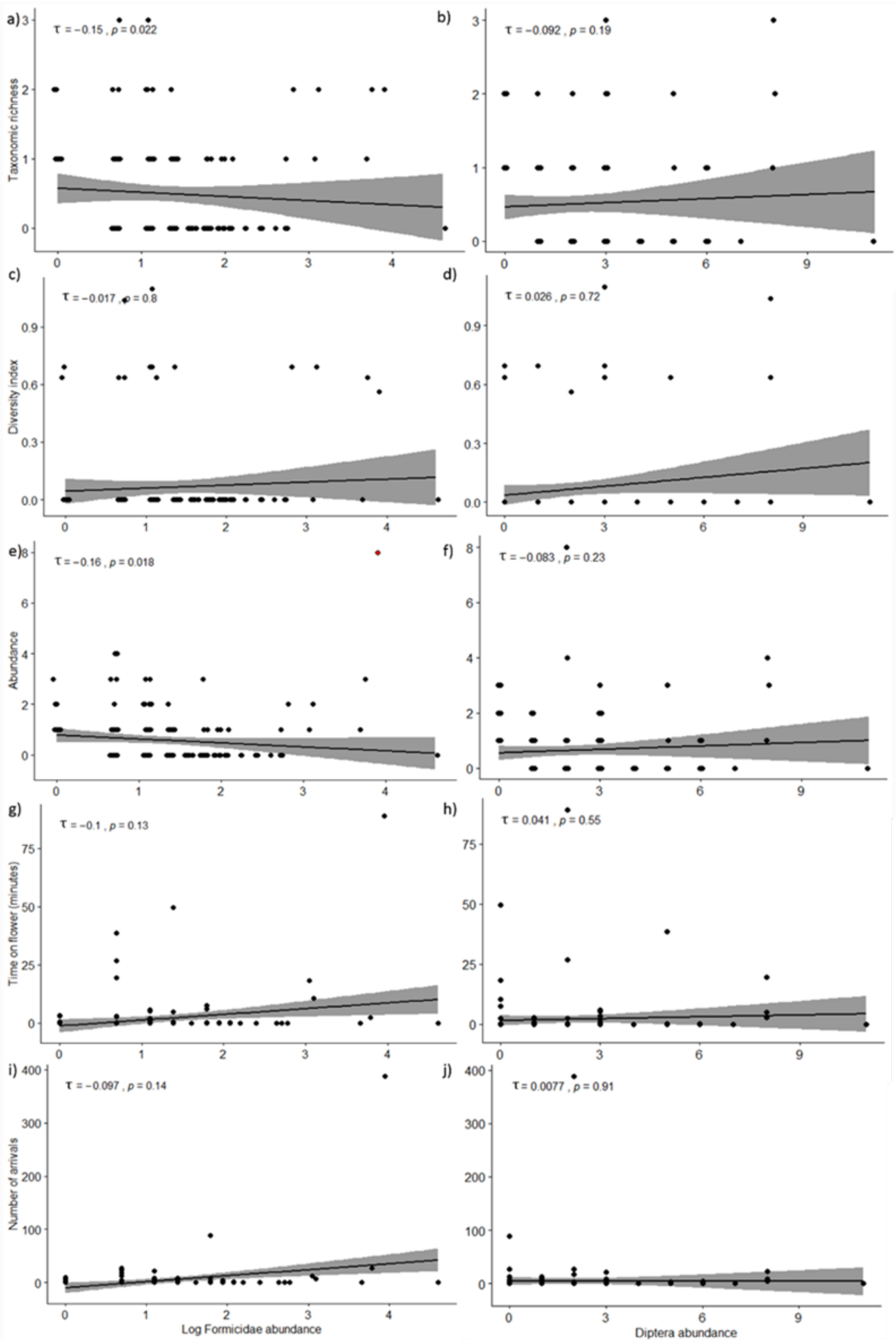

Figure 11: Correlations plots of native bee taxonomic richness, Shannon diversity (diversity index) and activity in response to Log + 1 transformed Formicidae (ant) abundance and Diptera (fly) abundance (Native bees and ants: n = 156, Native bee and flies: n = 154). Correlation coefficients (Tau) and p-values for Kendall rank correlations are shown. Trend direction is indicated by Tau (-1: negative, 1: positive) and a regression line with confidence intervals is shown. Plots a-f has added jitter along Formicidae (ant) and Diptera (fly) abundance axes for clarity. Regression line in plot e is excluding an outlier recordings with native bee abundance = 8.

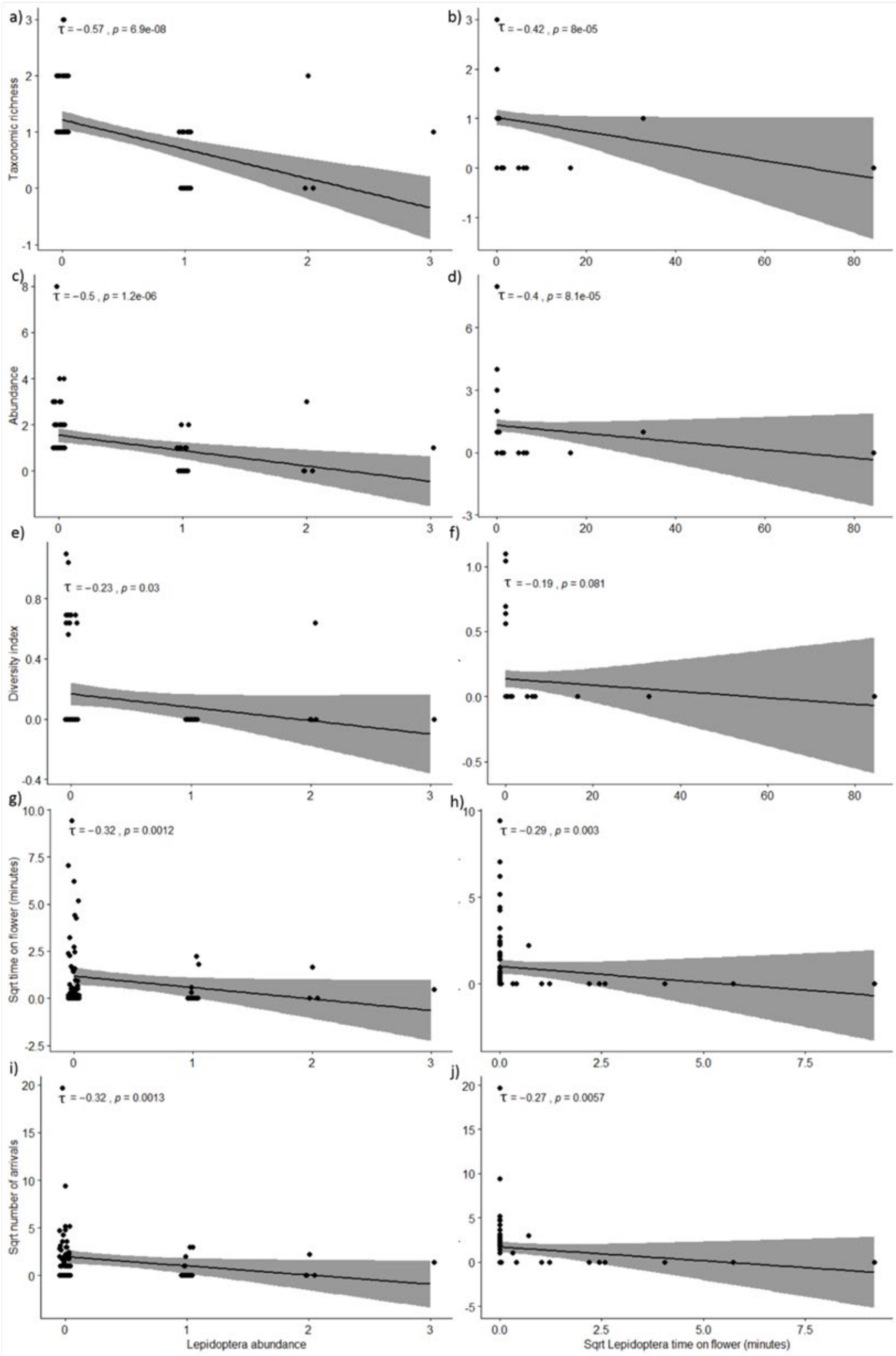

Figure 12: Correlations plots of native bee taxonomic richness, Shannon diversity (diversity index) and activity in response to Lepidoptera (butterflies and moths) abundance and time on flower (minutes) (n = 77). Correlation coefficients (Tau) and p-values for Kendall rank correlations are shown. Trend direction is indicated by Tau (-1: negative, 1: positive) and a regression line with confidence intervals are shown. Plots a, c, e, g and i have added jitter along Lepidoptera (butterflies and moths) abundance axes for clarity.

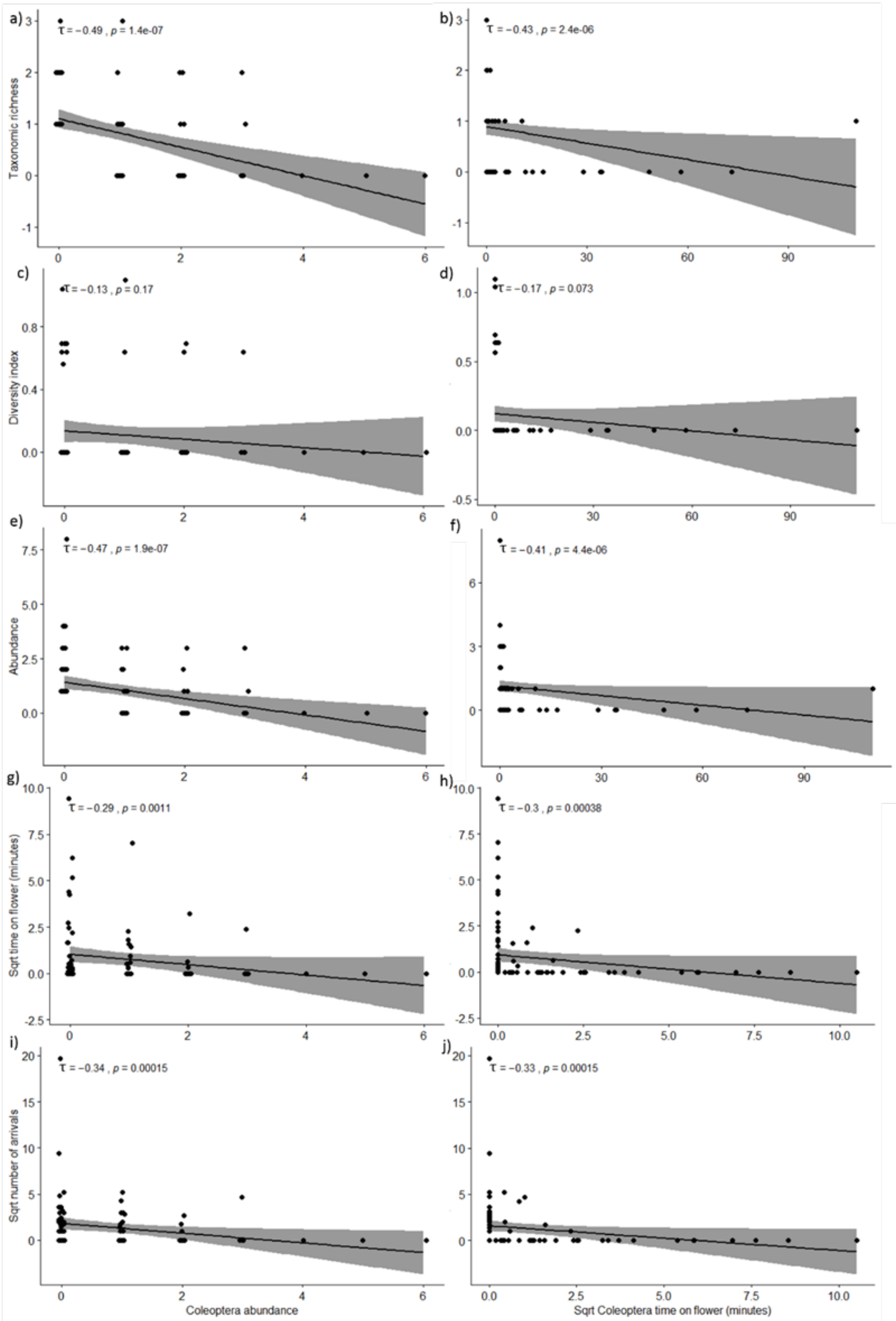

Figure 13: Correlations plots of native bee taxonomic richness, Shannon diversity (diversity index) and activity in response to Coleoptera (beetle) abundance and time on flower (minutes) (n = 92). Correlation coefficients (Tau) and p-values for Kendall rank correlations are shown. Trend direction is indicated by Tau (-1: negative, 1: positive) and a regression line with confidence intervals are shown. Plots a, c, e, g and i have added jitter along Coleoptera (beetle) abundance axes for clarity.

Discussion

There was an abundance of flower visitors in recordings over all trips. Bees (both native and honey) accounted for only 13.9% of flower visitors, with the remaining 86.1% mainly being ants and flies (Figure 5). The inclusion of these other native flower visitors when considering the competitive exclusion of native bees is limited to few studies. One exception is Goulson et al. (2002), who observed bees as 45.4% of flower visitors in Tasmania with half of these bees being honey bees. Bee proportion of total flower visitors observed by Goulson et al. (2002) was higher than our observations, but the proportion of honey bees to native bees was similar (~50%). We highlight that the flower visitor community is diverse and bees are one of many species that collect resources from the flowers on North Stradbroke Island.

Honey bees are an introduced species to this ecosystem and the only confirmed exotic flower visitor. Any exotic flower visitor species may compete for resources despite not being dominant. Honey bees may have a larger impact on the resource collecting ability of native bees than other native flower visitors due to their shared reliance on both pollen and nectar for their brood (Paini, 2004). To definitively test for competition from a relatively small proportion of flower visitors, the long-term survival of native bees in honey bee presence and excluding honey bee presence would need to be monitored. It should be noted that honey bees have been on North Stradbroke Island for at least 50 years and impacts to native bee survival may have already occurred prior to the introduction of additional hives. Even after honey bees has been present on North Stradbroke island for this long period, this study recorded a wide taxonomic diversity of native bees and in the same proportions to honey bees as recorded elsewhere in Australia (Goulson et al., 2002).

We found that all flower visitors liked the same flowers. Overall, honey bee activity was positively correlated with the taxonomic richness, diversity and abundance of native flower visitors. Plants closer to apiary locations also had a higher abundance of native flower visitors that spent longer on flowers and arrived on flowers more often. A study investigating honey bee and bumble bee competition with native flower visitors (Goulson et al., 2002) found a similar result showing that honey bee abundance was positively correlated with native flower visitor abundance. Like Goulson et al. (2002), we attribute this positive correlation between native flower visitors and honey bees to both groups being attracted to locations with many flowers or highly desirable flowers. We also attribute native flower visitors arriving and spending longer on flowers closer to apiary sites to these locations having more flowers desirable for honey bees that are also desirable for native flower visitors.

With the low abundance of honey bees in comparison to all native flower visitors, it is important to determine whether a decline in native bee activity can occur due to the activity of the other native flower visitors. When looking at the activity of specific flower visitor groups: ants, beetles and butterflies and moths (with the exception of flies), we found negative correlations with native bee activity (Table 16). These negative correlations are suggestive of competitive exclusion between native bees and ants, beetles and butterflies and moths – as a part of the native flower visiting ecosystem. With ants accounting for the majority of flower visitors (42.7 ± 7%) and the highest niche overlap found between native bees and ants, it is likely that these species are more competitive with native bees than any other group. Additionally, beetles (6.6 ± 2.1% of flower visitors) and butterflies and moths (2.5 ± 0.7% of flower visitors) are also likely to be competitors with native bees.

When honey bees were active, no evidence was found for a decline in native bee time on flower or number of arrivals (Table 16). This activity was measured through honey bee abundance, time on flower and number of arrivals. However, we did observe a weak-medium correlation for a lower abundance and taxonomic richness of native bees in recordings with higher honey bee abundance (Table 16). This is suggestive of competitive exclusion of some native bee species by honey bees.

If honey bee and native bee competitive exclusion is investigated further, different relationships were observed across plant groups. There was no evidence of competition on Acacia and the tree plant groups (Eucalyptus, Corymbia and Elaeocarpos species; Table 17). However, we observed weak-medium correlations suggesting competition with honey bee abundance and native bee taxonomic richness on the spike plant group and native bee taxonomic richness and abundance on the shrub plant group. The spike plant group appears to be the most important floral resource for native bees, followed by the tree plant group, shrub plant group and the Acacia plant group. These plant groups were also a major floral resource for honey bees. A similar decline in native bee activity was observed on Leptospermum plant species; however these plants may be of minimal importance to resource gathering for native bees, as native bees were least likely to be found on these plant species compared to their other floral resources in our observations (7.3% of total native bee abundance).

In general, most native bees are active during Spring/Summer (Houston, 2018), and this appears to coincide with our measures of native bee activity being highest during the warmer months of February - May and lowest in July – December. However, our results show no obvious flowering periods to avoid to have complete certainty of possible native bee and honey bee competition. This may be in part due to our results being limited by our single year sample size. It is possible that different patterns may emerge with further replication over multiple years. As native bee activity is highly variable between seasons with many solitary native bees having a narrow plant preference, limiting their activity to several weeks at a particular location (Houston, 2018), a focus on different genera or species may provide a clearer picture.

We have shown that honey bees and native bees share resources and made observations that are suggestive of small scale competitive exclusion, but this does not necessarily mean that competition is occurring. Moreover, what we observed could change with a climatically-influenced different flora source the next year. To provide further assurance, additional monitoring is suggested. A causative link between the long-term survival of native bees (i.e. individual survival, fecundity or population numbers) and the presence of honey bees is required. Investigations attempting to investigate the long-term survival of native bees has been limited to few studies (e.g. Roubik and Wolda, 2001, Roubik, 1983, Sugden and Pyke, 1991, Thoenes, 1993), which resulted in little evidence to suggest honey bee competitive exclusion can lead to native bee population declines (Mallinger et al., 2017, Paini, 2004, Goulson, 2003). A low-cost approach to test for a causative link would be to measure native bee survival, fecundity and population numbers through routine monitoring of bee 'hotels' for solitary bee species and hives for stingless bees in areas of the island with differing numbers of honey bee hives. Coupling this monitoring with artificial manipulation of honey bee hives would provide a powerful definitive test for competition between native bees and honey bees.

If competition is occurring, there is the choice of manipulating honey bee densities. We are aware of no study that has investigated identifying optimum honey bee densities to reduce resource competition with native bees in other parts of the world, however similar studies have been conducted to avoid competition with other honey bee hives (e.g. Al-Ghamdi et al., 2016).

Alternatively, competition could be overcome, and compliment the survival of insects, through native flora resource development on North Stradbroke island. Reclaiming native landscapes provides more floral resources for both native flower visitor species and honey bees and can benefit other species in these ecosystems (Hopwood, 2008, Menz et al., 2011). A similar approach has been employed where roadside plantings are actively cultivated by honey bees in Australia (Sugden et al., 1996, Environment, 1980) and roadside plantings around the world have been shown to aid in the restoration of native bee and other native flower visitor diversity and abundance (Hopwood, 2008, Hopwood, 2013, Ries et al., 2001). For a conceptual and practical framework for the restoration of pollinator and plant mutualisms, see Menz et al. (2011). Interesting is that, during this year, we did not see evidence for competition on all flora. The critical flora for native bees appeared to be the spike and shrub plant group. If revegetation projects focussed on these species, ample floral resources for all flower visitors, especially native bees, would be available. There may also be rare or highly specialist native bees that exclusively forage on particular plant species, so maintaining plant diversity in revegetation projects is important.

Rehabilitation of previous sand mine areas in North Stradbroke Island (with these mines operated by Sibelco set to close by the end of 2019) with native plant species provide an opportunity to increase floral resources to reduce resource limitation by honey bees. To optimise the positive effects of these projects, we recommend coupling these efforts with monitoring of native bee or native flower visitor population numbers and activity. Such a project also provides a unique opportunity to study the effects of honey bee presence on native bee population growth, or even potential benefits of honey bees on native plant restoration (as discussed in Hobbs and Hopkins, 1990). Other methods to increase floral resources are through seizing opportunities to plant native nectar producing plants when changing urban landscapes (e.g. for erosion control) (Sugden et al., 1996).

The introduction of honey bees provides another potential impact to native ecosystems by changing plant species diversity and aiding the spread of exotic weeds. Honey bees vary in their pollination efficiency of different native flora (Huryn, 1997, Vaughton, 1996) and have been shown to preferentially forage from exotic plant species (Goodell, 2008, Abe et al., 2011, Barthell et al., 2001). This foraging preference can produce invasive mutualisms between honey bees and exotic plants or preferred native plants, facilitating their spread (Hanley and Goulson, 2003, Goulson and Derwent, 2004). The subsequent change in plant distributions can result in the decline of certain native plants foraged by native flower visitors (Abe et al., 2011), potentially leading to a loss of native bees or other native flower visitor diversity and abundance (Aizen et al., 2008, Biesmeijer et al., 2006). A study by Goulson and Derwent (2004), recognised honey bees as effective pollinators that help spread the invasive Lantana camara in other national parks in Queensland. In our observations on Lantana camara (limited to 10 recordings), we observed only 2 honey bees visiting the plant species. Visitations to *Lantana camara* were not unique to honey bees. The majority of flower visitors we observed were ants (*Crematogaster laeviceps* and *Polyrachis* species) and flies (e.g. *Ligyra satyrus*) and we also observed 3 *Amegilla* native bees. It is possible that native flower visitors such as these are also effective pollinators of the exotic weed.

A final medium for honey bees to affect native bees is through the transmission of shared pathogens. Managed bees, including honey bees, are highly social and occur in high densities, making them potentially more likely to harbour pathogens than solitary native species (Jong et al., 1995, Chen et al., 2006, Goodell, 2008, Abe et al., 2011, Barthell et al., 2001). Potential means for the transmission of pathogens from honey bees to native bees is through contaminated pollen (Singh et al., 2010), faeces (Whitehorn et al., 2013) or physical contact while collecting resources (Durrer and Schmid-Hempel, 1994). The literature suggests that honey bees can transmit pathogens to native bees (e.g. Nosema ceranae detected in stingless Meliponini bees Porrini et al., 2017) and these pathogens may contribute to native bee population declines (Mallinger et al., 2017). We observed Nosema, small hive beetle, chalkbrood, wax moth, American foulbrood (AFB) and possible European foulbrood (EFB) from laboratory testing and visual inspections conducted in 2018-2019. These diseases were detected at low levels compared to average levels for Queensland (Roberts et al., 2015) and were already likely to be present in other hives on the island before the introduction of additional hives. From our observations of generally low amounts of disease in the new apiaries, it is unlikely that disease from these hives spread to native bees more than from other hives already present on the island.

Implications

Honey bees have been on the island for more than 50 years. Even with their presence for this period of time, a wide variety of flower visitor biodiversity remained present on the island. Unfortunately, as this was the first study of its kind, there is no comparison. This study does, however, lay a foundation for future similar studies to monitor flower visitor diversity.

This research did show that flower visitor monitoring can change with season and available flowering. This variation may also link with the breeding cycle of each of the insect species. From similar work on an annual scale, it has also been observed that annual fluctuations can also occur so regular long-term monitoring would be ideal.

Rehabilitation of the island with a bias to the spike, shrub and Leptospermum flowering plants would be welcomed by all flower visitors.

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Using the cameras enabled the quantification of all native flower visitors. Whilst often competition between the honey bee and the native bee is discussed in the litertaure, this study showed that there is a greater complexity to consider.

On further investigation this competition between native and honey bees was observed on particular floral resources. Floral species to be aware of that were favoured by native bees and honey bees include the spike and shrub plants groups. Leptospermum were least favoured by the native bees, but results were suggestive of competition with honey bees on these plant species.

It is recommended that a long-term monitoring study be undertaken to see how these relationships change with the annual changing floral resource. Additionally, establishing native bee hotels and stingless bee hives could assess the long-term reproductive status of native bees to provide a definitive test for competition through their ability to reproduce.

Revegetation of plant species, particularly from the spike and shrub groups, would likely increase native bee numbers and is an approach to prevent resource competition between native and honey bees.

Recommendations

- Island rehabilitation is biased to native flowering plants.
- Monitoring of the flower visitor biodiversity is maintained on a regular basis
- Native bee hotels are established for focussed monitoring of their breeding
- A tourism offering is developed with the native bees and honey bees – showing their similarities and differences, together with discussing the flora on the island.

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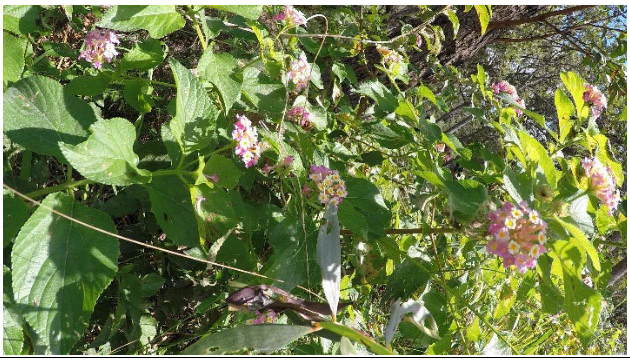
APPENDIX 1: Plants selected for monitoring

Acacia concurrens Flowers are arranged in solitary spikes that are 3.5–11 cm long, pale yellow.	
Acacia longifolia Inflorescences usually attached directly to the stem. Spikes solitary or twinned, 2–5 cm long.	
Alphitonia excelsa The individual small flowers form cyme clusters that cover the tree.	
Aotus lanigera Legume flowers arranged on the stem in short terminal racemes.	

Astrotricha longifolia Inflorescence to 60 cm long and form cyme clusters.	
Austromyrtus dulcis Flowers are about 1 cm in diameter so could be dealt with individually	
Banksia integrifolia Flowers occur in Banksia's characteristic "flower spike", an inflorescence made up of several hundred flowers densely packed in a spiral around a woody axis. There is a rapid opening of flowers from the base to apex.	
Banksia serrata Flowers occur in Banksia's characteristic "flower spike", an inflorescence made up of several hundred flowers densely packed in a spiral around a woody axis. There is a rapid opening of flowers from the base to apex.	

Conospermum taxifolium	
Corymbia intermedia	
Dilwynia retorta Legume flowers arranged at the end of the stem in short terminal racemes.	
Elaeocarpus obovatus A rainforest tree of eastern Australia with white flowers that appear from September to November on racemes.	

Eucalyptus haemastoma	
Eucalyptus robusta	
Lantana camara	
Leptospermum juniperinum	

Leptospermum liversidgei	
Leptospermum trinervium	
Melaleuca pachyphylla	
Melaleuca quinquenervia	

Persoonia virgata	
Ricinocarpos pinifolius	
Woollsia pungens	
Xanthorrhoea australis	

APPENDIX 2: Flower visitor spectrum

Group	Taxa
Anthophila (native)	*Amegilla sp*
	Apidae sp
	Clade_Anthophila sp
	Colletidae sp
	Hylaeus sp
	Leioproctus sp
	Subfamily_Euryglossinae sp
	Subfamily_Hylaeinae sp
	Tribe_Meliponini sp
	Xylocopa sp
European honey bee	*Apis mellifera*
Blattodea	Order_Blattodea sp
Coleoptera	*Apolinus lividigaster*
	Buprestidae sp
	Coccinellidae sp
	Curculionidae sp
	Nitidulidae sp
	Oedemeridae sp
	Order_Coleoptera sp
	Superfamily_Cucujoidea sp
	Superfamily_Scarabaeoidea sp
Diptera	*Apiocera sp*
	Bombyliidae sp
	Calliphora sp
	Culicidae sp
	Dideopsis aegrota
	Episyrphys sp
	Episyrphys viridaureus
	Eumerus sp
	Ligyra satyrus
	Muscidae sp
	Neomyia sp
	Order_Diptera sp
	Parapalaeosepsis sp
	Platystomatidae sp
	Sapromyza sp
	Sarcophagidae sp
	Scaptia sp
	Sphaerophoria sp

	Stratiomyidae sp Subfamily_Bombyliinae sp Subfamily_Goniinae sp Suborder_Nematocera sp Syrphidae sp Tabanidae sp Tachinidae sp Tephritidae sp Tipulidae sp
Formicidae	*Camponotus nigroaneus* *Camponotus sp* *Crematogaster laeviceps* Formicidae sp *Iridomyrmex purpureus* *Leptomyrmex rufipes* *Myrmecia sp* *Polyrhachis ammon* *Polyrhachis australis* *Polyrhachis daemeli* *Polyrhachis sp*
Hemiptera	Cicadellidae sp Coreidae sp Order_Himiptera sp
Lepidoptera	*Candalides sp* *Delias nigrina* Geometridae sp Hesperiidae sp Lycaenidae sp *Melanitis leda* Nymphalidae sp Order_Lepidoptera sp *Papilio aegeus* *Papilio sp* Pieridae sp *Prosotas dubiosa* *Prosotas felderi* Subfamily_Agaristinae sp
Meliphagidae	*Lichmera indistincta* Meliphagidae sp *Philemon corniculatus* *Phylidonyris niger*

	Phylidonyris pyrrhopterus
Spheciformes	*Bembix sp* Crabronidae sp *Larra sp* Sphecidae sp
Vespoidea	*Polistes sp* *Polistes stigma* Pompilidae sp *Tachyphron armidalensis* Tiphiidae sp *Turneromyia sp* Vespidae sp

APPENDIX 3: North Stradbroke Island plant species list

Season	Family	Scientific Name	Common Name	Flowering Period	Pollen/Nectar/Honey	Height (m)	Moisture, soil, cultivation requirements
Dec-Jan	Myrtaceae	Acmena smithii	lillypilly satinash	Nov-Jan	low honey; low pollen	15	moist soil; loam; clay
Dec-Jan	Primulaceae	Aegiceras corniculatum	river mangrove	Oct-Dec	[HPF] is a prolific pollen producer, which benefit bees. Has grey pollen. provides honey surpluses where river mangrove is plentiful	3; 4	mangrove; swamp; mud; sand
Dec-Jan	Proteaceae	Banksia integrifolia	coast banksia	Jan-Jul; Jun-Aug; Mainly May-Aug; Odd flowers through out year	It is an important species to apiculture for its pollen and for the dark amber coloured honey which is of medium value [4] Clemson A (1985) Honey and Pollen Flora. Inkata Press, Melbourne; Flowers are especially attractive to Nectivorous birds; [HPF] Produce masses of nectar. Abundant source of pollen. Minor-med source of pollen for bees. Medium importance as source of honey. Honey does not appeal to packers and small amounts can be incorporated into blends.	5-15; often stunted growth in exposed areas	Dunes; clay loam; loam; sandy loam; sand
Dec-Jan	Proteaceae	Banksia serrata	red honeysuckle/old man banksia	Dec-Apr; Jan-May, although some flowers may be present for most of year	med honey; med pollen; [HPF] Min-Med importance for honey; Minor importance for pollen for bees.	3m coastal; 16m favourable habitats; 15	
Dec-Jan	Rhizophoraceae	Bruguiera gymnorhiza	large-fruited orange mangrove/ black mangrove	Aug-Jan		0.45	mangrove; mud; estuaries
Dec-Jan	Cupressaceae	Callitris columellaris (glaucophylla)	white cypress pine	Sept-Dec	[HPF] Periodically produces a useful supply of pollen which is of some benefit to bees.	10; 18; 15-20	coastal; sandy; loamy, often with clay at depth
Dec-Jan	Aizoaceae	Carpobrotus glaucescens	pigface	All Year; Oct-Jan		2	Sand dunes
Dec-Jan	Myrtaceae	Corymbia gummifera (previously Eucalyptus)	red bloodwood	Dec-Jun; Mar-May	High honey; low pollen	35	Coast
Dec-Jan	Myrtaceae	Corymbia intermedia (previously Eucalyptus)	pink bloodwood	Oct-Feb; Jan-Mar; [HPF] Feb-Mar	Min-Med honey; Med pollen for bees	35; 24-33; 15 on less favourable sites	Coastal forests; soils of med fertility
Dec-Jan	Elaeocarpaceae	Elaeocarpus reticulatus	ash quandong	Dec-Feb		3-15	along watercourses; eucalypt forests; rainforest

Dec-Jan	Myrtaceae	Eucalyptus pilularis	blackbutt	Oct-Jul; Oct-Mar; Dec-Feb; Apr-Jun	med honey; med pollen; [HPF] Temperamental to weather changes, so bee keepers generally do not depend on it. Honey is usually second grade because it lacks density has a rather strong flavour.	70; 30-60	Coast
Dec-Jan	Myrtaceae	Eucalyptus planchoniana		Oct-Dec; Nov-Mar	Couldn't find any info	20; 25	
Dec-Jan	Myrtaceae	Eucalyptus racemosa subsp. Racemosa (formerly signata)	scribbly gum	Jan-Feb; Jul-Sept; [HPF] Jan, but also possibly Autumn-Spring;	[HPF] Flowers regularly, but minor value for honey production. In good seasons satisfactory honey yields are obtained. Light pollen supply.	20	sandy soils; coastal; forest; woodland
Dec-Jan	Dilleniaceae	Hibbertia scandens		All Year; Sept-Feb		2-5	
Dec-Jan	Myrtaceae	Leptospermum liversidgei	olive tea-tree	Dec-Feb; Sept-Nov; mostly Jan		2	
Dec-Jan	Myrtaceae	Leptospermum polygalifolium Subsp. Polygalifolium (previously flavescens)	tantoon	Nov-Dec;	[HPF] Generally avoided by beekeepers, as nature of honey has thixotropic or jellying characteristics that make it virtually impossible to extract by normal means; minor importance for honey; bees work this species actively for both nectar and pollen	0.5-3; 4	Sandy soil, sandstone, basalt soils and rocks
Dec-Jan	Myrtaceae	Leptospermum trinervium (previously attenuatum)	woolly tea-tree	Sept-Nov; Oct-Dec	[HPF] Minor source of nectar and pollen. Worked by bees when conditions are favourable (warmer);	4	Coast; heath; scrubby areas; sandstone soils
Dec-Jan	Proteaceae	Persoonia cornifolia	broad-leaved geebung	Nov-Feb; Dec-Feb	nectar and pollen important for Leioproctus bees; pollination by native bees, especially Leioproctus subgenus Cladocerapis (Colletidae), which rarely visit any plants but Persoonia has been studied in detail; Leioproctus, subgenus Filiglossa, also specialises in feeding on Persoonia flowers but these smaller bees seem to be nectar and pollen “thieves”, not effective pollinators; Leioproctus, subgenus Exoneura, also pollinate Persoonia; also pollinated by bird and mammal species	0.9-6	woodland; forest; well-drained; sandstone; granite

Dec-Jan	Proteaceae	Persoonia stradbrokensis		Dec-Feb; Dec-May	nectar and pollen important for Leioproctus bees; pollination by native bees, especially Leioproctus subgenus Cladocerapis (Colletidae), which rarely visit any plants but Persoonia has been studied in detail; Leioproctus, subgenus Filiglossa, also specialises in feeding on Persoonia flowers but these smaller bees seem to be nectar and pollen "thieves", not effective pollinators; Leioproctus, subgenus Exoneura, also pollinate Persoonia; also pollinated by bird and mammal species	1-6	coastal; forest; coastal sand; sandstone
Dec-Jan	Proteaceae	Persoonia virgata	small-leaved geebung	Dec-Feb; Mainly Dec-Mar; Nov-Jul;	nectar and pollen important for Leioproctus bees; pollination by native bees, especially Leioproctus subgenus Cladocerapis (Colletidae), which rarely visit any plants but Persoonia has been studied in detail; Leioproctus, subgenus Filiglossa, also specialises in feeding on Persoonia flowers but these smaller bees seem to be nectar and pollen "thieves", not effective pollinators; Leioproctus, subgenus Exoneura, also pollinate Persoonia; also pollinated by bird and mammal species	0.4-4	
Dec-Jan	Xanthorrhoeaceae	Xanthorrhoea johnsonii	johnson's grass tree	Apr-Dec	most common visitors to the flowers of X. johnsonii have previously been identified as the introduced bee Apis mellifera and the native bee Trigona carbonaria (Zalucki, 1998). Is a pollen source for these bees	0.1-5	forest; well-drained
Dec-Jan	Acanthaceae	Avicennia marina subsp. australasica		All year; Late Summer	[HPF] Minor importance as commercial source of honey. Medium importance for pollen. small surplus of honey produced some seasons. Produces amber-coloured honey with strong flavour and usually lacking density. Pollen and nectar can be beneficial for brood rearing	9; 6-12	saltwater swamps and estuaries; mangrove
Dec-Jan	Laxmanniaceae	Lomandra longifolia		Spring-Early summer; Spring	Source of nectar; nectar attracts pollinating beetles		sandy; clay; tolerant of dryness
Feb-Mar	Casuarinaceae	Allocasuarina torulosa		Mar-May	Other Casuarinaceae: Nil Honey; Med Pollen; Useful for pollen. [HPF] no value as source of honey. Small quantities of pollen is collected for bees and is only of minimal importance for bees.	commonly: 15-20; favourable: 30	Coast; tablelands; forests; hillsides
Feb-Mar	Acanthaceae	Avicennia marina subsp. australasica		All year; Late Summer	[HPF] Minor importance as commercial source of honey. Medium importance for pollen. small surplus of honey produced some seasons. Produces amber-coloured honey with strong flavour and usually lacking density. Pollen and nectar can be beneficial for brood rearing	9; 6-12	saltwater swamps and estuaries; mangrove

Feb-Mar	Proteaceae	Banksia aemula	wallum banksia	mainly Mar-Jun; All year according to [VNSI]	nectar attractive to nectivorous birds and insects	8	woodland; shrubland; sandy; sand dunes
Feb-Mar	Proteaceae	Banksia serrata	red honeysuckle/old man banksia	Dec-Apr; Jan-May, although some flowers may be present for most of year	med honey; med pollen; [HPF] Min-Med importance for honey; Minor importance for pollen for bees.	3m coastal; 16m favourable habitats; 15	
Feb-Mar	Myrtaceae	Corymbia gummifera (previously Eucalyptus)	red bloodwood	Dec-Jun; Mar-May	High honey; low pollen	35	Coast
Feb-Mar	Myrtaceae	Corymbia intermedia (previously Eucalyptus)	pink bloodwood	Oct-Feb; Jan-Mar; [HPF] Feb-Mar	Min-Med honey; Med pollen for bees	35; 24-33; 15 on less favourable sites	Coastal forests; soils of med fertility
Feb-Mar	Elaeocarpaceae	Elaeocarpus reticulatus	ash quandong	Dec-Feb		3-15	along watercourses; eucalypt forests; rainforest
Feb-Mar	Myrtaceae	Eucalyptus pilularis	blackbutt	Oct-Jul; Oct-Mar; Dec-Feb; Apr-Jun	med honey; med pollen; [HPF] Temperamental to weather changes, so bee keepers generally do not depend on it. Honey is usually second grade because it lacks density has a rather strong flavour.	70; 30-60	Coast
Feb-Mar	Myrtaceae	Eucalyptus planchoniana		Oct-Dec; Nov-Mar	Couldn't find any info	20; 25	
Feb-Mar	Dilleniaceae	Hibbertia scandens	guinea flower/snake vine	All Year; Sept-Feb		2-5	
Feb-Mar	Myrtaceae	Leptospermum liversidgei	olive tea-tree	Dec-Feb; Sept-Nov; mostly Jan		2	

Feb-Mar	Proteaceae	Persoonia cornifolia	broad-leaved geebung	Nov-Feb; Dec-Feb	nectar and pollen important for Leioproctus bees; pollination by native bees, especially Leioproctus subgenus Cladocerapis (Colletidae), which rarely visit any plants but Persoonia has been studied in detail; Leioproctus, subgenus Filiglossa, also specialises in feeding on Persoonia flowers but these smaller bees seem to be nectar and pollen "thieves", not effective pollinators; Leioproctus, subgenus Exoneura, also pollinate Persoonia; also pollinated by bird and mammal species	0.9-6	woodland; forest; well-drained; sandstone; granite
Feb-Mar	Proteaceae	Persoonia stradbrokensis		Dec-Feb; Dec-May	nectar and pollen important for Leioproctus bees; pollination by native bees, especially Leioproctus subgenus Cladocerapis (Colletidae), which rarely visit any plants but Persoonia has been studied in detail; Leioproctus, subgenus Filiglossa, also specialises in feeding on Persoonia flowers but these smaller bees seem to be nectar and pollen "thieves", not effective pollinators; Leioproctus, subgenus Exoneura, also pollinate Persoonia; also pollinated by bird and mammal species	1-6	coastal; forest; coastal sand; sandstone
Feb-Mar	Proteaceae	Persoonia virgata	small-leaved geebung	Dec-Feb; Mainly Dec-Mar; Nov-Jul;	nectar and pollen important for Leioproctus bees; pollination by native bees, especially Leioproctus subgenus Cladocerapis (Colletidae), which rarely visit any plants but Persoonia has been studied in detail; Leioproctus, subgenus Filiglossa, also specialises in feeding on Persoonia flowers but these smaller bees seem to be nectar and pollen "thieves", not effective pollinators; Leioproctus, subgenus Exoneura, also pollinate Persoonia; also pollinated by bird and mammal species	0.4-4	
Apr-May	Mimosaceae	Acacia suaveolens	sweet wattle	Early Spring; Apr-Sept	no nectar; med pollen / can produce good quantities of pollen, no nectar	0.3-2.5	forest; woodland; shrubland; sandy soil; coastal
Apr-May	Mimosaceae	Acacia ulicifolia		Early Spring; Apr-Oct	no nectar; med pollen / can produce good quantities of pollen, no nectar	0.5-2	florest; woodland; sandy soil; coastal
Apr-May	Casuarinaceae	Allocasuarina littoralis		Apr-Sept	Other Casuarinaceae: Nil Honey; Med Pollen; Useful for pollen; [HPF] No value as source of honey. Bees regularly work male flowers, eagerly gathering pollen together with certain floral parts.	5-15; 12	Versatile; well-drained soil; nitrogen fixing

Apr-May	Casuarinaceae	Allocasuarina torulosa		Mar-May	Other Casuarinaceae: Nil Honey; Med Pollen; Useful for pollen. [HPF] no value as source of honey. Small quantities of pollen is collected for bees and is only of minimal importance for bees.	commonly: 15-20; favourable: 30	Coast; tablelands; forests; hillsides
Apr-May	Proteaceae	Banksia aemula	wallum banksia	mainly Mar-Jun; All year according to [VNSI]	nectar attractive to nectivorous birds and insects	8	woodland; shrubland; sandy; sand dunes
Apr-May	Proteaceae	Banksia integrifolia	coast banksia	Jan-Jul; Jun-Aug; Mainly May-Aug; Odd flowers through out year	It is an important species to apiculture for its pollen and for the dark amber coloured honey which is of medium value [4] Clemson A (1985) Honey and Pollen Flora. Inkata Press, Melbourne; Flowers are especially attractive to Nectivorous birds; [HPF] Produce masses of nectar. Abundant source of pollen. Minor-med source of pollen for bees. Medium importance as source of honey. Honey does not appeal to packers and small amounts can be incorporated into blends.	5-15; often stunted growth in exposed areas	Dunes; clay loam; loam; sandy loam; sand
Apr-May	Proteaceae	Banksia serrata	red honeysuckle/old man banksia	Dec-Apr; Jan-May, although some flowers may be present for most of year	med honey; med pollen; [HPF] Min-Med importance for honey; Minor importance for pollen for bees.	3m coastal; 16m favourable habitats; 15	
Apr-May	Proteaceae	Banksia spinulosa var. collina	Hairpin banksia	Apr-Aug	[HPF] Bees are attracted in large numbers. Med-Major source of nectar for bees. Not favoured by packers. Special significance for providing stores for needy hives during winter when the weather is favourable.	1-2	heath; forest; woodland
Apr-May	Myrtaceae	Corymbia gummifera (previously Eucalyptus)	red bloodwood	Dec-Jun; Mar-May	High honey; low pollen	35	Coast
Apr-May	Fabaceae	Dillwynia floribunda	eggs and bacon/parrot pea	Sept-Nov; Possibly late autumn to spring	[HPF] Mainly useful to bees for pollen	0.2-2.5; 1-2	sandy soils; heath

Apr-May	Myrtaceae	Eucalyptus pilularis	blackbutt	Oct-Jul; Oct-Mar; Dec-Feb; Apr-Jun	med honey; med pollen; [HPF] Temperamental to weather changes, so bee keepers generally do not depend on it. Honey is usually second grade because it lacks density has a rather strong flavour.	70; 30-60	Coast
Apr-May	Xanthorrhoeaceae	Xanthorrhoea johnsonii	johnson's grass tree	Apr-Dec	most common visitors to the flowers of X. johnsonii have previously been identified as the introduced bee Apis mellifera and the native bee Trigona carbonaria (Zalucki, 1998). Is a pollen source for these bees	0.1-5	forest; well-drained
Jun-Jul	Mimosaceae	Acacia concurrens (previously split from cunninghamii)		Early Spring; Jul-Sept	no nectar; med pollen / can produce good quantities of pollen, no nectar	3-10	forest; woodland; shrubland; shale and sandstone derived soils
Jun-Jul	Mimosaceae	Acacia suaveolens	sweet wattle	Early Spring; Apr-Sept	no nectar; med pollen / can produce good quantities of pollen, no nectar	0.3-2.5	forest; woodland; shrubland; sandy soil; coastal
Jun-Jul	Mimosaceae	Acacia ulicifolia		Early Spring; Apr-Oct	no nectar; med pollen / can produce good quantities of pollen, no nectar	0.5-2	florest; woodland; sandy soil; coastal
Jun-Jul	Casuarinaceae	Allocasuarina littoralis		Apr-Sept	Other Casuarinaceae: Nil Honey; Med Pollen; Useful for pollen; [HPF] No value as source of honey. Bees regularly work male flowers, eagerly gathering pollen together with certain floral parts.	5-15; 12	Versatile; well-drained soil; nitrogen fixing
Jun-Jul	Proteaceae	Banksia aemula	wallum banksia	mainly Mar-Jun; All year according to [VNSI]	nectar attractive to nectivorous birds and insects	8	woodland; shrubland; sandy; sand dunes
Jun-Jul	Proteaceae	Banksia integrifolia	coast banksia	Jan-Jul; Jun-Aug; Mainly May-Aug; Odd flowers through out year	It is an important species to apiculture for its pollen and for the dark amber coloured honey which is of medium value [4] Clemson A (1985) Honey and Pollen Flora. Inkata Press, Melbourne; Flowers are especially attractive to Nectivorous birds; [HPF] Produce masses of nectar. Abundant source of pollen. Minor-med source of pollen for bees. Medium importance as source of honey. Honey does not appeal to packers and small amounts can be incorporated into blends.	5-15; often stunted growth in exposed areas	Dunes; clay loam; loam; sandy loam; sand
Jun-Jul	Proteaceae	Banksia spinulosa var. collina	Hairpin banksia	Apr-Aug	[HPF] Bees are attracted in large numbers. Med-Major source of nectar for bees. Not favoured by packers. Special significance for providing stores for needy hives during winter when the weather is favourable.	1-2	heath; forest; woodland

Jun-Jul	Rutaceae	Boronia rosmarinifolia	forest boronia	Jul-Oct	low nectar; low pollen	0.3-1	Forest; sandstone; coastal sand; well-drained; various
Jun-Jul	Myrtaceae	Eucalyptus racemosa subsp. Racemosa (formerly signata)	scribbly gum	Jan-Feb; Jul-Sept; [HPF] Jan, but also possibly Autumn-Spring;	[HPF] Flowers regularly, but minor value for honey production. In good seasons satisfactory honey yields are obtained. Light pollen supply.	20	sandy soils; coastal; forest; woodland
Jun-Jul	Myrtaceae	Corymbia gummifera (previously Eucalyptus)	red bloodwood	Dec-Jun; Mar-May	High honey; low pollen	35	Coast
Jun-Jul	Myrtaceae	Eucalyptus pilularis	blackbutt	Oct-Jul; Oct-Mar; Dec-Feb; Apr-Jun	med honey; med pollen; [HPF] Temperamental to weather changes, so bee keepers generally do not depend on it. Honey is usually second grade because it lacks density has a rather strong flavour.	70; 30-60	Coast
Jun-Jul	Myrtaceae	Eucalyptus robusta	swamp mahogany/ swamp messmate (Do not confuse with Lophostemon suaveolens)	Can extend May-Aug; Peak Jun-Jul	[HPF] Fairly reliable source of pollen. Med source of pollen for NSW. Minor importance as source of honey in NSW. If weather is favourable, stimulates brood-rearing, thus strengthening colonies. In wet weather, bees may be lost through flying under adverse weather, supporting belief of many bee keepers that Swamp mahogany kills bees.	15	Sandy soils; clay; tidal flats; salt-water lagoons
Jun-Jul	Myrtaceae	Eucalyptus tereticornis		Jun-Nov	a major source of pollen and honey for apiculture [5] Clemson A (1985) Honey and Pollen Flora. Inkata Press, Melbourne	20-50	
Jun-Jul	Myrtaceae	Eucalyptus tereticornis subsp. tereticornis		Jun-Nov	a major source of pollen and honey for apiculture [5] Clemson A (1985) Honey and Pollen Flora. Inkata Press, Melbourne	50 (grows larger than 20 max of other mediana sub-species)	

Jun-Jul	Proteaceae	Persoonia virgata	small-leaved geebung	Dec-Feb; Mainly Dec-Mar; Nov-Jul;	nectar and pollen important for Leioproctus bees; pollination by native bees, especially Leioproctus subgenus Cladocerapis (Colletidae), which rarely visit any plants but Persoonia has been studied in detail; Leioproctus, subgenus Filiglossa, also specialises in feeding on Persoonia flowers but these smaller bees seem to be nectar and pollen "thieves", not effective pollinators; Leioproctus, subgenus Exoneura, also pollinate Persoonia; also pollinated by bird and mammal species	0.4-4	
Jun-Jul	Euphorbiaceae	Ricinocarpos pinifolius	wedding bush	Jun-Nov		1-3	sandy; coastal
Jun-Jul	Xanthorrhoeaceae	Xanthorrhoea johnsonii	johnson's grass tree	Apr-Dec	most common visitors to the flowers of X. johnsonii have previously been identified as the introduced bee Apis mellifera and the native bee Trigona carbonaria (Zalucki, 1998). Is a pollen source for these bees	0.1-5	forest; well-drained
Aug-Sept	Mimosaceae	Acacia baueri subsp. baueri	tiny wattle	Early Spring	no nectar; med pollen / can produce good quantities of pollen, no nectar		
Aug-Sept	Mimosaceae	Acacia concurrens (previously split from cunninghamii)		Early Spring; Jul-Sept	no nectar; med pollen / can produce good quantities of pollen, no nectar	3-10	forest; woodland; shrubland; shale and sandstone derived soils
Aug-Sept	Mimosaceae	Acacia disparrima subsp. disparrima		Early Spring	no nectar; med pollen / can produce good quantities of pollen, no nectar		
Aug-Sept	Mimosaceae	Acacia fimbriata	Brisbane golden wattle	Early Spring	no nectar; med pollen / can produce good quantities of pollen, no nectar		
Aug-Sept	Mimosaceae	Acacia longifolia	Sydney golden wattle	Early Spring	no nectar; med pollen / can produce good quantities of pollen, no nectar		
Aug-Sept	Mimosaceae	Acacia melanoxylon	blackwood	Early Spring	no nectar; med pollen / can produce good quantities of pollen, no nectar		
Aug-Sept	Mimosaceae	Acacia podalyriifolia	Queensland silver wattle	Early Spring	no nectar; med pollen / can produce good quantities of pollen, no nectar		
Aug-Sept	Mimosaceae	Acacia saligna	golden wreath wattle	Early Spring	no nectar; med pollen / can produce good quantities of pollen, no nectar		
Aug-Sept	Mimosaceae	Acacia sophorae	coastal wattle	Early Spring	no nectar; med pollen / can produce good quantities of pollen, no nectar		
Aug-Sept	Mimosaceae	Acacia suaveolens	sweet wattle	Early Spring; Apr-Sept	no nectar; med pollen / can produce good quantities of pollen, no nectar	0.3-2.5	forest; woodland; shrubland; sandy soil; coastal
Aug-Sept	Mimosaceae	Acacia ulicifolia		Early Spring; Apr-Oct	no nectar; med pollen / can produce good quantities of pollen, no nectar	0.5-2	flforest; woodland; sandy soil; coastal

Aug-Sept	Casuarinaceae	Allocasuarina littoralis		Apr-Sept	Other Casuarinaceae: Nil Honey; Med Pollen; Useful for pollen; [HPF] No value as source of honey. Bees regularly work male flowers, eagerly gathering pollen together with certain floral parts.	5-15; 12	Versatile; well-drained soil; nitrogen fixing
Aug-Sept	Proteaceae	Banksia aemula	wallum banksia	mainly Mar-Jun; All year according to [VNSI]	nectar attractive to nectivorous birds and insects	8	woodland; shrubland; sandy; sand dunes
Aug-Sept	Proteaceae	Banksia integrifolia	coast banksia	Jan-Jul; Jun-Aug; Mainly May-Aug; Odd flowers throughout year	It is an important species to apiculture for its pollen and for the dark amber coloured honey which is of medium value [4] Clemson A (1985) Honey and Pollen Flora. Inkata Press, Melbourne; Flowers are especially attractive to Nectivorous birds; [HPF] Produce masses of nectar. Abundant source of pollen. Minor-med source of pollen for bees. Medium importance as source of honey. Honey does not appeal to packers and small amounts can be incorporated into blends.	5-15; often stunted growth in exposed areas	Dunes; clay loam; loam; sandy loam; sand
Aug-Sept	Proteaceae	Banksia spinulosa var. collina	Hairpin banksia	Apr-Aug	[HPF] Bees are attracted in large numbers. Med-Major source of nectar for bees. Not favoured by packers. Special significance for providing stores for needy hives during winter when the weather is favourable.	1-2	heath; forest; woodland
Aug-Sept	Rutaceae	Boronia rosmarinifolia	forest boronia	Jul-Oct	low nectar; low pollen	0.3-1	Forest; sandstone; coastal sand; well-drained; various
Aug-Sept	Rhizophoraceae	Bruguiera gymnorhiza	large-fruited orange mangrove/ black mangrove	Aug-Jan		0.45	mangrove; mud; estuaries
Aug-Sept	Cupressaceae	Callitris columellaris (glaucophylla)	white cypress pine	Sept-Dec	[HPF] Periodically produces a useful supply of pollen which is of some benefit to bees.	10; 18; 15-20	coastal; sandy; loamy, often with clay at depth
Aug-Sept	Myrtaceae	Corymbia torelliana	cadaghi	Aug; Oct-Nov		30	
Aug-Sept	Casuarinaceae	Casuarina glauca	swamp she-oak	Genus are All Year; Usually Sept-Oct	Nil Honey; Med Pollen; Useful for pollen	20	Coast; clay loam; heavy clay; clay; sandy clay loam; sandy loam

Aug-Sept	Fabaceae	Dillwynia floribunda	eggs and bacon/parrot pea	Sept-Nov; Possibly late autumn to spring	[HPF] Mainly useful to bees for pollen	0.2-2.5; 1-2	sandy soils; heath
Aug-Sept	Elaeocarpaceae	Elaeocarpus obovatus	blueberry ash	Sept-Nov		45	littoral (on the shore) and dry rainforest
Aug-Sept	Myrtaceae	Eucalyptus racemosa subsp. Racemosa (formerly signata)	scribbly gum	Jan-Feb; Jul-Sept; [HPF] Jan, but also possibly Autumn-Spring;	[HPF] Flowers regularly, but minor value for honey production. In good seasons satisfactory honey yields are obtained. Light pollen supply.	20	sandy soils; coastal; forest; woodland
Aug-Sept	Myrtaceae	Eucalyptus tereticornis		Jun-Nov	a major source of pollen and honey for apiculture [5] Clemson A (1985) Honey and Pollen Flora. Inkata Press, Melbourne	20-50	
Aug-Sept	Myrtaceae	Eucalyptus tereticornis subsp. tereticornis		Jun-Nov	a major source of pollen and honey for apiculture [5] Clemson A (1985) Honey and Pollen Flora. Inkata Press, Melbourne	50 (grows larger than 20 max of other mediana sub-species)	
Aug-Sept	Fabaceae	Hardenbergia violacea	purple coral pea	mostly sept-nov	low nectar; high pollen	climber	Well-drained sandy loam to heavy clay, alkaline tolerant
Aug-Sept	Dilleniaceae	Hibbertia scandens	guinea flower/snake vine	All Year; Sept-Feb		2-5	
Aug-Sept	Myrtaceae	Leptospermum juniperinum	prickly tea-tree	Sept-Nov; irregularly, mostly Nov		2-3	Swamp; heath; sandy peat soils; sandstone
Aug-Sept	Myrtaceae	Leptospermum laevigatum	coast tea-tree	Sept-Nov; Aug-Oct		4	Coastal heath; forest; sand; dunes
Aug-Sept	Myrtaceae	Leptospermum liversidgei	olive tea-tree	Dec-Feb; Sept-Nov; mostly Jan		2	
Aug-Sept	Myrtaceae	Leptospermum semibaccatum	wallum tea-tree	Sept-Nov; Nov			

Aug-Sept	Myrtaceae	Leptospermum speciosum		Sept-Nov; Aug-Sept		Usually 1-3; Occasionally 5-6	Swampy heath; sandy soil
Aug-Sept	Myrtaceae	Leptospermum trinervium (previously attenuatum)	woolly tea-tree	Sept-Nov; Oct-Dec	[HPF] Minor source of nectar and pollen. Worked by bees when conditions are favourable (warmer);	4	Coast; heath; scrubby areas; sandstone soils
Aug-Sept	Laxmanniaceae	Lomandra longifolia		Spring-Early summer; Spring	Source of nectar; nectar attracts pollinating beetles		sandy; clay; tolerant of dryness
Aug-Sept	Fabaceae	Phyllota phylicoides	yellow pea	Sept-Nov		1	heath
Aug-Sept	Euphorbiaceae	Ricinocarpos pinifolius	wedding bush	Jun-Nov		1-3	sandy; coastal
Aug-Sept	Xanthorrhoeaceae	Xanthorrhoea johnsonii	johnson's grass tree	Apr-Dec	most common visitors to the flowers of X. johnsonii have previously been identified as the introduced bee Apis mellifera and the native bee Trigona carbonaria (Zalucki, 1998). Is a pollen source for these bees	0.1-5	forest; well-drained
Oct-Nov	Mimosaceae	Acacia ulicifolia		Early Spring; Apr-Oct	no nectar; med pollen / can produce good quantities of pollen, no nectar	0.5-2	florest; woodland; sandy soil; coastal
Oct-Nov	Myrtaceae	Acmena smithii	lillypilly satinash	Nov-Jan	low honey; low pollen	15	moist soil; loam; clay
Oct-Nov	Primulaceae	Aegiceras corniculatum	river mangrove	Oct-Dec	[HPF] is a prolific pollen producer, which benefit bees. Has grey pollen. provides honey surpluses where river mangrove is plentiful	3; 4	mangrove; swamp; mud; sand
Oct-Nov	Rutaceae	Boronia rosmarinifolia	forest boronia	Jul-Oct	low nectar; low pollen	0.3-1	Forest; sandstone; coastal sand; well-drained; various
Oct-Nov	Rhizophoraceae	Bruguiera gymnorhiza	large-fruited orange mangrove/ black mangrove	Aug-Jan		0.45	mangrove; mud; estuaries
Oct-Nov	Cupressaceae	Callitris columellaris (glaucophylla)	white cypress pine	Sept-Dec	[HPF] Periodically produces a useful supply of pollen which is of some benefit to bees.	10; 18; 15-20	coastal; sandy; loamy, often with clay at depth
Oct-Nov	Aizoaceae	Carpobrotus glaucescens	pigface	All Year; Oct-Jan		2	Sand dunes
Oct-Nov	Casuarinaceae	Casuarina glauca	swamp she-oak	Genus are All Year; Usually Sept-Oct	Nil Honey; Med Pollen; Useful for pollen	20	Coast; clay loam; heavy clay; clay; sandy clay loam; sandy loam
Oct-Nov	Myrtaceae	Corymbia intermedia (previously Eucalyptus)	pink bloodwood	Oct-Feb; Jan-Mar; [HPF] Feb-Mar	Min-Med honey; Med pollen for bees	35; 24-33; 15 on less favourable sites	Coastal forests; soils of med fertility

Oct-Nov	Myrtaceae	Corymbia torelliana	cadaghi	Aug; Oct-Nov		30	
Oct-Nov	Fabaceae	Dillwynia floribunda	eggs and bacon/parrot pea	Sept-Nov; Possibly late autumn to spring	[HPF] Mainly useful to bees for pollen	0.2-2.5; 1-2	sandy soils; heath
Oct-Nov	Elaeocarpaceae	Elaeocarpus obovatus	blueberry ash	Sept-Nov		45	littoral (on the shore) and dry rainforest
Oct-Nov	Myrtaceae	Eucalyptus pilularis	blackbutt	Oct-Jul; Oct-Mar; Dec-Feb; Apr-Jun	med honey; med pollen; [HPF] Temperamental to weather changes, so bee keepers generally do not depend on it. Honey is usually second grade because it lacks density has a rather strong flavour.	70; 30-60	Coast
Oct-Nov	Myrtaceae	Eucalyptus planchoniana		Oct-Dec; Nov-Mar	Couldn't find any info	20; 25	
Oct-Nov	Myrtaceae	Eucalyptus tereticornis		Jun-Nov	a major source of pollen and honey for apiculture [5] Clemson A (1985) Honey and Pollen Flora. Inkata Press, Melbourne	20-50	
Oct-Nov	Myrtaceae	Eucalyptus tereticornis subsp. tereticornis		Jun-Nov	a major source of pollen and honey for apiculture [5] Clemson A (1985) Honey and Pollen Flora. Inkata Press, Melbourne	50 (grows larger than 20 max of other mediana sub-species)	
Oct-Nov	Fabaceae	Hardenbergia violacea	purple coral pea	mostly sept-nov	low nectar; high pollen	climber	Well-drained sandy loam to heavy clay, alkaline tolerant
Oct-Nov	Dilleniaceae	Hibbertia scandens	guinea flower/snake vine	All Year; Sept-Feb		2-5	
Oct-Nov	Myrtaceae	Leptospermum juniperinum	prickly tea-tree	Sept-Nov; irregularly, mostly Nov		2-3	Swamp; heath; sandy peat soils; sandstone
Oct-Nov	Myrtaceae	Leptospermum laevigatum	coast tea-tree	Sept-Nov; Aug-Oct		4	Coastal heath; forest; sand; dunes
Oct-Nov	Myrtaceae	Leptospermum liversidgei	olive tea-tree	Dec-Feb; Sept-Nov; mostly Jan		2	

Oct-Nov	Myrtaceae	Leptospermum polygalifolium Subsp. Polygalifolium (previously flavescens)	tantoon	Nov-Dec;	[HPF] Generally avoided by beekeepers, as nature of honey has thixotropic or jellying characteristics that make it virtually impossible to extract by normal means; minor importance for honey; bees work this species actively for both nectar and pollen	0.5-3; 4	Sandy soil, sandstone, basalt soils and rocks
Oct-Nov	Myrtaceae	Leptospermum semibaccatum	wallum tea-tree	Sept-Nov; Nov			
Oct-Nov	Myrtaceae	Leptospermum speciosum		Sept-Nov; Aug-Sept		Usually 1-3; Occasionally 5-6	Swampy heath; sandy soil
Oct-Nov	Myrtaceae	Leptospermum trinervium (previously attenuatum)	woolly tea-tree	Sept-Nov; Oct-Dec	[HPF] Minor source of nectar and pollen. Worked by bees when conditions are favourable (warmer);	4	Coast; heath; scrubby areas; sandstone soils
Oct-Nov	Laxmanniaceae	Lomandra longifolia		Spring-Early summer; Spring	Source of nectar; nectar attracts pollinating beetles		sandy; clay; tolerant of dryness
Oct-Nov	Proteaceae	Persoonia cornifolia	broad-leaved geebung	Nov-Feb; Dec-Feb	nectar and pollen important for Leioproctus bees; pollination by native bees, especially Leioproctus subgenus Cladocerapis (Colletidae), which rarely visit any plants but Persoonia has been studied in detail; Leioproctus, subgenus Filiglossa, also specialises in feeding on Persoonia flowers but these smaller bees seem to be nectar and pollen “thieves”, not effective pollinators; Leioproctus, subgenus Exoneura, also pollinate Persoonia; also pollinated by bird and mammal species	0.9-6	woodland; forest; well-drained; sandstone; granite
Oct-Nov	Proteaceae	Persoonia virgata	small-leaved geebung	Dec-Feb; Mainly Dec-Mar; Nov-Jul;	nectar and pollen important for Leioproctus bees; pollination by native bees, especially Leioproctus subgenus Cladocerapis (Colletidae), which rarely visit any plants but Persoonia has been studied in detail; Leioproctus, subgenus Filiglossa, also specialises in feeding on Persoonia flowers but these smaller bees seem to be nectar and pollen “thieves”, not effective pollinators; Leioproctus, subgenus Exoneura, also pollinate Persoonia; also pollinated by bird and mammal species	0.4-4	
Oct-Nov	Fabaceae	Phyllota phylicoides	yellow pea	Sept-Nov		1	heath
Oct-Nov	Euphorbiaceae	Ricinocarpos pinifolius	wedding bush	Jun-Nov		1-3	sandy; coastal

Oct-Nov	Xanthorrhoeaceae	Xanthorrhoea johnsonii	johnson's grass tree	Apr-Dec	most common visitors to the flowers of X. johnsonii have previously been identified as the introduced bee Apis mellifera and the native bee Trigona carbonaria (Zalucki, 1998). Is a pollen source for these bees	0.1-5	forest; well-drained
All Year	Acanthaceae	Avicennia marina subsp. australasica		All year; Late Summer	[HPF] Minor importance as commercial source of honey. Medium importance for pollen. small surplus of honey produced some seasons. Produces amber-coloured honey with strong flavour and usually lacking density. Pollen and nectar can be beneficial for brood rearing	9; 6-12	saltwater swamps and estuaries; mangrove
All Year	Proteaceae	Banksia aemula	wallum banksia	mainly Mar-Jun; All year according to [VNSI]	nectar attractive to nectivorous birds and insects	8	woodland; shrubland; sandy; sand dunes
All Year	Cupressaceae	Callitris rhomboidea	dune cypress pine/oyster bay pine	All year	No data, see other Callitris spp.	9-15	coastal; woodlands
All Year	Aizoaceae	Carpobrotus glaucescens	pigface	All Year; Oct-Jan		2	Sand dunes
All Year	Casuarinaceae	Casuarina equisetifolia subsp. incana		All Year	Nil Honey; Med Pollen; Useful for pollen	6-12	Dunes
All Year	Casuarinaceae	Casuarina glauca	swamp she-oak	Genus are All Year; Usually Sept-Oct	Nil Honey; Med Pollen; Useful for pollen	20	Coast; clay loam; heavy clay; clay; sandy clay loam; sandy loam
All Year	Dilleniaceae	Hibbertia scandens	guinea flower/snake vine	All Year; Sept-Feb		2-5	
All Year	Rhizophoraceae	Rhizophora stylosa	spotted mangrove	most of year			mangrove; swamp; mud; sand

References

[VNSI] = The Vegetation of North Stradbroke Island
[HPF] = Clemson, A., 1985. Honey and pollen flora. Inkata Press.

Useful website for overview of North Strad plant habitats: http://stradbrokeisland.com/straddie/view/flora
https://search.informit.com.au/fullText;dn=551711888189054;res=IELHSS
http://www.florabank.org.au/lucid/key/species%20navigator/media/html/index.htm#A
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