Resin-foraging by colonies of *Trigona sapiens* and *T. hockingsi* (Hymenoptera: Apidae, Meliponini) and consequent seed dispersal of *Corymbia torelliana* (Myrtaceae)*

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Abstract – Resins are a critical resource for stingless bees and resin-collecting bees act as seed dispersers in tropical plants. We describe the diurnal foraging patterns of colonies of *Trigona sapiens* and *T. hockingsi* on resin and pollen. We also document patterns of waste removal and seed dispersal of *Corymbia torelliana*. At most, only 10% of foragers collected resin or dispersed seed. Nevertheless, bees dispersed 1–3 seeds outside the nest per 5 minutes, and 38–114 seeds per day for each nest. The proportion of returning bees carrying pollen was highest in the morning for both species. The proportion of foragers returning with resin loads showed no significant diurnal variation in any season. Waste removal activity peaked in the afternoon for *T. sapiens* and in the morning for *T. hockingsi*. Seed removal peaked in the afternoon in one year only for *T. sapiens*. Bees dispersed thousands of seeds of *C. torelliana* over the season even though only a small proportion of the colony was engaged in seed transport.

stingless bees / mellitochory / seed dispersal / resin / *Corymbia*

1. INTRODUCTION

In stingless bees, individual workers make behavioural decisions that determine the foraging patterns of the colony. Decisions are based on intrinsic factors, and on information from the colony and environment (Biesmeijer and Slaa, 2004). Colonies can show distinct diurnal patterns of foraging, often determined by environmental cues such as temperature, wind speed and solar radiation (Heard and Hendrikz, 1993) and resource availability (Bartareau, 1996; De Bruijn and Sommeijer, 1997; Nagamitsu and Inoue, 2002). Colony foraging patterns in stingless bees have been well studied for pollen and nectar (Biesmeijer et al., 1999a, b; Biesmeijer and Ermers, 1999; Leonhardt et al., 2007) and the behavioural decision process of individual bees is becoming well understood (De Bruijn and Sommeijer, 1997; Biesmeijer et al., 1999a, b; White et al., 2001; Slaa et al., 2003). Plant resins are an essential resource for nest building, and defence, and resin availability limits colony size and growth (Wille and Michener, 1973; Howard, 1985; Roubik, 1989, 2006; Lehmberg et al., 2008). In contrast with pollen and nectar, resin resources are generally unpredictable and short-lived, and are aggressively defended by some species (Armbruster, 1984; Howard, 1985). Colony foraging patterns for resin have not been studied in stingless bees despite the importance of resin resources.
Resin-foraging bees are critically important for seed dispersal of three plant species: a rainforest eucalypt, *Corymbia torelliana* (Wallace and Trueman, 1995; Wallace et al., 2008); a tree legume, *Zygia racemosa* (Bacelar-Lima et al., 2006); and an epiphyte, *Coussapoa asperifolia* (Garcia et al., 1992; Nunez et al., 2008). Fruits of these species contain resin or waxes, and stingless bees collecting resin or waxes disperse their seeds (Nunez et al., 2008; Wallace et al., 2008). In *C. asperifolia* and *C. torelliana*, stingless bees are the only biotic seed dispersers and fruits show specific adaptations to seed dispersal by bees (Nunez et al., 2008; Wallace et al., 2008). This unusual seed dispersal syndrome, termed mellitochory, has not been recorded in other species.

The mechanisms of mellitochory have been studied in *C. torelliana*. The fruits of *C. torelliana* are hollow, and resin and seeds are presented inside the fruits behind the valve (Wallace and Trueman, 1995). Stingless bees enter the fruit to collect resin and emerge with either resin, or resin and seeds in their corbiculae (Wallace and Trueman, 1995). Around one quarter of resin collectors at fruits carry seeds (Wallace et al., 2008). Bees attempt to dislodge the seed at the fruit and on surrounding leaves (Wallace and Trueman, 1995), but many transport resin and seeds to their nest and discard seeds outside the nest, thus dispersing them (Wallace and Trueman, 1995; Wallace et al., 2008). In *C. torelliana*, *Trigona* spp. disperse seeds greater than 100m from the parent tree and bee dispersal is critical to the tree’s population dynamics (Wallace et al., 2008). However, where *C. torelliana* is planted outside its natural range, the interaction with stingless bees is controversial. Stingless bee keepers report that during the fruiting season of *C. torelliana*, bees abandon all other resin sources and neglect normal foraging to collect resin and seeds, and that seeds and resin in some circumstances can cause colony death (Klumpp, 2007). Colony foraging, resin collection and seed dispersal behaviour, especially in the natural range where *C. torelliana* and stingless bees have coevolved, have not been studied.

The aim of this study was to examine colony foraging patterns for resin and the consequent seed dispersal by two species of stingless bees, *Trigona sapiens* and *T. hockingsi* in the natural range of *C. torelliana*. We specifically addressed the following questions: (1) How much colony activity is allocated to resin foraging, seed transport and seed disposal activities? (2) How many seeds are dispersed by stingless bee colonies? (3) what are the diurnal patterns of colony pollen and resin foraging, waste removal and seed dispersal?

## 2. MATERIALS AND METHODS

### 2.1. Study site

The study was conducted at Kuranda, Far North Queensland, Australia (E145°38’S16°49’). Two species of *Trigona*, *T. sapiens* and *T. hockingsi* were located in the study area. The site was close to a large natural population of *C. torelliana* and the surrounding vegetation was a mosaic of rainforest and disturbed areas cleared for human occupation. We monitored two nests of *Trigona* over 3 years: *T. hockingsi* at the base of a hollow dead tree and *T. sapiens* in a permanent dwelling. All observations were conducted between December and February, during the fruiting season of *C. torelliana*. Resin foraging patterns of bees change significantly over the fruiting season as resin becomes less available (Wallace et al., 2008). Observation days within each season were carried out within a short period (1 week) on days when the availability of resin was similar. *T. sapiens* and *T. hockingsi* were monitored for 5 days in the 2003 summer, *T. sapiens* was monitored for 4 days in 2004 and 3 days in 2005. Due to collapse of the tree and subsequent death of the colony of *T. hockingsi* in 2004 it was not possible to monitor this species in 2004 and 2005. The *T. sapiens* nest was 100 m to the nearest *C. torelliana* and the *T. hockingsi* nest was 20 m to the nearest *C. torelliana*.

### 2.2. Bee activity and seed dispersal at the hives

Nest entrances were observed for 15 minutes each hour. At each nest, data were collected on: the number of bees returning and the number of those with pollen in a 5-minute period; the number of bees returning and the number of those with resin or resin and seeds in the corbiculae in a 5 minute period; the