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COMMUNICATION

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PLATINUM OPEN ACCESS

Rediscovery of the 'extinct' bee *Hesperocolletes douglasi* Michener, 1965 (Colletidae: Colletinae: Paracolletini) in Western Australia and first description of the female

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Abstract: The second known specimen of the bee *Hesperocolletes douglasi* Michener, 1965 is here reported as a serendipitous find among a collection of insect pollinators from an isolated woodland remnant in the Southwest Floristic Region of Western Australia. The unique male holotype of this monotypic genus of bees was collected 80 years ago and officially gazetted as presumed extinct in 1994. With our collection of a female specimen in 2015, however, it now appears that *H. douglasi* may persist as an extant localised population. Follow-up efforts to find more specimens at the collection locality so far proved unsuccessful, indicating that the species is likely either very rare or inhabits an ecological niche that is yet to be discovered. Analysis of the pollen load carried by the female indicates that the species may be polylectic. We discuss the context of the rediscovery of the bee, provide a detailed description and illustrations of the female, and make observations about the unusual morphological characteristics of the species. The rediscovery of *H. douglasi* emphasizes the importance of conservation efforts for remnant woodlands in the region, both as potential habitat for the bee and as remaining habitat essential for other rare and threatened species in this global biodiversity hotspot.

Keywords: Banksia woodlands, Douglas's Broad-headed Bee, global biodiversity hotspot, Hesperocolletes, pollinator, rediscovery, Southwest Australian Floristic Region, threatened species.

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Author Contribution: JPA conceived and designed the project, conducted fieldwork, collected the bee, and analysed its pollen load; RKD contributed to project setup and design and data collection; RKD and JPA obtained funding for the project; MVM initially identified the specimen; TFH confirmed the bee identity and described the specimen; JPA wrote the first draft of the manuscript; all authors contributed substantially to revisions. Specimen illustrations are by TFH.

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INTRODUCTION

Wild bees are crucially important to crop production and the maintenance of native plant biodiversity globally (Ollerton et al. 2011; Winfree et al. 2011; Garibaldi et al. 2013; Mallinger & Gratton 2015; Ollerton 2017). In the Southwest Floristic Region (SWFR), a global hotspot of biodiversity in Western Australia (WA), the diverse fauna of native bees in the families Colletidae, Halictidae, Stenotritidae, Megachilidae, and Apidae are particularly important for the pollination of native plants (Brown et al. 1997; Houston 2000). While many bee species in the SWFR are generalist foragers (polylectic), many others are specialized to varying degrees on certain host plants, with some even showing morphology or behaviour adaptations related to oligolecty or monolecty (Houston 2000). The pollination biology of the exceptionally diverse insect-pollinated flora of the SWFR remains largely understudied, even though native insects and their plant hosts are highly vulnerable to environmental change (Phillips et al. 2010).

Native bees are under threat worldwide due to environmental degradation (Potts et al. 2010; Vanbergen 2013), with habitat loss and fragmentation being some of the main causes of species declines (Winfree et al. 2009, 2011). In the SWFR, vegetation clearing historically occurred at very high rates and, when associated with other impacts such as land use intensification, imposed serious threats to native fauna and flora (Threatened Species Scientific Committee 2016). Despite widespread land clearing and degradation, the last decade saw an increase of 10% on the number of recorded plant species in the SWFR (Gioia & Hopper 2017), indicating that the region still harbours very high levels of biodiversity that is yet to be described. Other anthropogenic disturbances such as sand extraction, inappropriate fire regimes, dieback, invasive species, hydrologic degradation, climate change, and loss of keystone species are currently threatening the region's ecosystems (Hobbs 1998; Coates & Atkins 2001; Threatened Species Scientific Committee 2016), potentially resulting in declines of pollinating and seed-dispersing fauna and their associated flora.

Banksia woodlands, one of the most threatened habitat types in the SWFR, is an extremely diverse ecosystem that declined significantly in extent throughout the Swan Coastal Plain (Fig. 1), where WA's state capital Perth is located. It is now highly fragmented, with only about 35% of its original cover (Government of Western Australia 2018), and was recently listed as a threatened ecological community under the Environment Protection and Biodiversity Conservation Act 1999 (Threatened Species Scientific Committee 2016). Despite increasing fragmentation, many Banksia woodlands fragments still have important conservation value since they represent critical remaining habitat for a large number of rare and threatened plant and animal species (Harvey et al. 1997; How & Dell 2000; Hopper & Gioia 2004).

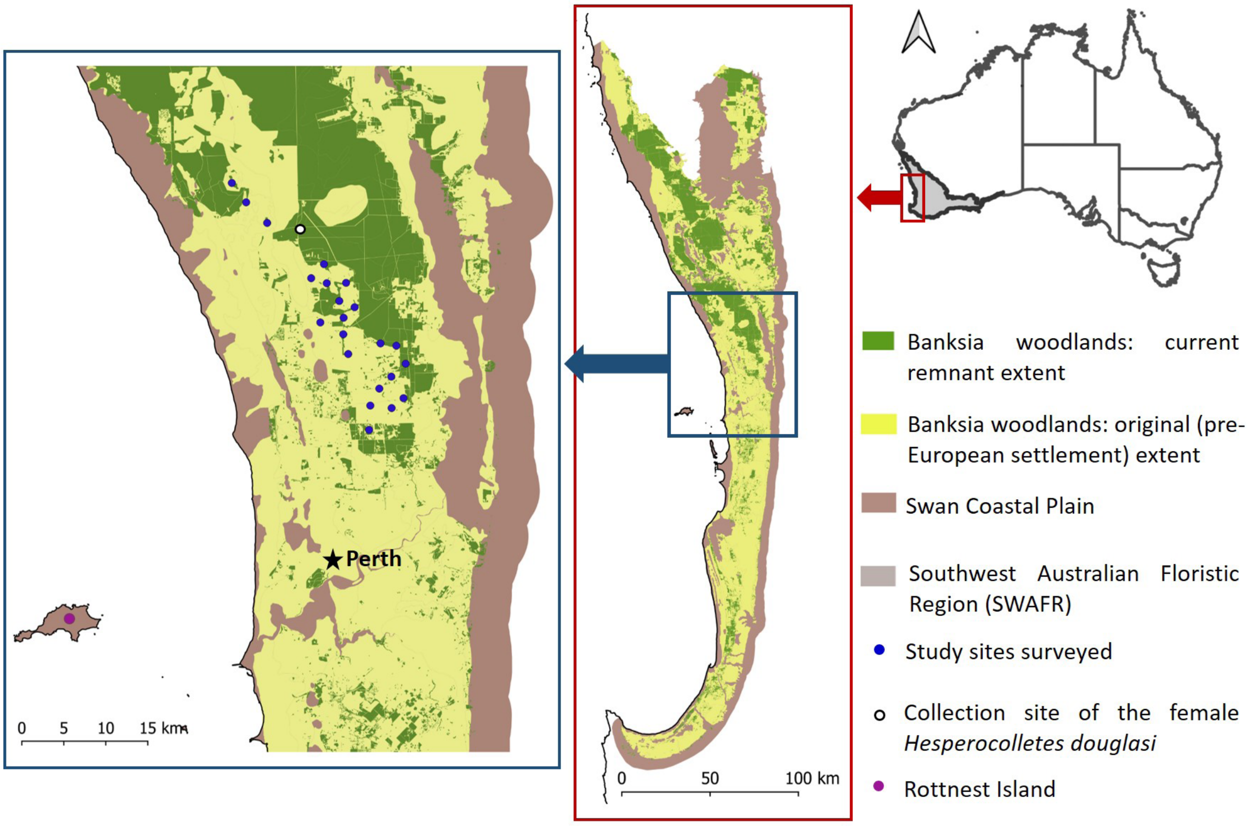
Douglas's Broad-headed Bee *Hesperocolletes douglasi* Michener, 1965 (Colletidae: Paracolletini) is a short-tongued bee species from WA that was not recorded in the region for almost 80 years and was presumed extinct until now. This enigmatic species is known only from a single male specimen that was collected by A.M. Douglas in November 1938 on Rottnest Island, located approximately 18km off the coast of Perth (Fig. 1). From the single specimen, it was clear that Douglas's Broad-headed Bee represented a unique phylogenetic lineage of colletid bees, and Michener (1965) erected the genus *Hesperocolletes* for the new species.

Following the publication of Michener's treatise on the bees of Australia (Michener 1965), and particularly during the period 1978–1992, extensive collecting of native bees in the Perth region and WA failed to produce any further specimens of *Hesperocolletes*. Targeted searches at the type locality (Rottnest Island) and nearby Garden Island likewise proved fruitless. As a consequence, in 1994, *H. douglasi* was gazetted by the WA Government as presumed extinct under the Wildlife Conservation Act 1950 (Department of Conservation and Land Management 1994). The fact that there was little information associated with the original specimen, such as detailed locality records or details of host plant species visited by the bee, made the search for additional specimens much more difficult.

Here we report the collection in 2015 of a second specimen and the first known female of the species, providing evidence that the species is extant. This female was identified among insect floral visitors collected during a survey of plant-pollinator interaction networks in Banksia woodlands remnants in the Perth region. We describe the rediscovery of *H. douglasi*, provide details of the location and circumstances of collection of the specimen, report on the pollen load the bee was carrying, and present the first formal description of the female. While generally morphologically consistent with the male specimen, the female exhibits some unusual characteristics. We compare the female of *H. douglasi* with females of other paracolletine genera and discuss whether it supports Michener's placement of the species in its own genus. The rediscovery of *H. douglasi* in remnant Banksia woodlands highlights the importance of preservation of remnant vegetation in the face of ongoing anthropogenic threats. We briefly discuss key strategies for ensuring adequate conservation and protection of this threatened bee species.

MATERIALS AND METHODS

We collected the female of *H. douglasi* during surveys to study plant-pollinator interaction networks on the Swan Coastal Plain in the SWFR. For this study, we sampled 23 fragments of Banksia woodlands within a 152km^2 study area located in the Gnangara-Moore River State Forest, north of Perth, WA (Fig. 1). The woodland fragments show a small amount of within-patch degradation but are located in distinctive matrix contexts that vary greatly in habitat type, cover, structure, and microclimate, which are all likely to influence the survival and dispersal rates of insect pollinators. We randomized the order in which the study sites were visited for collection of insect-plant association data throughout the sampling season. In each woodland fragment, we established four belt transects (50m x 4m) spaced equally 20m apart. We subdivided each belt transect into 10m sections and in each section we spent 15min hand-collecting flower visiting insects alighting on flowers up to 2m from the ground with the use of a sweep net. We recorded each plant-pollinator association in the field, and insects collected were preserved in 70% ethanol until pinning for identification. We surveyed each of the four transects per study site once during each field season, which ran from September to November in 2015 and 2016. In 2015, however, we could only survey 16 of the 23 sites because the flowering season was shorter due to higher than average temperatures in the spring (Bureau of Meteorology 2016). To account for temporal variation in pollinator assemblages and flower visitation throughout the day, we surveyed transects on different days in a random order and at random times during the



Mapping data source: Department of the Environment, © Commonwealth of Australia, 2016. Banksia woodlands (remnant): Specified Beard Vegetation and System Associations mapping units that occur within the Swan Coastal Plain (SCP) boundary. SCP IBRA region plus a 5km buffer that occurs constrained to the Jarrah forest IBRA region. Caveat: Mapping is indicative only, data has been collated from a range of sources at various resolutions. GEODATA Coast 100K, 1:250,000, Geoscience Australia, 2004. Projection: Geographic Datum GDA94.

Figure 1. Twenty-three study sites surveyed and collection site of the female of *Hesperocolletes douglasi* in the Gnangara-Moore River State Forest, ca. 41km north of Perth, Western Australia, Australia; Rottnest Island, the type collection site; the original (pre-European settlement) and current extent of Banksia woodlands in the Swan Coastal Plain in the Southwest Australian Floristic Region.

peak activity period (09.00–16.00 h). We conducted sampling only in calm, sunny weather when bees were most likely to be active. Additionally, following recognition of the female of *H. douglasi* collected in 2015, TFH made separate visits to the collection site in the spring of 2016 (21 September, 05 & 27 October, and 14 November) and 2017 (06 & 19 October) in search of further specimens. These searches (each of 3–4 h in duration) were carried out between 09.30h and 15.00h.

We also searched for the bee amongst a second Hymenoptera collection we carried out previously in the same 23 study sites using UV-reflective pollinator vane traps (SpringStar Inc., Woodinville, USA). Vane traps, which consist of coloured plastic cross-vanes slotted into a funnel and screwed to a collecting jar containing preservative (100ml of 50% propylene glycol), is found to be extremely effective in attracting flower-visiting insects (Stephen & Rao 2005, 2007; Lentini et al. 2012). Blue vane traps are shown to be a particularly good method for capturing native bees (Kimoto et al. 2012; Joshi et al. 2015; Hall 2018). In each study site, we randomly deployed three blue vane traps in a 100m x 50m area near the northern and eastern boundaries of the remnant (i.e., 69 traps in total). Sampling was carried out for seven weeks in the spring of 2012 (5–7 day collections starting on 11 September, 23 October, 30 October, 6 November, 13 November, 20 November, 26 November), for five weeks in summer (a single collection from 20 December 2012 to 22 January 2013), and for one week in autumn (starting on 30 April 2013). Samples were stored in 70% ethanol and subsequently sorted and pinned for identification and analysis.

We identified specimens to species or morphospecies on the basis of morphology, with the aid of published keys and reference collections at the University of Western Australia's Entomology Laboratory and the Western Australian Museum. The confirmed female specimen of *H. douglasi* was deposited in the Entomology Collection of the Western Australian Museum (WAM # E 97779) after first recovering the pollen load of the specimen by washing using ultrasonic cleaning following a protocol based on Tur et al. (2014). Pollen grains on microscope slides were identified by comparison with a reference library of pollen slides including all of the dominant plant species found at the study sites (Jones 2012).

RESULTS

Across the 23 study sites, we collected a total of 3,168 specimens (bees, wasps, flies, butterflies, and beetles) using sweep nets over 156 surveys (115 net-hours sampling effort), and 13,150 bees and wasps using blue vane traps (5,838 trap-days sampling effort). Only a single female specimen of *Hesperocolletes douglasi* was collected with a sweep net on 08 October 2015 at 10.20h in a Banksia woodlands remnant located c. 15km west of Muchea Township and 41km north of Perth in Western Australia (Fig. 1). This location lies at the northern end of the rural suburb of Pinjar and on the western edge of the Australian Department of Defence Muchea Air Weapons Range (AWR), an extensive Banksia woodlands remnant with high-quality native vegetation and a relatively low degree of anthropogenic disturbance.

The collected female was captured while visiting flowers of a common native shrub called Pepper and Salt *Philotheca spicata* (A.Rich.) Paul G. Wilson (Rutaceae). Further searches for *H. douglasi* carried out at the collection site and several other locations in the surrounding region in 2016 and 2017, focusing chiefly on flowers of *P. spicata* but also surveying flowers of many other plant species, proved unsuccessful.

The pollen load analysis revealed that the bee was carrying pollen grains of eight different plant species representing five different families: Rutaceae (*Philotheca spicata* A. Rich. Paul G. Wilson, the species the bee was visiting when collected), Stylidiaceae (*Stylidium hesperium* Wege, *S. rigidulum* Sond., *Stylidium* sp., *Levenhookia stipitata* (Benth) F. Muell.), Iridaceae (*Patersonia occidentalis* R.Br.), Fabaceae (*Bossiaea eriocarpa* Benth.), and Myrtaceae (*Eremaea pauciflora* (Endl.) Druce var. *pauciflora*).

Description of female

Material examined: WAM # E 97779, 1 ex., female, 8.x.2015, site PER70, Pinjar, WA, Australia, -31.586^{0}S & 115.813^{0}E, elevation 60m, coll. J. Pille Arnold.

In size, general form, and colouration, the female makes a good match with the holotype male of *H. douglasi.* It shares with it, too, some of the diagnostic features noted for *Hesperocolletes* by Michener (1965, 2007), namely, the strong carina around the eyes (Image 1b) and the modified tarsal claws (Image 2e). In addition, both sexes share the strong carina around the upper part of the clypeus (although its presence in the male was not mentioned by Michener). Therefore, on morphologic grounds, there is no reason to doubt its conspecificity with the male type. Also, the collection

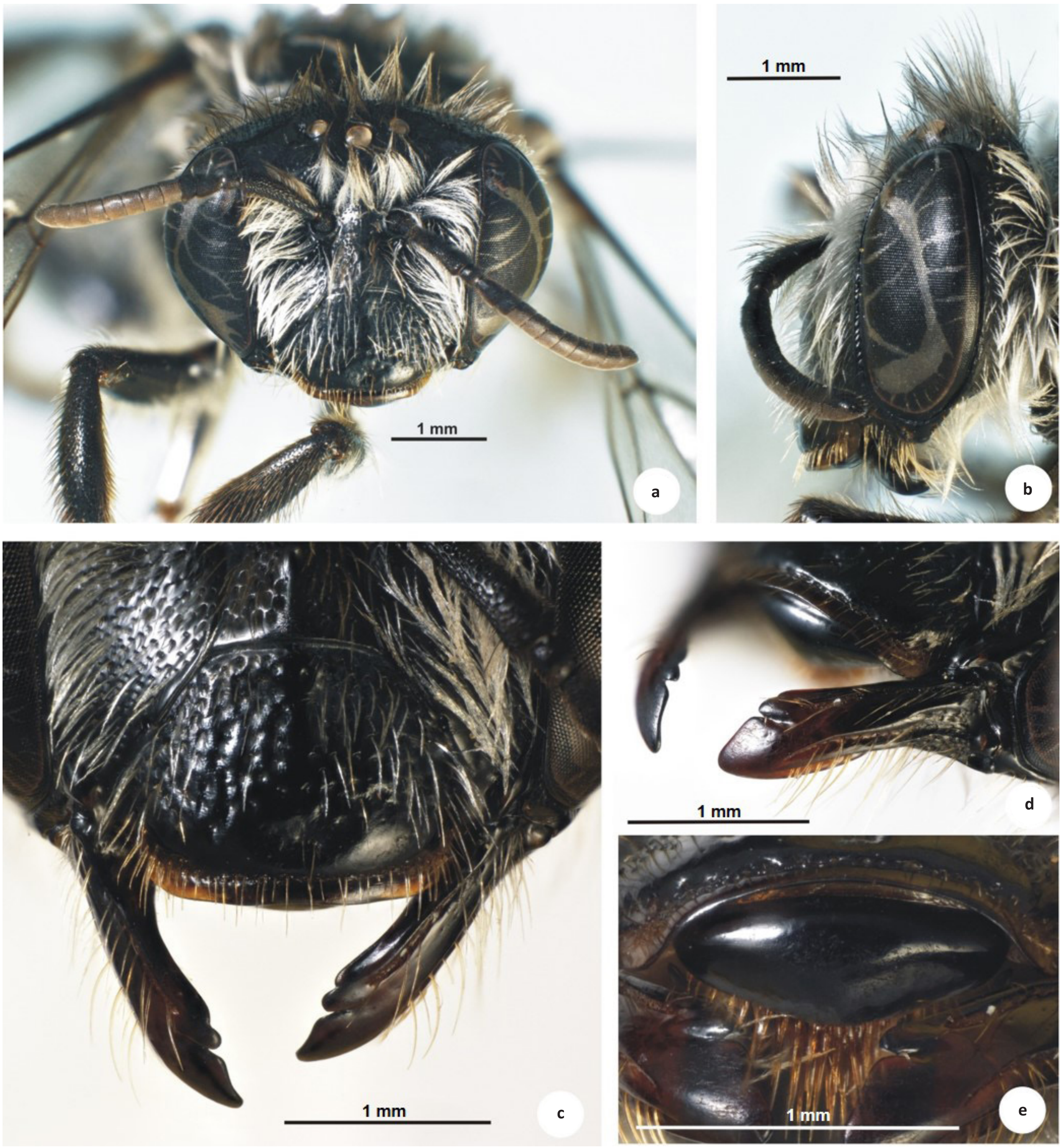


Image 1. *Hesperocolletes douglasi* female head features. a - head and antennae in anterior view; b - head and antennae in lateral view; c - lower part of face (note carina around upper part of clypeus, clearly demarcated ventral rim of clypeus, and somewhat tridentate apices of mandibles); d - outer view of left mandible; e - ventral view of labrum in situ. © T.F. Houston.

site of the female is only c. 51km from the type locality.

Dimensions: Body length c. 11.5mm; head width 4.1mm.

Relative dimensions (in mm): Head width 100; head length 78; upper width of face 63; lower width of face 55; clypeal length 28; clypeal width 46; upper width of clypeus 18; clypeoantennal distance 14; antennal socket diameter 8; width of mid ocellus 7; distance between lateral ocelli 14; ocellocular distance 20; width of ocellar cluster 26; ocelloccipital distance 10; scape length 25; scape width 6; length of flagellum c. 55; mandible length 38; basal width of mandible 15.

Habitus: Head (Image 1) markedly wider than long; vertex rising above level of ocelli; inner margins of eyes

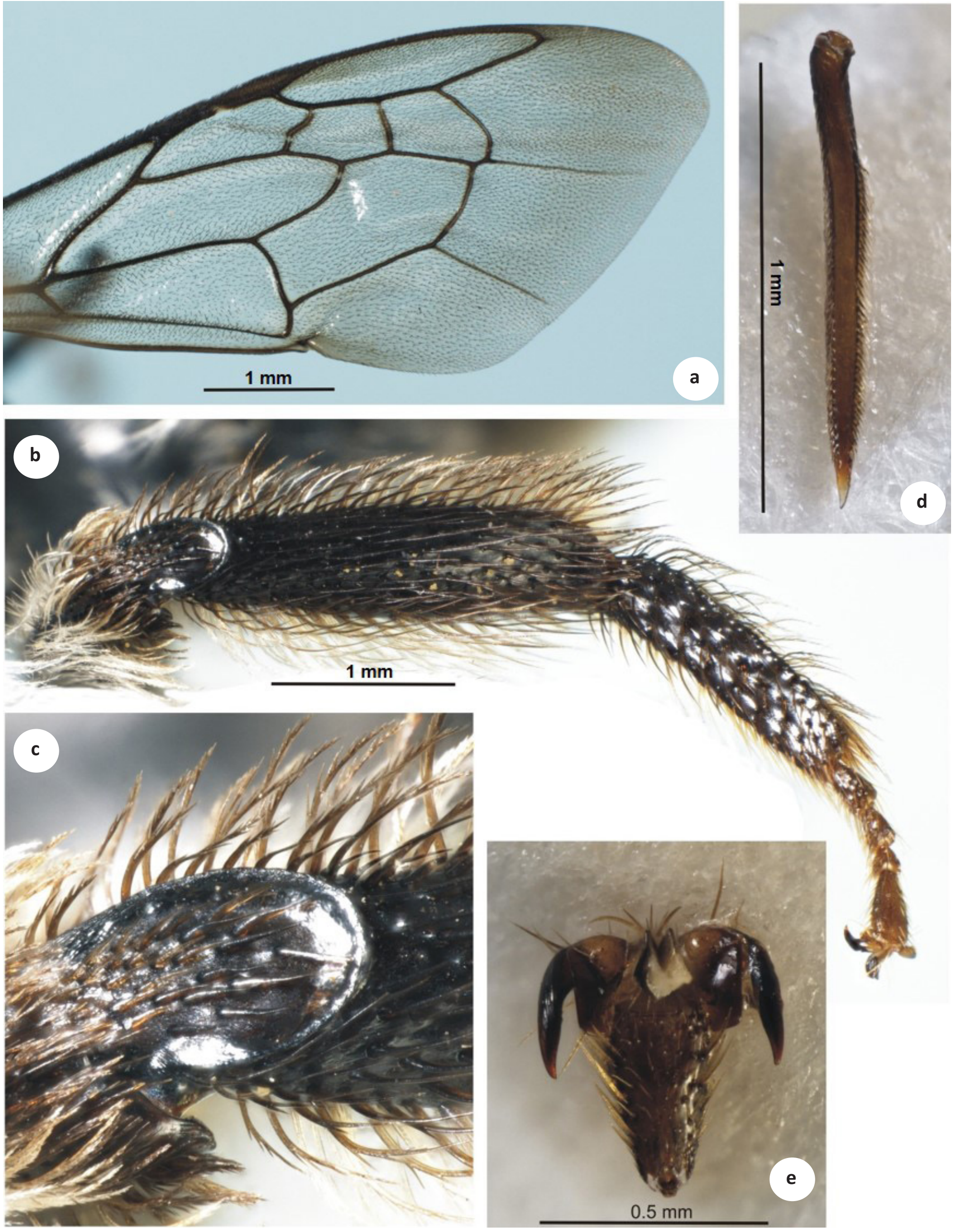


Image 2. *Hesperocolletes douglasi* female wing and leg features. a - outer part of fore wing; b - outer view of hind tibia and tarsus; c - basitibial plate; d - inner hind tibial spur; e - ventral view of distitarsus, showing expanded inner rami of tarsal claws. © T.F. Houston.

converging slightly below; facial foveae faintly indicated by duller, almost impunctate integument, rounded triangular; interantennal area rising to weak median ridge; subantennal sutures vertical and about 2x as long as height of antennal socket; clypeus (Image 1a–c) gently convex in profile and transversely, its impunctate ventral margin clearly defined by transverse furrow and not coplanar with rest of clypeus; upper clypeus depressed slightly below level of supraclypeal and paraocular areas forming a distinct carina along epistomal suture (Image 1c); compound eye surrounded by a carina; median ocellus set in depression with carinate margin, especially posteriorly; malar areas present but much shorter than basal width of mandible; gena about half as wide as eye viewed laterally; occipital cavity reaching almost to summit of vertex; mandibles (Image 1c,d) 2.7x as long as basal width, narrowest at mid-section, obliquely truncate at apices, weakly tridentate (i.e., bidentate with smaller anterior tooth weakly notched); labrum (Image 1e) largely exposed when mandibles closed, 0.4x

Image 3. *Hesperocolletes douglasi* female metasomal features. a - dorsal view; b - left lateral view (arrow indicates long, white, plumose setae of base of hind leg that may form the scopa, but note also the long, dense, plumose setae of sterna 2–5 that might serve this purpose).
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as long as wide, rather elliptical but with ventral margin slightly angulate medially, surface smooth and gently convex, lacking tubercles or transverse ridge; upper margin of pronotum set very low relative to scutum which curves down strongly anteriorly; episternal groove present below scrobal groove but shallow; propodeum almost wholly vertical, enclosure broad, smooth and unsculptured with sinuate lateral margins; anterior surface of T1 weakly creased medially, rounding gently onto dorsal surface; metasomal terga (Image 3a) smooth, lacking premarginal lines, hind margins of T1–T4 slightly translucent; T2 without evident foveae; pygidial plate well-developed, clearly defined by marginal carina, rounded apically, flat dorsally; fore wing (Image 2a) with first submarginal cross vein ‹-shaped, bent mesad; jugal lobe of hind wing long, just exceeding cu-v; basitibial plate (Image 2b,c) distinct, rounded, and saucer-like because of raised carinate margin, about one-fourth the length of hind tibia; inner hind tibial spur (Image 2d) simple with ciliate margins; hind basitarsus viewed laterally (Image 2b) about 2/3 as wide and 0.6x as long as tibia, tapering slightly from base to apex; tarsal claws (Image 2e) deeply cleft with inner prongs broad (as in male); relatively long arolia present on all tarsi.

Colouration: Integument generally black, lacking iridescence; clypeus lacking the yellow-brown colouration of the male; only the underside of the flagellum, the distitarsi, and the mandibles somewhat brownish.

Sculpture: Integument generally moderately shining with fine, open pitting; clypeus (except impunctate lower quarter) with strong, coarse pitting; areas between ocelli and upper ends of eyes almost impunctate; metasomal terga lacking distinct pits; pygidial plate finely, longitudinally striate.

Pubescence: Head, mesosoma, T1, and bases of legs generally with long, moderately dense, plumose setae; setae of face, genae, lateral, ventral and posterior areas of mesosoma, T1 and bases of legs white; setae of vertex, scutum, and scutellum blackish; pubescence of clypeus and supraclypeal area sparser than that of paraocular areas and frons; lower one-third of clypeus virtually bare; metasomal T2–T4 with black, sparse, short, simple, erect setae except on hind margins where setae are whitish, somewhat adpressed and laterally directed, not forming bands; T5 and T6 with weak fimbriae of rust-coloured, plumose setae; posterior third of metasomal S2–S5 with dense, long, rust-coloured, plumose setae directed posteriorly, extending well beyond hind margins (Image 3b); fore tarsi clothed in moderately long, soft, brownish setae; basitibial plates with sparse, short, simple setae (Image 2c); hind tibia and basitarsus (Image 2b) covered on outer side with moderately dense, stiff, simple, black setae, only on dorsal and ventral margins of tibia and basitarsus are setae plumose; inner surface of hind tibia with dense, erect, simple, white setae (not keirotrichia), similar but denser setae on inner side of hind basitarsus.

Remarks

It is unfortunate that no details of the proboscis could be observed: the specimen's proboscis was tightly retracted into the proboscidial fossa and attempts to relax and extend it proved unsuccessful (probably stemming from the specimen's protracted immersion in ethanol). Also, the pubescence suffered slightly from the specimen being put through a wash and ultrasound cleaner to remove its pollen load for analysis.

DISCUSSION

Michener noted that *Hesperocolletes douglasi* resembles species of *Paracolletes, Trichocolletes*, and *Leioproctus.* Indeed, there are many similarities between various members of these taxa. Table 1 shows the distribution of certain character states of *Hesperocolletes* among the three other genera. *Hesperocolletes* shares more character states with *Paracolletes* (sensu Michener 2007) than with the other taxa. Despite this, we do not question Michener's placement of *H. douglasi* in its own genus. Michener also noted that the peculiar tarsal claws of *H. douglasi* resemble those of various cleptoparasitic bees. Such claws, however, are not peculiar to cleptoparasitic species and are found in at least four Western Australian species of *Leioproctus* s. str. known to collect pollen loads.

Although the female carried a pollen load when it was collected, the position of the scopa was not noted, nor is it clear from the examination of the female where its scopa is situated. It is unlikely to be situated on the hind tibiae, given that they are covered externally with mostly simple setae. The hind coxa, trochanters, and femora bear numerous long, plumose setae (Image 3b) that might form the scopa. The unusual vestiture of long, dense, highly plumose setae on metasomal sterna 2–5 (Image 3b) has the appearance of a scopa, but we must await collection of a pollen-laden female to learn the truth.

Collection dates for the two known specimens of *H. douglasi* suggest that the species is active in mid-spring. The wing margins of the female (collected on 8 October) are entire indicating that the female was newly emerged. The holotype male (collected on 9 November) had ragged wings. It should be noted that Michener erred in his original description in giving the collection date as "February 9". We obtained the date of collection from the hand-written register book of the WA Museum for 1938 as the specimen's hand-written data label carried only a registration number and the locality name. Michener's error went undetected for many years and the first targeted searches for the species were doubtless too late in the season.

The some doubt was raised about the provenance of the holotype by Michener (2007) who remarked on the possibility that specimen labels may have been swapped. No doubt that was made in the knowledge that one of us (TFH) had searched for the species on Rottnest Island and nearby Garden Island without success and, despite extensive bee collecting in the Perth region over two decades, did not encounter any further specimens. The WAM register indicates that the holotype was among a batch of various insects collected by A.M. Douglas on Rottnest Island from 9 to 12 November 1938. Some specimens were identified individually, but the holotype (#2607) was included in a bracket of unidentified specimens numbered 2606–2613. Seven of these specimens, in addition to the holotype of *H. douglasi*, were located and are various kinds of native bees. Therefore, the register tends to corroborate the holotype data label.

From the collection record, we know that the female visits flowers of *P. spicata*, but other plant species might also be used as food resource. Since pollen grains may remain attached to bees' legs and body between flower visits (either incidentally or collected in a scopa), pollen load analysis increases the detectability of interaction links between pollinators and plants over simple flower visitation data (Bosch et al. 2009; Olesen et al. 2011).

Table 1. Character states shared between Hesperocolletes and three other genera of Paracolletini (N.B.: *Paracolletes* s. lato includes the subgenus *Anthoglossa*). Key: (+): present; (-): absent.

Hesperocolletes characters	*Paracolletes* s. lato	*Trichocolletes*	*Leioproctus*
Median ocellus set in depression	-	-	in some
Labrum smoothly convex	+	+	-
Mandibles somewhat tridentate	+	-	rarely
Basitibial plate not defined in male	+ some	+ most	rarely
Tarsal claws with expanded inner prongs	-	-	a few species
Clypeus of male yellow-brown	+ in some	+ in some	rarely (subgenus *Andrenopsis)*
Inner hind tibial spur of female simple	+ in most	-	in some

The results of this analysis indicate that *H. douglasi* may be a generalist forager since it was carrying pollen from a diverse set of plant species common to Banksia woodlands. However, it will be difficult to accurately assess the degree of resource specialization of this species without additional records. It should be noted that *P. spicata*, as well as the other plant species visited by the bee according to the pollen load analysis results, were not recorded on Rottnest Island (Rippey et al. 2003), which could be another indication that the bee is a generalist.

The collection of just one specimen despite a comprehensive survey of the 23 study sites using sweep nets and vane traps over multiple flowering seasons, in addition to a focused survey at the collection site and surrounding region, suggests that *H. douglasi* is extremely rare. It is also possible, however, that the sampled female was not in its typical habitat, and that we are yet to discover its particular ecological niche. The female specimen was collected in almost pristine Banksia woodlands, a habitat not represented at the type locality of Rottnest Island (Hesp et al. 1983; Rippey et al. 2003). The collection site lies within an area of multiple land uses, with extensive area of Banksia woodlands at the AWR military site, and intermixed areas of pine plantations, rural, and mixed-use land with encroaching suburban developments. The military area is protected and has restricted public access (Government of Western Australia 2000). More than 90% of the vegetation in the military area is considered in excellent to pristine condition (Government of Western Australia 2000). While we cannot yet claim Banksia woodlands as a definite habitat of *H. douglasi* without further successful collections, there is a high chance that the pristine woodlands within the AWR military site are important to the species. Moreover, the pollen load record is evidence that the bee was foraging on flowers of typical Banksia woodlands plant species. Several studies recognized military training areas as sites of conservation value for fauna and flora throughout the world, including for threatened and endangered species (Warren et al. 2007; Warren & Büttner 2008; Kim et al. 2015). Due to the restricted public access and heterogeneous habitat types they contain, often including patches of untouched vegetation, military training sites can even match the conservation value of formal conservation reserve areas (Cizek et al. 2013). Because there is no information on the ability of *H. douglasi* to disperse across the anthropogenic landscapes surrounding this area, we do not know if other populations could be using smaller, degraded, and more isolated woodland patches in the Perth region.

Ecological and life-history traits of bees are strongly associated with species responses to environmental disturbances (Williams et al. 2010; Cariveau & Winfree 2015). Since there is little to no knowledge of the distribution, dispersal ability, life cycle, nesting requirements, and foraging resources of *H. douglasi*, the preservation of the woodlands in this region is of paramount importance for the conservation of this rare bee species. Any human disturbances that are likely to have an impact on the bee (e.g., vegetation clearing, prescribed burning, public access, and recreational activities) should be mitigated or managed appropriately to minimize extinction risk. Enhancing connectivity between suitable habitat patches as well as habitat restoration are also essential to ensure long-term viability of the species. Further studies to determine the ecological requirements, geographic range, population size, and key threatening processes of the species must be conducted as a matter of urgency.

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