Systematics and phylogeny of Cheloninae (Hymenoptera: Braconidae) with an emphasis on Australian species

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Abstract

This study explores the systematics of the genera of Cheloninae (Hymenoptera: Braconidae) and presents a number of taxonomic revisions of Australian species. The phylogenetic relationships of the world genera were analysed by applying molecular phylogenetic analyses (based on three markers: *CO1*, *28S* and *ef1α*, totalling 1454 bp of sequenced data) combined with morphological data. The results show that most genera are monophyletic, although the current tribes were not. Also the previously recognised subgenera of *Chelonus* were not recovered as monophyletic and thus do not represent valid subgenera. A total-evidence approach of 84 sequenced species and 16 dated fossil taxa to calibrate the molecular clock was performed to estimate the age of the subfamily and component genera. Divergence dating analyses and ancestral range reconstruction suggest that the Cheloninae evolved in the Neotropics 150 Ma ago.

Prior to this study, 45 chelonine species were recognised from Australia, of which the majority were described more than 80 years ago. Yet there are many undescribed species, some of which could not be easily assigned to existing genera. Thus the first step of a taxonomic revision was to assess the current state of the fauna. This study evaluates the species richness of the Australian chelonines, provides a key to genera to facilitate their identification, provides a checklist of species and notes on their taxonomy, and discusses their biology. In so doing two new genera, *Austroascogaster* gen. nov. and *Phanaustrotoma* gen. nov. were recognised from Australia, together comprising six new species. Additionally, the genus of *Wushenia*, which was previously known only from a single species from Taiwan has been found in Australia and is represented by a new species. A revision of the Australian *Phanerotomella* species has been conducted, revealing 18 new species. They are described and the three previously species of *Phanerotomella* redescribed. Additionally, nine species belonging to the genera *Phanerotoma* and *Ascogaster* were discovered from central arid Australia, and two species of *Phanerotoma* from this area are redescribed. Dichotomous keys are included to facilitate identification of the species. Finally, the broader implications of the study and future research directions are discussed.

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university of other tertiary institutions to Rebecca Kittel and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due references is made in the text.

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Kittel, R. N., & Austin, A. D. (2013). Remarkable range extension of the previously monotypic braconid genus *Wushenia* Zettel (Hymenoptera: Braconidae: Cheloninae), with description of a second species from Australia. *Zootaxa, 3694*(5), 486-492.

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Chapter 1: General Introduction

1.1 Overview

This study explores the systematics of the genera of Cheloninae (Hymenoptera: Braconidae) and presents a number of taxonomic revisions of Australian species. The parasitic wasp subfamily Cheloninae comprises more than 1,375 known species worldwide (Yu et al. 2012). They are egg-larval endoparasitoids of Lepidoptera, but development is usually delayed until the host hatches. Adults have a distinct carapace that covers the dorsal metasoma (abdomen). The majority of Australian chelonine species were described more than 80 years ago, while many species both from the continent and other parts of the world are still being discovered. Some preliminary studies have examined the phylogeny of the genera of Cheloninae, but only limited morphological data have been used. This introductory chapter outlines the broad placement of the Cheloninae within the insect order Hymenoptera and family Braconidae, the taxonomic and phylogenetic status of the group, its biology, the importance of chelonines in biological control, and sets out the aims of the study.

1.2 Hymenoptera

The Hymenoptera is one of the largest orders of insects (along with Coleoptera, Lepidoptera and Diptera) with approximately 153,100 described species (Aguiar et al. 2013). Hymenoptera can be found in all terrestrial habitats and their species richness exhibits different life-styles; for example, many Hymenoptera are plant pollinators, seed dispersers or they act as natural enemies due to their parasitic or predatory life style. No other insect order provides humans with so many beneficial attributes (Hill 1997). As holometabolous insects, the life cycle of Hymenoptera comprises egg, larval, pupal, and adult stages. All Hymenoptera have a sex determination system called haplodiploidy, in which the male develops from unfertilised eggs (haploid) and the female from fertilised eggs (diploid). In addition, most adult Hymenoptera have two pairs of membranous wings and (depending on their feeding strategies) either lapping mouthparts (proboscis) or mandibles that are used for chewing food (Gauld & Bolton 1988). Uniquely among the holometabolous insects, hymenopterans have a valvular ovipositor, which in most groups is used to lay eggs.

The order has traditionally been divided into two suborders; Symphyta and Apocrita, distinguished by the absence or presence of a narrow waist (petiole) between the first and second abdominal segments. However, the symphytans are now known to represent a basal grade of lineages, rather than a monophyletic group (Vilhelmsen 2001). Hymenopterans, especially the Apocrita, show a variety of morphological adaptations due to their different life styles. Historically they are divided into two groups based on their ovipositor form and function. In the “Parasitica“ (parasitic wasps), the ovipositor is used to insert the eggs on or into a host, whereas in the Aculeata (ants, bees and wasps), the ovipositor is no longer used for laying eggs but is modified into a sting to deliver venom for defence or to immobilise prey (Gauld & Bolton 1988). In the Aculeata eggs are laid through a separate opening (Whitfield 1998). While the Aculeata form a natural (monophyletic) group, the “Parasitica“ is paraphyletic which contains several superfamilies, including the aculeate groups (Sharkey 2007). Virtually all “Parasitica“ are parasitoids of arthropods, mostly other insects, although a few have become secondarily phytophagous (Gauld & Bolton 1988).

Several studies have attempted to resolve the phylogeny of the Hymenoptera, first using a morphological approach (Königsmann 1978; Rasnitsyn 1988), and more recently with molecular data (Dowton & Austin 1994; Whitfield 1998; Ronquist et al. 1999; Dowton & Austin 2001; Sharkey & Roy 2002; Sharkey 2007) and finally employing whole mitochondrial genomes (Dowton et al. 2009). Rasnitsyn (1988) placed the Orussoidea as the likely sister group to the Apocrita (Sharkey et al. 2012), which he divided into the four groups; Proctotrupomorpha, Evaniomorpha and Aculeata + Ichneumonomorpha (comprising only the Ichneumonoidea) (see Fig. 1). However, only the Proctotrupomorpha and Ichneumonomorpha have been supported by molecular analysis (Dowton & Austin 2001; Heraty et al. 2011; Heraty et al. 2013; Klopfstein et al. 2013). The monophyletic Ichneumonoidea, where species are parasitoids or hyperparasitoids on a range of host groups, has traditionally been divided into two families, the Ichneumonidae and the Braconidae, and this is supported by all recent studies.

1.3 Family Braconidae

The Braconidae is one of the most diverse families of parasitic Hymenoptera, comprising minute to large wasps which, with only rare exceptions (Macedo & Monteiro 1989; Austin & Dangerfield 1998), have a parasitic larval stage mostly utilising other insect larvae or rarely adults as hosts. The most common hosts for the solitary or gregarious larvae are Lepidoptera, Coleoptera or Diptera. A total of 19,205 species in 46 subfamilies are recognised (Aguiar et al. 2013).

The first compilation of 26 subfamilies was made more than 150 years ago (Förster 1862), followed by Ashmead (1900a), who was the first to provide a key to subfamilies for more than one region. Szépligeti (1904) provided a more comprehensive key to the Braconidae, which recognised 31 subfamilies. A revision of the subfamilies was conducted by Fahringer

(1928), but it was not particularly informative. The differences among subfamily definitions was discussed by van Achterberg (1976), who diagnosed all known subfamilies, recognised 22 new subfamilies, and provided a preliminary key to all groups. In addition, he provided an intuitive phylogeny of the subfamilies, which was highly influential in that it provided a basis for all future phylogenetic studies on the family. In a later study, van Achterberg (1993) provided a more comprehensive key to the 43 recognised subfamilies.

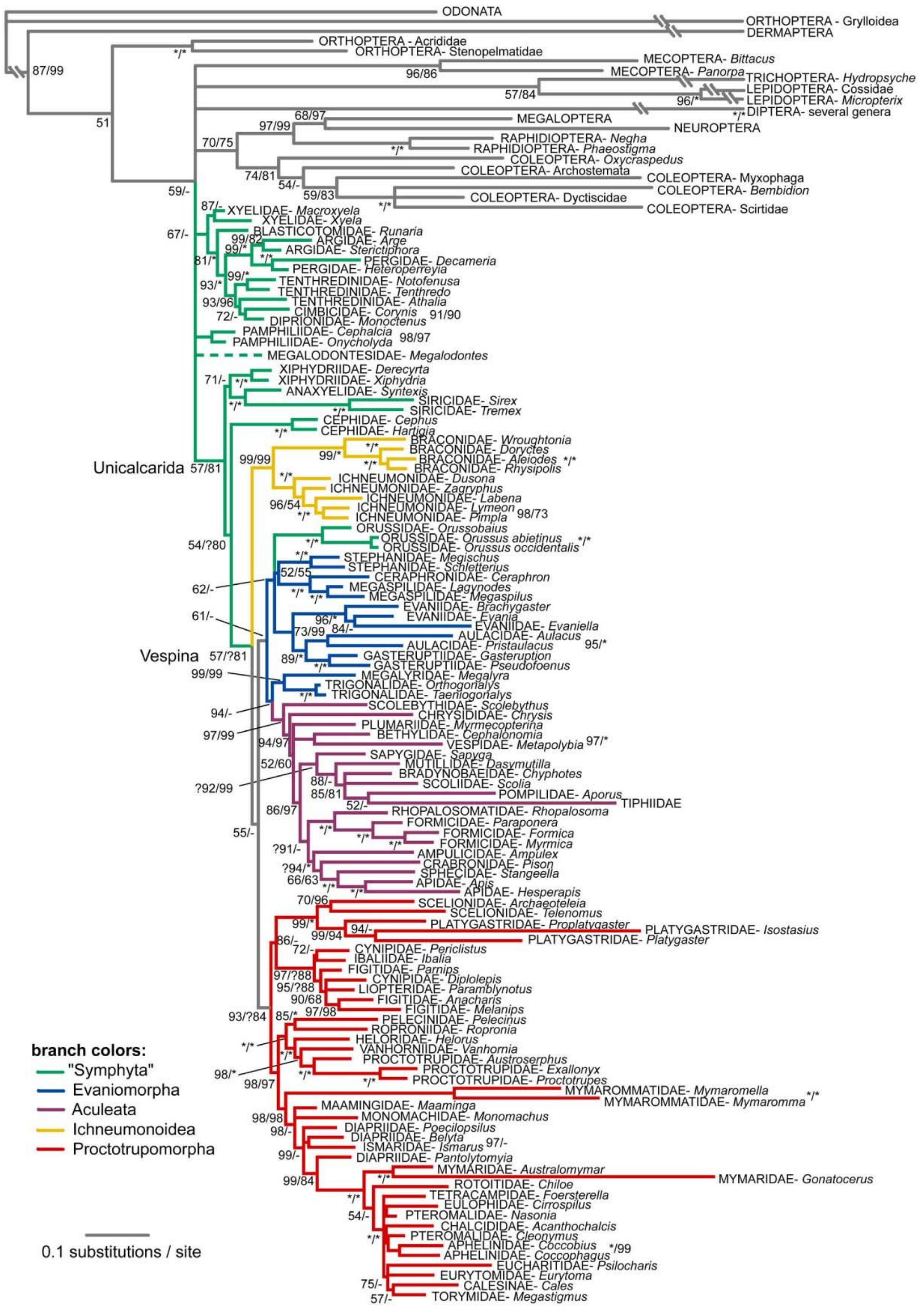

Figure 1. Bayesian tree from the analysis of sequence data from two ribosomal genes *18S* and *28S* after Klopfstein et al. (2013). This is the most recent phylogenetic hypothesis for the Hymenoptera, showing putative relationships among the major groups.

1.3.1 Phylogeny of the Braconidae

The first attempt to provide a phylogeny for the Braconidae was made by Tobias (1967) and was intuitively based on morphological characters. It was followed by an intense discussion of character coding, character weighting and outgroups over the next 30 years (Čapek 1969, 1970; van Achterberg 1976; van Achterberg & Quicke 1992; Wharton et al. 1992; Whitfield & Mason 1994; Dowton et al. 2002; Whitfield et al. 2002). Molecular phylogenies showed that some long-held relationships based on morphology (Belshaw et al. 1998a; Dowton et al. 1998), were likely due to convergence. Thus analyses of combined morphological and molecular data developed (Whitfield 1997; Dowton & Austin 1998; Quicke et al. 1999) and were followed by more comprehensive studies (Dowton et al. 2002; Shi et al. 2005).The latest phylogeny and classification for the braconids was based on a comprehensive analysis of 4kb of molecular data but it is somewhat limited in taxon sampling and has a number of critical groups missing, such as the Trachypetinae (Sharanowski et al. 2011).

Braconid subfamilies can be divided into the monophyletic cyclostomes and the paraphyletic non-cyclostomes (see Fig. 2) (Whitfield 1992; Quicke 1993; Sharanowski et al. 2011). The cyclostome complex differs from the non-cyclostomes by the morphology of the clypeal area of the lower face. The aphidoid complex is often regarded as belonging to the cyclostomes or being the sister clade to them (see Fig. 2). The non-cyclostomes are further divided into several complexes: the microgastroid complex (including Adeliinae and Cheloninae), the helconoid complex, the euphorid complex, and the sigalphoid complex (Sharanowski et al. 2011).

1.3.2 Microgastroid complex

The monophyly of the microgastroid complex is well established (Wharton et al. 1992; Whitfield & Mason 1994; Sharanowski et al. 2011). However, the delimitation of the subfamilies within this complex and relationships among them is still under review, but definitely includes the following subfamilies Adeliinae, Cheloninae, Cardiochilinae, Khoikhoiinae, Mendesellinae, Microgastrinae, and Miracinae (Whitfield & Mason 1994; Whitfield 1997; Belshaw et al. 1998b; Dowton & Austin 1998; Whitfield et al. 2002; Shi et al. 2005; Banks & Whitfield 2006; Pitz et al. 2007; Murphy et al. 2008). The most comprehensive study of the microgastroid complex to date which utilised sequence data from seven genes (Murphy et al. 2008), however, the Adeliinae was not included. Although the Cheloninae and the Adeliinae form the basal groups to the rest of the microgastroid complex, it now appears that Adeliinae is nested within the Cheloninae (Dowton & Austin 1998; Dowton et al. 2002). A more comprehensive phylogeny, based on morphological and molecular data, testing the relationships of the Adeliinae is an aim of this study (**chapter 2**).

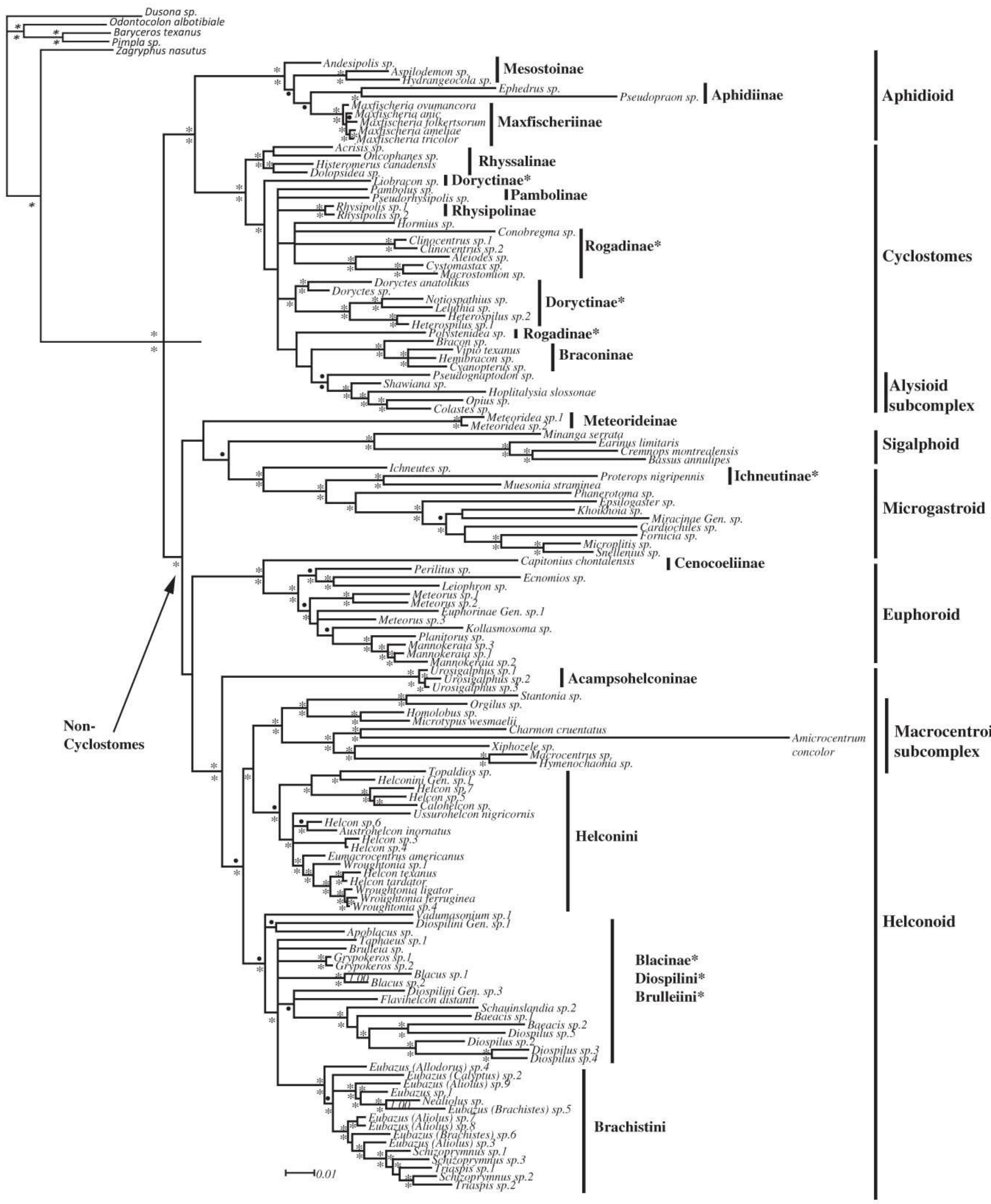

Figure 2. The latest phylogeny for the Braconidae after Sharanowski et al. (2011), based on sequence data from *28S*, *18S* rDNA an nuclear protein-coding genes *CAD* and *ACC*.

1.3.3 Polydnavirus

Polydnaviruses (PDV) occur in both Ichneumonidae and Braconidae (Whitfield, 1997). They are virus-like entities that are morphologically different in both families: the

Campopleginae and Banchinae (Ichneumonidae) possess different kinds of ichnoviruses (Lapointe et al. 2007), while all members of the microgastroid complex including the Cheloninae possess bracoviruses (Whitfield 2002). PDVs are incorporated into the wasp genome, where they replicate and thus are passed on maternally to the next generation. The virus particles are produced in a specialised region of the reproductive system (the calyx) and are then injected into a host together with the wasp egg(s) during oviposition. In the host, the PDVs genes are expressed and act to suppress the immune response of the host so the developing wasp avoids being encapsulated. Thus, the relationship between wasps and their PDVs is mutualistic. According to Beckage & Gelman (2004) PDVs are also responsible for various changes in the body of the host, together with venoms and teratocytes cells, which are also injected with the wasp's eggs. They are, i.e. causing the host larva to wander at an earlier stage than normal, to castrate the host larva, and to arrest the development of the larva at a precocious metamorphic stage just before pupating.

1.4 Braconidae / Cheloninae in biological control

Biological control utilising natural enemies is an effective method of decreasing pest populations in agriculture. Biological control agents can include predators, parasitoids or pathogens (Hill 1997). Wasps and flies are the most common parasitoids, and the narrow host range of many species means that they can be targeted to a particular pest (Dudarenko 1974). For the biological control of (accidently introduced) pest species, parasitoids from the area of origin of the pest are introduced to the new area (Hentz et al. 1997). In such cases, it is crucial to keep voucher specimens of the introduced parasitoids for further taxonomic verification or for monitoring the success of the program. Sometimes pests as well as parasitoids have been (accidently) introduced to new areas, without being noticed and later have been described as native to the new area. For instance the pest *Aulacophora quadrimaculata* was described from the Cape of Good Hope but is probably of Australian origin (Waterhouse & Norris 1987). Without voucher specimens it is difficult to resolve such issues. Cheloninae are frequently used in biological control programs against lepidopteran pests around the world (Legner & Thompson 1977; Jackson et al. 1978), and have been introduced into Australia either accidently or purposely (Shenefelt 1973) (see also **chapter 3**). These introductions have been poorly documented in the past, and are not mentioned in Waterhouse & Norris (1987), who summarise the species of Braconidae that have been introduced to Australia for biological control.

1.5 Subfamily Cheloninae

The Adeliinae were always considered to have a strong morphological association with the Cheloninae and recent studies indicated that the Adeliinae are nested within the Cheloninae. Due to time limitations of this project, I excluded the Adeliinae from the taxonomic treatment of the Australian Cheloninae fauna (see **chapter 3** and **chapter 6**), but tested their relationship with the Cheloninae in **chapter 2**.

The chelonines are a large subfamily of Braconidae with approximately 1,375 described species in 17 genera worldwide (Yu et al. 2012). Two genera are represented only by fossils (*Eobracon* Cockerell 1921 and *Diodontogaster* Brues 1933) and the remaining 15 extant genera are *Ascogaster* Wesmael 1835, *Austroascogaster* Kittel & Austin 2014, *Chelonus* Jurine 1801, *Megascogaster* Baker 1926, *Odontosphaeropyx* Cameron 1910, *Dentigaster* Zettel 1990, *Huseyinia (*Zettel 1990), *Leptochelonus* Zettel 1990, *Phanaustrotoma* Kittel & Austin 2014, *Phanerotoma* Wesmael 1838, *Phanerotomella* Szépligeti 1900, *Phanerotomoides* Zettel 1990, *Pseudophanerotoma* Zettel 1990, *Siniphanerotomella* He, Chen & van Achterberg 1994 and *Wushenia* Zettel 1990, of which *Austroascogaster* and *Phanaustrotoma* are described as new in **chapter 3**. Additionally there are four Adeliinae genera described, *Adelius* Haliday 1837, *Paradelius* de Saeger 1942, *Sinadelius* He & Chen 2000, and *Sculptomoriyola* Belokobylskij 1988.

Members of the Cheloninae are easy to distinguish from other Braconidae by the venation of the wings (three submarginal cells) and the possession of a complete postpectal carina. The most prominent character is the presence of a carapace formed by the fusion of the first three metasomal tergites (van Achterberg 1976; Shaw 1997). However, a carapace (see cover image) also occurs convergently in a number of other subfamilies (e.g. Brachistinae, Ichneutinae, Microgasterinae, and Sigalphinae), but it is generally rare outside of the Cheloninae (Dudarenko 1974).

1.6 Australian chelonine species

The first attempt to compile a catalogue of the described Australian Hymenoptera was made by Froggatt (1891), but no chelonines were known at that time from the continent. The first Cheloninae from Australia, *Phanerotoma australiensis*, was described by Ashmead (1900b), followed soon after by Szépligeti (1900) who described species of *Phanerotoma, Phanerotomella* and *Chelonus*. Later, Szépligeti continued to describe new species of *Chelonus* and *Ascogaster* (1905, 1908a). In the following years, several authors described additional new species (Cameron 1911; Turner 1917; Girault 1924; Baker 1926). Parrott (1953) summarised the known species of Braconidae of Australia including Cheloninae, listing 23 species of chelonines, but he missed at least two species from his catalogue, viz. *Chelonus rufipes* Szépligeti 1900 and *Phanerotoma coccinellae* Girault 1924 (see **chapter 3**). In 1973 a more comprehensive catalogue of world braconids was published (Shenefelt 1973). This listed 29 chelonines for Australia, but again, the species described by Girault was not included, probably because the paper was published privately and was overlooked. More recently, Zettel (1988, 1989) revised the tribe Phanerotomini on a worldwide basis, and described six new species of *Phanerotoma* from Australia additonal to the two known species, and redescribed all previously known species (Zettel 1988, 1989, 1990).

The most recent revison of Cheloninae concerning the Australian fauna was that of Huddleston & Walker (1994), who redescribed *Chelonus scrobiculatus* Szépligeti, separated the former species into three taxa, and synonymised three other species. The most recent catalogue of chelonine species and their distribution is included in the electronic catalogue of Yu et al. (2012). This work lists 37 species of Cheloninae for Australia, but they do not include all introduced species. A comprehensive review of the literature shows that 45 species of Cheloninae were recorded in Australia prior to this study – including several species introduced for biocontrol: *Ascogaster quadridentata* Wesmael, *Chelonus blackburni* Blackburn & Cameron, *Chelonus phthorimaeae* Gahan, *Chelonus curvimaculatus* Cameron, and *Phanerotoma hendecasisella* Cameron. An updated checklist of the Australian species was compiled as part of the current study (**chapter 3)**.

1.7 Systematics of Cheloninae

Some taxa within the Cheloninae are not clearly delimited. For example, *Microchelonus* was described as a genus by Szépligeti (1908b). It is now either considered as a separate genus (Papp 1995; Lozan & Tobias 2006) or as a subgenus of *Chelonus* (Zhang et al. 2008; Yu et al. 2012). Papp (1995) described characters to distinguish *Chelonus* and *Microchelonus*, but it seems likely that *Microchelonus* represents a lineage within a broader *Chelonus* group.To date, no comprehensive study has been undertaken to clarify the phylogenetic status of both groups. Also the status of *Leptodrepana*, which was described by Shaw (1983) from the New World, is possibly not consistent with current phylogenetic concepts. Its status as a separate genus is accepted by some authors (Brajkovic et al. 2010), but others, e.g. Yu et al. (2012), treat *Leptodrepana* as a synonym of *Ascogaster*. Shaw (1997) discussed the difficult status of *Leptodrepana*, arguing for its status as a separate genus. This may likely render

Ascogaster as paraphyletic but, to date, no comprehensive molecular or morphological analyses have been untertaken to resolve this question. These two issues are examined in detail in **chapter 2**.

1.8 Biology of Cheloninae

Cheloninae are solitary koinobiont endoparasitoids of Lepidoptera (especially Pyralidae and Tortricidae), inserting their eggs into the host egg. Development is then delayed until the host larva hatches and the parasitoid eventually kills the host larva (Shaw 1997). The final instar wasp larva then emerges from the host and feeds from outside until it forms a pupal cocoon (Jackson et al. 1978; Huddleston & Walker 1994). Although other braconids (some Alysiinae, Helconinae, Ichneutinae) also oviposit in host eggs, it is only universal within the Cheloninae (Clausen 1956).

Ascogaster generally occurs in shrubby areas, *Chelonus* tend to live in prairies and grasslands, while *Phanerotoma* are rather common in arid and seasonally dry habitats (Shaw 1997). Some species are nocturnal and can therefore be found at light traps (*Phanerotoma* and *Phanerotomella*), but usually the females spend time in vegetation and can be caught by sweeping foliage (Shaw 1997).

1.9 Aims of project

The aim of this study was to contribute to knowledge on the taxonomy and systematics of the Chelonine with an emphasis on the Australian fauna. Specifically, the aims were:

- To develop a robust phylogeny for world genera of Cheloninae, and test the status of the Adeliinae in regards to the Cheloninae using both morphological and molecular data (**chapter 2**).

- To test the relationship and phylogenetic status of *Chelonus* and *Microchelonus,* and *Ascogaster* and *Leptodrepana* with both morphological and molecular data (**chapter 2**).

- To conduct taxonomic revisions of select Australian chelonine taxa, depending on the available material, to revise the Australian species, redescribe existing species with consistent morphological characters, and to develop keys for their identification (**chapter 3**, **chapter 4**, **chapter 5**, and **chapter 6**).

The results chapters of this thesis have been formatted as journal papers, with **chapters 3 and 4** already published and **chapters 5 and 6** submitted. For this reason, there is some repetition among chapters, particularly for information presented in their introductions and reference lists. This could not be avoided but an attempt has been made to limit this repetition given the focus of each chapter.

In the last section (**chapter 7**) a general discussion is presented on the broader implications of this study, its limitations and ideas discussed for future research.

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Chapter 2: Phylogenetics and biogeography of chelonine parasitoid wasps (Hymenoptera: Braconidae) based on a fossil calibrated multigene analysis

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Abstract

Although the species-level taxonomy of Cheloninae appears to be relatively robust there is no clear understanding of relationships among higher-level taxa (genera and subgenera). By applying molecular phylogenetic analyses (based on three markers: Cytochrome c Oxidase subunit 1 (*COI*), elongation factor 1α copy F2 (*EF1α*) and the nuclear 28S rRNA gene D2-D3 region (*28S*), totalling 1454 bp of sequenced data) combined with morphology, the evolution and systematics of chelonine parasitoid wasps are elucidated. Employing a dataset based on 87 species, representing 13 genera, a total-evidence approach was performed and 16 fossil taxa used to calibrate the molecular clock and to estimate the age of the subfamily. All genera except *Ascogaster, Phanerotoma,* and *Pseudophanerotoma* formed monophyletic groups; the previously recognised tribes, did not and only two tribes Chelonini and Phanerotomini were recovered. The included subgenera of *Chelonus* were not recovered as monophyletic and thus do not represent valid subgenera. Divergence time estimate and ancestral range reconstruction suggest that the Cheloninae evolved in the Neotropics about 150 Ma ago. The results will have implications for the generic classification of the chelonines and the age of the microgastroid complex.

Keywords

phylogeny, total-evidence, molecular clock, ancestral area, evolution

1. Introduction

The Cheloninae are a large subfamily of braconid wasps (Hymenoptera) with some 1,375 described species in 17 genera worldwide (Table 1) (D. S. Yu et al., 2012; Kittel and Austin, 2014). They are sister to the remaining microgastroid complex (Murphy et al., 2008), which comprises five additional subfamilies (Cardiochilinae, Khoikhoiinae, Mendesellinae, Microgastrinae, Miracinae) (Murphy et al., 2008), all of which exploit Lepidoptera as hosts. Members of the Cheloninae can be easily distinguished from other Braconidae based on wing venation, possession of a complete postpectal carina, and a carapace formed by the fusion of the first three metasomal tergites (van Achterberg, 1976; Shaw, 1997). However, the latter character also occurs convergently in a number of other subfamilies (e.g. Brachistinae, Ichneutinae, Microgasterinae, and Sigalphinae), but is generally rare outside of the Cheloninae (Dudarenko, 1974).

All chelonines are considered to be solitary koinobiont endoparasitoids of Lepidoptera (especially Pyralidae and Tortricidae), inserting their eggs into the host egg. Development is then delayed until the host larva emerges and the parasitoid eventually kills it (Shaw, 1997). The final instar wasp larva then emerges from the host larva and feeds from outside until it forms a pupal cocoon (Jackson et al., 1978; Huddleston and Walker, 1994). Although other braconids (Alysiinae, Helconinae, Ichneutinae) also oviposit into host eggs, this behaviour is universal within the Cheloninae (Clausen, 1956).

The Adeliinae have been treated as a separate subfamily previously (Quicke and van Achterberg, 1990; Wharton et al., 1992; van Achterberg, 1993; Shi et al., 2005), but molecular analyses place them inside the Cheloninae with reasonable confidence (Dowton and Austin, 1998; Dowton et al., 2002). Chelonines occur on all continents (except Antarctica), but the largest number of species was described from the Palaearctic. On the other hand, many genera are endemic to the Neotropics, while most genera found in the Palaearctic have a global distribution (Table 1) (D. S. Yu et al., 2012).

Although the species level taxonomy of Cheloninae appears to be relatively robust (McComb, 1968; Shenefelt, 1973; Huddleston, 1984; van Achterberg, 1990; Zettel, 1992), there is no clear understanding of relationships among higher level taxa (tribes, genera and subgenera) that can be used to interpret biological attributes. The only previous attempt to determine the relationships among genera was based solely on morphological characters and focussed on the Phanerotomini (Zettel, 1990). The current classification is hindered by weak delimitation of some genera, for example whether *Microchelonus* forms a valid genus or is nested within *Chelonus* (McComb, 1968; Papp, 1995; Lozan and Tobias, 2006; Zhang et al., 2008). Also the status of *Leptodrepana* has been variously treated as a genus (Shaw, 1983), or as part of *Ascogaster* (Tang and Marsh, 1994; van Achterberg and Polaszek, 1996; Shaw, 1997; Brajkovic et al., 2010; D. S. Yu et al., 2012). To date, no comprehensive phylogenetic analysis incorporating molecular data has been untertaken to resolve key questions concerning relationships within this species-rich and biologically interesting group of braconid parasitoids.

The aims of this study are to use an extensive dataset comprising sequences from multiple genes and morphology to investigate chelonine relationships with a view to testing the monophyly of genera and tribes, including the position of Adeliinae, and to clarify the status of the problematic genera *Microchelonus* and *Leptodrepana*. Further, a divergence time analysis, calibrated with an extensive array of fossils, is used to estimate the age of the subfamily and of the major lineages therein and examine their likely ancestral areas.

Table 1. Genera of chelonine wasps by tribes modified after Zettel (1990) including distribution, number of described species, and number of species used in this study.

Tribe	**Taxa**	**spp**	**Taxa incl.**	**Distribution**
Chelonini Förster 1826	*Ascogaster* Wesmael 1835	154	14	Worldwide
	Leptodrepana Shaw 1983		6	
	Chelonus Jurine 1801	905		Worldwide
	Chelonus		10	
	Microchelonus Szépligeti 1908		12	
	Areselonus Braet 1999		-	
	Baculonus Braet & van Achterberg 2001		2	
	Carinichelonus Tobias 2000		1	
	Cubochelonus Baker 1926		-	
	Megachelonus Baker 1926		-	
	Parachelonus Tobias 1995		-	
	Scrabichelonus He, Chen & van Achterberg 1997		1	
	Rasnichelonus Tobias 2011		-	
	Diodontogaster Brues 1933	1	-	Fossil
	Eobracon Cockerell 1921	1	-	Fossil
	Megascogaster Baker 1926	1	1	Oriental
	Austroascogaster Kittel & Austin 2014	4	1	Australasian
Odonto-sphaeropygini Zettel 1990	*Odontosphaeropyx* Cameron 1910 *Pachychelonus* Brues 1924	6	3	Afrotropical
Pseudo-phanerotomini Zettel 1990	*Pseudophanerotoma* Zettel 1990 *Furcidentia* Zettel 1990	7 3	3 3	Nearctic
	Dentigaster Zettel 1990	7	2	Neotropical
	Leptochelonus Zettel 1990	1	0	Neotropical
Phanerotomini Baker 1926	*Huseyinia* (Zettel 1990)	1	1	Neotropical
	Phanerotoma Wesmael 1838 *Bracotritoma* Csiki 1909	197	14	Worldwide
	*Phanerotomella** Szépligeti 1900	71	5	Old World
	Phanerotomoides Zettel 1990	1	-	Neotropical
	Siniphanerotomella He, Chen & van Achterberg 1994	2	-	Oriental
	Wushenia Zettel 1990	2	-	Oriental
	Phanaustrotoma Kittel & Austin 2014	2	1	Australasian
Adeliini Viereck 1918	*Adelius* Haliday 1837	26	1	Worldwide
	Paradelius de Saeger 1942	5	1	Afrotropical, Palaearctic, Nearctic, Oriental
	Sinadelius He & Chen 2000	2	-	Palaearctic, Oriental
	Sculptomoriyola Belokobylskij 1988	3	-	Palaearctic

2. Material and Methods

2.1 Taxon sampling and gene selection

For this study, 83 specimens representing 80 species from all major biogeographic regions, 11 of 15 currently recognised extant genera of Cheloninae, and two of four recognised genera of Adeliinae were sequenced for three molecular markers (Table 2). The alignment included two additional sequences of chelonines obtained from GenBank (*Wushenia* and *Chelonus* (*Carinichelonus*)) (see Table 2 for GenBank accession numbers; https://www.ncbi.nlm.nih.gov/genbank/). Four representatives of other subfamilies of Braconidae were additionally used as outgroup taxa: the two closely related microgastroid subfamilies Microgastrinae and Miracinae, the sister clade to the microgastroid complex Ichneutinae, and the more distantly related Euphorinae. The selected markers included the protein coding mitochondrial gene Cytochrome c Oxidase subunit 1 (*COI*), the nuclear protein coding gene elongation factor 1α copy F2 (*EF1α*), and the nuclear 28S rRNA gene D2-D3 region (*28S*) were used, resulting in a total of 1,454 bp (444 bp *COI*, 378 bp *EF1α*, and 632 bp *28S*) (for primers used, see Table 3). All *EF1α* sequences were compared against F1 and F2 copies from hymenoptera taxa analysed by Klopfstein and Ronquist (2013) and were confirmed to belong to the F2 copy.

Table 2. Species used in this study, with internal code/voucher number, country of origin and GenBank accession numbers. Annotations: ● single sequence; ♦(Shi et al., unpublished); ♣ (Murphy et al., 2008); ■ (Kittel and Austin, submitted); * has been included, but is too short for a Genbank accession number.

Taxon	Voucher No.	Country	*COI*	*EF1α*	*28S*
Adelius sp.	RK395	France	KJ472526	-	KJ472639
Ascogaster sp. (AS)	RK91	South Korea	KJ472527	KJ472584	KJ472640
Ascogaster sp. (AS)	RK29	Australia	KJ438543■	-	KJ472641
Ascogaster sp. (AS)	RK36	Australia	-	KJ472585	KJ472642
Ascogaster sp. (AS)	RK28	Australia	KJ438541■	-	KJ472643
Ascogaster sp. (AS)	RK141	Australia	KJ438561■	KJ472586	KJ472644
Ascogaster sp. (AS)	RK167	New Caledonia	KJ472528	-	KJ472645
Ascogaster sp. (AS)	RK85	Australia	KJ438636■	KJ472587	KJ472646
Ascogaster sp. (AS)	RK88	Australia	KJ472529	KJ472588	KJ472647
Ascogaster sp. (AS)	RK301	Australia	KJ438554■	KJ472589	KJ472648
Ascogaster sp. (AS)	RK168	New Caledonia	KJ472530	-	KJ472649
Ascogaster sp. (AS)	RK380	Costa Rica	KJ472531	KJ472590	-
Ascogaster sp. (AS)	RK379	Costa Rica	KJ472532	KJ472591	KJ472650

Ascogaster sp. (AS)	RK385	USA	KJ472533	KJ472592	-
Ascogaster sp. (AS)	RK383	USA	KJ472534	KJ472593	KJ472651
Austroascogaster varia (AAG)	RK424	Australia	KJ472535	-	KJ472652
Austroascogaster varia (AAG)●	RK473	Australia	-	-	√ *
Chelonus sp. (CH)	RK100	Guatemala	KJ472536	KJ472594	KJ472653
Chelonus sp. (CH)	RK99	Honduras	KJ472537	KJ472595	KJ472654
Chelonus sp. (MC)	RK217	French Guiana	KJ472538	-	KJ472655
Chelonus sp. (MC)	RK107	Guatemala	-	KJ472596	KJ472656
Chelonus sp. (MC)	RK392	USA	-	KJ472597	KJ472657
Chelonus sp. (CH)	RK384	USA	-	√ *	KJ472658
Chelonus sp. (CH)	RK221	Gabon	KJ472539	-	KJ472659
Chelonus sp. (CH)	RK102	South Korea	KJ472540	-	KJ472660
Chelonus sp. (MC)	RK109	Thailand	KJ472541	-	KJ472661
Chelonus sp. (CH)	RK387	Republic of the Congo	KJ472542	KJ472598	KJ472662
Chelonus sp. (CH)	RK05	Australia	KJ472543	KJ472599	KJ472663
Chelonus sp. (MC)	RK66	Australia	KJ472544	KJ472600	KJ472664
Chelonus sp. (CH)	RK38	Australia	KJ438520■	KJ472601	KJ472665
Chelonus sp. (MC)	RK105	Slovakia	KJ472545	KJ472602	KJ472666
Chelonus sp. (MC)	RK106	Honduras	KJ472546	KJ472603	KJ472667
Chelonus sp. (MC)	RK142	Australia	KJ472547	KJ472604	KJ472668
Chelonus sp. (MC)	RK20	Australia	KJ472548	KJ472605	KJ472669
Chelonus sp. (MC)	RK76	Australia	KJ472549	KJ472606	KJ472670
Chelonus sp. (MC)	RK110	South Korea	KJ472550	-	KJ472671
Chelonus sp. (CH)	RK389	Costa Rica	KJ472551	KJ472607	KJ472672
Chelonus sp. (CH)	RK381	Costa Rica	KJ472552	-	KJ472673
Chelonus sp. (MC)	RK39	Australia	KJ472553	KJ472608	KJ472674
Baculonus sp. (BC)	RK201	French Guiana	KJ472554	-	KJ472675
Baculonus sp. (BC) ●	RK204	French Guiana	-	-	KJ472676
Scrabichelonus sp. (SC)	RK397	Vietnam	KJ472555	KJ472609	KJ472677
Carinichelonus sp. (CA) ●	n/a	China	-	-	AY973198♦
Dentigaster sp. (DG)	RK203	French Guiana	KJ472556	√ *	KJ472678
Dentigaster sp. (DG)	RK214	French Guiana	KJ472557	KJ472610	KJ472679
Huseyinia sp. (FI)	RK401	French Guiana	KJ472558	-	KJ472680
Leptodrepana sp. (LD)	RK96	Costa Rica	KJ472561	KJ472614	KJ472683
Leptodrepana sp. (LD)	RK138	USA	KJ472562	KJ472615	KJ472684

Leptodrepana sp. (LD) ●	RK165	Costa Rica	-	-	KJ472685
Leptodrepana sp. (LD)	RK391	USA	KJ472563	√ *	KJ472686
Leptodrepana sp. (LD)	RK393	USA	KJ472564	KJ472616	KJ472687
Leptodrepana sp. (LD)	RK378	Sweden	KJ472565	KJ472617	KJ472688
Megascogaster sp. (MA)	RK422	Indonesia	√ *	-	KJ472689
Odontosphaeropyx sp. (PC)	RK399	Tanzania	√ *	-	KJ472690
Odontosphaeropyx leucocoxo (PC) ●	RK420	Madagascar	√ *	-	-
Odontosphaeropyx gracilis (PC)	RK421	Madagascar	KJ472566	-	KJ472691
Paradelius rubra (PD)	RK396	USA	KJ472567	KJ472618	KJ472692
Phanerotomella sp. (PL)	RK131	Madagascar	KJ472568	KJ472619	KJ472693
Phanerotomella sp. (PL)	RK170	Madagascar	-	√ *	KJ472694
Phanerotomella sp. (PL)	RK133	Madagascar	KJ472569	KJ472620	KJ472695
Phanerotomella sp. (PL)	RK302	Australia	KJ472570	KJ472621	KJ472696
Phanerotomella sp. (PL)	RK122	Thailand	KJ472571	KJ472622	KJ472697
Phanaustrotoma pallida (PAT)	RK426	Australia	√ *	-	KJ472698
Phanerotoma sp. (PH)	RK119	Costa Rica	KJ472572	KJ472623	KJ472699
Phanerotoma sp. (PH)	RK124	Republic of the Congo	KJ472573	KJ472624	KJ472700
Phanerotoma sp. (PH)	RK136	USA	KJ472574	KJ472625	KJ472701
Phanerotoma sp. (PH)	RK113	Mexico	KJ472575	KJ472626	KJ472702
Phanerotoma sp. (PH)	RK261	Australia	KJ438631■	KJ472627	KJ472703
Phanerotoma sp. (PH)	RK123	South Korea	KJ472576	KJ472628	KJ472704
Phanerotoma sp. (PH)	RK403	South Korea	KJ472577	KJ472629	KJ472705
Phanerotoma sp. (PH)	RK402	South Korea	KJ472578	KJ472630	KJ472706
Phanerotoma sp. (PH)	RK405	South Korea	KJ472579	KJ472631	KJ472707
Phanerotoma sp. (PH)	RK02	Australia	KJ438586■	KJ472632	KJ472708
Phanerotoma sp. (PH)	RK250	Australia	KJ438601■	KJ472633	KJ472709
Phanerotoma behriae (PH)	RK01	Australia	KJ438611■	KJ472634	KJ472710
Phanerotoma behriae (PH)	RK171	Australia	KJ438616■	KJ472635	KJ472711
Phanerotoma sp. (PH)	RK135	USA	KJ472580	KJ472636	KJ472712
Pseudophanerotoma sp. (PP)	RK218	French Guiana	KJ472581	-	KJ472713
Pseudophanerotoma sp. (PP)	RK314	French Guiana	KJ472582	-	KJ472714
Pseudophanerotoma sp. (PP)	RK114	Guatemala	KJ472583	KJ472637	KJ472715
Pseudophanerotoma (Furcidentia) sp. (LC) ●	RK115	Guatemala	-	KJ472611	-
Pseudophanerotoma (Furcidentia) sp. (LC)	RK116	Guatemala	KJ472559	KJ472612	KJ472681

Pseudophanerotoma (Furcidentia) sp. (LC)	RK315	French Guiana	KJ472560	KJ472613	KJ472682
Microgastrinae	JW58	Australia	-	KJ472638	KJ472716
Ichneutinae	M124	USA	EU106967♣	EU106996♣	EU106928♣
Euphorinae	JW56	Australia	EU106964♣	EU106993♣	EU106925♣
Miracinae	JW65	Australia	EU106971♣	EU106999♣	EU106929♣

2.2 Morphological characters, species identification, and fossils

Thirty-seven morphological characters were coded for Cheloninae including Adeliinae and the outgroups (see Table 4 and 5). The characters used were mostly adapted from Zettel (1990) for chelonine genera or those used by van Achterberg (1984) to define the outgroups. Additionally, character 3 in Table 4 'Occipital carina touching hypostomal carina' was identified during the course of this study and included. The program DELTA editor was used to code specimens (Dallwitz et al., 1999 onwards) (see Table 5). Additionally, 16 fossil ingroup specimens were examined and used for calibrations for the divergence time analysis (Pyron, 2011) (see Table 6).

Table 3. List of primers used in this study.

Gene	Primer name	Sequence 5' – 3'	Reference and annealing Temp.
COI			47°C
Forward 1	CI-J-1718	GGAGGATTTGGAAATTGATTAGTTCC	(Simon et al., 1994)
Reverse 1	CI-N-2191	CCCGGTAAAATTAAAATATAAACTTC	(Simon et al., 1994)
Reverse 2	CI-N-2329	ACTGTAAATATATGATGAGCTCA	(Simon et al., 1994)
Forward 2	M72 (L)	TGATTCTTCGGTCACCCAGAAGTGTA	(Georges et al., 1998)
Reverse 3	HCO2198	TAAACTTCAGGGTGACCAAAAAATCA	(Folmer et al., 1994)
EF1α			50°C
Forward	ef1α 1F	AGATGGGYAARGGTTCCTTCAA	(Belshaw and Quicke, 1997)
Reverse	ef1α 1R	AACATGTTGTCDCCGTGCCATCC	(Belshaw and Quicke, 1997)
28S			60 °C
Forward	28S D2F	AGAGAGAGTTCAAGAGTACGTG	(Mardulyn and Whitfield, 1999)
Reverse	28S D3R	TAGTTCACCATCTTTCGGGTCCC	(Mardulyn and Whitfield, 1999)
Forward	2379	BGGKCAGCGACGCTACTGCTTT	This study (first third)
Reverse	2380	ATVCCCCRGGAATGCGAGAT	This study
Forward	2377	DRAACCCCAAAGATCGAATGAGGAG	This study (second third)
Reverse	2378	AGGRGAAGKGCRCGCCGACA	This study
Forward	2337	GTCCGTGTTTCAAGACGGGTCC	This study (last third)
Reverse	2338	TCGGCGTGCACTTCTYCYYTA	This study

Genera were verified using the keys from Zettel (1990) and Shaw (1997). For the identification of *Chelonus* and *Microchelonus,* McComb's (1968) definition was followed: female *Microchelonus* by having 16 antennomeres or male with a pit present on the posterior metasoma, or both characters present.

Table 4. List of morphological characters and their character states.

Character	Character state
1. Teeth on clypeus	1. absent, 2. one tooth present, 3. two teeth present, 4. three teeth present
2. Mandible separated by transverse carina	1. absent, 2. present
3. Occipital carina touching hypostomal carina	1. absent, 2. present
4. Temple	1. swollen, 2. not swollen
5. Shape of eyes	1. oval, 2. round
6. Hairs on eyes	1. glabrous, 2. densely setose
7. Number of female antennomeres	1. 16, 2. 17-22, 3. 23, 4. more than 24
8. Arrangement of ocelli	1. equilateral, 2. isosceles 'on line', 3. isosceles 'not on line'
9. Occipital carina	1. complete, 2. reduced/dorsal absent
10. Notauli	1. absent, 2. present
11. Precoxal sulcus	1. absent, 2. present
12. Blister on mesotibia	1. absent, 2. present
13. Teeth on claws	1. absent, 2. present
14. Prepectal carina	1. absent; 2. completely present, 3. partly present
15. Postpectal carina	1. absent, 2. short ventral part present, 3. complete
16. Vein r-m of fore wing	1. absent, 2. sclerotised, 3. unsclerotised
17. r in fore wing	1. absent, 2. present
18. 1-SR+M	1. absent, 2. present, from parastigma, 3. present, from 1-M
19. 2-SR+M	1. antefurcal, 2. interstitial, 3. postfurcal
20. 1-cu1	1. antefurcal, 2. interstitial, 3. postfurcal
21. CU1b	1. absent (subdiscal cell open), 2. present (subdiscal cell closed)
22. SR-1 (+3-SR)	1. complete (sclerotised), 2. incomplete (not sclerotised)
23. (SR1+)3-SR	1. absent, 2. present as SR1+3-SR (interstitial), 3. two present as SR1 and 3-SR (antefurcal), 4. two present as SR1 and 3-SR (postfurcal)
24. R	1. extending to apex of wing, 2. not extending to apex of wing
25. 2-R1	1. absent, 2. present
26. Second cubital cell	1. at least half the length of first, 2. reduced or much shorter than half of first cell, 3. about half as long
27. Ratio of pterostigma to 1-R1:	1. same length, 2. much longer, 3. shorter
28. r in hind wing	1. absent, 2. present
29. Fused tergite 1-3 on metasoma (carapace)	1. absent, 2. present, 3. partly fused
30. Sutures on metasoma	1. absent, 2. present
31. Posterior pit in males	1. absent, 2. present

32. Tip of carapace	1. round, 2. with spike, 3. with lobes, 4. with teeth, 5. membranous
33. Shape of metasoma in lateral view	1. posteriorly bend under, 2. flat, 3. broad
34. Shape of metasoma in dorsal view	1. round, 2. elongate/parallel sides, 3. oval, 4. with petiole
35. Pairs of abdominal spiracles	1. 4 pairs, 2. 5 pairs, 3. 6 pairs, 4. 7 or more pairs
36. Attachment of metasoma	1. sclerotised median plate, 2. membranous part of tergum
37. Spiracles of first metasomal tergite	1. in notum, 2. in epipleuron

2.3 Molecular techniques

2.3.1 DNA extraction protocols

Genomic DNA was extracted from specimens that had been preserved in ethanol (75-100%) or were dry and pin-mounted. One hind leg was removed from each specimen and kept in the fridge for 10 min to let the ethanol evaporate, or a non-destructive approach was applied using the whole specimen. DNA extractions were performed using the Gentra Systems Puregene® DNA Purification Kit (Qiagen). A leg or the whole specimen was heated to 55°C in a 300 µl Cell lysis solution with 1.5 µl Proteinase K solution. After 12 -24 hr, excessive proteins were removed by adding 100 µl Protein Precipitation solution. The DNA was then washed in 300 µl Isopropanol (plus 0.5 µl Glycogen) and afterwards in 300 µl ethanol (70%). DNA was restored using 50 µl DNA hydration Solution.

Table 5. List of coded character states per species used in morphological analysis and total-evidence analyses, in alphabetical order of genera.

Species name	Morphological codings
	00000 00001 11111 11112 22222 22223 33333 33
	12345 67890 12345 67890 12345 67890 12345 67
AD_RK395	11221 2?311 21111 11232 12121 22121 15232 11
AS_SK_RK91	21221 1?212 21123 32313 21321 21121 11332 11
AS_AUS_RK29	11221 14312 21123 32223 21321 22121 11332 11
AS_AUS_RK36	11221 12312 21123 32213 21321 2?121 11332 11
AS_AUS_RK28	11221 14311 21123 322?3 21322 21121 11332 11
AS_AUS_RK141	11221 1?312 21123 32213 21321 21121 11332 11
AS_NC_RK167	11221 1?112 21123 32223 21321 22121 11332 11
AS_AUS_RK85	11121 14312 21123 32213 21321 22121 11332 11
AS_sp_RK88	11?21 1?212 ?1123 32313 21322 21121 12132 11
AS_AUS_RK301	31121 14312 11123 32223 21321 22121 11332 11
AS_NC_RK168	11?21 1?312 21123 32213 22321 23121 11332 11
AS_CR_RK380	11221 1?312 21123 32313 21321 22121 11332 11
AS_CR_RK379	11?21 1?212 21123 32333 21321 21121 11332 11
AS_USA_RK385	11221 1?212 11123 32333 21321 22121 11132 11

AS_USA_RK383	11221 14212 11123 32333 21321 21121 11132 11
*Ascogaster_diletata*_fossil	???21 1421? ?1123 32??3 2132? 2?121 11?32 11
*Ascogaster_gracilicornis*_fossil	???21 1?212 ?1123 32??3 2132? 2?121 11?32 11
*Ascogaster_pinicola*_fossil	???21 12212 ?1123 32??3 2132? 2?121 11?32 11
*Ascogaster_praevolans*_fossil	???21 14212 ?1123 32??3 2132? 2?121 11?32 11
*Ascogaster_pentagona*_fossil	???21 14212 ?1123 32??3 2132? 2?121 11?32 11
*Ascogaster_robusta*_fossil	???21 14212 ?1123 32333 2131? 2?121 11?32 11
*Ascogaster_sylvetris*_fossil	???21 14212 ?1123 32??3 2132? 2?121 11?32 11
*Ascogaster_submersa*_fossil	???21 14212 ?1123 32??3 2132? 2?121 11?32 11
AAG_AUS_RK424	11221 14321 21123 32233 21321 21121 11332 11
AAG_AUS_RK473	11221 14321 21123 32233 21321 21121 11332 11
CH_GUA_RK100	11121 2?312 11123 321?3 21322 21121 ?1332 11
CH_HON_RK99	11121 2?212 11123 321?3 21322 21121 ?1132 11
MC_FRG_RK217	11?21 2?312 21123 321?3 21321 22121 21332 11
MC_GUA_RK107	11121 21312 11123 321?3 21322 22121 ?1332 11
MC_USA_RK392	11?21 2?312 21123 321?3 21321 22121 ?1332 11
CH_USA_RK384	11121 2?312 21123 321?3 21321 22121 ?1132 11
CH_GAB_RK221	11121 213?2 11123 321?3 21321 21121 ?1132 11
CH_SK_RK102	11121 2?3?2 21123 321?3 21322 21121 ?1132 11
MC_THA_RK109	11?21 ?1312 11123 321?3 21321 21121 ?4332 11
CH_ROC_RK387	11?21 2?212 11123 321?3 2132? 2?121 ?1332 11
CH_AUS_RK05	11?21 ??312 21123 321?3 21322 22121 11132 11
MC_sp_RK66	11?21 21311 ?1123 321?3 21321 22121 2?332 11
CH_sp_RK38	11?21 2?312 ?1123 321?3 21322 22121 ?1132 11
MC_SLO_RK105	11?21 2?312 21123 321?3 21322 22121 2?132 11
MC_HON_RK106	11?21 21212 21123 321?3 21322 22121 ?1332 11
MC_AUS_RK142	11121 ??312 11123 321?3 21322 22121 21132 11
MC_AUS_RK20	11121 11312 11123 321?3 21322 22121 ?1332 11
CH_RKAUS_RK76	11121 ?1312 11123 321?3 21322 22121 ????2 11
MC_SK_RK110	11?21 21312 21123 321?3 2?322 22121 ?1332 11
CH_CR_RK389	11?21 2?312 21123 321?3 21321 22121 ?1332 11
MC_CR_RK381	11121 21312 21123 321?3 21321 22121 ?1132 11
CH_AUS_RK39	11?21 14312 11123 321?3 21321 22121 ?1132 11
BC_FRG_RK201	11?21 21312 21123 321?3 21321 22121 ?1332 11
BC_sp_RK204	11121 21311 21123 321?3 21322 21121 ?1332 11
SC_sp_RK397	11?11 2?312 11123 321?3 21322 22121 ?1322 11
*Chelonus_depressus*_fossil	1??21 ???1? ?1123 321?3 2132? 2?121 ?1?32 11
*Chelonus_muratus*_fossil	1??21 ???1? ?1123 321?3 2132? 2?121 ?1?32 11
*Chelonus_solidus*_fossil	1??21 ???1? ?1123 321?3 2132? 2?121 ?1?32 11
DG_sp_RK203	31?21 1?112 11123 32233 21322 31122 14332 11
DG_FRG_RK214	?1??2 ????? ??123 32??3 2?3?? ??122 1???2 11
*Diodontogaster_bidentata*_type	11?21 14??2 ?1123 32333 21311 22121 14332 11
*Eobracon_cladurus*_type	?1?2? ????? ?1123 32213 21311 23?21 11?32 11
FI_sp_RK401	31?22 1?112 12123 32223 21312 23122 15232 11
LC_GUA_RK115	11222 1?1?2 22123 32233 21311 23122 13232 11
LC_sp_RK116	11222 1?112 22123 32333 21311 21122 13232 11
LC_FRG_RK315	11222 14112 22123 32232 21311 23122 13232 11
LD_CR_RK96	11221 12112 11123 32313 21321 22121 14332 11
LD_USA_RK138	11?21 121?2 11123 32323 21321 22121 14332 11

LD_CR_RK165	11221 12122 21123 32213 21321 22121 12332 11
LD_USA_RK391	11221 1?122 21123 32323 21321 22121 11332 11
LD_USA_RK393	11?21 1?122 21123 32323 21321 21121 11322 11
LD_SWE_RK378	11221 1?312 21123 323?3 21321 2?121 11322 11
MA_IND_RK422	31221 1?322 21123 32213 21322 32121 12322 11
PC_sp_RK399	21221 14112 11223 32313 21321 33222 11132 11
PC_leucocoxus_RK420	21221 14112 21223 32313 21322 31222 11322 11
PC_gracilis_RK421	21?22 14112 21223 32313 21321 31222 11322 11
PA_RK396	11221 2?311 21111 11332 12121 22122 15232 11
PL_MAD_RK131	11222 14111 11123 32233 11422 23122 13232 11
PL_MAD_RK170	11?22 14111 11123 32233 11422 23122 13232 11
PL_MAD_RK133	11222 14112 11123 32233 11422 22122 1???2 11
PL_variata_sp_nov_RK302	11?22 13111 ?1123 32233 11222 21122 13232 11
PL_THA_RK122	11222 14111 11123 32233 11422 21122 13232 11
PAT_AUS_RK426	31222 13112 11123 32233 11311 23122 11222 11
PH_CR_RK119	31222 13112 12123 32223 21311 23122 14232 11
PH_ROC_RK124	41?22 13112 22123 32223 21311 23122 11232 11
PH_sp_RK136	41?22 13121 ?2123 32223 21311 23122 11232 11
PH_MEX_RK113	31?22 13112 22123 32233 21312 21122 13232 11
PH_AUS_RK261	31222 13112 22123 32213 21311 23122 13232 11
PH_SK_RK123	31222 13112 22123 32223 21312 2?122 14232 11
PH_SK_RK403	41222 13112 12123 32223 21311 23122 13232 11
PH_SK_RK402	41?22 13112 22123 32223 21311 21122 11232 11
PH_SK_RK405	31?22 13112 11123 32223 21311 23122 11232 11
PH_AUS_RK02	31?22 13112 22123 32223 21311 23122 14232 11
PH_AUS_RK250	31222 13112 22123 32223 21311 23122 14232 11
PH_sp_RK01	41?22 13111 ?2123 32223 21311 23122 13232 11
PH_AUS_RK171	41222 13111 22123 32223 21311 23122 13232 11
PH_USA_RK135	41222 13112 22123 3222 21311 23122 11232 11
*Phanerotoma_baltica*_fossil	???21 ?4?12 ??123 32?33 ?13?? ??122 1??32 11
*Phanerotoma_extensa*_fossil	???21 14?12 ??123 32?3 ?13?? ??122 1??32 11
*Phanerotoma_menieri*_fossil	3??22 14?12 1?123 32231 21311 ??122 1??32 11
PP_FRG_RK218	31122 14112 22123 32333 21311 13122 11232 11
PP_FRG_RK314	31122 1?112 22123 32333 21311 13122 11232 11
PP_sp_RK114	11?22 1?112 ?1123 32333 21311 33122 11232 11
Euphorinae_JW56	1??22 1?112 ?1111 ?232? 11222 21131 11344 2?
Ichneutinae_M124	1??22 1?122 ?1111 ?121? 21322 21111 11234 2?
Mircacinae_JW65	1??22 1?111 ?1111 ?231? 21221 22111 11332 22

2.3.2 Amplification and sequencing

Eppendorf thermal sequencers were employed to carry out PCR amplifications. Each reaction of 25 µl comprised 2.5 µl 10 x Taq Gold Buffer, 3 µl 25 mM MgCl2, 2 µl 10 mM dNTPs, 1µl of each forward and reverse 5 µM Primer (see Table 3), 0.1 units (µl) AmpliTaq Gold® DNA Polymerase (Applied Biosystems Inc.), and 1 µl DNA (approximately 0.2 µg DNA). In some reactions Immolase™ DNA Polymerase (Bioline) was used. PCR settings started with a denaturation step of 9 min at 95ºC, followed by 35 cycles of 30 sec 94ºC, 30 sec annealing temp (see Table 3), and an extension step of 1 min at 72ºC. The final extension step was for 6 min at 72ºC and 6 min at 24ºC. PCR products were purified using the Ultraclean™ PCR Clean-up™ Kit (MoBio Biosystems Inc.) and sequenced by the Australian Genome Research Facility Ltd. (AGRF) using capillary separation.

Table 6. Fossils used to calibrate the molecular clock, ordered by age of the deposits.

Taxon	Reference	Deposit	Age range	Age reference
Phanerotoma menieri	(Belokobylskij et al., 2010)	French amber	52-53 Ma	(Nel et al., 1999)
Diodontogaster bidentata	(Brues, 1933)	Baltic amber	40-44 Ma	(Ritzkowski, 1997)
Ascogaster diletata	(Brues, 1933)	Baltic amber	40-44 Ma	(Ritzkowski, 1997)
Ascogaster gracilicornis	(Brues, 1933)	Baltic amber	40-44 Ma	(Ritzkowski, 1997)
Ascogaster pinicola	(Brues, 1933)	Baltic amber	40-44 Ma	(Ritzkowski, 1997)
Ascogaster praevolans	(Brues, 1933)	Baltic amber	40-44 Ma	(Ritzkowski, 1997)
Ascogaster pentagona	(Brues, 1933)	Baltic amber	40-44 Ma	(Ritzkowski, 1997)
Ascogaster robusta	(Brues, 1933)	Baltic amber	40-44 Ma	(Ritzkowski, 1997)
Ascogaster sylvetris	(Brues, 1933)	Baltic amber	40-44 Ma	(Ritzkowski, 1997)
Ascogaster submersa	(Brues, 1933)	Baltic amber	40-44 Ma	(Ritzkowski, 1997)
Phanerotoma baltica	(Brues, 1933)	Baltic amber	40-44 Ma	(Ritzkowski, 1997)
Phanerotoma extensa	(Brues, 1933)	Baltic amber	40-44 Ma	(Ritzkowski, 1997)
Chelonus depressus	(Brues, 1910)	Florissant shale	33-34 Ma	(McIntosh et al., 1992)
Chelonus muratus	(Brues, 1910)	Florissant shale	33-34 Ma	(McIntosh et al., 1992)
Chelonus solidus	(Brues, 1910)	Florissant shale	33-34 Ma	(McIntosh et al., 1992)
Eobracon cladurus	(Cockerell, 1920)	White River	28-35 Ma	(Emry, 1973)

2.3.3 Primer design

In order to obtain sequences from older pinned museum specimens, primers were designed for shorter fragments of *28S* (see Table 3) using the Geneious Pro (by Biomatters, http://www.geneious.com/) plugin Primer 3 (Koressaar and Remm, 2007). Consensus sequences were created for these shorter fragments and they were concatenated with Geneious Pro and analysed together with the other sequences.

2.3.4 Sequence alignment

The sequences were edited in Geneious Pro v. 5.3.6 (Drummond et al., 2011) and a consensus sequence was created for each forward and reverse sequence. Alignments for each marker were conducted with the Geneious Pro plug-in Clustal W v. 2.1 (Thompson et al.,

1994) with penalties setting of 15 for gap open costs and 6.66 gap extend costs. Both *COI* and *EF1α* had open reading frames, and *COI* had a typical mtDNA AT bias and therefore it was unlikely to belong to a nuclear copy (Chandra et al., 2006). The concatenated alignment of all three genes was then produced using Geneious Pro.

2.4 Phylogenetic inference

The morphological analysis, separate gene analyses, concatenated genes analyses, and a combined analysis of the molecular data with the morphological data (total-evidence analysis) were each conducted with Bayesian inference (BI), maximum likelihood (ML) and maximum parsimony (MP) approaches. The best fitting partitioning scheme and most likely substitution model for each partition were identified using PartitionFinder (Lanfear et al., 2012) by applying the Akaike information criterion (Posada and Buckley, 2004) (see Table 7).

Table 7. Models chosen for markers and partition schemes, according to Partitionfinder.

Marker and partitions	**#bp**	**#var**	**#par**	**CG%**	**Model**
COI mtDNA	444	257	224	26.3	
COI_1	148	73	63		TVM+I+ Γ
COI_2	148	46	35		TVM+I+ Γ
COI_3	148	138	126		HKY+I+ Γ
EF1α F2 nuclear DNA	378	148	108	41.3	
ef1α_1	126	19	8		GTR+I+ Γ
ef1α_2	126	15	2		TVM+I+ Γ
ef1α_3	126	114	98		TVM+I+ Γ
28S nuclear DNA					
28S_123	632	469	357	40.9	GTR+I+Γ
morphology					
n/a	37	32	31	n/a	Mk + Γ
Combined morph and mol	1491				
Morphology, COI_1, COI_2, COI_3, ef1α_1, ef1α_2, ef1α_3, 28S_123					Mk + Γ, GTR+I+Γ
concatenated	1454				
COI_1, COI_2, COI_3, ef1α_1, ef1α_2, ef1α_3, 28S_123					GTR+I+Γ
Total-evidence with fossils	1491				
Morphology, COI_1&2, ef1α_1&2, ef1α_3, 28S_123					Mk + Γ, GTR+I+Γ

For the BI analyses, MrBayes v. 3.2.2 was used (Ronquist et al., 2012). Each analysis was run for 20 million generations, with four independent runs, each with four chains, otherwise with default settings, random starting trees, trees sampled every 1000 generations and without modified heating. The first 25% of the generations were omitted as a burn-in. We considered the analyses as having converged if the standard deviation of the split frequencies fell below a 0.01 threshold (Ronquist and Huelsenbeck, 2003).

The ML analysis was conducted in RAxML v. 7.7.0 (Stamatakis, 2006) with 1000 random staring trees with the GTRGAMMAI model (GTR with estimate of proportion of invariable sites) (Stamatakis, 2006). Clade support was obtained using 1000 non-parametric bootstrap iterations, applying fast bootstrapping.

The MP analysis applied a tree-bisection-reconnection (TBR) heuristic approach as implemented in PAUP* (Swofford, 2003), with 1000 random stepwise addition replicates each holding 100 trees. The characters were treated as unordered and had equal weight. Bootstrap support was calculated by the analyses above without replicates for the random stepwise addition step.

All analyses were conducted on tizard, the eResearch South Australia high-performance computing cluster (PAUP* and RAxML) or on the CIPRES Science Gateway V 3.3 (MrBayes) (Miller et al., 2010).

2.5 Total-evidence dating analysis

The calibration of the phylogeny was based on a total-evidence approach as in Ronquist et al. (2012). For this, the combined dataset containing molecular and morphological information was extended by including morphological data for the 16 fossil taxa (Table 6), with sequences for fossils coded as missing data. For this analysis, the molecular data were not partitioned according to Partitionfinder, but an evolutionary more simple partitioning scheme was used (compare Simmons et al., 2006) (see Table 7), in which the first and second codon positions of both *COI* and *EF1α* formed one partition each and the third codon positions of *EF1α* formed another (see Table 7), *28S* was represented by a single partition, and the third codon positions of *COI* was omitted due to saturation. When not excluding the third codon positions of *COI*, the age of the chelonines became much older due to the high evolutionary rate at these positions (data not shown). For an initial analysis, the clockrate (lognorm (-7.08069, 2.458582)) and the independent gamma rates (IGR) (exp(37.12)) priors were used as in Ronquist et al. (2012). After this first step, the IGR prior was modified to exp(84.65723), in an empirical Bayes approach in order to reflect the posterior resulting from this preliminary analysis. The clockrate posterior was not significantly different from the prior from Ronquist et al. (2012) and was thus not modified.

The analysis was performed with 50 million generations, sampling every 1000 generations, using four independent runs with four chains each. The minimum age of the root was set to 72 megayears (Ma), which has been identified as the age of the oldest fossil of Euphorinae (McKellar and Wolfe, 2010); and the mean age of the braconid family was set to 130 Ma following Whitfield (2002), using an offset exponential distribution. The ages of the fossils in this study are dated with the age ranges of the deposits (Table 6), following a uniform distribution. Topology convergence was verified by a 0.01 threshold of the split frequencies, parameter convergence was verified by an Effective Sample Size (ESS) of more than 200, and potential scale reduction factor (PSRF) approaching 1. The first 50% of generations were omitted as a burn-in, to ensure the convergence of the clockrate (over time).

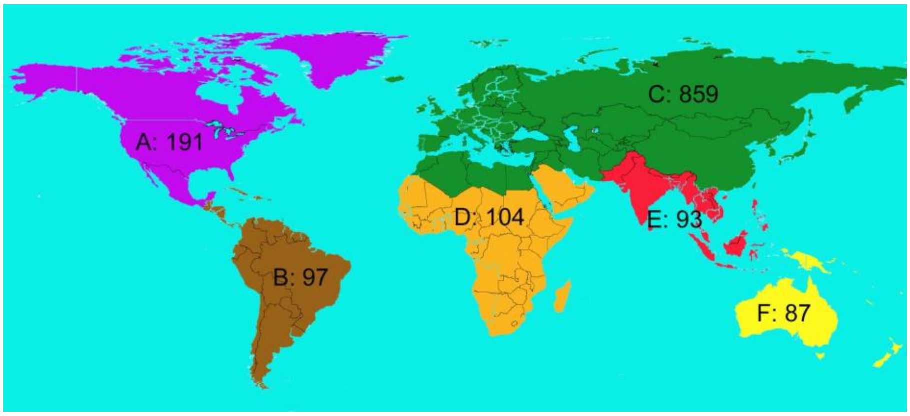

Figure 1. Biogeographical regions and the species richness: A) Nearctic, B) Neotropical, C) Palearctic, D) Afrotropical, E) Oriental, F) Australasia and Oceania.

2.6 Biogeographic inference

To infer the geographical origin of the subfamily, all tree files of the concatenated genes BI analysis were read into the program RASP (Reconstruct Ancestral State in Phylogenies) 2.0 (Y. Yu et al., 2012) and a condensed tree (consensus tree) was created. For the ancestral distribution analysis of chelonines, six biogeographic regions were used: A) Nearctic, B) Neotropical, C) Palearctic, D) Afrotropical, E) Oriental and F) Australasia and Oceania (Fig. 1). All taxa were coded for these regions based on their distribution records (D. S. Yu et al., 2012) (Table 2). The ancestral geographic area was inferred using a Bayesian MCMC approach to dispersal-vicariance analysis as implemented in RASP. The number of cycles was set to 50,000 and the root distribution was set to null. The variety of maximum areas was set to six (as many as the geographical regions included). All other options remained as default.

3. Results

3.1 Phylogenetic analysis

3.1.1 Topology

The Cheloninae + Adeliinae were recovered in all analyses as monophyletic relative to the outgroup subfamilies, with only the single gene trees for *COI* and *EF1α* not reaching significant Bayesian posterior probabilities (Fig. 2). The topology was also stable across the dating inference (Fig. 3) and the RASP analysis (Fig. 4), but it was less well resolved in the MP and ML analyses (not shown). The monophylies of the two proposed tribes Phanerotomini (including Adeliinae) and Chelonini are highly supported in the concatenated analyses and the total-evidence analysis; however, the single gene analyses and morphology alone showed substantial differences. The two tribes proposed by Zettel (1990), Odontosphaeropygini and Pseudophanerotomini, were not recovered as monophyletic.

The following major topological rearrangements were recovered: Apart from the morphological Bayesian analysis, the Adeliinae were recovered in all analyses within the Cheloninae, forming a sister clade with either *Phanerotomella* or *Dentigaster*, depending on the analysis. All genera were generally recovered as monophyletic, with *Ascogaster, Phanerotoma,* and *Pseudophanerotoma* being the exceptions. *Ascogaster* is split in almost all analyses into two clades, a (mostly) North American clade and a (mostly) Australian clade, thus rendered paraphyletic in regards to *Austroascogaster*, *Leptodrepana* and *Megascogaster*. The only exception to this finding came from the morphological analysis, in which *Ascogaster* forms a monophyletic clade. In all analyses, the genus *Phanerotoma* was rendered paraphyletic with respect to either *Huseyinia, Phanaustrotoma*, or both. Both subgenera of *Pseudophanerotoma* were used in the analyses, *Pseudophanerotoma* and *Furcidentia*. They were retrieved with strong support in all analyses as separate clades, but not necessarily as sister clades. The genus *Chelonus* was recovered as monophyletic with significant support in all analyses. However, neither subgenus *C. Chelonus* or *C. Microchelonus* (CH and MC, Fig. 2) nor the other included subgenera *Baculonus, Carinichelonus,* and *Scrabichelonus,* formed distinct clades.

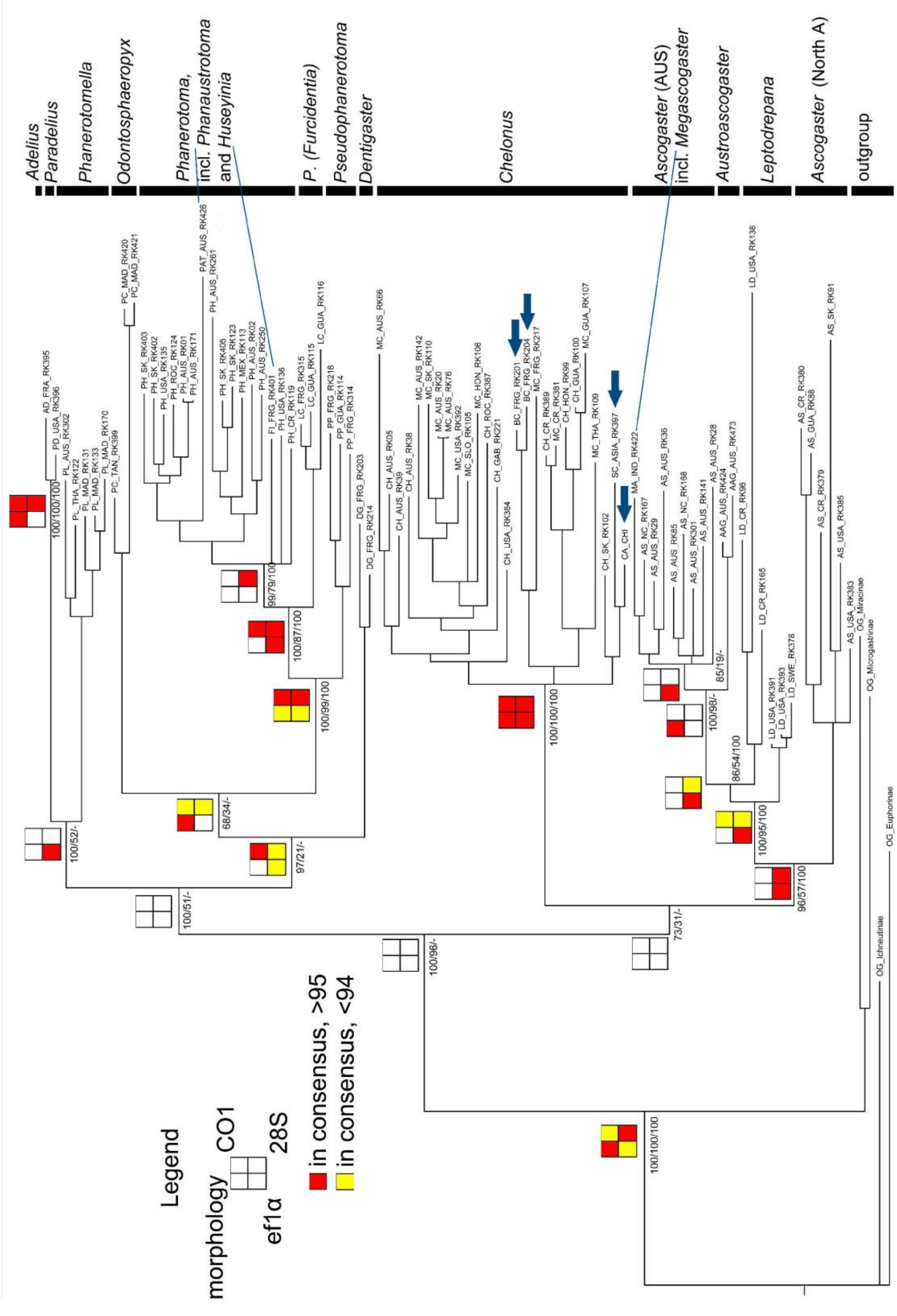

Figure 2. Bayesian analysis of morphological and molecular data. The values under the nodes show the posterior probabilities from Bayesian analyses, bootstrap of maximum likelihood and bootstrap of parsimony. A dash indicates that this clade was not present in the consensus tree. The squares depict the posterior probabilities of a Bayesian analysis of the individual partitions (morphology, *COI*, *EF1α* and *28S*). A white square indicates that this branch was not present in the consensus tree. Lines are indicating the position of the genera *Phanaustrotoma* and *Huseyinia* embedded in *Phanerotoma* and *Megascogaster* in *Ascogaster*. Arrows show the placement of *Baculonus, Carinichelonus,* and *Scrabichelonus* within Chelonus.

3.2 Total-evidence dating analyses

The topology generated using the total-evidence dating analysis (Fig. 3) was overall the same as that obtained for the other analyses (see above) and almost all the fossils were placed where expected. The fossil *Chelonus* and *Ascogaster* were recovered with their extant counterparts. *Diodontogaster* was placed within the *Ascogaster* fossils, thus rendering the North American *Ascogaster* paraphyletic. *Eobracon*, on the other hand, was placed in the proximity of the Australian clade of *Ascogaster*, close to *Austroascogaster* and *Megascogaster*. The three fossil *Phanerotoma* species also did not fall within the extant *Phanerotoma*, but rather appear to be more closely related to *Dentigaster*, *Pseudophanerotoma (Furcidentia)*, and *Pseudophanerotoma*.

Table 8. Estimated ages of Cheloninae, tribes and genera and probabilities of the ancestral area.

Taxon	**mean age**	**95% credibility interval**	**% Ancestral area probabilities**
Cheloninae	150	105-245	95
Chelonini	140	100-225	95
Phanerotomini	135	108-245	95
Adeliine genera	14	1-38	90
Adelius	14	1-38	-
Paradelius	14	1-38	-
Austroascogaster	20	2-50	98
Ascogaster (Australia)	88	53-148	90
Ascogaster (North America)	118	79-190	70
Chelonus	120	80-198	96
Dentigaster	32	8-62	99
Diodontogaster (fossil)	40-44	n/a	-
Eobracon (fossil)	28-35	n/a	-
Huseyinia	72	40-127	99
Leptodrepana	20/91	5-45/53-157	80
Megascogaster	38	11-68	80
Odontosphaeropyx	30	7-63	99
Phanaustrotoma	65	32-112	-
Phanerotoma	88	55-148	55
Phanerotomella	60	30-102	70
Phanerotomoides	n/a	n/a	-
Pseudophanerotoma	70	34-130	100
Pseudophanerotoma (Furcidentia)	40	15-180	99
Sculptomoriyola	n/a	n/a	-
Sinadelius	n/a	n/a	-
Siniphanerotomella	n/a	n/a	-
Wushenia	n/a	n/a	-

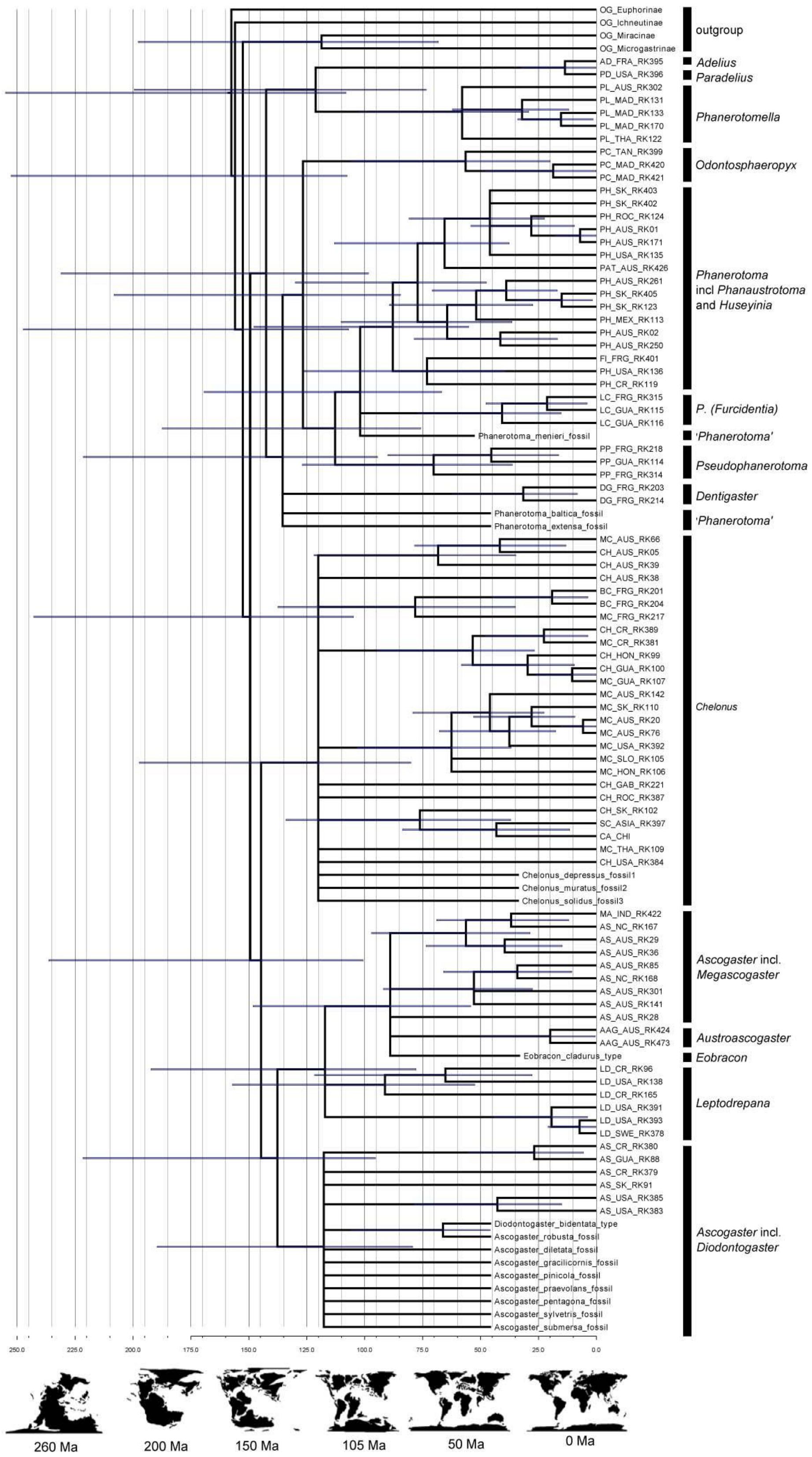

Figure 3. Divergence time analysis based on total-evidence data.

The total-evidence approach infers a median age for the subfamily of about 150 Ma, with a range of 105-245 Ma (95% credibility interval) (Table 8). Both Chelonini and

Phanerotomini evolved around the same time, 135-140 Ma ago, with *Ascogaster* (North America) and *Chelonus* originating 118-120 Ma, followed by the *Ascogaster* (Australia), *Phanerotoma* and *Leptodrepana* shortly afterwards, around 90 Ma ago. The reminding small genera evolved more recently; *Pseudophanerotoma*, *Phanaustrotoma*, *Huseyinia* and *Phanerotomella* at 60-72 Ma ago, and the adeliine genera, *Austroascogaster*, *Dentigaster*, *Diodontogaster*, *Eobracon*, *Pseudophanerotoma* (*Furcidentia*), *Megascogaster*, and *Odontosphaeropyx* at 14-38 Ma ago.

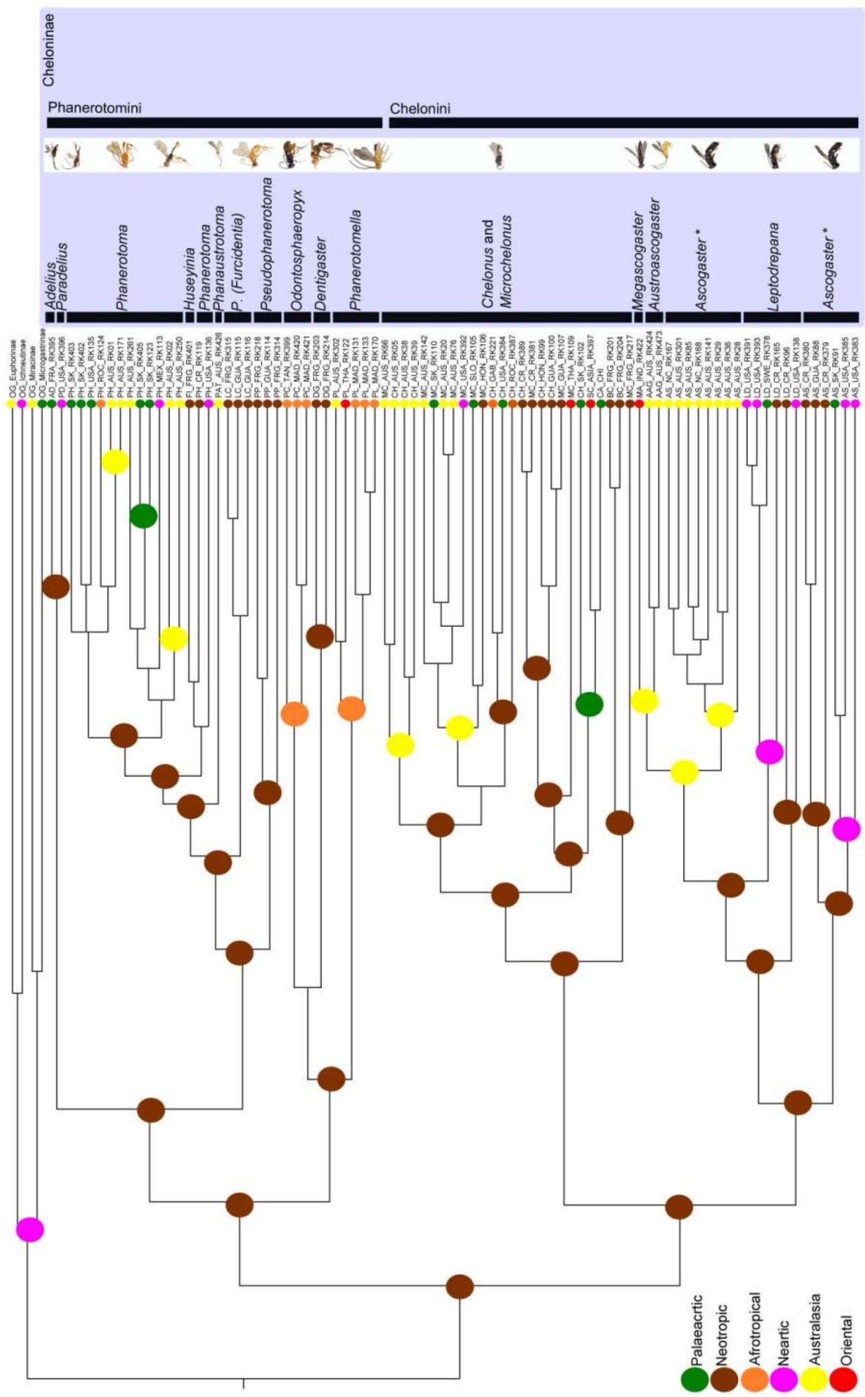

Figure 4. RASP analysis based on concatenated genes *COI*, *EF1α* and *28S*. Two tribes are depicted, the monophyletic Phanerotomini and the monophyletic Cheloninae. The genus *Ascogaster* is divided into two clades: the North American clade (comprising mostly of North American specimens) and the Australian clade (comprising of Australian and New Caledonian specimens). The genus *Phanerotoma* is paraphyletic in regards to *Huseyinia*.

3.3 Biogeographic inference

The RASP analysis performed on the concatenated multigene BI results inferred with a 95% probability an ancestral area of the subfamily in the Neotropics as it is known today (Fig. 4) (for probabilities per node, see Table 8). All higher taxa (tribes and genera) were also recovered with the Neotropics as their ancestral area. The exceptions are clades which have extant species on distant continents, e.g. *Ascogaster* (Australia), together with *Austroascogaster*, and *Megascogaster*, however, even they show the Neotropics as the ancestral area at the next highest level.

4. Discussion

4.1 Implications for classification

Within Cheloninae, Zettel (1990) proposed four tribes (see Table 1), but more recently, van Achterberg (1990) argued for just two, Chelonini and Phanerotomini, with both authors treating Adeliinae as a separate subfamily. Our results support a classification with two tribes *sensu* van Achterberg, but with Phanerotomini also including the adeliine genera as a monophyletic group without higher rank.

Microchelonus is not monophyletic and is nested in multiple places within *Chelonus* in all analyses as predicted by van Achterberg and Polaszek (1996). Hence, the subgenus *Microchelonus* should be treated as invalid and synonymised with *Chelonus*. This should also be applied to the tested subgenera of *Microchelonus (Baculonus, Carinichelonus)* and *Chelonus (Scrabichelonus)*. There is no evidence that the reminder of the subgenera of *Microchelonus (Areselonus, Megachelonus, Parachelonus, Rasnichelonus,* and *Stylochelonus),* and of *Chelonus (Cubochelonus,),* can be synonymised and further studying is required (see Table 1).

The recovery of *Ascogaster* as paraphyletic in all analyses and particularly the recognition of two *Ascogaster* clades, a North American clade and an Australian clade are interesting. The latter is sister to *Leptodrepana*, *Austroascogaster* and *Megascogaster,* while the North American clade is sister to all of them. The paraphyletic status of *Ascogaster* has been discussed previously by Shaw (1997), Tang and Marsh (1994), and Huddleston (1984). Based on the phylogenetic results here, two options are possible; the first is to treat them all within an expanded *Ascogaster* or to recognise two separate genera, a North American genus (including the type of the genus) and a new genus with all Australian *Ascogaster* along with *Leptodrepana, Megascogaster,* and *Austroascogaster*. Before such changes are considered a detailed exploration of the characters defining each group would be required along with a more comprehensive sampling of sequenced taxa.

The genus *Phanerotoma* is paraphyletic with respect to *Huseyinia* and *Phanaustrotoma* in all analyses. However, both species representing these latter two genera have not only the marker *EF1α* missing, but also incomplete *COI* and *28S* sequences. Such a level of missing data may have caused the paraphyly of *Phanerotoma*, thus the support is only significant in the *28S* BI analysis, but not in the other gene trees or combined analyses.

As both subgenera of *Pseudophanerotoma* (*Pseudophanerotoma* and *Furcidentia*) were retrieved as separate but not closely related clades with strong support values in all analyses, we suggest that the subgenus *Furcidentia* should be raised to genus level with the following characters to distinguish them from *Pseudophanerotoma* as discussed in Zettel (1990): 1-SR+M emanating from parastigma, clypeus without teeth and wings infused with white stripe under parastigma. All other genera are monophyletic and are well diagnosed by a range of morphological characters (Zettel, 1990).

4.2 Divergence time estimates

Our results show a much older age (150 Ma) for the chelonines than previous studies (Whitfield, 2002; Murphy et al., 2008). Murphy et al. (2008) calculated a mean age of 85 Ma ± 4.31 for Cheloninae and 103.38 Ma ± 4.41 Ma for the microgastroid complex using a fossil calibrated penalised likelihood estimation. Previously, Whitfield (2002) calculated a mean age for the microgastroid complex of 73.7 Ma ± 10 Ma, also calibrated with fossils, albeit far fewer than the Murphy et al. study. Although our calculations place the radiation of the Cheloninae at 65-76 Ma earlier than previous studies and approximately 70 Ma prior to the first fossil record for the microgastroid complex, we believe this age reflects the evolution more accurately. The range of ages for the chelonine lineages are large, spanning 105-245 Ma, but it does not cover the ages estimated in previous studies, which are just outside of the 95% confidence interval. The age of chelonine wasps is supported by the radiation of the Lepidoptera (Labandeira et al., 1994), who estimate the earliest Lepidoptera evolved around 250 Ma ago, with the major radiation occurring from 170 Ma ago. The radiation of the Lepidoptera began earlier than the radiation of the angiosperms (Grimaldi and Engel, 2005), which had two major radiations, the earliest one from 130-103 Ma ago with a low rate and a later radiation rate 102-77 Ma ago with a higher rate (Magallón and Castillo, 2009).

There is a general tendency for more recent studies to estimate older ages of wasp lineages than previous attempts, for a range of both positive and negative reasons: the latter include an incomplete fossil record, biases in the prior settings, model mis-specification or a combination of these (Thorne and Kishino, 2002; Ronquist et al., 2012). Alternatively, positive effects leading to older and more accurate estimates might be attributed to recent studies being more comprehensive (more taxa and a greater number of markers), using more sophisticated analytical techniques, and including a greater array of fossils distributed more evenly across the tree.

The tendency for calculating older splits in calibrated trees is not restricted to the microgastroid complex, but can be found widely among Hymenopteran studies. For instance the most recent analyses of the order Hymenoptera by Ronquist et al. (2012) estimated an age for the Ichneumonoidea of about 260 Ma and for Hymenoptera of 309 Ma, based on a total-evidence dating approach. Previous studies have estimated a mean age for the Hymenoptera as 220 Ma (Wiegmann et al., 2009) based on node dating (calibrating nodes of the tree based on fossils). Grimaldi and Engel (2005) dated the age of the modern Hymenoptera of 200 Ma and Ichneumonoidea to 150 Ma based on fossil specimens. The ages of two other braconid subfamilies have been estimated (Zaldivar-Riverón et al., 2008a; Zaldivar-Riverón et al., 2008b), however, in both cases their ages were inferred with a mean age of approximately 50 Ma (Rogadinae: 36-51 Ma, Doryctinae: 55-59 Ma). Divergence times were in both cases inferred with a comprehensive set of taxa and markers, but only a small number of fossils were used for the calibration in the node-dating penalised likelihood estimation. But as shown and discussed by Ronquist et al. (2012), the age of node-dating tends to show a younger age than from total-evidence dating.

4.3 Biogeographic inference

The inferred time and ancestral area of the Cheloninae indicates that they evolved in what is today known as South America, but was 150 Ma ago part of Gondwana, after the supercontinent broke up with Laurasia (approximately 180-200 Ma ago) (Condie, 1989).

Chelonus evolved during the time of Gondwana and is cosmopolitan, however, *Ascogaster* (North America) which is estimated to have evolved at the same time is not. Similarly, the genus *Phanerotoma*, which evolved during the time when Gondwana split into West and East Gondwana, is cosmopolitan, but the second clade of *Ascogaster* (Australia), which evolved around the same time is not. Thus two of the three earlier genera seem to be cosmopolitan (*Chelonus* and *Phanerotoma*), but *Ascogaster* is not, as it split into two clades which evolved at different times. One possible scenario would be that ancestral *Ascogaster* was cosmopolitan, but by the time Gondwana was breaking up into West and East, there was no dispersal of the genus from other areas into the Australasian region. Thus they look morphologically the same, but are genetically different. This scenario is supported by the fact that there is not a monophyletic clade for a single area within *Chelonus* and *Phanerotoma*, which is otherwise common in other braconid groups (e.g. Zaldivar-Riverón et al., 2008a; Shaukat and Quicke, 2011). For some reason it appears that *Chelonus* and *Phanerotoma* have dispersed more easily than *Ascogaster*.

The genera that have evolved more recently, at a time when the continents almost reached their current position, are all restricted to one continent or region. The exceptions are the adeliine genera, which have a cosmopolitan distribution and *Phanerotomella*, which is widely distributed in the Old World but absent from the Americas. Thus the chelonines do not show a similar distributional pattern to other braconids, where the diversification bears traces of vicariance events, and the majority of the extant taxa belonging to cosmopolitan groups have dispersed across the globe (de Jong and van Achterberg, 2007).

5. Conclusion

This study represents the most comprehensive phylogenetic estimate of relationships for chelonine wasps and has employed a total-evidence dating approach, combining molecular and morphological data from extant and fossil taxa. The results show the presence of two well resolved lineages (tribes) and the monophyly of most genera. Unfortunately, some rare genera (*Phanerotomoides, Sculptomoriyola, Sinadelius, Siniphanerotomella* and *Wushenia*) could not be included, because specimens were unavailable or the quality or the quantity of their DNA was inadequate. Including more adeliine genera and taxa closely related to them could improve our phylogenetic results by providing more robust information on their sister clade. The results indicate that the Cheloninae are much older than previous studies have suggested, about 65-75 Ma older. Further, the current biogeography of the Cheloninae is explained by a dynamic process of both vicariance and long distance dispersal.

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Chapter 3: Synopsis of Australian chelonine wasps (Hymenoptera: Braconidae: Cheloninae) with description of two new genera

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Chapter 4: Remarkable range extension of the previously monotypic braconid genus *Wushenia* Zettel (Hymenoptera: Braconidae: Cheloninae), with description of a second species from Australia

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Chapter 5: Systematics of the parasitic wasp genus *Phanerotomella* Szépligeti (Hymenoptera: Braconidae: Cheloninae) for Australia, with descriptions of 18 new species

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Abstract

Australian chelonine wasps have been poorly studied and yet they are a common feature of the continent's braconid fauna. *Phanerotomella* Szépligeti has previously been considered to be a small genus known from three described species for Australia. However, recent intensive collecting reveals a more species rich fauna. Here we undertake a systematic revision of Australian *Phanerotomella* and, in so doing, redescribe the three previous species (*P. longipes* Szépligeti, 1900, *P. minuta* Zettel, 1989, and *P. sculpturata* Szépligeti, 1900) and describe 18 new species; *P. ashmeadi* sp. n., *P. brevivena* sp. n., *P. castanea* sp. n., *P. curtogaster* sp. n., *P. dentata* sp. n., *P. dimorpha* sp. n., *P. discoloria* sp. n., *P. flavens* sp. n., *P. kimbaensis* sp. n., *P. kriegeri* sp. n., *P. microcellata* sp. n., *P. naumanni* sp. n., *P. nivistigma* sp. n., *P. obscura* sp. n., *P. phanerotomoides* sp. n., *P. pungogaster* sp. n., *P. szepligetii* sp. n., and *P. variata* sp. n. A dichotomous key is included to facilitate identification of the species along with a discussion of the monophyly and distribution of the genus.

Keywords

egg-larval parasitism; parasitoid; revision; taxonomy.

Introduction

The chelonines are a moderate-sized subfamily of braconid wasps with about 1,300 described species in 17 genera worldwide (Yu *et al.* 2005; Kittel & Austin 2014). The group can be recognised from other braconids by the presence of a metasomal carapace which comprises the fusion of the first three metasomal tergites, a complete postpectal carina, and three submarginal cells in the fore wing (Shaw 1983; van Achterberg 1990; Zettel 1990; Shaw 1997). Virtually all members of the subfamily are solitary egg-larval koinobiont parasitoids of Lepidoptera, where oviposition occurs into a host egg but development of the parasitoid is delayed until the host has emerged as a larva (Shaw & Huddleston 1991; Shaw 1997; LaSalle 2003).

Within Cheloninae, *Phanerotomella* is a relatively small genus compared with the huge genera *Phanerotoma* Wesmael, 1938 and *Chelonus* Panzer, 1801. First described by Szépligeti (1900), *Phanerotomella* comprises 70 described species (Yu *et al.* 2005), is distributed across the Old World, but is absent from the Americas (Zettel 1990). Zettel (1990) placed *Phanerotomella* in the subtribe Phanerotomellina (tribe Phanerotomini) as sister to *Wushenia* Zettel, 1990.

As part of an on-going comprehensive study of Australian Cheloninae (Kittel & Austin 2013, 2014) we here revise the systematics of *Phanerotomella* for the continent. Previously, the genus was only known from three species on the continent, *P. longipes* Szépligeti, 1900, *P. minuta* Zettel, 1989, and *P. sculpturata* Szépligeti, 1900, all described from northern Australia (Northern Territory and Queensland) (Szépligeti 1900; Zettel 1989). Using the material available from more intensive collecting in Australia over the last 25 years, we here describe an additional 18 species, redescribe the three existing species, and also present a dichotomous key to facilitate the identification of species and the distribution of the genus.

Material and Methods

Specimens from all major museum collections within Australia and three overseas collections (AEI, NMNH, and UNHM) were examined, as well as material collected from recent extensive field surveys. A total of 225 specimens of Australian *Phanerotomella* were available for the study.

Terminology for morphology and wing venation follows van Achterberg (1988) and Karlsson and Ronquist (2012), while sculpturing is based on Eady (1968). In addition, the following abbreviations are given for ocellar meassurements/ratios: LOL, lateral ocellar line (distance between lateral and anterior ocelli); OOL, ocular ocellar line (distance between lateral ocellus and compound eye); POL, posterior ocellar line (distance between lateral ocelli).

Images were taken using a Visionary Digital BK+ photo system with a K2 lens system attached to a Canon 7D digital camera. For images of the holotypes of *P. longipes* and *P. sculpturata* a Nikon Coolpix 990 attached to Leica MZ 7.5 was used. Final images were stacked from multiple images using Zerene Stacker software (version 1.04) and edited in Adobe Photoshop CS5 (extended version 12.0x64). Images for *P. minuta* were acquired with an EntoVision micro-imaging system, using a Leica M16 zoom lens attached to a JVC KY-75U 3-CCD digital video camera. The program Cartograph 5.6.0 was used to stack images into a single in-focus image (Buffington *et al.* 2005). Measurements were taken using a Zeiss stereomicroscope and Adobe Photoshop CS5. The distribution maps were produced with DIVA-GIS (Hijmans *et al.* 2004).

Abbreviations for collections are as follows:

AEI American Entomological Institute, Gainesville, USA

ANIC Australian National Insect Collection, CSIRO, Canberra, Australia

AMS	Australian Museum, Sydney, Australia
NMNH	National Museum Natural History, Smithsonian Institute, Washington, USA
UNHM	Hungarian Natural History Museum, Budapest, Hungary
QM	Queensland Museum, Brisbane, Australia
SAM	South Australian Museum, Adelaide, Australia
WAM	Western Australia Museum, Perth, Australia
WINC	Waite Insect and Nematode Collection, Adelaide, Australia

Taxonomy

Genus *Phanerotomella* Szépligeti, 1900

Phanerotomella Szépligeti, 1900: 59. Type species: *Phanerotomella longipes* Szépligeti, 1900 (by subsequent designation, Viereck, 1914) UNHM [examined].

Plesiosphaeropyx Cameron, 1912: 82, 84. Type species: *Plesiosphaeropyx albipalpis* Cameron, 1912 (synonymy by de Saeger 1948).

Phanerotomella: Belokobylskij, 1986: 41-48; Sigwalt, 1977: 525-535; Sigwalt, 1978: 715-725; van Achterberg, 1990: 1-106; Zettel, 1989: 15-142. For world species list see Shenefelt (1973) and Yu et al. (2005).

Diagnosis

Ocelli arranged as an equilateral triangle; eyes round, glabrous, and rather small; clypeus with or without teeth; occipital carina complete; antenna with at least 24 antennomeres (up to 60, but variable within species); notauli present or absent; fore wing 1-SR+M present and emanating from parastigma; 1-cu1 postfurcal; 2-SR+M antefurcal, postfurcal or interstitial; R not reaching apex of wing; 2-R1 present or absent; often only with two radial abscissa present (3-SR absent, interstitial), if third abscissa (3-SR) present then 3-SR postfurcal or antefurcal; subdiscal cell open (cu1b absent); propodeal tubercles absent or present; mid tibia without blister; metasomal carapace with transverse sutures; posterior carapace with up to five teeth or lobes.

Monophyly of the genus and generic limits

Zettel's (1990) recognition of the subtribe Phanerotomellina (tribe Phanerotomini) is based on the absence of the cub1 vein, thus rendering the subdiscal cell open. The two genera comprising this subtribe, *Phanerotomella* and *Wushenia*, are both distributed in the old world.

Phanerotomella differs from *Wushenia* by having a complete occipital carina and usually more than 25 antennomeres. Based on these characters, the genus is postulated to be monophyletic (Kittel & Austin 2013) but, ideally, this needs to be confirmed from a comprehensive phylogenetic analysis employing multiple mitochondrial and nuclear markers.

With this revision of the Australian fauna, the inclusion of two additional characters, the morphological limits of the genus have been expanded. In his revision of *Phanerotomella* Zettel (1989) described the majority of species as having the fore wing vein 3-SR postfurcal. However, this is not the case for some Australian species, where only a minority of species has this character state (i.e. *P. dentata* sp. n., *P. dimorpha* sp. n., *P. discoloria* sp. n., and *P. kimbaensis* sp. n.); all other species have 3-SR antefurcal or interstitial.

Further, previously described species have had the clypeal margin smooth, however, in Australia three species have two teeth on their clypeus, namely *P. dentata* sp. n., *P. dimorpha* sp. n., and *P. kimbaensis* sp. n.

Distribution

Phanerotomella has a wide distribution in the Old World (Zettel 1990). In Australia the genus has a much wider distribution than previously known, and appears to be most species rich in the tropical north (Queensland and Northern Territory), but also occurs in the central arid desert (Northern Territory, South Australia), Mediterranean habitats (Western Australia, South Australia), and the eastern coastal margin (Victoria and Australian Capital Territory). The genus is clearly underrepresented from the central arid region, possibly due to less intensive collecting, while in the temperate south-east of the continent the genus is represented by only two species.

Biology

No hosts are known for any Australian species, with the only host record for the genus being the potato moth *Stoeberhinus testaceus* Butler, 1881 (Oecophoridae) for the Hawaiian species *P. hawaiiensis* (Ashmead, 1901) (Yu *et al.* 2005).

Taxonomically important characters

Although some fore wing veins vary intraspecifically for a few species (2-SR+M, most notably in *P. longipes* and *P. sculpturata*), overall venation is consistent within species and differs among species, with the position of 3-SR, presence or absence of 2-R1, and shape and sclerotisation of SR-1 being useful characters. Sculpturing of various body parts are also critical taxonomic characters and are more strongly developed within species of this subfamily than many other braconid groups (Huddleston 1984). Sculpturing of the face, clypeus, vertex, mesonotum, mesopleuron, and metasomal carapace are of particular importance at species level.

Sexual dimorphism is known within the Phanerotomini with females of various genera exhibiting broader and shorter antennomeres than males for some species. Additionally, some species of *Phanerotomella* show slight colour variation between the sexes (Zettel 1989), however, differences in sculpturing and overall colour patterns have not been reported.

Key to the Australian species of *Phanerotomella*

1 Fore wing 3-SR postfurcal (Fig. 2) …………………………………………………… 2

- Fore wing 3-SR interstitial (absent) or antefurcal (sometimes short) (Fig. 1) ……….... 6

2 Clypeus without teeth (Fig. 4) ………………………………………………………. 3

- Clypeus with teeth (Fig. 23) ………………………………………………………… 4

3 Vein SR-1 completely sclerotised (Fig. 1); face rugose (Fig. 13); notauli present (Fig. 26); precoxal sulcus present (Fig. 22) ……………………………… *P. discoloria* sp. n.

- Vein SR-1 only basally sclerotised (Fig. 10); face smooth (Fig. 8); notauli absent (Fig. 15); precoxal sulcus absent (Fig. 12) …………………………………*P. brevivena* sp. n.

4 Body overall yellow in colour (Fig. 43); SR-1 curved (Fig. 63) ..… *P. kimbaensis* sp. n.

- Body of different colour, including metasoma being dichromatic; SR-1 straight (Fig. 92) ………………………………………………………………………………….…5

5 Body longer than 3 mm; antenna shorter than body length; posterior spur on hind leg 0.33 length of barsitarsus ……………………………………………. *P. dentata* sp. n.

- Body shorter than 3 mm; antenna longer or equal to body length; posterior spur on hind leg 0.5 length of barsitarsus ………………………………………… *P. dimorpha* sp. n.

6 Fore wing 2-R1 absent (Fig. 2); metasomal tergites strigose longitudinally (Fig. 11) ….. ………………………………………………………………………... *P. flavens* sp. n.

- Fore wing 2-R1 present (Fig. 1); metasomal tergites rugose (Fig. 14) ……………..… 7

7 Interocellar area yellow (Fig. 42) …………………………………………………… 8

- Interocellar area black (Fig. 50) …………………………………………………….. 9

8 Scape brown (Fig. 55); precoxal sulcus present (Fig. 55); SR-1 curved (Fig. 57); first metasomal tergite yellow, second and third tergite brown (Fig. 58) ……………………. ……………………………………………………………….. *P. microcellata* sp. n.

- Scape orange (Fig. 68); precoxal sulcus absent (Fig. 67); SR-1 straight (Fig. 71); all three metasomal tergites yellow (Fig. 70) ………………………….. *P. nivistigma* sp. n.

9 Scape, pedicel, coxa, and trochanter white (Fig. 12) ……………..…. *P. castanea* sp. n.

- Scape, pedicel, coxa, and trochanter yellow, orange or brown……………….…. 10

10 3-SR absent, interstitial (Fig. 6) ……………………………………………………… 11

- 3-SR present, antefurcal (Fig. 1) ……………………………………………………... 12

11 Carapace almost round in dorsal view (Fig. 21); wings much longer than body; body overall yellow with last metasomal tergite dark (Fig. 21) ………… *P. curtogaster* sp. n.

- Carapace elongate oval in dorsal view (Fig. 95); wings shorter than body; body overall brown, sometimes first metasomal segment beige (Fig. 95) …………... *P. variata* sp. n.

12 Metasomal carapace monochromatic (Fig. 88) ……………………………………… 13

- Metasomal carapace dichromatic (Fig. 91) …………………………………………... 16

13 Propodeal tubes absent (Fig. 47) …………………………………………………... 14

- Propodeal tubes present (Fig. 51) ………………………………………………….. 15

14 Length of antenna shorter than length of body ……………………….. *P. kriegeri* sp. n.

- Length of antenna longer than length of body …………. *P. sculpturata* Szépligeti, 1900

15 Colour of scape yellow-orange; mesopleuron rugose (Fig. 51) ………………………….
……………………………………………………………... *P. longipes* Szépligeti, 1900

- Colour of scape brown; mesopleuron punctate (Fig. 72) …………….. *P. obscura* sp. n.

16 Metasoma longer than mesosoma ………………………………………………..17

- Metasoma equal in length to mesosoma ……………………………………………… 18

17 Fore wing 2-SR+M postfurcal or interstitial (Fig. 2); with 24-25 antennomeres ………..
………………………………………………………………… *P. minuta* Zettel, 1989

- Fore wing 2-SR+M antefurcal (Fig. 1); with more than 30 antennomeres ………………
……………………………………………………………….. *P. pungogaster* sp. n.

18 Propodeal tubercles present (Fig. 20); dichromatic carapace with anterior half white, posterior half dark brown (Fig. 66) ……………………………………………... 19

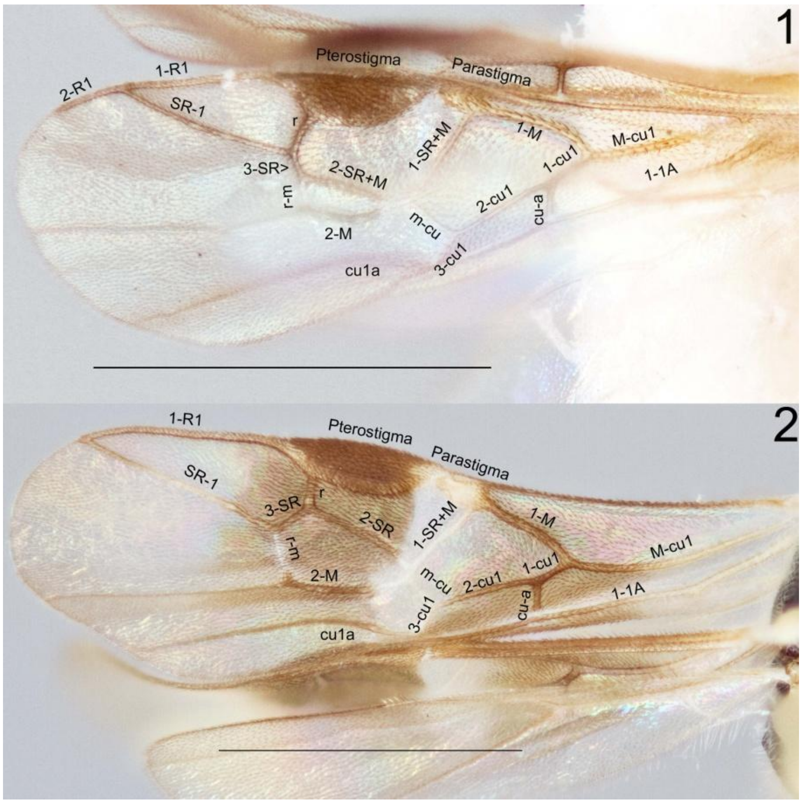
- Propodeal tubercles absent (Fig. 5); dichromatic carapace with either first or third tergite differently coloured (Fig. 58) …………………………………………………. 20

19 Antenna to body length same; shape of occipital carina strongly indented (Fig. 66); antennomeres between 28 and 31; SR-1 curved (Fig. 63) …………... *P. naumanni* sp. n.

- Antenna to body length longer; shape of occipital slightly indented (Fig. 50); antennomeres between 32 and 41; SR-1 straight (Fig. 78) ….. *P. phanerotomoides* sp. n.

20 First metasomal tergite yellow, second and third tergites dark brown (Fig. 5); wings shorter than body………………………………………………….. *P. australiensis* sp. n.

\- First two metasomal tergites yellow, third tergite dark brown (Fig. 91); wings same length as body……………………………………………………... *P. szepligetii* sp. n.



Figs 1-2. Wing venation (1) *Phanerotomella pungogaster* sp. n., paratype, 2-R1 present, 3-SR present and antefurcal, 2-SR+M antefurcal, scale = 1 mm; (2) *Phanerotomella dimorpha,* paratype, 2-R1 absent, 3-SR present and postfurcal, 2-SR+M postfurcal, scale = 1 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Treatment of Species

***Phanerotomella ashmeadi* sp. n.** (Figs 3-6, 98)

urn:lsid:zoobank.org:act:40EE20E9-FD1A-40E7-9FB9-90A7E00E14DA

Type material

Holotype. Australia, Queensland: 1 ♀, “N.E. QLD: Windsor T'land [Tableland] via Mt. Carbine, MT, 26 xii 1983-24 i 1984, Storey and Halfpapp” (QMENT13.36). *Paratypes*. Australia, Queensland: 6 ♀♀, same as holotype (WINC); 2 ♀♀, Windsor T'land via Mt. Carbine, 26 xii 1983-24 i 1984, collector unknown, MT (WINC); 2 ♀♀, Windsor T'land via Mt. Carbine, 10 x-26 xii 1983, Storey & Titmarsh, MT (WINC); 1 ♀, Mt. Haigh, 17.06S, 145.36E, 1150 m, GS1, 1 xii 1994-3 i 1995, P. Zborowski, FIT ANIC (ANIC); 1 ♂, NEQ

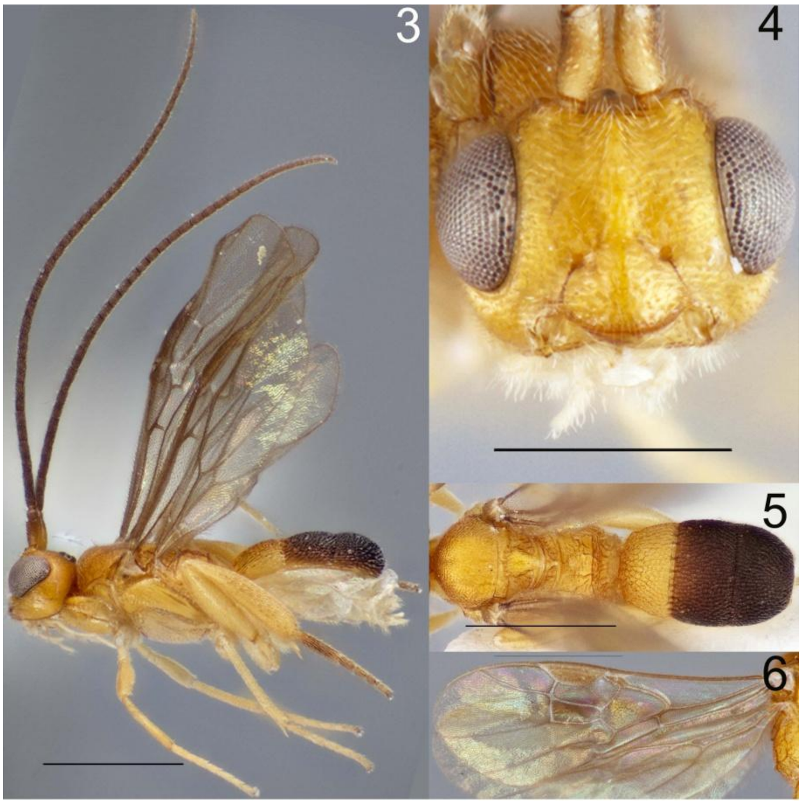
Charmillin Ck, 17°42'S ,145°31'E, 1xii 1997, C.J. Burwell, 940 m rainforest (QM ENT13.36); 1 ♂, NEQ SSE Mt Spurgeon, 16°27'S, 145°12'E 2 km, 1100 m, 19-22 xi 1997, C.J. Burwell, rainforest (QM ENT13.36).

Other material examined

Australia, Queensland: 2 ♀♀, N.E. QLD: Windsor T'land via Mt. Carbine, 10 x-26 xii 1983, Storey & Titmarsh, MT (WINC); 1 ♀, Windsor Tableland, N Qld, 8 i 1989, 1170 m, E. Schmidt & ANZSES site 8 pyrethrum (QM ENT13.36); 1 ♂, 3 ♀♀, NEQ Charmillin Ck, 17°42'S, 145°31'E, 940 m rainforest, 1 xii 1997, C.J. Burwell (QM ENT13.36).

Diagnosis

This species can be recognised from all other Australian species by the following combination of characters: second and third metasomal tergites brown; 3-SR antefurcal; propodeal tubercles absent.



Figs 3-6. *P. australiensis* sp. n., (3) habitus, lateral, holotype, scale = 1 mm; (4) head, anterior view, holotype, scale = 0.5 mm; (5) mesosoma and metasoma, dorsal view, paratype, scale = 1 mm; (6) fore wing, paratype, scale = 1 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Description

Body measurements. Length of body 2.25–3.0 mm; ratio of antenna to length of body 1.3; ratio of length of fore wing to body 1.0; ratio of metasoma to mesosoma 1.05.

Head. Antenna with 32–35 antennomeres; ratio of length of third antennomere to fourth 1.1; length of third, fourth, penultimate, and terminal antennomere 4.0–4.8, 3.6–4.0, 2.5–3.5, and 3.3–4.0 their width, respectively; ratio of width of face in frontal view 1.2–1.5 its height; ratio of width of clypeus 1.5–1.7 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 2.0 in female, 1.2 in male; ratio of length of eye in dorsal view to length of temple 1.7–2.3 in female, 1.4 in male; ratio of posterior ocelli:POL:LOL:OOL 1.0:0.8–1:0.8:2.6–3.0; occipital weakly indented; face, frons, and vertex weak costate.
Mesosoma. Notauli absent; scutellum finely punctate, weakly convex, shiny; propodeal tubercles absent; mesopleuron shiny, smooth, finely punctate; precoxal sulcus absent; ratio of height of mesosoma to length 1.6–1.7 in female, 1.3–1.5 in male; hind coxa shiny, finely punctate; ratio of hind coxa, hind femur, hind tibia, and hind tarsus to their width 2.2, 3.7, 4.1, and 15.0 in female and 2.2–2.4, 4.0, 4.7, and 10.0–11.0 in male, respectively; ratio of length of posterior spur to length of basitarsus 0.4 in female, 0.5 in male; ratio of tarsus to basitarsus 2.2–2.4 in female, 2.0–2.1 in male; fore wing: third radial abscissa (3-SR) short, antefurcal; SR-1 curved; 2-SR+M postfurcal; 2-R1 present; ratio of 2-R1 to 1-R1 0.5 in female, 0.4 in male; ratio of length of 1-R1 to length of pterostigma 0.8–1.0; ratio of width to length of pterostigma 3.0–3.6; ratio of r:3-SR:SR-1:r-m 1.0:0.3:4.0:1.3:3.0 in female, 1.0:0.4–0.5:4.4–5.3:1.2:3.0 in male.
Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.55–0.57; shape of carapace in lateral view straight, shape of individual tergites rounded; ratio of keels to metasomal length 0.1, keels parallel; first tergite rugose, second and third tergites more finely rugose; third tergite with small reduced lobes; ratio of length of three metasomal tergites 1.0:1.0:0.9 in female, 1.0:0.9:0.8–0.9 in male; sutures parallel.
Colour. Head and mesosoma yellow; ventral areas more orange; antenna brown except scape and pedicel yellow; interocellar area dark; legs yellow; wing venation, pterostigma, and parastigma light brown to brown; wings lightly infuscate; first metasomal tergite yellow, second and third tergites dark brown.

Comments

The specimens listed under ‘other material examined’ have been excluded from the type material due to them being damaged.

Etymology

This species is named after William Harris Ashmead, a great systematic entomologist.

Distribution

Phanerotomella ashmeadi is known from two locations in north-east Queensland (Fig. 98).

***Phanerotomella brevivena* sp. n.** (Figs 7-11, 101)

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Figs 7-11. *P. brevivena* sp. n., (7) habitus, lateral, paratype, scale = 1 mm; (8) head, dorsal view, holotype, scale = 0.5 mm; (9) head, anterior view, paratype, scale = 0.5 mm; (10) fore wing, holotype, scale = 1 mm; (11) mesosoma and metasoma, dorsal view, paratype, scale = 1 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Type material

Holotype. Australia, Victoria: 1 ♀, "Club Terrace, 120 m, Vic 5 xii 1974 I. Naumann", "beating and sweeping in moist tree fern gully" (QM ENT13.36). *Paratypes.* Australia, Victoria: 1 ♂, 2 unknown sex, same as holotype (QM ENT13.36); 5 ♂♂, Acheron Way, 300-480 m, via Warburton, 16 xii 1975, I. Naumann; sweeping low vegetation by creek, *Nothofagus* eucalypt forest (QM ENT13.36); 1 ♂, Acheron Way, 300-480 m, via Warburton, 16 xii 1975, I. Naumann; sweeping low vegetation by creek, *Nothofagus* eucalypt forest (QM ENT13.36); Australia, Queensland: 5 ♂♂, 1 unknown sex, Lever's Plateau, 640-670 m, via Rathdowney, S.E. Qld, 1 xi 1975, I. Naumann; sweeping low vegetation in rainforest (QM ENT13.36).

Diagnosis

This species can be recognised from all other Australian species by a unique character, SR-1 not completely sclerotised.

Description

Body measurements. Length of body 2.5–3.3 mm; ratio of antenna to length of body 1.0–1.3; ratio of length of fore wing to body 0.7–0.9; ratio of metasoma to mesosoma 1.1–1.2.

Head. Antenna with 31–32 antennomeres; ratio of length of third antennomere to fourth 1.3; length of third, fourth, penultimate, and terminal antennomere 4.8–5.5, 3.9–4.0, 1.7, and 1.7 their width, respectively; ratio of width of face in frontal view 1.7 its height; ratio of width of clypeus 2.0 in female, 1.5 in male, its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 1.2–1.4; ratio of length of eye in dorsal view to length of temple 1.2; ratio of posterior ocelli:POL:LOL:OOL 1.0:0.8:0.8:3.0 in female, 1.0:1.0:1.0:3.6–4.0 in male; occipital weakly indented; face, frons, and vertex smooth and shiny.

Mesosoma. Notauli absent; scutellum punctate, weakly convex, shiny; propodeal tubercles absent; mesopleuron shiny, punctate; precoxal sulcus absent; ratio of height of mesosoma to length 1.6; hind coxa shiny and smooth; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 2.3–2.4, 3.9–4.3, 5.0–5.6, and 14.0–15.0 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.36–0.42; ratio of tarsus to basitarsus 2.3; fore wing: third radial-abscissa (3-SR) present, postfurcal; SR-1 straight; 2-SR+M interstitial or postfurcal; 2-R1 absent; ratio of length of 1-R1 to length of pterostigma 1.0–1.1; ratio of width to length of pterostigma 4.3–4.9; ratio of r:3-SR:SR-1:r-m 1.0:0.4:5.4:0.9 in female, 1.0:0.6:4.7–5.9:1.0–1.1 in male.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.48–0.5; shape of carapace in lateral view straight, shape of individual tergites flat; without visible keel; all tergites strigate longitudinally; third tergite without lobes; ratio of length of three metasomal tergites 1.0:0.8:1.0 in female, 1.0:0.9:1.2 in male; sutures parallel.

Colour. Overall brown; head reddish brown; antenna, pedicel, and scape yellow, gradually browner to tip; legs brown, except yellow coxae; wings infuscate, white around parastigma; wing venation brown; white parastigma; brown pterostigma.

Etymology

This species is named after the short sclerotised part of SR-1.

Distribution

Phanerotomella brevivena is recorded from Queensland and Victoria (Fig. 101).

***Phanerotomella castanea* sp. n.** (Figs 12-16, 99)

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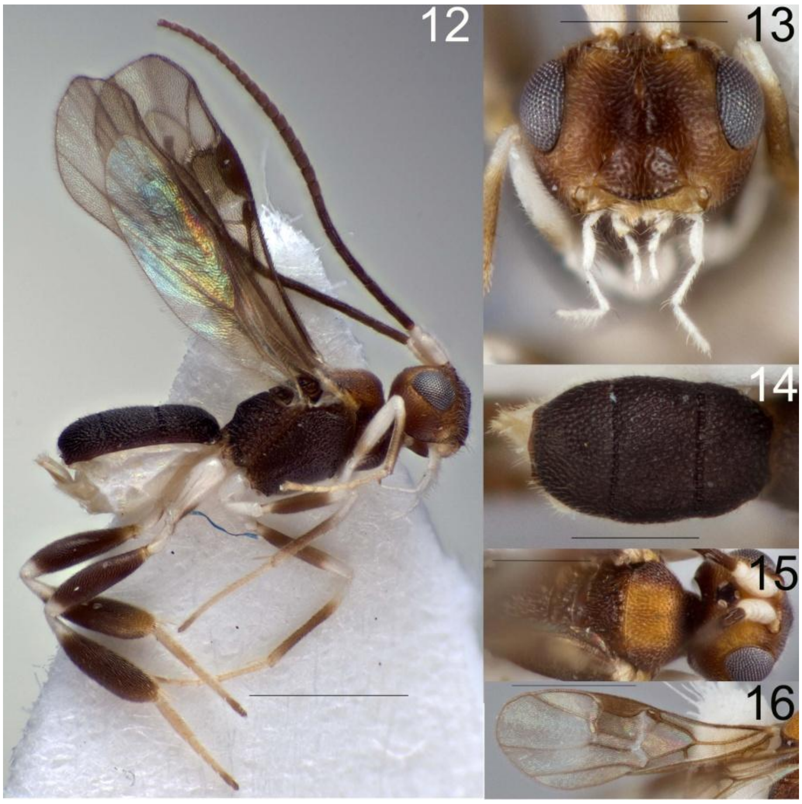


Figs 12-16. *P. castanea* sp. n., (12) habitus, lateral, holotype, scale = 1 mm; (13) head, anterior view, holotype, scale = 0.5 mm; (14) metasoma, dorsal view, holotype, scale = 0.5 mm; (15) mesosoma, dorsal view, holotype, scale = 0.5 mm; (16) fore wing, paratype, scale = 1 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Type material

Holotype. Australia, Queensland: 1 ♀, "17.06S, 145.37E, 1050 m GS2, Mt Edith, QLD, 1 Dec 1994-3 Jan 1995, P. Zborowski, Malaise Trap" (ANIC). *Paratypes.* Australia, Queensland: 2 ♀♀, same as holotype (ANIC); 2 ♀♀, NEQ Charmillin Ck, 17°42'S, 145°31'E, 940 m rainforest, 1 xii 1997, C.J. Burwell (QM ENT13.36); 1 ♀, NEQ 2 km SSE Mt Spurgeon, 16°27'S, 145°12'E, 1100 m, 19-22 xi 1997, C.J. Burwell rainforest (WINC); 2 ♀♀, Hugh Nelson Ra, 2.5 km S of Crater N.P., N Qld 5 xii 1988, 1100 m, Monteith & Thompson pyrethrum/logs & trees (QM ENT13.36).

Diagnosis

This is one of the few dark (reddish) brown *Phanerotomella* in Australia. It is similar in body colour and its white pedicel to females of *P. dimorpha*, but *P. castanae* has no teeth on the clypeus and both tibiae and tarsi are completely brown.

Description (female)

Body measurements. Length of body 2.1–2.5 mm; ratio of antenna to body 1.2; ratio of length of fore wing to body 1.05; ratio of metasoma to mesosoma 1.0.

Head. Antenna with 33 antennomeres; ratio of length of third antennomere to fourth 1.15; length of third, fourth, penultimate, and terminal antennomere 4.0, 3.5, 1.7–2, and 2.2–2.4 their width, respectively; ratio of width of face in frontal view 1.6 its height; ratio of width of clypeus 1.5–1.7 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 2.2; ratio of length of eye in dorsal view to length of temple 1.4; ratio of posterior ocelli:POL:LOL:OOL 1.0:0.8–1.0:0.7:2.6–3.3; occipital weakly indented; face, frons, and vertex finely rugose.

Mesosoma. Notauli absent; scutellum finely rugose, flat, not shiny; propodeal tubercles present; mesopleuron finely rugose; precoxal sulcus absent; ratio of height of mesosoma to length 1.5; hind coxa smooth; ratio hind coxa, hind femur, hind tibia, and hind tarsus 2.2, 4.2, 4.3, and 11.4 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.35; ratio of tarsus to basitarsus 1.7–2.6; fore wing: third radial-abscissa (3-SR) present, antefurcal; SR-1 straight or weakly curved; 2-SR+M postfurcal; 2-R1 present; ratio of 2-R1 to 1-R1 0.53 (straight SR-1)–0.76 (curved SR-1); ratio of length of 1-R1 0.7 to length of pterostigma (curved SR-1) –0.85 (straight SR-1); ratio of width to length of pterostigma 2.7 (SR-1 curved) –3.2 (SR-1 straight); ratio r:3-SR:SR-1:r-m 1.0:0.6:3.3:0.9 (SR-1 curved) and 1.0:0.4:6.0:0.9 (SR-1 straight).

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of metasomal width to length 0.6; shape of carapace in lateral view straight, shape of individual tergites flat; ratio of short keels to metasoma length 0.1, keels parallel; tergites rugose; third tergite with reduced lobes; ratio of length of three metasomal tergites 1.0:0.9:0.7; sutures parallel.

Colour. Reddish brown; antenna brown except scape and pedicel white; interocellar area dark; mesosoma reddish brown except prosoma orange brown; coxae and trochanters white; femorae and tibiae brown; tarsi beige; wings infuscated; wing venation, pterostigma, and parastigma brown; metasoma dark brown almost black.

Male. Unknown.

Etymology

This species is named after the dark reddish-brown colour of this species.

Distribution

Phanerotomella castanea is known from north-east Queensland (Fig. 99).

***Phanerotomella curtogaster* sp. n.** (Figs 17-21, 100)

urn:lsid:zoobank.org:act:ED1C1E3E-1CB2-4A05-9A2E-EEBC98852562

Type material

Holotype. Australia, Western Australia: 1 ♂, "15.25S, 124.38E, WA, Augustus Island, CALM site 26/1, 11-16 June 1988, I.D. Naumann" (ANIC).

Diagnosis

This species can be recognised from all other Australian species by the rather rounded metasoma in dorsal view, 2-R1 being present, the antenna shorter than the body, and the wings longer than the body.

Description (male)

Body measurements. Length of body 1.9 mm; ratio of length of antenna to body 0.98; ratio of length of fore wing to body 1.6; ratio of metasoma to mesosoma 1.0.

Head. Antenna with 27 antennomeres; ratio of length of third antennomere to fourth 1.2; length of third, fourth, penultimate, and terminal antennomere 2.2, 2.25, 1.5, and 2.5 their width, respectively; ratio of width of face in frontal view 1.5 its height; ratio of width of clypeus 2.1 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 1.2; ratio of length of eye in dorsal view to length of temple 2.2; ratio of posterior ocelli:POL:LOL:OOL 1.0:0.8:1.0:2.5; occipital strongly indented; face and vertex finely rugose; frons strigose.

Mesosoma. Notauli absent; scutellum flat, not shiny; propodeal tubercles present; mesopleuron rugose; precoxal sulcus absent; ratio of height of mesosoma to length 1.45; hind coxa smooth; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 2.4, 3.5, 4.7, and 14.3 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.59; ratio of tarsus to basitarsus 2.5; fore wing: third radial-abscissa (3-SR) absent, interstitial; SR-1 slightly curved; 2-SR+M interstitial; 2-R1 present; ratio of 2-R1 to 1-R1 0.46, ratio of length of 1-R1 to pterostigma length 0.75; ratio of width to length of pterostigma 3.6; ratio r:3-SR:SR-1:r-m 1.0:?:3.4:0.5.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.67; shape of carapace in lateral view slightly convex, shape of individual tergites flat; ratio of length keels to metasoma 0.1, keels parallel; tergites rugose; third tergite with two developed lobes latero-posterior; ratio of length of three metasomal tergites 1.0:1.0:0.9; sutures parallel.

Colour. Head, antenna and mesosoma golden orange; interocellar area dark; legs yellow; wings hyaline; wing venation, pterostigma, and parastigma brown; metasoma yellow with last tergite dark orange to brown.

Female. Unknown.

Figs 17-21. *P. curtogaster* sp. n., (17) habitus, lateral, holotype, scale = 1 mm; (18) head, anterior view, holotype, scale = 0.5 mm; (19) fore wing, holotype, scale = 1 mm; (20) mesosoma, dorsal view, holotype, scale = 0.5 mm; (21) metasoma, dorsal view, holotype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Comments

We describe *P. curtogaster* on the basis of a single male because it is so different from all other species in the shape of the metasoma, the sculpturing of the head, the absence of clypeal teeth, and that these characters are unlikely to be sexually dimorphic.

Etymology

This species is named after its short and rounded metasoma.

Distribution

Phanerotomella curtogaster is only known from the type locality, Augustus Island, north-western Australia (Fig. 100).

Phanerotomella dentata **sp. n.** (Figs 22-26, 97)

urn:lsid:zoobank.org:act:21E4DD27-C5E6-4BF1-8D8D-B3608DAD2557

Type material

Holotype. Australia, South Australia: 1 ♀, “S. Aust, Mannum, Jan-Mar 1986, J. Hardy, L.T” (SAM). *Paratype. Aus*tralia, South Australia: 1 ♀, S. Aust, Murray Bridge, ii-iii 1986, J. Hardy, L.T. (WINC).

Diagnosis

This species can be easily recognised from all other Australian taxa by having teeth present on the clypeus, and the body red-brown in colour.

Description (female)

Body measurements. Length of body 3.1–3.4 mm; ratio of length of antenna to body 0.9; ratio of length of fore wing to body 0.8; ratio of metasoma to mesosoma 0.85–1.0.

Head. Antenna with more than 30 antennomeres (partly broken off); ratio of length of third antennomere to fourth length 1.2–1.4; length of third and fourth antennomere 3.2–4.5 and 2.7–3.2 their width, respectively; ratio of width of face in frontal view 1.9–2.0 its height; ratio of width of clypeus 2.0–2.3 its height; two teeth on clypeus present; ratio of length of malar space to length of base of mandible 1.3–1.4; ratio of length of eye in dorsal view to length of temple 1.7; ratio of posterior ocelli:POL:LOL:OOL 1.0:1.0:1.0:3.0; occipital weakly indented; face punctate; frons and vertex transverse strigose.

Mesosoma. Notauli weakly present; scutellum flat, finely punctate, shiny; propodeal tubercles absent; mesopleuron shiny, finely rugose; precoxal sulcus absent; ratio of height of mesosoma to length 1.9; hind coxa smooth, shiny; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 2.0–2.6, 3.7, 5.0–5.8, and 18.0–23.0 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.3–0.45; ratio of tarsus to basitarsus 1.6–2.3; fore wing: third radial-abscissa (3-SR) present, postfurcal; SR-1 straight, 2-SR+M postfurcal; 2-R1 absent, ratio of length of 1-R1 to pterostigma length 1.0–1.1; ratio of width to length of pterostigma 3.3–3.6; ratio of r:3-SR:SR-1:r-m 1.0:0.4–0.6:5.0:1.0–1.3.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.52–0.6; shape of carapace in lateral view straight, shape of individual tergites flat; ratio of keels to metasomal length 0.1–0.16, keels converging; tergites strigose longitudinally; third tergite without lobes or teeth; ratio of length of three metasomal tergites 1.0:0.8:1.0; sutures parallel.

Colour. Head, antenna, mesosoma orange; interocellar area dark; coxae beige; femorae brown; base of tibiae beige, posterior end of tibiae and tarsi brown; wings infuscated with pale white stripe below parastigma; parastigma brown; pterostigma dark brown; wing venation brown; metasoma dark brown except first tergite beige.

Male. Unknown.

Figs 22-26. *P. dentata* sp. n., (22) habitus, lateral, holotype, scale = 1 mm; (23) head, anterior view, holotype, scale = 0.5 mm; (24) fore wing, holotype, scale = 1 mm; (25) metasoma, dorsal view, paratype, scale = 0.5 mm; (26) mesosoma, dorsal view, holotype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Etymology

This species is named after the presence of teeth on the clypeus, which is uncommon among *Phanerotomella* species.

Distribution

Phanerotomella dentata is only known from south-eastern South Australia (Fig. 97).

Phanerotomella dimorpha sp. n. (Figs 2, 27-35, 98)

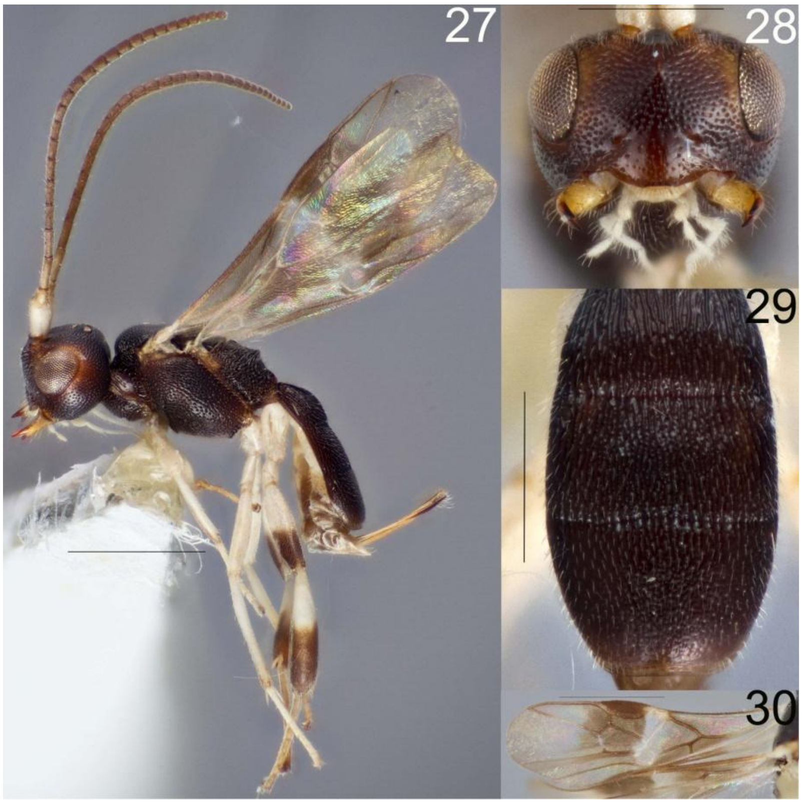
urn:lsid:zoobank.org:act:2310991F-985B-4F42-B2A9-5BC979211CA2

Type material

Holotype. Australia, Queensland: 1 ♀, "Q'ld: Mareeba, 16 km up Davies Crk Rd, MT, 2 x-6 xi 1984, Storey and Brown" (QM). *Paratypes.* Australia, Queensland: 20 ♀♀, 18 ♂♂, same as holotype (WINC).

Diagnosis

This is one of the few dark coloured *Phanerotomella*. It can be distinguished from *P. castanea* by the presence of clypeal teeth, and the hind tibia and hind tarsi being half brown and half white. Males have a uniquely coloured dark scutum and scutellum, while the propodeum and metasoma are beige.



Figs 27-30. *P. dimorpha* sp. n. (♀), (27) habitus, lateral, holotype, scale = 1 mm; (28) head, anterior view, holotype, scale = 0.5 mm; (29) metasoma, dorsal view, holotype, scale = 0.5 mm; (30) fore wing, paratype, scale = 1 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Description

Body measurements. Length of body 2.6–3.0 mm; ratio of length of antenna to body 1.0–1.3; ratio of length of fore wing to body 0.9–1.0; ratio of metasoma to mesosoma 1.0.

Head. Antenna with 30–31 (males) and 29–30 (females) antennomeres; ratio of length of third antennomere to fourth 1.2–1.4; length of third, fourth, penultimate, and terminal antennomere

4.2, 3.2, 1.3, and 1.5–2.0 in female and 5.0, 3.5–4.3, 2.0–3.0, and 3.4 in males their width, respectively; ratio of width of face in frontal view 1.5 (males) –1.8 (females) its height; ratio of width of clypeus 2.0–2.3 its height; two teeth on clypeus present; ratio of malar space to length of base of mandible 1.3–1.6; ratio of length of eye in dorsal view to length of temple 1.0 (females) –1.6 (males); ratio of posterior ocelli:POL:LOL:OOL 1.0:0.8–1.0:0.8–1:3.6–4.4; occipital weakly indented; face, frons, and vertex punctate.

Mesosoma. Notauli absent; scutellum punctate, weakly convex, shiny; propodeal tubercles absent; mesopleuron punctate; precoxal sulcus absent; ratio of height of mesosoma to length 1.7–1.9; hind coxa smooth, shiny; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 2.0–2.3, 3.6–4.9, 3.9–4.9, and 12.0–16.0 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.44–0.56; ratio of tarsus to basitarsus 2.3–2.5; fore wing: third radial-abscissa (3-SR) present, postfurcal; SR-1 straight; 2-SR+M postfurcal; 2-R1 absent; ratio of length of 1-R1 is equal in length to pterostigma; ratio of width to length of pterostigma 2.8–3.0; ratio of r:3-SR:SR-1:r-m 1.0:0.5–0.6:6.0–7.0:1.3–1.7 (larger specimens) and 1.0:1.3–1.4:7.0–10.0:2.2–2.4 (smaller specimens).

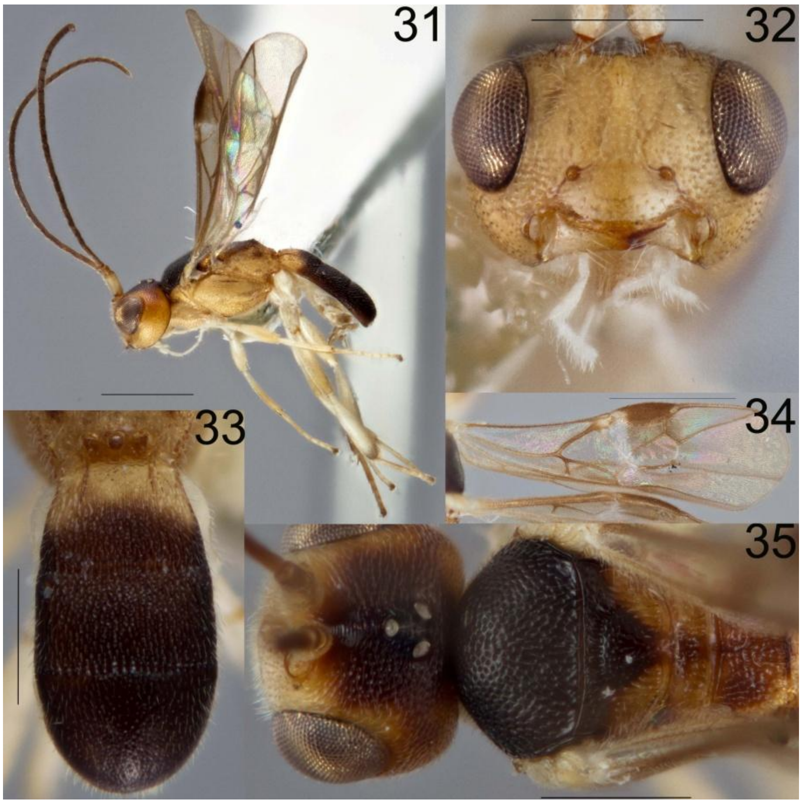
Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.54–0.56 in female and 0.53 in male; shape of carapace in lateral view straight, shape of anterior tergite rounded; ratio of keels to length of metasoma 0.12–0.14 in female and 0.17–0.21 in male, keels parallel; tergites finely strigose longitudinally; third tergite without lobes or teeth; ratio of length of three metasomal tergites 1.0:0.8:1.2; sutures parallel.

Colour. Head reddish brown, light around the eyes; scape white; pedicel and flagellomeres light brown; pronotum dark brown; mesosoma and metasoma reddish brown; legs white except hind femur and hind tibia distal brown; wings infuscated with hyaline apex and vertical white stripe under parastigma; pterostigma brown; parastigma white; wing venation brown.

Male. Head light brown with an orange area around ocelli; scape white; pedicel and flagellomeres light brown; scutum and scutellum dark; propodeum and metasoma beige; legs white with only the tibiae distal brown; wing as in female only lighter; metasoma reddish brown, anterior beige.

Etymology

This species is named due to the fact that males and females have different colour patterns.



Figs 31-35. *P. dimorpha* sp. n. (♂), (31) habitus, lateral, paratype, scale = 1 mm; (32) head, anterior view, paratype, scale = 0.5 mm; (33) metasoma, dorsal view, paratype, 0.5 mm; (34) fore wing, paratype, scale = 1 mm; (35) mesosoma, dorsal view, paratype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Distribution

Phanerotomella dimorpha is only known from the type locality, Mareeba, north-east Queensland (Fig. 98).

***Phanerotomella discoloria* sp. n.** (Figs 36-39, 97)

urn:lsid:zoobank.org:act:DBD6CAC7-D523-45C1-9419-4BBB51B2D1AD

Type material

Holotype. Australia, Western Australia:1 ♀, "24.52S, 113.39E, WA, 2 km N Carnavon, 17 Oct 1992, E.D. Edwards, E.S. Nielsen" (ANIC). *Paratype. Aus*tralia, South Australia: 1 ♂, Wilkowie Forest Res, 8 km SbyW Wilmington, 12.44S, 118.95E, 11 xi 1987, I. Naumann & C. Cardale, ex ethanol (WINC).

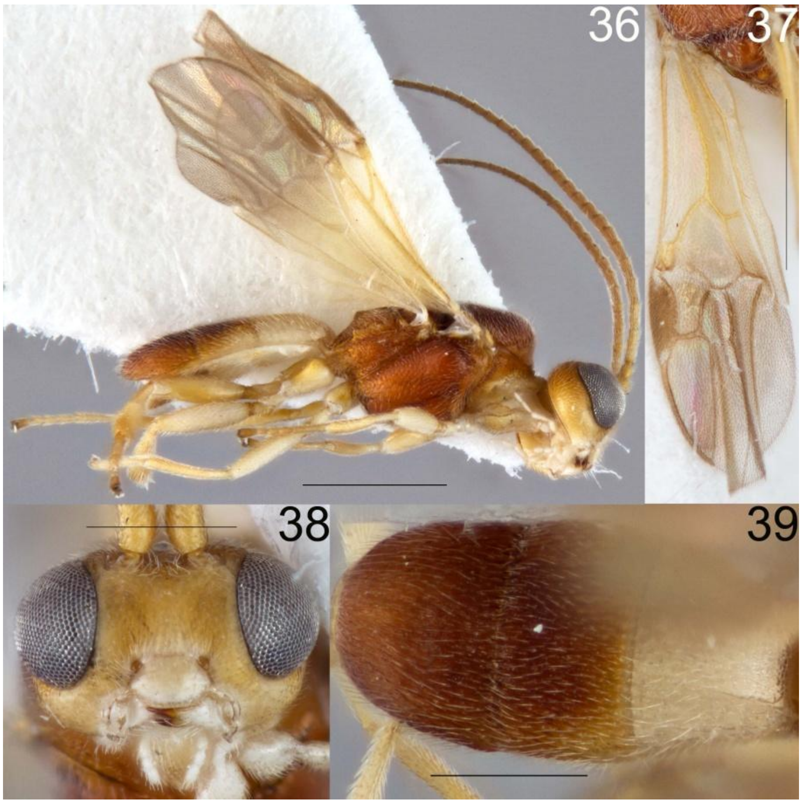
Diagnosis

This is the only Australian species with the wing colour being pale proximal to the pterostigma, and brown in the distal part.

Description

Body measurements. Length of body 3.1–3.2 mm; ratio of length of antenna to body 1.0; ratio of length of fore wing to body 0.85; ratio of metasoma to mesosoma 1.0–1.1.

Head. Antenna with 28 antennomeres; ratio of length of third antennomere to fourth 1.2–1.3; length of third, fourth, penultimate, and terminal antennomeres 3.5, 2.8, 3.0, and 3.0–4.0 their width, respectively; ratio of width of face in frontal view 1.5–1.6 its height; ratio of width of clypeus 1.4–1.6 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 0.9–1.3; ratio of length of eye in dorsal view to length of temple 1.2 (male) –2.5 (female); ratio of posterior ocelli:POL:LOL:OOL 1.0:1.0:0.8–1.0:2.5; occipital weakly indented; face punctate; frons and vertex finely rugose.



Figs 36-39. *P. discoloria* sp. n., (36) habitus, lateral, holotype, scale = 1 mm; (37) fore wing, holotype, scale = 1 mm; (38) head, anterior view, holotype, scale = 0.5 mm; (39) metasoma, dorsal view, holotype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Mesosoma. Notauli present anteriorly; scutellum weakly convex, shiny; propodeal tubercles present; mesopleuron punctate; precoxal sulcus present; ratio of height of mesosoma to length 1.5–1.8; coxa shiny and smooth; ratio of hind coxa, hind femur, hind tibia, and hind tibia 1.9–2.0, 3.7–4.0, 5.8–6.3, and 12.0–21.0 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.4; ratio of tarsus to basitarsus 2.4–2.7; fore wing: third radial-abscissa (3-SR) present, postfurcal; SR-1 straight; 2-SR+M postfurcal; 2-R1 absent; ratio of length 1-R1 to pterostigma 1.0-1.2; ratio of width to length of pterostigma 2.7–3.5; ratio of r:3-SR:SR-1:r-m 1.0:0.5:5.4:0.8–1.4.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.54; shape of carapace in lateral view straight, shape of individual tergites flat; ratio of keels to metasomal length 0.3, keels converging; tergites strigose longitudinally; third tergite without lobes or teeth, completely reduced; ratio of length of three metasomal tergites 1.0:0.8:1.0; sutures parallel.

Colour. Orange-yellow head with white clypeus and mandibles; antenna same orange-yellow; interocellar area dark; mesosoma reddish-orange; legs yellowish white; wing infuscated proximal of pterostigma; anterior wing venation yellow until parastigma, posterior end brown; pterostigma brown; parastigma yellow; first metasomal tergite white; second and third tergite reddish orange.

Male. Darker than female.

Etymology

This species is named after the partly yellow coloured wings.

Distribution

Phanerotomella discoloria is known from two disjunct localities in Western Australia and South Australia (Fig. 97).

***Phanerotomella flavens* sp. n.** (Figs 40-42, 101)

urn:lsid:zoobank.org:act:08998F79-8426-4028-9FFD-9165E5CB86D6

Type material

Holotype. Australia, Queensland: 1 ♂, "Camp Milo, Cooloola SEQ, open forest 22 iv 1981 G. Sarnes" (QM ENT13.36).

Diagnosis

This species differs from all other Australian *Phanerotomella* by 3-SR being antefurcal and 2-R1 absent.

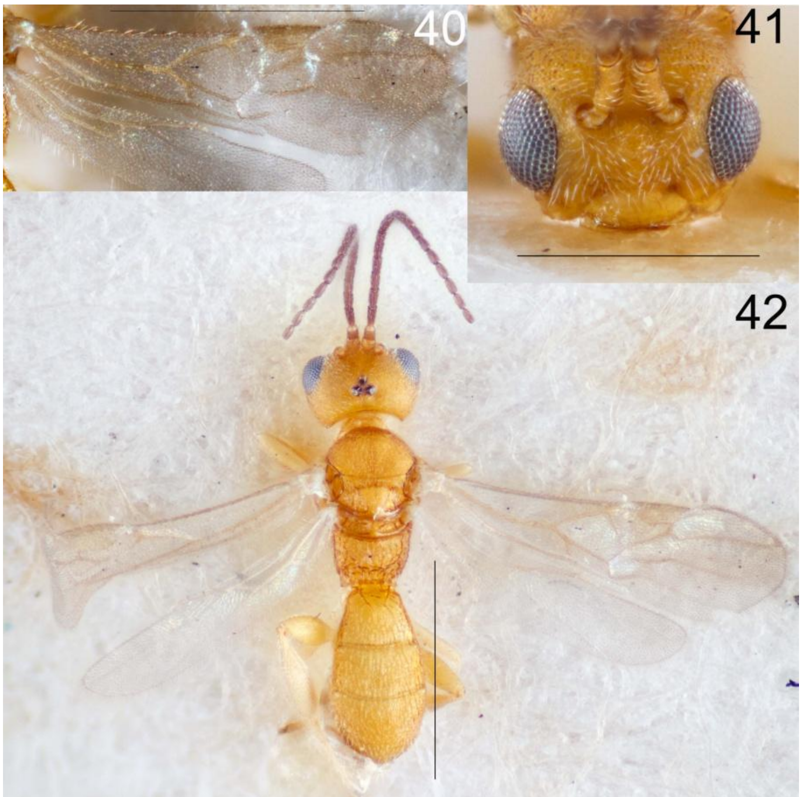
Description (male)

Body measurements. Length of body 1.75 mm; ratio of length of fore wing to body 0.95; ratio of metasoma to mesosoma 1.1.

Head. Antenna broken off; teeth on clypeus absent; ratio of length of eye in dorsal view to length of temple 1.9; ratio of posterior ocelli:POL:LOL:OOL 1.0:1.0:1.0:4.3; occipital weakly indented; face, frons, and vertex finely punctate.

Mesosoma. Notauli absent; scutellum punctate, flat, not shiny; propodeal tubercles absent; mesopleuron shiny, finely punctate; precoxal sulcus weakly present; ratio of height of mesosoma to length 1.8; hind coxa finely punctate; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 1.9, 3.1, 4.0, and 13.0 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.3; ratio of tarsus to basitarsus 3.0; fore wing: third radial-abscissa (3-SR) present, antefurcal; SR-1 straight; 2-SR+M interstitial; 2-R1 absent; ratio of length of 1-R1 to length of pterostigma 1.1; ratio of width to length of pterostigma 3.1; ratio of r:3-SR:SR-1:r-m 1.0:1.0:10.0:2.0.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.52; shape of carapace in lateral view straight, shape of individual tergites flat; ratio of keels to metasoma length 0.1, keels converging; tergites strigose longitudinally; third tergite without teeth or lobes; ratio of length of three metasomal tergites 1.0:0.9:1.2; posterior suture curved anteriorly.



Figs 40-42. *P. flavens* sp. n., (40) fore wing, holotype, scale = 1 mm; (41) head, anterior view, holotype, scale = 0.5 mm; (42) habitus, dorsal view, holotype, scale = 1 mm;. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Colour. Overall yellow; interocellar area yellow; antenna light brown, except scape and pedicel yellow; wings hyaline; wing venation, parastigma and pterostigma beige.

Female. Unknown.

Comments

We describe *P. flavens* on the basis of a single male because the punctate sculpturing of the head and the absence of clypeal teeth are very unlikely to be sexually dimorphic characters. On this basis we postulate that *P. flavens* is a new species and not the male counterpart of any of the species described solely on females.

Etymology

This species is named after the yellow colouration of the species.

Distribution

Phanerotomella flavens is only known from the type locality Cooloola, south-east Queensland (Fig. 101).

***Phanerotomella kimbaensis* sp. n.** (Figs 43-46, 97)

urn:lsid:zoobank.org:act:5D4F4D2D-B9BB-4F9D-904F-9B9CB23FFACE

Type material

Holotype. Australia, South Australia: 1 ♀, “S. Australia, 28 mi W Kimba, 27 Oct '69; coll H. Evans, R.W. Matthews” (NMNH).

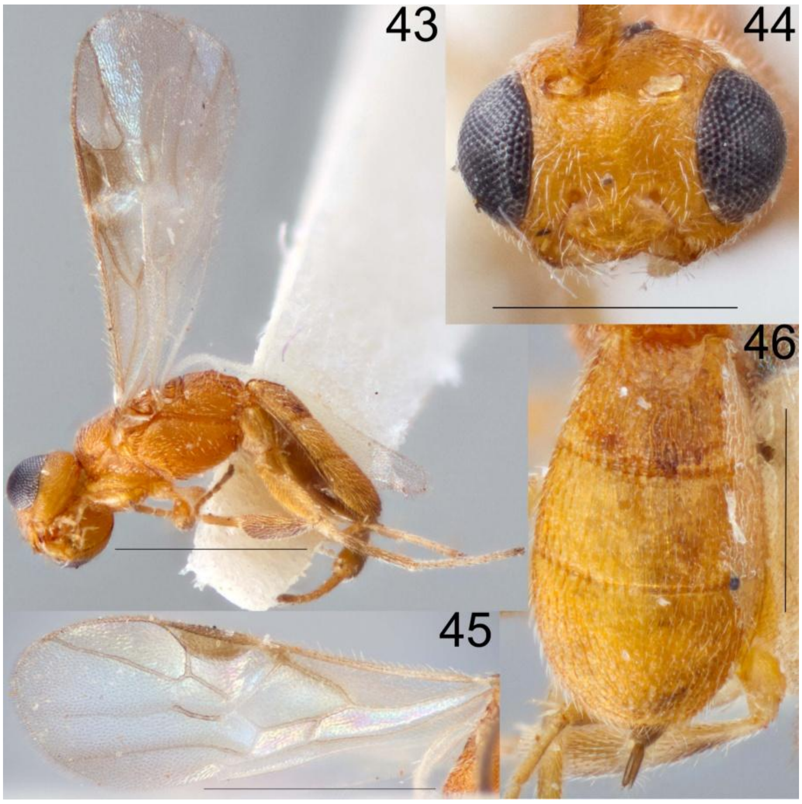
Diagnosis

This species can be recognised from all other Australian *Phanerotomella* by its completely yellow body, clypeus with two teeth, and 3-SR being postfurcal.

Description (female)

Body measurements. Length of body 2.2 mm; ratio of length of fore wing to body 0.89; ratio of metasoma to mesosoma 1.0.

Head. Antenna mostly broken off; ratio of length of third antennomere to fourth 1.1; length of third and fourth antennomere 2.7 and 2.3 their width, respectively; ratio of width of face in frontal view 1.8 its height; ratio of width of clypeus 1.7 its height; two teeth on clypeus present; ratio of length of malar space to length of base of mandible 1.25; ratio of length of eye in dorsal view to length of temple 1.8; ratio of posterior ocelli:POL:LOL:OOL 1.0:1.0:0.8:3.3; occipital weakly indented; face, frons, and vertex finely rugose.



Figs 43-46. *P.kimbaensis* sp. n., (43) habitus, lateral, holotype, scale = 1 mm; (44) head, anterior view, holotype, scale = 0.5 mm; (45) fore wing, holotype, scale = 1 mm; (46) metasoma, dorsal view, holotype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Mesosoma. Notauli present; scutellum finely rugose, flat, not shiny; propodeal tubercles absent; mesopleuron punctate; precoxal sulcus absent; ratio of height of mesosoma to length 1.8; hind coxa not shiny, punctate; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 2.3, 3.6, 4.8, and 15.0 their width, respectively; ratio of length of posterior spur to length of basal tarsus 0.4; ratio of tarsus to basitarsus 2.8; fore wing: third radial-abscissa (3-SR) present, postfurcal; SR-1 slightly curved; 2-SR+M postfurcal; 2-R1 absent; length of 1-R1 equal to pterostigma length; ratio of width to length of pterostigma 3.0; ratio of r:3-SR:SR-1:r-m 1.0:0.7:6.7:1.2.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0. 6; shape of carapace in lateral view straight, shape of individual tergites flat; keels short, 0.14 of metasoma, keels converging; tergites rugose; third tergite without lobes or teeth; ratio of length of three metasomal tergites 1.0:0.8:1.0; both sutures curved posteriorly.

Colour. Overall orange; antenna light brown, except scape and pedicel yellow; interocellar area dark; wins hyaline; wing venation, pterostigma, and parastigma light brown.

Male. Unknown.

Etymology

The name refers to the location Kimba, where it has been collected.

Distribution

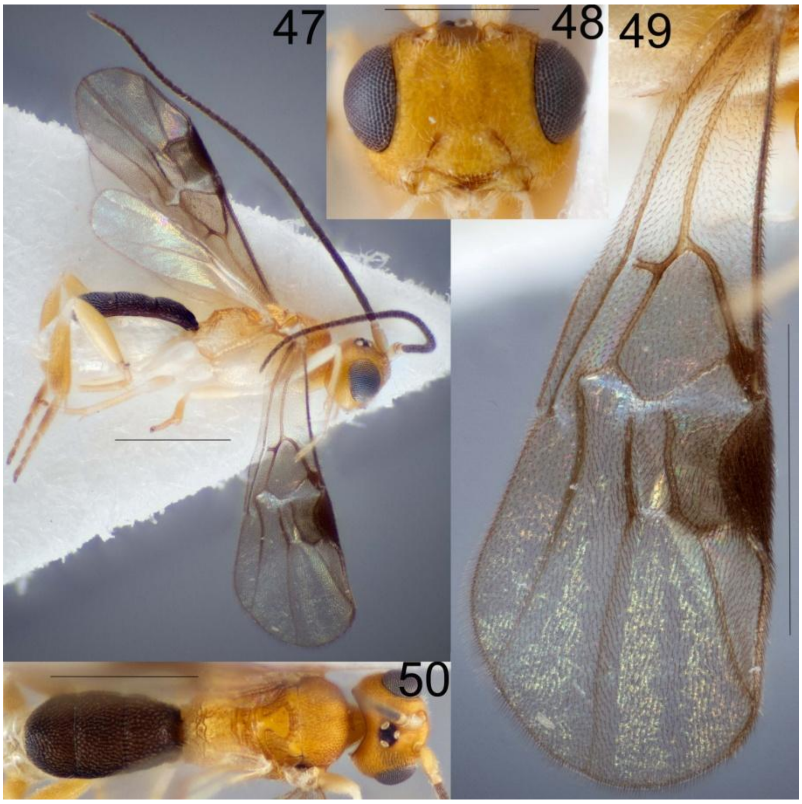
Phanerotomella kimbaensis is only known from the type locality Kimba, South Australia (Fig. 98).

***Phanerotomella kriegeri* sp. n.** (Figs 47-50, 101)

urn:lsid:zoobank.org:act:58CD9B22-D1E2-4C7A-9262-4F9575B49570

Type material

Holotype. Australia, Queensland: 1 ♂, NEQ 16°27'S 145°12'E 2 km SSE Mt Spurgeon, 1100 m 19-22Nov 1997 C.J. Burwell rainforest (QM ENT13.36). *Paratype*. Australia, Queensland: 1 ♂, same as holotype (QM ENT13.36).



Figs 47-50. *P. kriegeri* sp. n., (47) habitus, lateral, holotype, scale = 1 mm; (48) head, anterior view, holotype, scale = 0.5 mm; (49) fore wing, holotype, scale = 1 mm; (50) habitus, dorsal view, holotype, scale = 1 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Diagnosis

This is the only Australian species with a completely yellow mesosoma and brown metasoma.

Description (male)

Body measurements. Length of body 2.35–2.5 mm; ratio of antenna to length of body 0.95; ratio of length of fore wing to body 1.0–1.3; ratio of metasoma to mesosoma 0.95–1.0.

Head. Antenna with 33 antennomeres; ratio of length of third antennomere to fourth 1.2; length of third, fourth, penultimate, and terminal antennomere 3.4–3.6, 2.8–3, 2.0, and 2.7 their width, respectively; ratio of width of face in frontal view 1.6–1.7 its height; ratio of width of clypeus 1.8–2.1 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 1.1; ratio of length of eye in dorsal view to length of temple 1.6–1.75; ratio of posterior ocelli:POL:LOL:OOL 1.0:1.0:1.0:2.6; occipital weakly indented; face, frons, and vertex costate.

Mesosoma. Notauli absent; scutellum punctate, convex, shiny; propodeal tubercles absent; mesopleuron shiny, punctate; precoxal sulcus absent; ratio of height of mesosoma to length 1.6; hind coxa shiny and smooth; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 1.8–2.1, 3.7–3.8, 4.5–4.8, and 11.0–12.0 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.52–0.58; ratio of tarsus to basitarsus 2.5–2.6; fore wing: third radial-abscissa (3-SR) present, antefurcal; SR-1 curved; 2-SR+M postfurcal; 2-R1 present; ratio of 2-R1 to 1-R1 0.3; ratio of length of 1-R1 to length of pterostigma 1.0; ratio of width to length of pterostigma 3.0–3.3; ratio of r:3-SR:SR-1:r-m 1.0:0.6:4.0–4.6:0.9–1.1.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.55; shape of carapace in lateral view straight, shape of first and third tergite rounded; ratio of keels to metasoma length 0.1, keels parallel; tergites rugose; third tergite with lobes; ratio of length of three metasomal tergites 1.0:0.9:0.9 (larger specimens), 1.0:1.1:1.1 (smaller specimens); sutures parallel.

Colour. Overall yellow; interocellar area dark; antenna brown, except scape and pedicel yellow; coxae white, rest of legs yellow; wings infuscate; wing venation, parastigma and pterostigma brown; carapace brown.

Female. Unknown.

Comments

We describe *P. kriegeri* on the basis of two male specimens because the costate sculpturing of the head and the absence of clypeal teeth strongly indicate that this species does not represent the sexually dimorphic male of any other taxon described solely based on females.

Etymology

This species is named after the first author’s first class field assistant Lars Krieger.

Distribution

Phanerotomella kriegeri is only known from the type locality, Mt Spurgeon, in the rainforest of north-east Queensland (Fig. 101).

***Phanerotomella longipes* Szépligeti, 1900** (Figs 51-54, 98)

urn:lsid:zoobank.org:act:91B9C35D-B3E8-4879-9680-82D5AAC62EE2

Phanerotomella longipes Szépligeti, 1900: 59. Holotype: UNHM [examined].

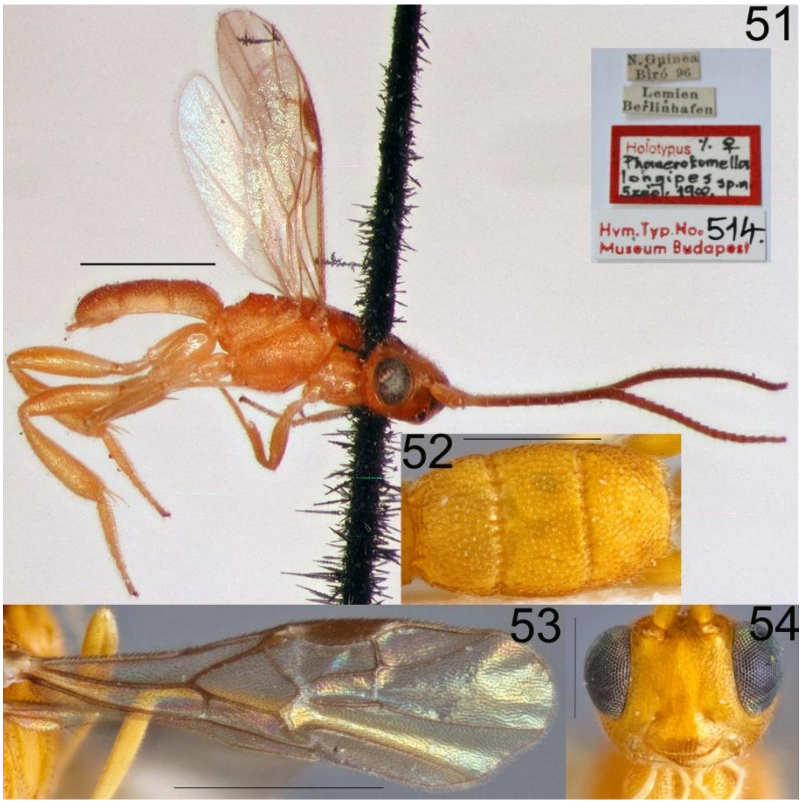
Type material

Holotype. Papua New Guinea: 1 ♀, "N. Guinea Biró 96" "Lemien Berlinhafen" Hym Typ No 514.

Other material examined.

Australia, Queensland: 2 ♀♀, 1 ♂, Mt Webb Nat Pk, 15.04S, 145.07E, 27 - 20 [sic!] iv 1981, I.D. Naumann, ex ethanol (ANIC); 1 ♂, 15 km WNW Bald Hill McIlwraith Ra, 13.43S, 143.19E, 420 m, 27 vi-12 vii 1989, I. Naumann, at light, weather station site (ANIC); 1 ♂, 15 km WNW Bald Hill McIlwraith Ra, 13.43S, 143.19E, 500 m, 27 vi-12 vii 1989, I. Naumann, at light (ANIC); 2 ♀♀, Mt Webb Nat Pk, 15.04S, 145.07E, 28-30 ix 1980, J.C. Cardale, ex ethanol (ANIC); 2 ♀♀, Coen, 13.57S, 143.12E, 25 ii - 23 iv 1994, P. Zborowski & W. McKay, FIT (ANIC); 1 ♂, 15 km NE by E Heathlands, 11.41S, 142.42E, 15-26 i 1992, I. Naumann & T. Weir (ANIC); 1 ♀, Batavia Downs, 12.40S, 142.40E, 12 vii 1993, K. Halfpapp & S. DeFaveri, at light (ANIC); 1 ♂, 3 km ENE Mt. Tozer, 12.44S, 143.14W, 28 vi-4 vii 1986, J.C. Cardale, MT/ethanol (ANIC); 1 ♂, 5 km WbyN Rounded Hill nr Hope Vale Mission, 15.17S, 145.10E, 7 x 1980, J.C. Cardale, ex ethanol (ANIC); 1 ♀, Moreton HS, 12.27S, 142.38E, 21 viii 1992, J. Cardale & P. Zborowski, light trap (ANIC); 1 ♀, Julatten, 20-29 x 1987, A. Walford-Huggins, edge of rainforest along creek, ex intercept trap (ANIC); 1 ♀, Mt Lamond, Qld (Summit), 15 i 1972, D.K. McAlpine & G.A. Holloway (AMS K358103); 1 ♂, Claudie R, 5 miles W Mt Lamond, 14 i 1972, D.K. McAlpine & G.A. Holloway (AMS K358104); 1 ♀, The Crater, near Herberton, 30 i 1972, D.K. McAlpine & G.A. Holloway (AMS K358084); 1 ♂, Mt Daubulan, 5 km, ESE Quald Rd, 16°44'S, 145°29'E, 500 m, 5 i - 9 ii 1998, DeFaveri & Halfpapp, MDPI Site 2, FIT (WINC); 1 ♂, Townsville, 10-17 xii 1987, T. Goertemiller, Malaise Trap (NMNH); 1 ♀, 1 mile NE Mt. Lamond Iron Range, 21 xii 1971, D.K. McAlpine, G.A. Holloway, G.P. Sands (AMS

K358106); 1 ♂, Mt Sorrow, 3 km W Cape Tribulation, 16°05'S, 145°27'E, 14 vi 1996, 300-500 m C.J. Burwell, rainforest (QM ENT13.36); 1 ♀, Archer River crossing 13°25'S, 142°56'E, 7 iv 1989, G. & A Daniels mv lamp (QM ENT13.36).



Figs 51-54. *P. longipes* Szépligeti, 1900, (51) habitus, lateral, holotype, scale = 1 mm; inset type label; (52) metasoma, dorsal view, other material, scale = 0.5 mm; (53) fore wing, other material, scale= 1 mm; (54) head, anterior view, other material, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Diagnosis

This species can be distinguished from the other yellow species by its size, interocellar colour (dark brown) and the absence of clypeal teeth. It is most similar to *P. sculpturata*, although they differ in numerous subtle ways; the best character to distinguish them is the sculpturing on the carapace, which is more foveolate in *P. sculpturata*.

Redescription

Body measurements. Length of body 2.25–2.8 mm; ratio of length of antennae to body 1.2–1.3; ratio of length of fore wing to body 0.89–0.93; ratio of metasoma to mesosoma 1.0.

Head. Antenna with 28–35 antennomeres; ratio of length of third antennomere to fourth 1.0; length of third, fourth, penultimate, and terminal antennomere 2.6–4.0, 2.8–3.8, 1.3–2.0, and 2.0–2.5 their width, respectively; ratio of width of face in frontal view 1.4–1.7 its height; ratio of width of clypeus 1.8–2.0 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 1.3–1.4; ratio of length of eye in dorsal view to length of temple

2.0–2.8; ratio of posterior ocelli:POL:LOL:OOL 1.0:0.8–1.5:0.8–1.3:2.2–4.0; occipital weakly indented; face and vertex finely rugose; frons transverse strigose.

Mesosoma. Notauli absent; scutellum rugose, not shiny; small propodeal tubercles present; mesopleuron rugose; precoxal sulcus absent; ratio of height of mesosoma to length 1.4–1.5; hind coxa smooth, shiny; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 2.3–2.5, 3.8–4.1, 4.1–4.5, and 10.0 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.52–0.6; ratio of tarsus to basitarsus 2.4–2.5; fore wing: third radial-abscissa (3-SR) present, antefurcal; SR-1 slightly curved to straight; 2-SR+M often postfurcal, sometimes interstitial or antefurcal; 2-R1 present; ratio of 2-R1 to 1-R1 0.4–0.5, ratio of length of 1-R1 to pterostigma length 0.9–1.1; ratio of width to length of pterostigma 2.5–3.8; ratio of r:3-SR:SR-1:r-m 1:0.1–0.3:4.0:0.9–1.0.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.57; shape of carapace in lateral view straight, shape of individual tergites rounded; keels absent or really short, then ratio of length of keels to metasomal length 0.1, keels parallel; tergites rugose; third tergite with two teeth latero-posteriorly; ratio of length of three metasomal tergites 1.0:0.9–1.0:0.8–1.0; sutures parallel.

Colour. Yellow to orange head, mesosoma, metasoma and legs; interocellar area dark; antenna, wing venation, pterostigma, and parastigma brown; wings hyaline; scape and pedicel yellow.

Male. Dark brown to black tarsi.

Distribution

This species is widely distributed in north-east Queensland (Fig. 98), Papua New Guinea, and the Solomon Islands.

***Phanerotomella microcellata* sp. n.** (Figs 55-58, 97)

urn:lsid:zoobank.org:act:2DE64CA5-B20E-4DC3-BDA0-A4031D7C386D

Type material

Holotype. Australia, South Australia: 1 ♀, “31.33S, 138.36E, SA, Wilpena Pound Gap, 5-10 Nov 1987, I. Naumann, J. Cardale, Malaise/ethanol” (ANIC). *Paratypes.* Australia, South Australia: 1 ♀, 1 ♂, same location (ANIC); 1 ♂, 1 ♀, Wilpena Pound Gap, 31.33S, 138.36E, 5-6 xi 1987, I. Naumann & J. Cardale, ex ethanol (WINC).

Diagnosis

This species differs from all other Australian *Phanerotomella* by the presence of the precoxal sulcus, the small ocelli, and the yellow interocellar area.

Description

Body measurements. Length of body 2.75–2.85 mm; ratio of length of antenna to body 1.0–1.2; ratio of length of fore wing to body 0.86–0.95; ratio of metasoma to mesosoma 1.0.

Figs 55-58. *P. microcellata* sp. n., (55) habitus, lateral, holotype, scale = 1 mm; (56) head, anterior view, holotype, scale = 0.5 mm; (57) fore wing, holotype, scale = 1 mm; (58) metasoma dorsal, holotype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Head. Antenna with 32 (males) to 36 (females) antennomeres; ratio of length of third antennomere to fourth 1.0–1.15; length of third, fourth, penultimate, and terminal antennomere 3.2–3.4, 2.8–3.0, 1.3–2.5, and 2.5 their width, respectively; ratio of width of face in frontal view 1.7–2.0 its height; ratio of width of clypeus 1.5–1.8 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 1.7–2.0; ratio of length of eye in dorsal view to length of temple 1.3–1.5; ratio of posterior ocelli:POL:LOL:OOL 1.0:1.5:1.3–1.8:4.0; occipital weakly indented; face, frons, and vertex transverse strigose.
Mesosoma. Notauli absent; scutellum flat, finely rugose, not shiny; propodeal tubercles present; mesopleuron rugose; precoxal sulcus anteriorly weakly present; ratio of height of mesosoma to length 1.8–2; hind coxa smooth, shiny; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 1.8–2.4, 3.5–4.0, 4.2–5.0, and 12.0–18.0 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.45–0.5; ratio of tarsus to basitarsus 2.2–2.5; fore wing: third radial-abscissa (3-SR) absent (interstitial) or short, antefurcal; SR-1

curved; 2-SR+M interstitial or postfurcal; 2-R1 present; ratio of 2-R1 to 1-Rs 0.3–0.4; ratio of length 1-R1 to pterostigma length 0.8–0.9; ratio of width to length of pterostigma 3.2; ratio of r:3-SR:SR-1:r-m 1.0:0.2:3.5:0.9–1.3.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.6–0.63; shape of carapace in lateral view straight, shape of individual tergites flat; keels short, ratio of keels to metasomal length 0.05–0.1, keels parallel; tergites rugose; third tergite with two small teeth latero-posteriorly; ratio of length of three metasomal tergites 1.0:0.9:0.6–0.8; sutures parallel.

Colour. Head and mesosoma yellow to orange; antenna brown; interocellar area yellow; legs yellowish; wings infuscated with a small white stripe between parastigma and pterostigma; pterostigma and parastigma brown; wing venation brown; first tergite of metasoma yellow, otherwise brown.

Male. Darker than female.

Etymology

This species is named after its small ocelli.

Distribution

Phanerotomella microcellata is only known from the type locality, Wilpena Pound Gap, in the Flinders Ranges, South Australia (Fig. 97).

***Phanerotomella minuta* Zettel, 1989** (Figs 59-62, 97)

urn:lsid:zoobank.org:act:9E9D5096-0867-47AE-8F87-4B8521A0D915

Phanerotomella minuta Zettel, 1989: 64. Holotype: AEI [examined].

Type material

Holotype. Australia, Northern Territory: 1 ♂, “Northern Territory, Yuendumu, viii”.

Diagnosis

This is only Australian *Phanerotomella* species with 24–25 antennomeres.

Redescription (male)

Body measurements. Length of body 1.8–2.2 mm; ratio of length of antenna to body 0.78; ratio of length of fore wing to body 0.79; ratio of metasoma to mesosoma 1.1.

Head. Antenna with 24–25 antennomeres; ratio of length third antennomere to fourth 1.1; length of third, fourth, penultimate, and terminal antennomere 3.2, 2.9, 2.4, and 2.4 their width, respectively; teeth on clypeus absent; ratio of length of eye in dorsal view to length of temple 2.4; ratio of posterior ocelli:POL:LOL:OOL 1.0:2.0:0.25:4.0; face costate; frons transverse strigose.

Figs 59-62. *P. minuta* Zettel, 1989, (59) habitus, lateral, holotype, scale = 0.5 mm; (60) mesosoma, dorsal view, holotype, scale = 0.5 mm; (61) head and mesosoma, laterofrontal view, holotype, scale = 0.2 mm; (62) metasoma, dorsal view, holotype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Mesosoma. Notauli absent; propodeal tubercles present; mesopleuron rugose; precoxal sulcus absent; ratio of height of mesosoma to length 1.2; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 1.7, 3.3, 3.4, and 6.7 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.6; ratio of tarsus to basitarsus 2.7; fore wing: third radial abscissa (3-SR) present, antefurcal; SR-1 straight; 2-SR+M postfurcal or interstitial; 2-R1 present; ratio of 2-R1 to 1-R1 0.27; ratio of length of 1-R1 to pterostigma length 1.3; ratio of width to length of pterostigma 2.9; ratio of r:3-SR:SR-1:r-m 1.0:0.4:5.5:2.0.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.61; shape of carapace in lateral view straight; shape of individual tergites flat; tergites rugose; third tergite with small lobes; ratio of length of three metasomal tergites 1.0:1.0:1.2; sutures parallel.

Colour. Head, interocellar area, antenna, mesosoma, and last two metasomal tergites reddish brown; legs and first metasomal tergite beige.

Female. Unknown.

Distribution

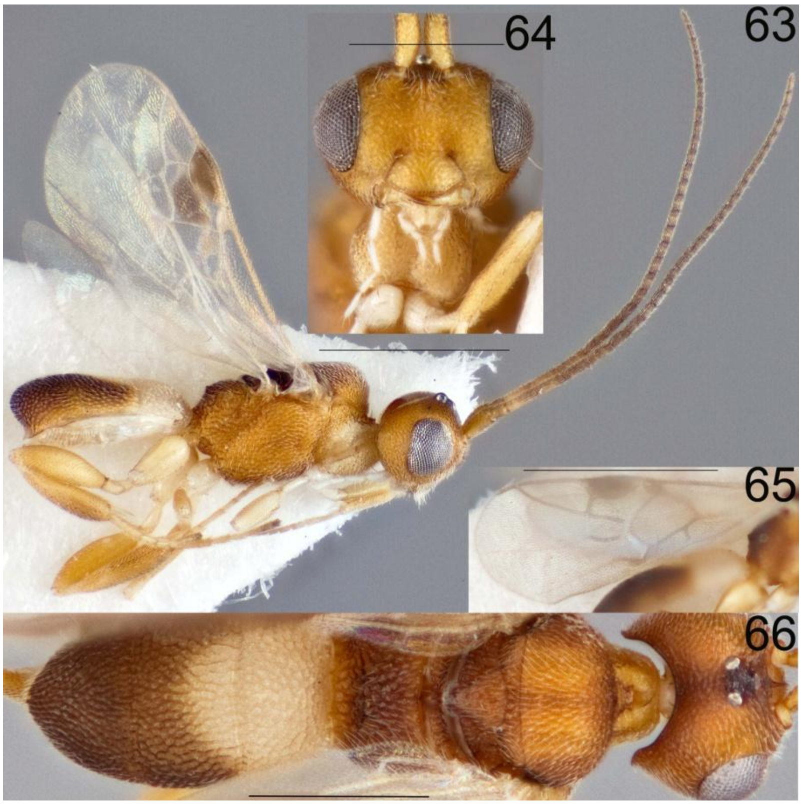
This species is only known from the type locality in the Northern Territory (Fig. 97).

Phanerotomella naumanni **sp. n.** (Figs 62-65, 100)

urn:lsid:zoobank.org:act:651CFA8A-68D4-4557-A3F4-63A43739BC7C

Type material

Holotype. Australia, Western Australia: 1 ♀, "15.25S, 124.38E, WA, Augustus Island, CALM site 26/1, 11 - 16 June 1988, I.D. Naumann", "at light, open forest, near closed forest margin" (ANIC). *Paratypes.* Australia, Western Australia: 1 ♀, same as holotype (ANIC); 3 ♂♂, Charnley Riv., 2 km SW Rolly Hill, 16.22S, 125.12E, 16 - 20 vi 1988, I.D. Naumann, CALM site 25/2 (ANIC); 1 ♀, Synnot Ck, 16.31S, 125.16E, 17 - 20 vi 1988, T.A. Weir, CALM site 25/1 (WINC).



Figs 63-66. *P. naumanni* sp. n., (63) habitus, lateral, paratype, scale = 1 mm; (64) head, anterior view, paratype, scale = 0.5 mm; (65) fore wing, paratype, scale = 0.5 mm; (66) habitus, dorsal view, paratype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Diagnosis

The carapace of this species broadens to the posterior end and, in this respect, it is unlike any other Australian *Phanerotomella*.

Description

Body measurements. Length of body 1.9–2.25 mm; ratio of length of antenna to body 1.0; ratio of length of fore wing to body 0.84–0.9; ratio of metasoma to mesosoma 1.0.

Head. Antenna with 28–29 (male) and 30–31 (female) antennomeres; ratio of length third antennomere to fourth 1.0–1.2; length of third, fourth, penultimate, and terminal antennomere 2.5–4.5, 2.5–4.3, 2.0–2.5, and 2.0–3.0 their width, respectively; ratio of width of face in frontal view 1.7–1.9 its height; ratio of width of clypeus 1.8–2.0 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandibles 1.3–2.0; ratio of length of eye in dorsal view to length of temple 1.9–3.1; ratio of posterior ocelli:POL:LOL:OOL 1.0:1.3:1.3:3.6–4.3 in female and 1.0:0.8:0.8–1.0:2.5–3.0 in male; occipit strongly indented; face and vertex finely rugose; frons transverse strigose.

Mesosoma. Notauli absent; scutellum flat, finely rugose, not shiny; propodeal tubercles present; mesopleuron rugose; precoxal sulcus absent; ratio of height of mesosoma to length 1.6–1.9; hind coxa shiny, smooth; ratio of length hind coxa, hind femur, hind tibia, and hind tarsus 1.8–2.2, 2.8–4.0, 3.9–4.3, and 10.0–14.7 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.6–0.7; ratio of tarsus to basitarsus 2.6–2.8; fore wing: third radial-abscissa (3-SR) present but short, antefurcal; SR-1 slightly curved; 2-SR+M usually postfurcal, sometimes interstitial; 2-R1 present; ratio of 2-R1 to 1-R1 0.4–0.5; ratio of length of 1-R1 to pterostigma length 0.78–0.87; ratio of width to length of pterostigma 2.3–3.0; r:3-SR:SR-1:r-m 1.0:0.8–1.0:5.0:1.2–1.5.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.59–0.63; shape of carapace in lateral view slightly bent under, shape of individual tergites flat; keels short, 0.07–0.13 the length of metasoma, keels parallel; tergites finely rugose; third tergite with small lobes; ratio of length of three metasomal tergites 1.0:1.0:0.8; sutures parallel.

Colour. Head and mesosoma orange; antenna brown; interocellar area dark; legs yellowish white; wings hyaline; wing venation white; pterostigma and parastigma brown; anterior half of metasoma white, posterior half dark brown.

Etymology

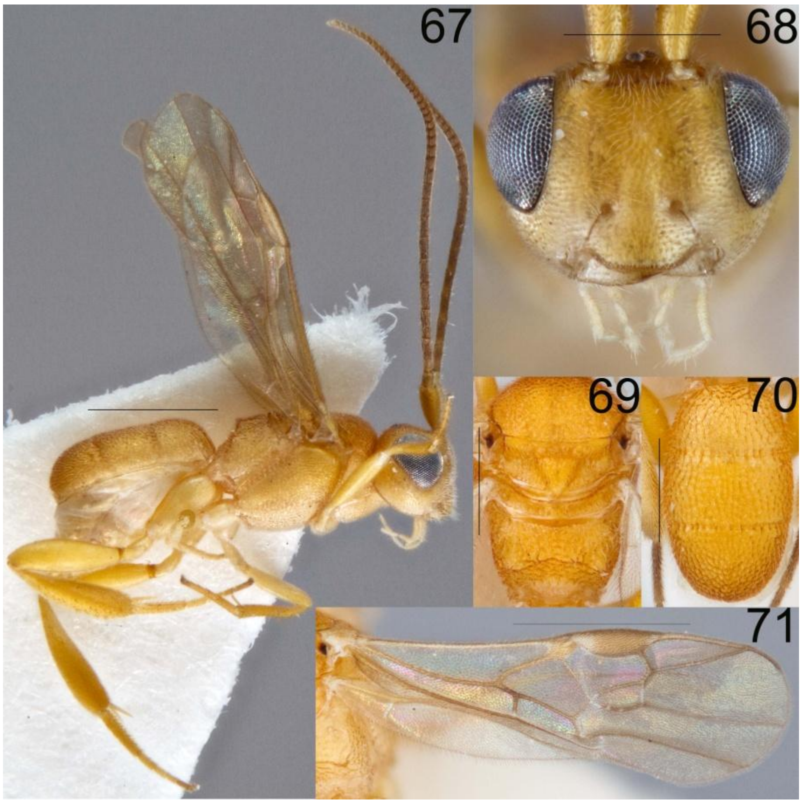
This species is named after Dr Ian Naumann, collector of many Australian parasitic Hymenoptera.

Distribution

Phanerotomella naumanni is known from north-western Australia (Fig. 100).

***Phanerotomella nivistigma* sp. n.** (Figs 66-70, 100)

urn:lsid:zoobank.org:act:65D111E3-BF3E-45D4-9C7A-E1D4A7699A97



Figs 67-71. *P. nivistigma* sp. n., (67) habitus, lateral, holotype, scale = 1 mm; (68) head, anterior view, holotype, scale = 0.5 mm; (69) mesosoma, dorsal view, paratype, scale = 0.5 mm; (70) metasoma, dorsal view, paratype, scale = 0.5 mm; (71) fore wing, paratype, scale = 1 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Type material

Holotype. Australia, Western Australia: 1 ♀, “W.A. 15.25S, 124,38E, Augustus Island, CALM Site 26/1, 11 - 16 June 1988, I.D. Naumann”, “Malaise, through and pan traps, closed forest and margins” (ANIC). *Paratypes.* Australia, Western Australia: 13 ♀♀, 1 ♂, 3 sex unknown, same as holotype (ANIC); 1 ♀, Kimbolton, iii-iv 1983, C. Sambell, ex ethanol (WINC); 1 ♀, 3 ♂♂, Prince Frederick Harbour, 15.00S, 125.21E, 6-11 June 1988, I.D. Naumann, 'Marun' CALM Site 8/4, (ANIC); 6 ♀♀, 3 ♂♂, 4 km W of Kind Cascade, 15.38S, 125.15E, 12-16 vi 1988, T.A. Weir, CALM Site 28/3, (ANIC); Australia, Northern Territory:

2 ♀♀, Kakadu NP Nourlangie Camp, 16-19 xi 1992, A.D. Austin & P.C. Dangerfield, M.T. (WINC); Australia, Queensland: 1 ♀, Mt. Webb Nat Pk, 15.04S, 145.07E, 28-30 ix 1980, J.C. Cardale, MT (ANIC).

Diagnosis
Similar to *P. sculpturata* and *P. longipes*, but specimens are smaller and have a pale pterostigma.

Description
Body measurements. Length of body 2–2.85 mm; ratio of length of antenna to body 1.1; ratio of length of fore wing to body 1.0; ratio of metasoma to mesosoma 1.0–1.1.
Head. Antenna with 33–37 antennomeres; ratio of length of third antennomere to fourth 1.1–1.3; length of third, fourth, penultimate, and terminal antennomere 3.8–4.3, 3.0–3.8, 1.3–2.5, and 1.7–3.0 their width, respectively; ratio of width of face in frontal view 1.5–1.8 its height; ratio of width of clypeus 1.5–2.0 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 1.5–1.7; ratio of length of eye in dorsal view to length of temple 1.6–2.5; ratio of posterior ocelli:POLP:LOL:OOL 1.0:0.8:0.8:2.6–2.8; occipital weakly indented; face and vertex finely rugose; frons transverse strigose.
Mesosoma. Notauli absent; scutellum convex, not shiny; propodeal tubercles present; mesopleuron rugose; precoxal sulcus absent; ratio of height of mesosoma to length 1.3–1.5; hind coxa shiny, smooth; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 1.9–2.1, 3.5–4.1, 4.3–5.0, and 10.0–14.0 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.45–0.54; ratio of tarsus to basitarsus 2.2–2.4; fore wing: third radial-abscissa (3-SR) present, antefurcal; SR-1 straight; 2-SR+M usually postfurcal, sometimes interstitial; 2-R1 present; ratio of 2-R1 to 1-R1 0.37–0.44; ratio of length 1-R1 to pterostigma length 0.9; ratio of width to length of pterostigma 2.9–3.1 r:3-SR:SR-1:r-m 1.0:0.6:5.0:0.8–1.1.
Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.57–0.63; shape of carapace in lateral view straight, shape of individual tergites rounded; keels present, 0.09–0.15 of the metasomal length, keels parallel; tergites rugose; third tergite with two small lobes; ratio of length of three metasomal tergites 1.0:0.9:0.8–0.9; sutures parallel.
Colour. Head, mesosoma, metasoma, and legs golden; interocellar area yellow; antenna light brown, except scape and pedicel yellow; wings hyaline; pterostigma and parastigma white to light brown; wing venation golden brown.

Etymology

This species is named after the white pterostigma exhibited by this species.

Distribution

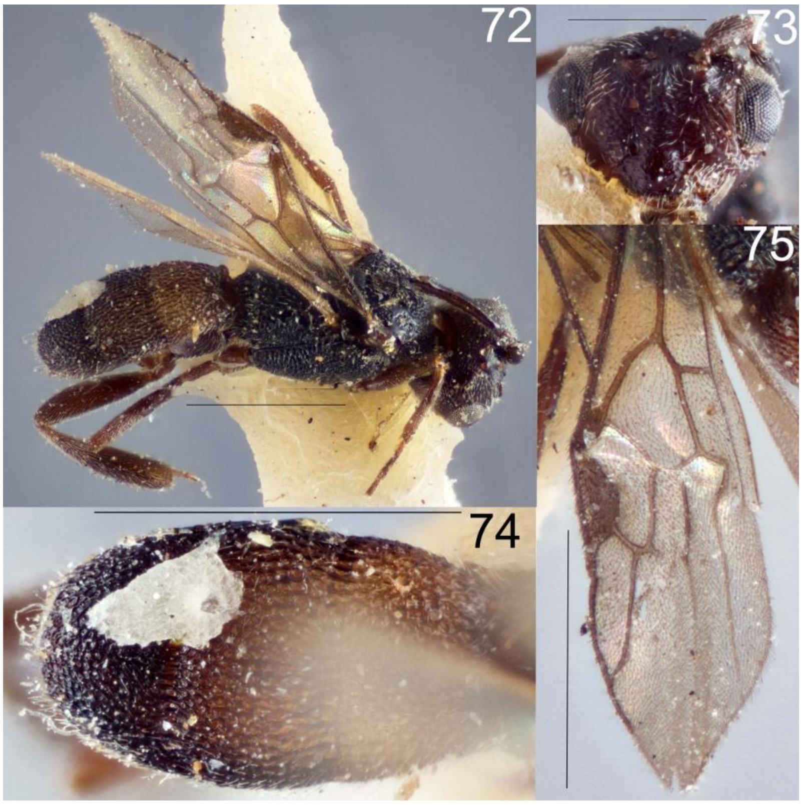
Phanerotomella nivistigma is known from northern Australia: north Western Australia, Northern Territory, and Queensland (Fig. 100).

***Phanerotomella obscura* sp. n.** (Figs 71-74, 101)

urn:lsid:zoobank.org:act:8C2AABB1-754D-48A4-B918-0396F47DBBB9

Type material

Holotype. Australia, Australian Capital Territory: 1 ♂, "by sweeping Vegetation Black Mountain Canberra, ACT 26 Nov 1969 D.F. Gross" (SAM).



Figs 72-75. *P. obscura* sp. n., (72) habitus, lateral, holotype, scale = 1 mm; (73) head, anterior view, holotype, scale = 0.5 mm; (74) metasoma, dorsal view, holotype, scale = 1 mm; (75) fore wing, holotype, scale = 1 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Diagnosis

One of the few dark brown Australian *Phanerotomella* species, but, it differs(together with *P. variata*) from other similar species by its dark brown legs and scape. It can be easily distinguished from *P. variata* by the sculpturing of the face and mesopleuron.

Description (male)

Body measurements. Length of body 2.8 mm; ratio of length of fore wing to body 0.9; ratio of metasoma to mesosoma 0.95.

Head. Antenna broken off; ratio of width of face in frontal view 1.9 its height; ratio of width of clypeus 1.5 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 1.9; ratio of length of eye in dorsal view to length of temple 1.2; ratio of posterior ocelli:POL:LOL:OOL 1.0:1.5:1.5:3.5; occipital weakly indented; face, frons, and vertex costate.

Mesosoma. Notauli absent; scutellum punctate, weakly flat, shiny; propodeal tubercles present; mesopleuron shiny, punctate; precoxal sulcus absent; ratio of height of mesosoma to length 0.59; hind coxa shiny and smooth; ratio of hind coxa, hind femur, hind tibia 1.9, 5.7, 5.4 their width, respectively; fore wing: third radial-abscissa (3-SR) present, antefurcal; SR-1 curved; 2-SR+M postfurcal; 2-R1 present; ratio of 2-R1 to 1-R1 0.36; ratio of length of 1-R1 to length of pterostigma 0.95; ratio of width to length of pterostigma 2.9; ratio of r:3-SR:SR-1:r-m 1.0:0.4:4.0:1.0.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.6; shape of carapace in lateral view straight, shape of individual tergites flat; ratio of keels to metasomal length 0.2, keels converging; all tergites coarse rugose; third tergite with lobes; ratio of length of three metasomal tergites 1.0:0.9:0.7; anterior suture curved posteriorly.

Colour. Generally dark brown; head reddish brown; legs light brown; wing hyaline; wing venation, parastigma and pterostigma brown; carapace lighter brown anteriorly and gradually darker posterior.

Female. Unknown.

Comments

We describe *P. obscura* on the basis of a single male because the costate sculpturing of the head and the absence of clypeal teeth strongly indicate that this species does not represent the sexually dimorphic male of any other taxon described solely based on females. These two characters are also used to justify the description of *P. kriegeri* based on male specimens alone, but these two species are very different from each other; *P. obscura* is an extremely dark species, while *P. kriegeri* the only Australian species with a complete yellow mesosoma and brown metasoma.

Etymology

This species is named after its dark colour.

Distribution

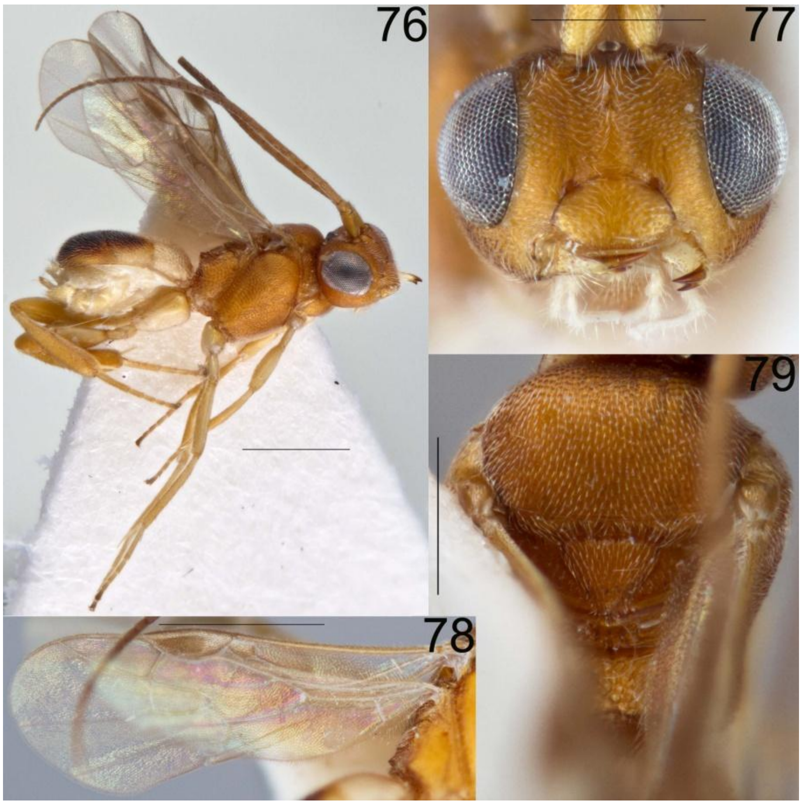
Phanerotomella obscura is only known from the type locality, Black Mountain, Australian Capital Territory (Fig. 101).

***Phanerotomella phanerotomoides* sp. n.** (Figs 75-78, 99)

urn:lsid:zoobank.org:act:EE9D46AF-DB37-447E-8144-354F6B8334B4

Type material

Holotype. Australia, Queensland: 1 ♀, “Hughenden Stn, QLD, 19-21 Nov 1984, D.S. Gibson, at light” (ANIC).



Figs 76-79. *P. phanerotomoides* sp. n., (76) habitus, lateral, holotype, scale = 1 mm; (77) head, anterior view, holotype, scale = 0.5 mm; (78) fore wing, holotype, scale = 1 mm; (79) mesosoma dorsal, holotype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Diagnosis

The combination of eye to temple ratio being greater than 1.6, the antenna being longer than the body and wings shorter than body distinguish this species from all other Australian *Phanerotomella*.

Description (female)

Body measurements. Length of body 2.95 mm; ratio of length of antenna to body 1.1; ratio of length of fore wing to body 0.88; ratio of metasoma to mesosoma 1.0.

Head. Antenna with 34 antennomeres; ratio of length of third antennomere to fourth 1.13; length third, fourth, penultimate, and terminal antennomere 3.4, 3.0, 2.5, and 2.5 their width, respectively; ratio of width of face in frontal view 1.6 its height; ratio of width of clypeus 1.6 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 1.4; ratio of length of eye in dorsal view to length of temple 3.8; ratio of posterior ocelli:POL:LOL:OOL 1.0:0.8:0.8:2.2; occipital weakly indented; face, frons, and vertex weakly transverse strigose.

Mesosoma. Notauli absent; scutellum flat, not shiny; propodeal tubercles present; mesopleuron rugose; precoxal sulcus absent; ratio of height of mesosoma to length 1.4; hind coxa shiny, smooth; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 1.8, 3.3, 4.5, and 12.6 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.54; ratio of tarsus to basitarsus 2.25; fore wing: third radial-abscissa (3-SR) present (short), antefurcal; SR-1 straight; 2-SR+M postfurcal; 2-R1 present; ratio of 2-R1 to 1-R1 0.4; ratio of length 1-R1 to length of pterostigma 0.88; ratio of width to length of pterostigma 4.0; ratio of r:3-SR:SR-1:r-m 1.0:0.23:3.0:0.8.

Metasoma. Shape of metasomal carapace round in dorsal view, ratio of width to length 0.9; shape in lateral view slightly convex and broader posteriorly, tergites flat; keels absent; tergites rugose; third tergite with small teeth; ratio of length of three metasomal tergites 1.0:1.0:0.8; sutures parallel.

Colour. Head, mesosoma, and legs orange; antenna light brown; interocellar area dark; wings hyaline; wing venation brown; pterostigma and parastigma light brown; anterior half of metasoma white, posterior half dark brown.

Male. Unknown.

Etymology

The name refers to the superficial similarity of this species to the genus *Phanerotoma*.

Distribution

Phanerotomella phanerotomoides is only known from the type locality, Hughenden Station, central Queensland (Fig. 99).

***Phanerotomella pungogaster* sp. n.** (Fig 2, 79-83, 100)
urn:lsid:zoobank.org:act:50734859-723A-48E5-B6D2-A0DFDA28E523

Type material

Holotype. Australia, Western Australia: 1 ♀, “15.38S, 125.15E, CALM Site 28/3, 4 km W of King Cascade, WA, 12-16 June 1988, T.A. Weir”, “at light; open forest” (ANIC). *Paratypes.* Australia, Western Australia: 3 ♀♀, same as holotype (ANIC); 1 ♀, Carson escarpment, 14.49S, 126.49E, 9-15 viii 1975, I.F.B. Common & M.S. Upton (WINC).

Diagnosis

The elongate shape of the metasoma which narrows to the posterior end clearly separates this species from all other Australian *Phanerotomella*.

Figs 80-84. *P. pungogaster* sp. n., (80) habitus, lateral, holotype, scale = 1 mm; (81) metasoma, dorsal, holotype, scale = 0.5 mm; (82) head, anterior view, holotype, scale = 0.5 mm; (83) fore wing, paratype, scale = 1 mm; (84) mesosoma, dorsal view, holotype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Description (female)

Body measurements. Length of body 2.35–2.85 mm; ratio of length of antenna to body 1.0; ratio of length of fore wing to body 0.8; ratio of metasoma to mesosoma 1.15–1.3.

Head. Antenna with 40 antennomeres; ratio of length of third antennomere to fourth 1.1; length of third, fourth, penultimate, and terminal antennomere 2.8, 2.6, 1.5, and 2.0 their width, respectively; ratio of width of face in frontal view 1.3 its height; ratio of width of

clypeus 1.8 its height; teeth on clypeus absent; ratio of malar space to length of base of mandible 0.6–0.8; ratio of length of eye in dorsal view to length of temple 2.8; ratio of posterior ocelli:POL:LOL:OOL 1.0:1.2:0.8–1.0:2.4–2.8; occipital strongly indented; face, frons, and vertex finely rugose.
Mesosoma. Notauli absent; scutellum convex, longitudinal strigose, not shiny; propodeal tubercles present; mesopleuron rugose; precoxal sulcus absent; ratio of height of mesosoma to length 1.4–1.7; hind coxa smooth, shiny; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 2.0–2.3, 3.1, 4.2–4.6, and 13.0–15.0 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.58–0.6; ratio of tarsus to basitarsus 2.5; fore wing: third radial-abscissa (3-SR) present, antefurcal; SR-1 straight; 2-SR+M antefurcal; 2-R1 present; ratio of 2-R1 to 1-R1 0.36; ratio length 1-R1 to pterostigma length 0.86–0.88; ratio of width to length of pterostigma 3.2; ratio of r:3-SR:SR-1:r-m 1.0:0.3:3.1–3.9:0.75.
Metasoma. Shape of metasomal carapace elongate oval in dorsal view, narrowing down posteriorly; ratio of width to length 0.52; shape of carapace in lateral view straight, shape of individual tergites flat; keels absent; tergites rugose; third tergite without lobes or teeth; ratio of length of three metasomal tergites 1.0:1.0:0.9–1.1; sutures parallel.
Colour. Head, antenna and mesosoma yellow to orange; interocellar area dark; scutellum dark; legs white with hind tibia brown; wings hyaline; wing venation and pterostigma brown; parastigma light brown; first metasomal tergite white, second and third tergite brown.
Male. Unknown.

Etymology

This species is named after the elongate, narrowed shape of the metasoma.

Distribution

Phanerotomella pungogaster is known from northern Western Australia (Fig. 100).

***Phanerotomella sculpturata* Szépligeti, 1900** (Figs 84-87, 99)

urn:lsid:zoobank.org:act:9C17A866-D35A-41C9-B500-2335158F2D88

Phanerotomella sculpturata Szépligeti, 1900: 59. Holotype: UNHM [examined].

Type material

Holotype. Papua New Guinea: ♂ [incorrectly listed as ♀], “N. Guinea Biró 96” “Friedrich-Wilh.-hafen”, Hym Typ No 515.

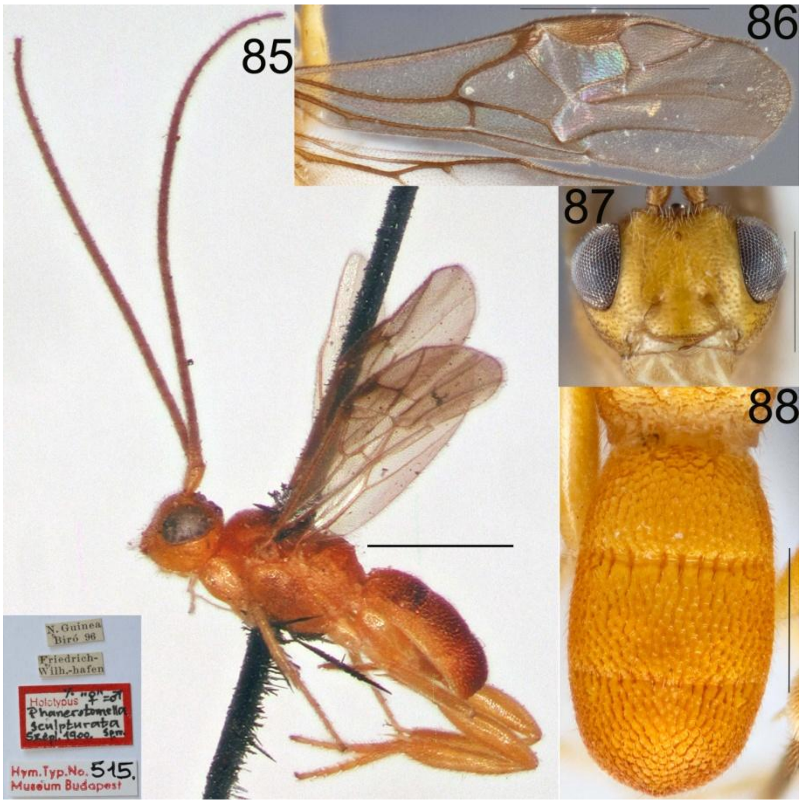
Other material examined

Australia, Queensland: 2 ♂♂, 14 km ENE Heathlands, 11.41S, 142.42E, 21 x - 12 xi 1993, P. Zborowski & M. Horak, Malaise Trap (ANIC); 1 ♂, 14 km ENE Heathlands, 11.41S, 142.42E, 20 viii 1992, J. Cardale & P. Zborowski, closed forest (ANIC); 1 ♀, 14 km ENE Heathlands, 11.41S, 142.42E, 12 xi-14 xii 1993, P. Zborowski, MT (ANIC); 1 ♀, 15 km WNW Bald Hill McIlwraith Ra, 13.43S, 143.19E, 420 m, 27 vi-12 vii 1989, I. Naumann, pantraps, weather station site (ANIC); 1 ♀, 1 ♂, 15 km WNW Bald Hill McIlwraith Ra, 13.43S, 143.19E, 420 m, 27 vi-12 vi 1989, I. Naumann, at light, weather station site (ANIC); 1 ♀, 15 km WNW Bald Hill McIlwraith Ra, 13.43S, 143.19E, 500 m, 27 vi-12 vii 1989, I. Naumann, at light, weather station site (ANIC); 1 ♂, 15 km WNW Bald Hill McIlwraith Ra, 13.43S, 143.19E, 420 m, 27 vi-12 vii 1989, I. Naumann, rainforest (ANIC); 1 ♂, 11 km WNW Bald Hill McIlwraith Ra, 13.43S, 143.19E, 520 m, 27 vi-12 vii 1989, I. Naumann, rainforest, search party campsite (ANIC); 1 ♀, 2 ♂♂, 12 km SSE Heathlands, 11.51S, 142.38E, 15-26 i 1992, I. Naumann & T Weir, MT/ethanol, rainforest margin (ANIC); 2 ♀♀, 12 km SSE Heathlands, 11.51S, 142.38E, 1-21 v 1992, P. Feehney, closed forest MT (ANIC); 2 ♂♂, 12 km SSE Heathlands, 11.51S, 142.38E, 26 i-1 iii 1992, P. Feehney, closed forest MT (ANIC); 1 ♀, 12 km SSE Heathlands, 11.51S, 142.38E, 22 x-22 xi 1992, P. Zborowski & A. Calder, FIT (ANIC); 2 ♂♂, 14 km ENE Heathlands, 11.41S, 142.42E, 19 vi-13 vii 1993, K. Halfpapp & S. DeFaveri, MT (ANIC); 1 ♂, Townsville, James Cook Uni Campus, dry Savannah, 21-26 v 88, A.D. Austin (WINC); 1 ♂, 9 km S Cape York, 10.45S, 142.30E, 20 vi 1993, I.C. Naumann & P. Zborowski (ANIC); 1 ♂, 13 km E by S Weipa, 12.40S, 143.00E, 24 x-15 xi 1993, P. Zborowski & M. Horak, MT (ANIC); 1 ♂, Cape York, 10.41S, 142.32E, 20 vi 1993, I.C. Naumann & P. Zborowski (ANIC); 1 ♀, Paluma via Townsville, 24 v 88, A.D. Austin, sweeping rainforest/wet sclerophyll (WINC); 1 ♂, turnoff to Captain Billy Landing, 11.41S, 142.42E, 20 viii 1992, J. Cardale & P. Zborowski (ANIC); 1 ♂, Wongabel S.F., 6 km S Atherton, 9 i - 10 ii 1984, Storey & Brown, MT (WINC); 1 ♀, Black Mountain Rd. Julatten 15 x -21 xi 1987, A. Walford-Huggins rainf. interc. trap. (ANIC), 2 ♂♂, 8 km NW Ellis Beach, 16°41'S, 145°35'E, 8 vi 1996, C.J. Burwell (QM ENT13.36); 3 ♂♂, 2 ♀♀, Rex Creek, 5 km W Mossman, 16°28'S, 145°19'E, 21 iv 1997, C.J. Burwell, rainforest (QM ENT13.36); 1 ♂, Pilgrim Sands, 1 km NW Cape Tribulation, 16°04'S, 145°"28'E, 13 iv 1996, C.J. Burwell

(QM ENT13.36); 1 ♀, 1 ♂, "Kingfisher Park" 1 km N Julatten, 16°36'S, 145°20'E, 29 xi 1997, C.J. Burwell (QM ENT13.36); 3 ♀♀, 4 ♂♂, West Claudie River, 4 km SW road junction, 12°44'S, 143°15'E, 28 xi 1986, G. Daniels & M.A. Schneider, MT (QM ENT13.36); 1 ♂, Gordon Creek area Claudie River district, 25 vi 1982, G. Daniels & M.A. Schneider (QM ENT13.36).

Diagnosis

This species can be distinguished from other species that have an overall yellow body colour by its size (larger than *P. flavens*), the interocellar colour (dark brown compared to golden yellow in *P. nivistigma*), and the absence of clypeal teeth (present in *P. kimbaensis*). It is most similar to *P. longipes*, although they differ in numerous subtle ways, the best character to distinguish them being the sculpturing on the carapace, which is more rugose in *P. longipes*.



Figs 85-88. *P. sculpturata* Szépligeti, 1900, (85) habitus, lateral, holotype, scale = 1 mm; inset type label; (86) fore wing, other material, scale = 1 mm; (87) head, anterior view, other material, scale = 0.5 mm; (88) metasoma, dorsal view, other material, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Redescription

Body measurements. Length of body 2.15–3.25 mm; ratio of length of antennae to body 1.33–1.48; ratio of length of fore wing to body 1.0; ratio of metasoma to mesosoma 1.0.

Head. Antenna with 33–41 antennomeres; ratio of length of third antennomere to fourth 1.2; length of third, fourth, penultimate, and terminal antennomere 3.8–5.2, 3.2–4.4, 2.5–3.0, and 3.0 their width, respectively; ratio of width of face in frontal view 1.3–1.6 its height; ratio of width of clypeus 1.75–2.0 its height; teeth on clypeus absent; ratio of malar space to length of base of mandible 1.5–1.6; ratio of length of eye in dorsal view to length of temple 1.75–2.5; ratio of posterior ocelli:POL:LOL:OOL 1.0:0.7–1.0:1:3.0; occipital weakly indented; face punctate; frons and vertex transverse strigose.

Mesosoma. Notauli absent; scutellum punctate, not shiny; propodeal tubercles absent; mesopleuron punctate; precoxal sulcus absent; ratio of height of mesosoma to length 1.5; hind coxa shiny, smooth; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 1.9–2.8, 3.3–4.5, 3.4–4.9, and 10.0–12.0 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.5; ratio of tarsus to basitarsus 2.1–2.4; fore wing: short third radial-abscissa (3-SR) present, antefurcal; SR-1 straight or curved; 2-SR+M interstitial, antefurcal or postfurcal; 2-R1 present; ratio of 2-R1 to 1-R1 0.52–0.53; ratio of length 1-R1 to pterostigma length 0.86–0.96; ratio of width to length of pterostigma 3.2–4.5; ratio of r:3-SR:SR-1:r-m 1.0:0.5–0.6:4.6–6.3:1.0–1.1.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.56–0.61; shape of carapace in lateral view straight, shape of individual tergites rounded; keels short, almost absent, 0.05–0.1 of the length of the metasoma, keels parallel; tergites foveolate; third tergite without teeth or lobes; ratio of length of three metasomal tergites 1.0:1.1:1.1 (smaller specimens) and 1.0:0.9:0.9 (larger specimens); sutures parallel.

Colour. Head, mesosoma, metasoma, and legs orange to yellow; antenna brown; interocellar area dark; hind tibia brown; wings hyaline; wing venation, pterostigma, and parastigma brown.

Male. Dark brown to black tarsi.

Distribution

This species is known from north Queensland and Papua New Guinea (Fig. 99).

***Phanerotomella szepligetii* sp. n.** (Figs 88-92, 98)

urn:lsid:zoobank.org:act:CA79769A-3D57-4442-B483-2A33929BE235

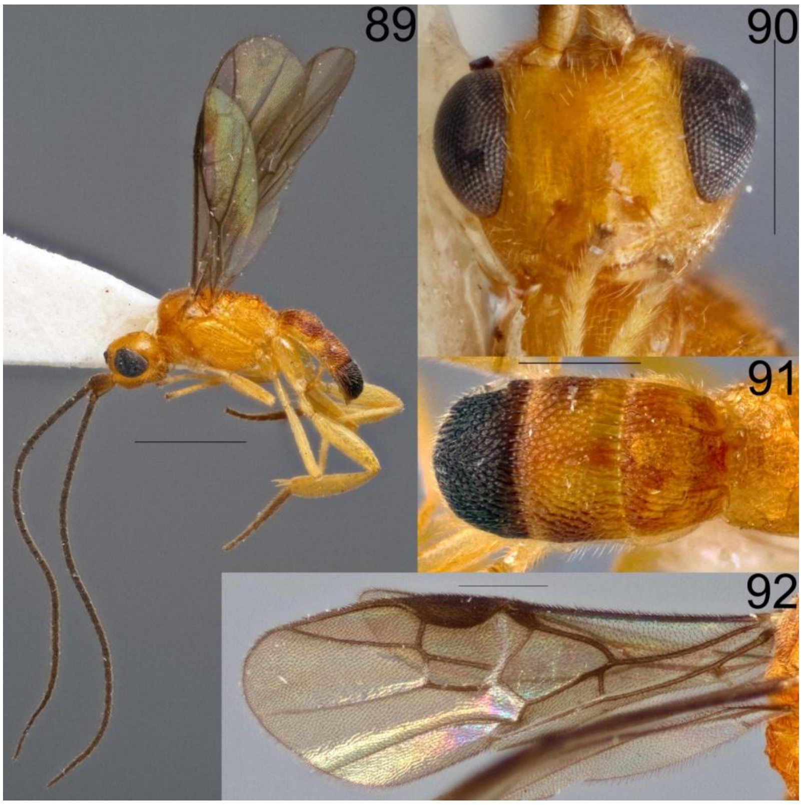
Type material

Holotype. Australia, Queensland: 1 ♀, “The Crater, near Herberton, N.Qld” “30. Jan 1972 D.K. McAlpine & G.A. Holloway” (AMS K358085). *Paratypes.* Australia, Queensland: 1 ♀, QLD: Hugh Nelson Ra., 21 km S of Atherton, 13 iii-1 v 1994, Storey & Brown, MT (WINC);

1 ♂, 2 km SSE Mt Spurgeon, 16°27'S, 145°12'E, 1100 m, 19-22 xi 1997, C.J. Burwell rainforest (QM ENT13.36).

Diagnosis

This species can be recognised by the combination of the overall yellow colour of the body and having long, brown antenna.



Figs 89-92. *P.szepligetii* sp. n., (89) habitus, lateral, holotype, scale = 1 mm; (90) head, anterior view, holotype, scale = 0.5 mm; (91) metasoma, dorsal view, holotype, scale = 0.5 mm; (92) fore wing, holotype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Description

Body measurements. Length of body 2.6–2.9 mm; ratio of antenna to length of body 1.3–1.6; ratio of length of fore wing to body 1.0–1.1; ratio of metasoma to mesosoma 1.0.

Head. Antenna with 33–34 antennomeres; ratio of length of third antennomere to fourth 1.2; length of third, fourth, penultimate, and terminal antennomere 4.4, 3.6, 2.0–2.6, and 2.6–4 their width, respectively; ratio of width of face in frontal view 1.3–1.4 its height; ratio of width of clypeus 2.1 in female, 1.2 in male its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 1.4; ratio of length of eye in dorsal view to length of temple 2.5 in female, 1.7 in male; ratio of posterior ocelli:POL:LOL:OOL 1.0:0.7–1.0:0.5–1.0:2.3–4.0; occipital strongly indented; face, frons, and vertex transverse costate.

Mesosoma. Notauli absent; scutellum rugose, weakly convex, not shiny; propodeal tubercles absent; mesopleuron shiny, coarse punctate; precoxal sulcus absent; ratio of height of mesosoma to length 1.4–1.5; hind coxa smooth; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 1.8–2.4, 3.7–3.8, 4.4, and 10.0–12.5 their width, respectively; ratio of length of posterior spur to length of basitarsus 0.5–0.53; ratio of tarsus to basitarsus 2.2; fore wing: third radial-abscissa (3-SR) present but short, antefurcal; SR-1 straight; 2-SR+M postfurcal; 2-R1 present; ratio of 2-R1 to 1-R1 0.46–0.53; ratio of length of 1-R1 to length of pterostigma 1.1; ratio of width to length of pterostigma 2.7–3.3; ratio of r:3-SR:SR-1:r-m 1.0:0.2–0.4:5.0–5.6:1.0–1.3.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.53–0.57; shape of carapace in lateral view straight, shape of individual tergites rounded; ratio of keels to metasoma length 0.1–0.18, keels parallel; tergites coarse rugose; third tergite with lobes; ratio of length of three metasomal tergites 1.0:1.0:0.9; sutures parallel.

Colour. Head, mesosoma, and legs yellow; antenna brown except scape and pedicel yellow; interocellar area dark; wings infuscated; wing venation, pterostigma, and parastigma brown; first two metasomal tergites yellow, third tergite dark brown.

Etymology

This species is named after G. Szépligeti for describing the genus *Phanerotomella*.

Distribution

Phanerotomella szepligetii is only known from north Queensland (Fig. 98).

Phanerotomella variata **sp. n.** (Figs 93-96, 97)

urn:lsid:zoobank.org:act:8B4A4FC0-D595-42DC-AE76-B3FC36B83BC3

Type material

Holotype. Australia, Western Australia: 1 ♂, “W.A.: Gleneagle State Forest. 29. xi. 2005, M.S. Harvey, Malaise Trap” (ANIC). *Paratype. Aus*tralia, Western Australia: 1 ♂, E of Blackwood NP, Blackwood Rd, 34°07.204'S, 115°32.406'E, 6 xi 2011, R. Kittel & L. Krieger sweeping (WAM SF008307-04).

Diagnosis

One of the few dark coloured species which differs from *P. castanea* and *P. dimorpha* by the white scape and legs, and from *P. obscura* by the sculpturing of the face and mesopleuron.

Figs 93-96. *P. variata* sp. n., (93) habitus, lateral, holotype, scale = 1 mm; (94) head, anterior view, holotype, scale = 0.5 mm; (95) metasoma, dorsal view, holotype, scale = 0.5 mm; (96) mesosoma, dorsal view, holotype, scale = 0.5 mm. This figure is published in colour in the online edition of this journal, which can be accessed via http://www.brill.nl/ise

Description (male)

Body measurements. Length of body 2.4–2.5 mm; ratio of length of antenna to body 1.2–1.3; ratio of length of fore wing to body 0.92–1.0; ratio of metasoma to mesosoma 1.0.

Head. Antenna with 34 antennomeres; ratio of length of third antennomere to fourth 1.1–1.5; length of third and fourth antennomere 3.5–4.0 and 2.6–3.3 their width, respectively; ratio of width of face in frontal view 1.8–2.3 its height; ratio of width of clypeus 1.3–1.6 its height; teeth on clypeus absent; ratio of length of malar space to length of base of mandible 3.5–3.8; ratio of length of eye in dorsal view to length of temple 1.1–1.2; ratio of posterior ocelli:POL:LOL:OOL 1.0:1.3–1.7:1.3–1.7:4.0–4.7; occipital weakly indented; face, frons, and vertex finely rugose.

Mesosoma. Notauli absent; scutellum finely rugose, not shiny; weak propodeal tubercles present; mesopleuron rugose; precoxal sulcus absent; ratio of height of mesosoma to length 1.7–1.8; coxa shiny, smooth; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 2.0–2.5, 4.0, 5.2, and 17.0 their width, respectively; ratio of length of posterior spur to length of basal tarsus 0.5; ratio of tarsus to basitarsus 2.6; fore wing: third radial-abscissa (3-SR) absent, interstitial; SR-1 slightly curved; 2-SR+M postfurcal; 2-R1 present; ratio of 2-R1 to 1-R1 0.23–0.26; ratio of length 1-R1 equal to pterostigma length; ratio of width to length of pterostigma 2.3–2.9; ratio of r:3-SR:SR-1:r-m 1.0:?:4.4–5.0:1.0–1.6.

Metasoma. Shape of metasomal carapace oval in dorsal view, ratio of width to length 0.56; shape of carapace in lateral view straight, shape of individual tergites flat; keels short, 0.06–0.1 of metasoma, keels converging; tergites coarse rugose; third tergite with four small lobes; ratio of length of three metasomal tergites 1.0:0.9–1.0:0.8; sutures parallel.
Colour. Antenna, head, and mesosoma dark brown; legs brown; wing infuscated; wing venation, pterostigma, and parastigma brown; first metasomal tergite dark white, second and third tergites dark brown. Paratype has a completely brown metasoma.
Female. Unknown.

Comments

We describe *P. variata* on the basis of two males because the rugose sculpturing of the head, the absence of clypeal teeth and the position of the 3-SR excludes them from being the sexually dimorphic form of any other described species.

Etymology

The name refers to the apparent variation in colour of the first metasomal tergite.

Distribution

This species is only known from south-western Western Australia (Fig. 97).

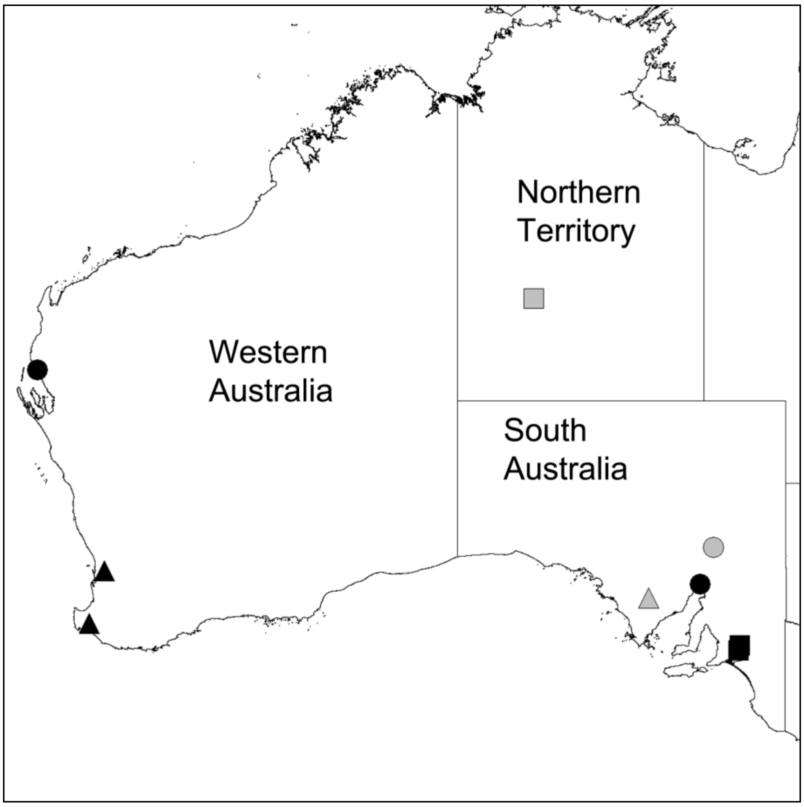


Fig. 97. Distribution map, black triangle: *P.variata* sp. n., black circle: *P. discoloria* sp. n., grey circle: *P. microcellata* sp. n., black square: *P. dentata* sp. n., grey triangle: *P. kimbaensis* sp. n., grey square: *P. minuta* Zettel, 1989 (type locality).

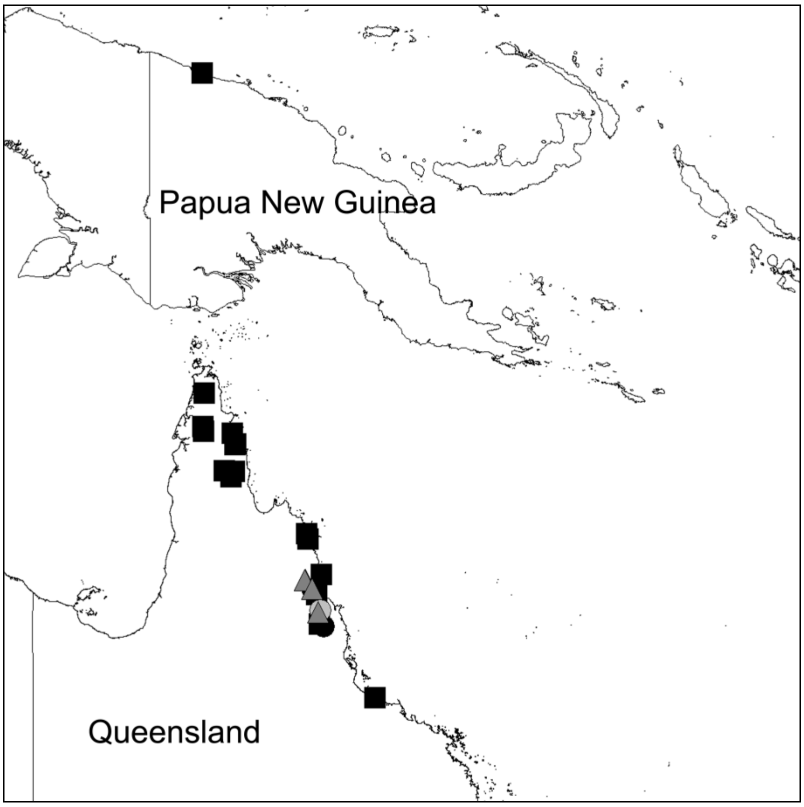


Fig. 98. Distribution map, black square: *P. longipes* Szépligeti, 1900 (including type locality), grey triangle: *P. australiensis* sp. n., grey circle: *P. dimorpha* sp. n., black circle: *P. szeptligetii* sp. n.

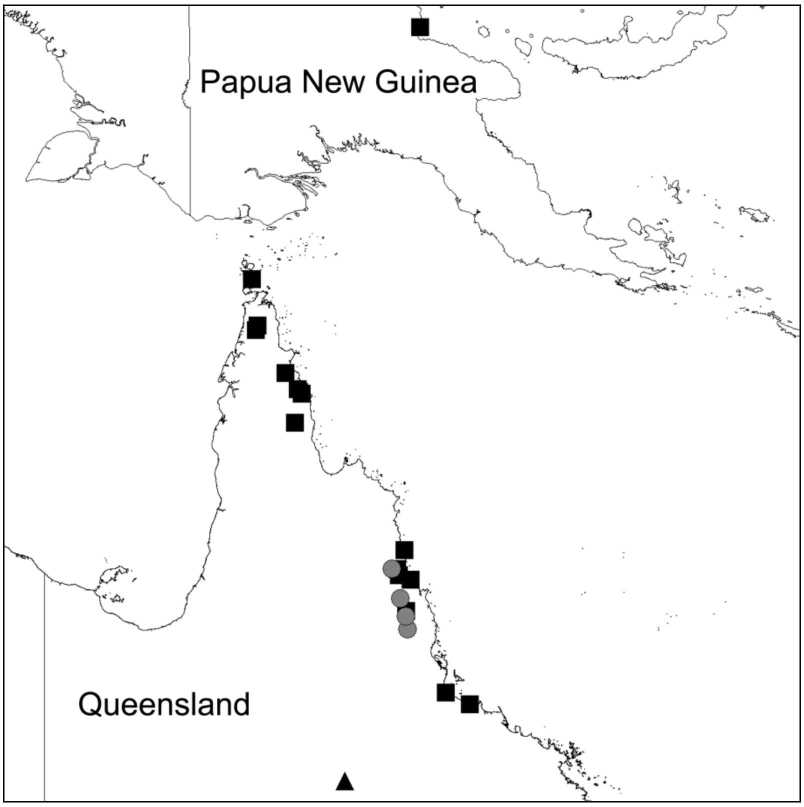


Fig. 99. Distribution map, black square: *P. sculpturata* Szépligeti, 1900 (including type locality), black triangle: *P. phanerotomoides* sp. n., grey circle: *P. castanea* sp. n.

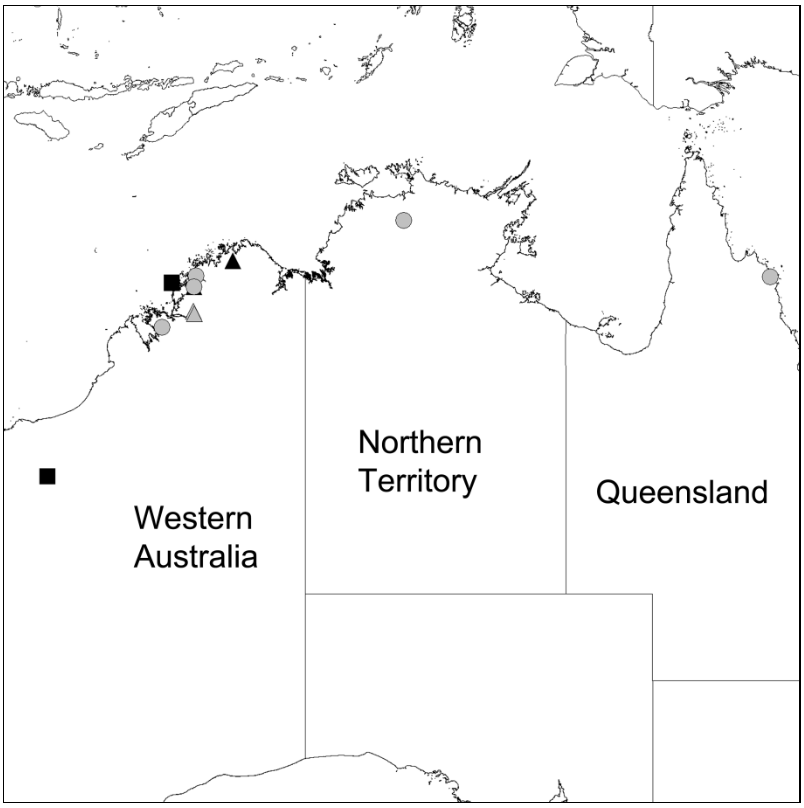


Fig. 100. Distribution map, black triangle: *P. pungogaster* sp. n., grey circle: *P. nivistigma* sp. n., grey triangle: *P. naumanni* sp. n., black square: *P. curtogaster* sp. n.

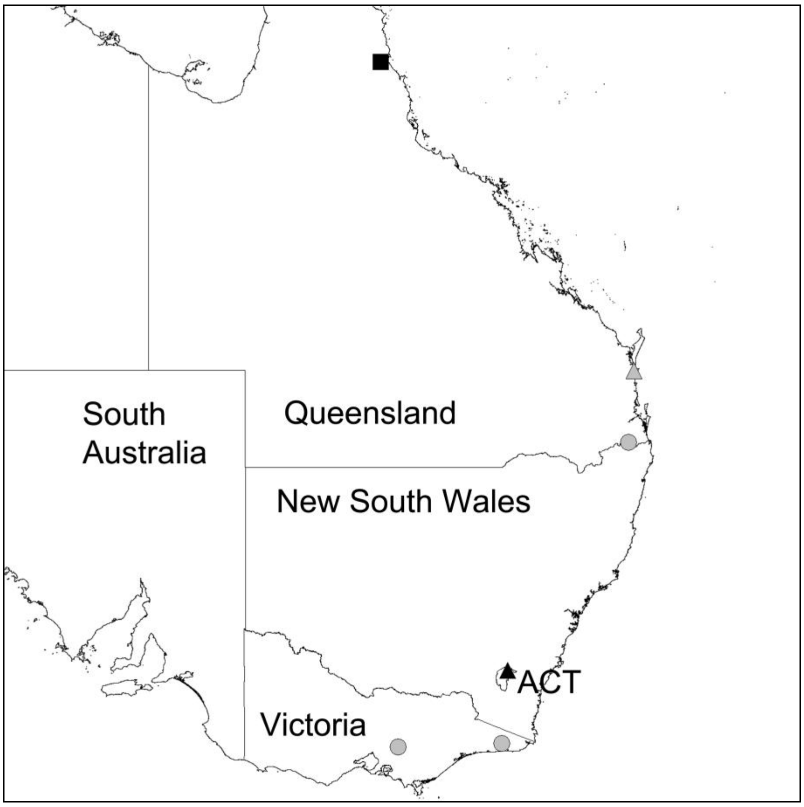


Fig. 101. Distribution map, black square: *P. kriegeri* sp. n., black triangle: *P. obscura* sp. n., grey circle: *P. brevivena* sp. n., grey triangle: *P. flavens* sp. n., ACT: Australian Capital Territory.

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We thank the Sir Mark Mitchell Foundation for supporting RNK by funding a visit to the Australian National Insect Collection, Canberra and a survey in south-west Western Australia. We also thank the Australian Biology Resources Study for their support of the project (TTC211-06 and ATC212-13 to RNK). This project was funded by the Adelaide PhD Scholarship International to RNK. We are in debt to Ms Nicole Fisher and Dr John La Salle (ANIC), Dr Gavin Broad (BNHM), Dr Jenö Papp and Mr Gellért Puskás (UNHM), Mr Brian Hanich and Dr Terry Houston (WAM), Dr David Britton (AMS), Mr Peter Hudson (SAM), and Dr Bob Kula (NMNH) for material and their hospitality during visits by RNK to their collections, as well as Dr David Wahl (AEI) for provided the images of *Phanerotomella minuta*. The survey in south-western Western Australia was conducted under the permit SF008307 issued by the Government of Western Australia. Our special thanks also go to Dr Lars Krieger for assistance on the field trip in Western Australia. We would like to thank the anonymous reviewers for their valuable comments and suggestions to improve the manuscript.

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Chapter 6: New species of chelonine wasps (Hymenoptera: Braconidae) from the Australian arid zone

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Statement of Authorship

Title of Paper	New species of chelonine wasps (Hymenoptera: Braconidae) from the Australian arid zone
Publication Status	○ Published ○ Accepted for Publication ● Submitted for Publication ○ Publication Style
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Author Contributions

By signing the Statement of Authorship, each author certifies that their stated contribution to the publication is accurate and that permission is granted for the publication to be included in the candidate's thesis.

Name of Principal Author (Candidate)	Rebecca N Kittel		
Contribution to the Paper	molecular work, morphological work, analysing the data, interpretation of data, writing the ms, obtaining funding		
Overall percentage (%)	90		
Signature		Date	

Name of Co-Author	Andy D Austin		
Contribution to the Paper	supervision of project, discussion of concepts, edit of manuscript		
Overall percentage (%)	10		
Signature		Date	12/3/14

Name of Co-Author			
Contribution to the Paper			
Overall percentage (%)			
Signature		Date	

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Abstract

Here we focus on the poorly studied braconid wasp subfamily Cheloninae for the southern arid zone of the continent using material, in part, resulting from comprehensive surveys of three arid reserves. The Bush Blitz Program is a multi-institutional project with the aim of documenting the diversity of the flora and fauna in Australia's National Reserve System, with describing new species being a key focus of the program. In total 11 species from the genera *Phanerotoma* and *Ascogaster* are treated, with species' delimitation based on both molecular and morphological data. Two species are redescribed (*Phanerotoma behriae* Zettel, 1988 and *P. decticauda* Zettel, 1988) and nine species are described as new (*Ascogaster brevivena* sp. nov., *A. ferruginegaster* sp. nov., *A. prolixogaster* sp. nov., *A. rubriscapa* sp. nov., *Phanerotoma bonbonensis* sp. nov., *P. bushblitz* sp. nov., *P. lutea* sp. nov., *P. nigerscapulata* sp. nov. and *P. witchelinaensis* sp. nov.). A key to the arid zone species of these two genera is provided, along with a species richness estimation of Australian chelonine wasps.

Keywords

Ascogaster, Bon Bon Station, Bush Blitz, Hiltaba Station, *Phanerotoma*, Witchelina Station.

Introduction

Although about 67,000 insects have been described for Australia (ABRS 2013), more than 45% of the continent has never been comprehensively surveyed for terrestrial invertebrates (Chapman 2009). To ameliorate this shortcoming, a biological survey program was initiated in 2010 to document the biodiversity of the national reserve system, with an emphasis on describing new species of plants and animals utilising the expertise of systematists from museums, herbaria, universities and other research institutions (e.g. Lambkin and Bartlett 2011, Namyatova et al. 2011, Baehr and Whyte 2012). This initiative, titled the Bush Blitz Program, is a partnership between the Australian Government, BHP Billiton and Earthwatch Australia, and is coordinated by the Australian Biological Resources Study (Bush Blitz 2013b, Bush Blitz 2013a).

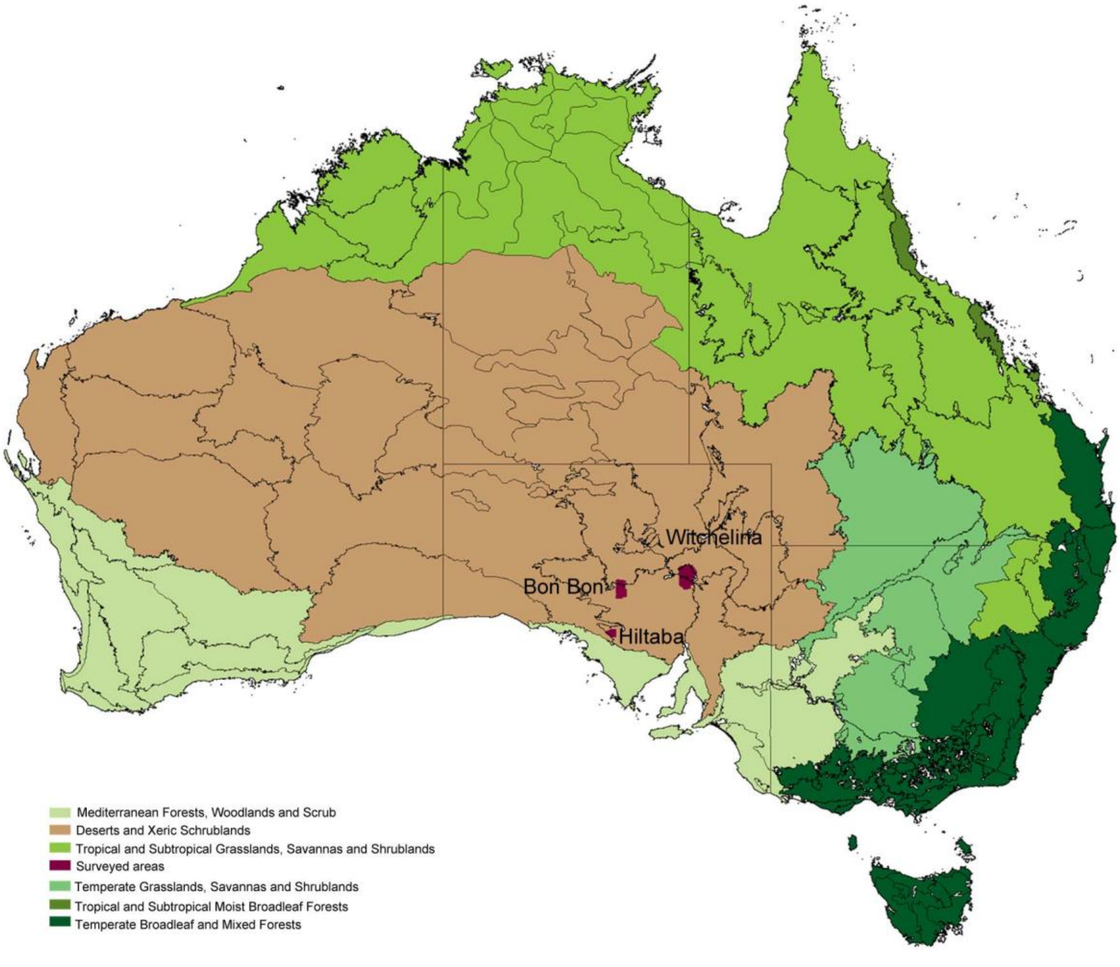

Figure 1. Map of the bioregions of Australia showing the central arid zone and the location of the three surveyed national reserves; Bon Bon Station, Hiltaba Station and Witchelina Station. The bioregions are based on the IBRA version 7 classification by the Australian Government.

As part of the Bush Blitz Program, the braconid wasp subfamily Cheloninae was surveyed for three arid zone locations of the National Reserve System in South Australia, viz. Bon Bon Station, Hiltaba Station and Witchelina Station (Fig. 1). Cheloninae is a moderately large subfamily of braconid wasps with more than 1,375 described species in 17 genera worldwide (Yu et al. 2005, Kittel and Austin 2014). The group can easily be distinguished from other braconid subfamilies on characters associated with the metasomal carapace, the postpectal carina, and fore wing venation (Shaw 1983, van Achterberg 1990, Zettel 1990c, Shaw 1997). Members of this subfamily are solitary egg-larval koinobiont parasitoids of Lepidoptera, where oviposition occurs into a host egg but development of the parasitoid is delayed until the host has emerged as a larva (Shaw and Huddleston 1991, Shaw 1997, LaSalle 2003).

The taxonomy of chelonine wasps is generally poorly known for Australia. The first species, *Phanerotoma australiensis,* was described by Ashmead (1900), followed soon after by Szépligeti (1900) who described species of *Phanerotoma*, *Phanerotomella* and *Chelonus*. In the following years several authors described additional new species (Cameron 1911, Turner 1917, Girault 1924, Baker 1926). After a hiatus of more than 50 years, further species were described by Zettel (1988a, 1989c) and Huddleston and Walker (1994). Most recently, (Kittel and Austin 2014, Kittel et al. in prep) have described two new genera, *Austroascogaster* and *Phanaustrotoma*, comprising six new species, and presented a key to genera and a synopsis of the 65 species known for the continent. Three interesting aspects can be identified in this overview of the continent's chelonine fauna; first, most previous species' descriptions, with a few exceptions, are based on very few specimens; second, little material has been added to Australian collections since about 1980, and third, the majority of described species have come from coastal regions, particularly areas around Sydney and Perth, while very few taxa have been described from the arid zone of central Australia.

As a first step to documenting the largely unknown chelonine fauna of the continent, particularly of the arid interior, we use material collected on the Bush Blitz surveys of the three arid southern Australian reserves above (Fig. 1), supplemented by material from major collections, to describe four new species of *Ascogaster* and five new *Phanerotoma*, to redescribe two widely distributed *Phanerotoma* species, and present a key to facilitate the species known from the region. In so doing we take an integrative approach to delineating species employing both fixed phenotypic differences and phylogenetic analysis of the Cytochrome c Oxidase subunit 1 (*COI*) barcoding region utilise GMYC and PTP analyses to estimate species boundaries. We also employ a Chao species richness estimator to calculate the likely diversity of the Australian fauna, and compare this to the number of morphospecies so far recognised.

Material and methods

Collecting locations, techniques and specimens

Three National Reserve System properties were surveyed as part of this project, all of which were previously large sheep grazing properties (stations), now set aside to preserve their biodiversity. Witchelina Station was surveyed from late September to early October 2010, and is located in the north-western part of the Flinders Ranges (Fig. 1). It was purchased by the Nature Foundation of South Australia and added to the National Reserve System in 2010. The property comprises 4,200 km^2 of river red gum and coolibah (eucalypt) woodland lining the usually dry creek beds, and bluebush (*Maireana* spp.) shrublands. Bon Station was surveyed in October 2010. This property has been owned by Bush Heritage Australia since 2008, is located 400 km west of Witchelina and 200 km south of Coober Pedy (Fig. 1). The area is situated between the Great Victoria Desert and the large salt lakes of Eyre, Torrens and Gairdner. Its desert landscape is dotted with salt lakes, freshwater wetlands, shrublands, bluebush plains, and arid-zone woodland. Hiltaba Station, a 775 km^2 area purchased by the Nature Foundation of South Australia in 2012, was survey in November 2012. It is located north of the Gawler Ranges, and is approximately 260 km west of Port Augusta (Fig. 1). It consists of rocky granite hills with open bluebush plains and mallee vegetation (*Eucalyptus* spp.).

A range of techniques were employed to collect material during the surveys, including yellow pan traps, light traps, Malaise traps and sweep-netting of vegetation. All material was initially stored in 100% ethanol (for DNA extractions) and later pinned. All available chelonine specimens were also borrowed from the major Australian collections (approximately 5,000 specimens in total) and, along with the material from Bush Blitz sites, were sorted to morphospecies. All relevant type material was examined and compared with the sorted morphospecies.

DNA sequencing

Genomic DNA was extracted from specimens preserved in 75-100% ethanol. The right hind leg was removed from each specimen and processed after the ethanol had evaporated. DNA extractions were performed using the Gentra Systems Puregene® DNA Purification Kit (Gentra Systems 2005): the leg was heated at 55°C in a 300 µl Cell lysis solution with 1.5 µl Proteinase K solution. After 12 -24 hrs, excessive proteins were removed by adding 100 µl Protein Perception solution. The DNA was washed in 300 µl Isopropanol (were 0.5 µl Glycogen was added) and afterwards in 300 µl 70% ethanol. DNA was restored using 50 µl

DNA hydration solution. Eppendorf thermal sequencers were employed to carry out the PCR amplification. Each reaction of 25 µl comprised 14.4 µl Nuclease free water, 2.5 µl Taq Gold Buffer, 3 µl $MgCl2$, 2 µl 10 mM dNTPs, 1µl of each forward and reverse Primer: Forward CI-J-1718 5'-GGAGGATTTGGAAATTGATTAGTTCC-3', reverse 1 CI-N-2191 5'-CCCGGTAAAATTAAAATATAAACTTC-3' (shorter) and reverse 2 CI-N-2329 5'-ACTGTAAATATATGATGAGCTCA-3' (longer) (Simon et al. 1994), 0.1 µl AmpliTaq Gold® DNA Polymerase (Applied Biosystems Inc.), and 1 µl DNA. PCR settings started with a denaturation step of 9 min at 95ºC, followed by 35 cycles of 30 sec 94ºC, 30 sec of 47 ºC, and an extension step of 1 min at 72ºC. The final extension step was for 6 min at 72ºC and 6 min at 24ºC. PCR products were purified using the Ultraclean™ PCR Clean-up™ Kit (MoBio Biosystems Inc.) and sequenced by the *Australian Genome Research Facility* Ltd (AGRF). For speciemens used and Genbank accession numbers see Table 1.

Table 1: Species of Ascogaster and Phanerotoma recognised in this study with their state distributions, project codes and GenBank accessions numbers.

Taxon	**Species names**	**State/Territory**	**Project code**	**GenBank #**
Ascogaster sp. 1		NSW	RK29	KJ438543
Ascogaster sp. 2		WA	RK196	KJ438545
Ascogaster sp. 3		NSW	RK28	KJ438541
Ascogaster sp. 4		SA	RK85	KJ438636
Ascogaster sp. 5		QLD	RK52	KJ438544
Ascogaster sp. 6		NSW	RK30	KJ438546
Ascogaster sp. 7		SA	RK181	KJ438555
Ascogaster sp. 8		QLD	RK192	KJ438556
Ascogaster sp. 9		QLD	RK280	KJ438557
Ascogaster sp. 10		SA	RK86	KJ438559
Ascogaster sp. 11		SA	RK141	KJ438561
Ascogaster sp. 12		SA	RK21	KJ438560
Ascogaster sp. 13		SA	RK16	KJ438562
Ascogaster sp. 14		SA	RK11	KJ438563
Ascogaster sp. 15		WA	RK191	KJ438564
Ascogaster sp. 16		WA	RK180	KJ438558
Ascogaster sp. 17		WA	RK308	KJ438565
Ascogaster sp. 18		QLD	RK279	KJ438638
Ascogaster sp. 19		WA	RK278	KJ438569
Ascogaster sp. 20		WA	RK324	KJ438570
Ascogaster sp. 21		QLD	RK187	KJ438550
Ascogaster sp. 22		NSW	RK70	KJ438635
Ascogaster sp. 23		QLD	RK289	KJ438530
Ascogaster sp. 24		NSW	RK35	KJ438535
Ascogaster sp. 24		SA	RK353	KJ438536
Ascogaster sp. 25		WA	RK320	KJ438538
Ascogaster sp. 26		NSW	RK27	KJ438537
Ascogaster sp. 27		WA	RK305	KJ438539
Ascogaster sp. 27		WA	RK304	KJ438637

Ascogaster sp. 27		WA	RK290	KJ438540
Ascogaster sp. 28		SA	RK80	KJ438566
Ascogaster sp. 28		SA	RK81	KJ438567
Ascogaster sp. 29	*ferruginegaster*	SA	RK48	KJ438568
Ascogaster sp. 30		QLD	RK277	KJ438542
Ascogaster sp. 31		SA	RK198	KJ438551
Ascogaster sp. 32		NSW	RK69	KJ438527
Ascogaster sp. 32		SA	RK10	KJ438528
Ascogaster sp. 33		SA	RK326	KJ438529
Ascogaster sp. 34	*rubriscapa*	SA	RK71	KJ438533
Ascogaster sp. 35	*prolixogaster*	SA	RK74	KJ438534
Ascogaster sp. 36	*brevivena*	QLD	RK186	KJ438547
Ascogaster sp. 36	*brevivena*	QLD	RK195	KJ438548
Ascogaster sp. 36	*brevivena*	SA	RK185	KJ438549
Ascogaster sp. 37		QLD	RK285	KJ438532
Ascogaster sp. 38		QLD	RK194	KJ438552
Ascogaster sp. 38		WA	RK293	KJ438553
Ascogaster sp. 38		WA	RK301	KJ438554
Ascogaster sp. 39		SA	RK158	KJ438639
Ascogaster sp. 40		SA	RK152	KJ438531
Ascogaster sp. 41		WA	RK200	KJ438526
Ascogaster sp. 42		SA	RK318	KJ438524
Ascogaster sp. 43		WA	RK337	KJ438525
Ascogaster sp. 44		SA	RK177	KJ438522
Ascogaster sp. 44		SA	RK178	KJ438523
Phanerotoma sp. 1		NSW	RK63	KJ438571
Phanerotoma sp. 1		SA	RK356	KJ438572
Phanerotoma sp. 1		WA	RK311	KJ438573
Phanerotoma sp. 2	*witchelinaensis*	SA	RK04	KJ438593
Phanerotoma sp. 3	*decticauda*	SA	RK491	KJ438574
Phanerotoma sp. 3	*decticauda*	SA	RK266	KJ438575
Phanerotoma sp. 3	*decticauda*	SA	RK413	KJ438576
Phanerotoma sp. 3	*decticauda*	SA	RK415	KJ438577
Phanerotoma sp. 3	*decticauda*	VIC	RK350	KJ438578
Phanerotoma sp. 3	*decticauda*	SA	RK267	KJ438579
Phanerotoma sp. 3	*decticauda*	SA	RK265	KJ438580
Phanerotoma sp. 3	*decticauda*	SA	RK409	KJ438581
Phanerotoma sp. 3	*decticauda*	SA	RK410	KJ438582
Phanerotoma sp. 3	*decticauda*	SA	RK02	KJ438586
Phanerotoma sp. 3	*decticauda*	SA	RK411	KJ438583
Phanerotoma sp. 3	*decticauda*	SA	RK416	KJ438584
Phanerotoma sp. 3	*decticauda*	SA	RK172	KJ438585
Phanerotoma sp. 3	*decticauda*	SA	RK271	KJ438587
Phanerotoma sp. 3	*decticauda*	SA	RK144	KJ438588
Phanerotoma sp. 3	*decticauda*	SA	RK150	KJ438589
Phanerotoma sp. 3	*decticauda*	SA	RK139	KJ438640
Phanerotoma sp. 3	*decticauda*	SA	RK263	KJ438591
Phanerotoma sp. 3	*decticauda*	SA	RK175	KJ438592
Phanerotoma sp. 3	*decticauda*	SA	RK269	KJ438590
Phanerotoma sp. 4	*nigerscapulata*	SA	RK251	KJ438594
Phanerotoma sp. 4	*nigerscapulata*	SA	RK09	KJ438595
Phanerotoma sp. 4	*nigerscapulata*	WA	RK310	KJ438597
Phanerotoma sp. 4	*nigerscapulata*	WA	RK309	KJ438598
Phanerotoma sp. 4	*nigerscapulata*	SA	RK412	KJ438596

Phanerotoma sp. 5		SA	RK408	KJ438603
Phanerotoma sp. 6		SA	RK418	KJ438604
Phanerotoma sp. 7		SA	RK140	KJ438605
Phanerotoma sp. 7		SA	RK143	KJ438606
Phanerotoma sp. 7		WA	RK258	KJ438607
Phanerotoma sp. 8		SA	RK351	KJ438608
Phanerotoma sp. 8		WA	RK313	KJ438609
Phanerotoma sp. 8		WA	RK312	KJ438610
Phanerotoma sp. 9		SA	RK160	KJ438625
Phanerotoma sp. 9		SA	RK249	KJ438626
Phanerotoma sp. 10		SA	RK03	KJ438634
Phanerotoma sp. 11	*bonbonensis*	SA	RK250	KJ438601
Phanerotoma sp. 11	*bonbonensis*	SA	RK58	KJ438599
Phanerotoma sp. 11	*bonbonensis*	SA	RK148	KJ438600
Phanerotoma sp. 11	*bonbonensis*	SA	RK417	KJ438602
Phanerotoma sp. 12	*bushblitz*	SA	RK272	KJ438627
Phanerotoma sp. 12	*bushblitz*	SA	RK407	KJ438628
Phanerotoma sp. 13		QLD	RK262	KJ438629
Phanerotoma sp. 14		SA	RK173	KJ438630
Phanerotoma sp. 14		SA	RK261	KJ438631
Phanerotoma sp. 15		SA	RK155	KJ438632
Phanerotoma sp. 15		WA	RK22	KJ438633
Phanerotoma sp. 16		WA	RK62	KJ438624
Phanerotoma sp. 17	*behriae*	SA	RK01	KJ438611
Phanerotoma sp. 17	*behriae*	WA	RK246	KJ438612
Phanerotoma sp. 17	*behriae*	SA	RK146	KJ438613
Phanerotoma sp. 17	*behriae*	SA	RK255	KJ438614
Phanerotoma sp. 17	*behriae*	SA	RK145	KJ438615
Phanerotoma sp. 17	*behriae*	SA	RK171	KJ438616
Phanerotoma sp. 17	*behriae*	SA	RK176	KJ438617
Phanerotoma sp. 17	*behriae*	SA	RK60	KJ438618
Phanerotoma sp. 17	*behriae*	WA	RK256	KJ438622
Phanerotoma sp. 17	*behriae*	SA	RK372	KJ438619
Phanerotoma sp. 17	*behriae*	SA	RK374	KJ438620
Phanerotoma sp. 17	*behriae*	SA	RK371	KJ438621
Phanerotoma sp. 18	*lutea*	SA	RK67	KJ438623
Phanerotomella sp.		WA	RK26	KJ438521
Chelonus sp.		SA	RK38	KJ438520
Euphorinae indent.		n/a	n/a	EU106964*
Ichneutinae indent.		n/a	n/a	EU106967*
Miracinae indent		n/a	n/a	EU106971*

* Murphy et al. 2008

Phylogenetic analysis of COI, species delimitation and concept

Onehundred and twenty one chelonine specimens were sequenced and three outgroups (Euphorinae, Ichneutinae, Miracinae taken from Murphy et al. (2008)) were used for the phylogenetic analyses. The sequences were aligned with the Clustal W (Thompson et al. 1994) plug-in in GeneiousPro (Drummond et al. 2011). The *COI* sequences comprise of 489 bp and have open reading frames. Six of the 54 specimens of *Ascogaster* had a 3bp indel in the *COI* sequence, representing the species 25, 28, 29, 34, and 35. This is rather uncommon, but not new among Hymenoptera (Schonfeld et al. 2011). Model selection was tested with JModeltest v.0.1.1 based on the Bayesian Information Criterion (Posada 2008). The alignments were exported in the appropriate format for further analysis.

Bayesian phylogenetic analysis was performed using MrBayes v.3.2.1 (Ronquist and Huelsenbeck 2003). Two independent analyses with four Monte Carlo Markov Chains (MCMC) each were run in parallel for 10 million generations under a GTR+I+G model. The first 25% were omitted as a burn-in. A consensus tree was created. Convergence was verified if the split frequencies fell below the 0.01 threshold.

The generalized mixed Yule-coalescent (GMYC) analysis is an established method to identify putative species based on molecular data. For the GMYC analyses the result of the phylogenetic analysis was used, although the optimal settings required the exclusion of outgroups (Astrin et al. 2012). The tree was first converted to an ultrametric tree using the package 'ape' (https://r-forge.r-project.org/projects/ape/) in the R environment (R Development Core Team 2011). The GMYC analyses were then conducted using the 'splits' package (http://r-forge.r-project.org/projects/splits/). We tested both analyses, one allowing for only a single speciation event and the other allowing for multiple events.

The Poisson tree processes (PTP) was also used to establish a putative species estimate based on the molecular data (Zhang et al. 2013). The PTP analysis requires a phylogenetic tree, however, recommends using a RAxML tree obtained through RAxML 7.6.3 Blackbox on the CIPRES Science Gateway V 3.3 (Miller et al. 2010). The analysis was conducted using Python. We then compared four independent species estimates; recognition of morphospecies based on fixed phenotypic differences, the PTP estimate, and GMYC with single threshold and multiple threshold estimates (Figs 2, 3) (see Pons et al. 2006, Fontaneto et al. 2007, Cook et al. 2010). Even though the PTP and GMYC analyses indicated the presence of cryptic species, we have refrained from describing them, and limited the study only to the description of the morphospecies (see Butcher et al. 2012), as the molecular data is based only on a single marker and the sequence variation is low in some cases. However, we indicate the presence of likely cryptic species in the comments section of for the relevant species, and plan to use the results here as a basis for testing cryptic species boundaries with additional markers in the future (Pons et al. 2006; Fontaneto 2007).

Species richness estimation

Species richness of Australian chelonines was calculated using a Chao species richness estimator implemented in the package 'SPECIES' (Wang 2011) (http://cran.r-project.org/web/packages/SPECIES/index.html) for the R environment (R Development Core Team 2011) for the morphospecies available, and based on frequencies of specimens per morphospecies (Wang and Lindsay 2005). These were calculated separately for each genus and summed, and also as a single estimate for Australian Cheloninae as a whole.

Terminology and Imaging

Terminology follows van Achterberg (1988), Karlsson and Ronquist (2012) and Eady (1968). Images were taken using a Visionary Digital BK+ photo system with a K2 lens system attached to a 7D Canon digital camera. Final images were stacked from multiple images using Zerene Stacker software (version 1.04) and edited in Adobe Photoshop CS5 (extended version 12.0x64). Measurements were taken using a Zeiss stereomicroscope and Adobe Photoshop CS5 software. The distribution maps were produced with DIVA-GIS (Hijmans et al. 2004). The bioregions in Figure 1 are based on the Interim Biogeographical Regionalisation for Australia (IBRA) version 7 classification by the Australian Government (28 November 2013).

Museums/collections

AMS Australian Museum Sydney, Sydney
ANIC Australian National Insect Collection, Canberra
BNHM British Natural History Museum, London, UK
GKIC RV Glatz Private Collection, Kangaroo Is, South Australia
IRSN Institut Royal des Sciences Naturelles de Belgique, Brussels
NMNH Smithsonian Institution National Museum of Natural History, Washington D.C.
MV Museum Victoria, Melbourne, Victoria
MAGNT Museum and Art Gallery of the Northern Territory, Darwin
QM Queensland Museum, Brisbane
SAM South Australian Museum, Adelaide
WAM Western Australian Museum, Perth
WINC Waite Insect and Nematode Collection, Adelaide

Results

Phylogenetic analysis and species delimitation

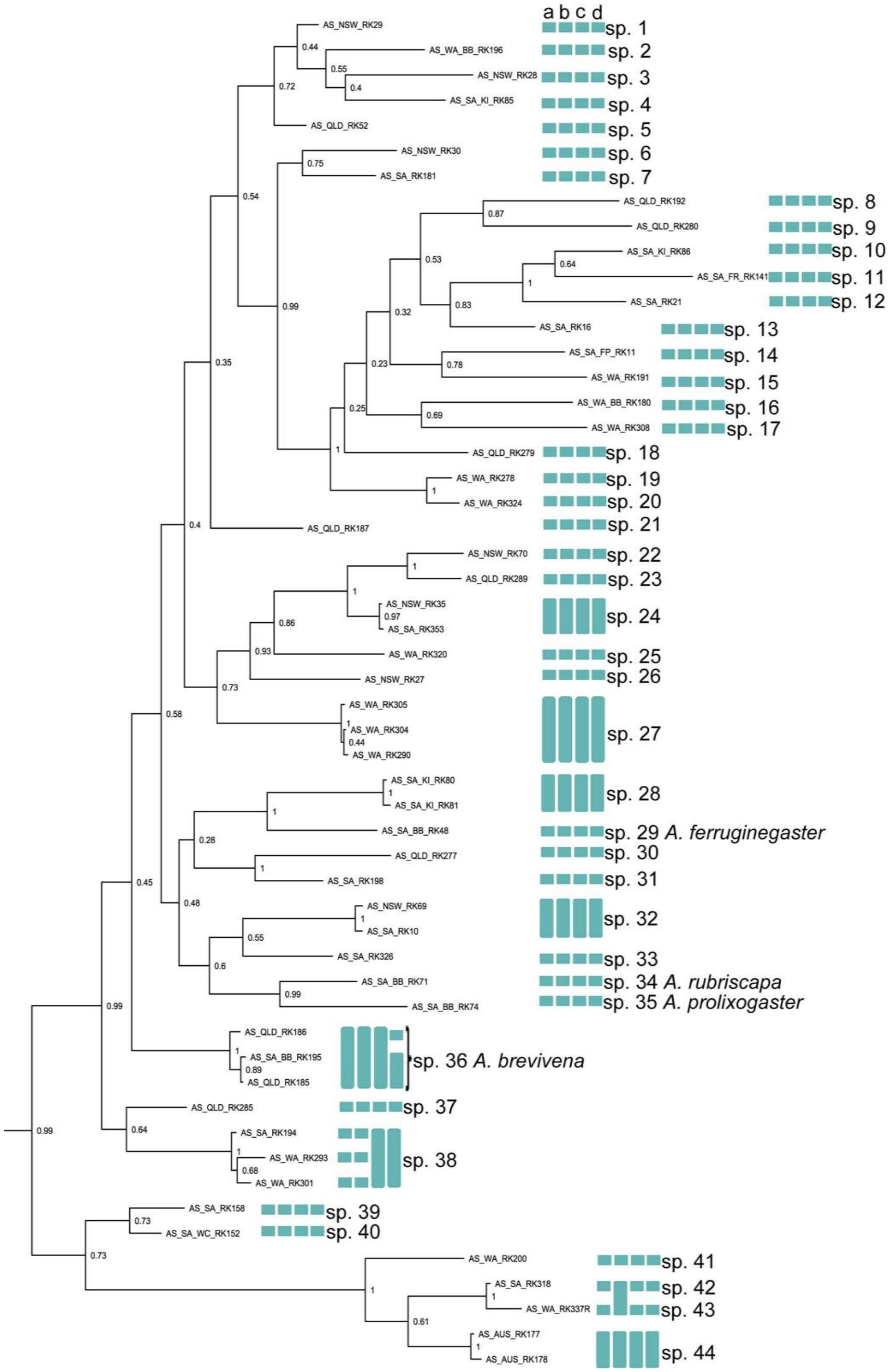

Figure 2. Resulting tree from the Bayesian phylogenetic analysis of the COI data for the genus *Ascogaster*. Numbers on branches show posterior probabilities. Abbreviations: (a) PTP analysis, (b) GMYC (single), (c) GMYC (multi), (d) morphology.

The Bayesian analysis of the *COI* data shows the phylogeny for Australian *Ascogaster* and *Phanerotoma* and the number of species predicted by the four estimation methods (Figs 2, 3).

For *Ascogaster* there was strong concordance between the four methods and, overall, the molecular-based estimates for species boundaries match our morphospecies. However, there are three exceptions.

For species 36, here described as *A. brevivena* sp. nov., PTP and GMYC predict a single species, but tentatively we initially recognised it as two morphospecies. It turned out that the two morphospecies were represented by single but opposite sexes, so we made the pragmatic decision that they represent a single sexually dimorphic taxon. For species 38, PTP and GMYC (single) both predicted three species but based on morphology and GMYC (multi), only one species could be identified thus suggesting, albeit inconclusively, the presence of cryptic species. Lastly, for species 42 and 43, GMYC (single) suggested a single species but the other three estimates including morphology suggested two separate species. In total, the data indicate 44 species of *Ascogaster* for which we have molecular data, four of which occur in the southern arid zone and are described here.

The results for *Phanerotoma* (Fig. 3) were similar to those for *Ascogaster* in that there was strong concordance between the molecular-based estimates and recognition of morphospecies. The major exception was for species 3, *P. decticauda*, which was estimated to represent seven species by PTP, GMYC (single) and GMYC (multi), thus suggesting the presence of cryptic species. The specimens showed some morphological variation but none of the seven clades had any fixed differences. Further studies of male genitalia, host association and sequence data from additional markers will undoubtedly help confirm the validity of these cryptic taxa.

Minor differences were evident in species 1, species 14 and species 17/18. But in each case two of the three molecular-based estimates matched the recognition of morphospecies. In total, the data indicate 18 species of *Phanerotoma* for which we have molecular data, seven of which occur in the southern arid zone and are described/redescribed here.

Species richness estimation

Examination of the approximately 5,000 Australian chelonine specimens available led to the recognition of 195 morphospecies (Table 2). When the Chao species richness estimator was applied to the same set of specimens for each genus separately it generated a figure of 262 species in total, with a range of 225-377 species (Table 2). When the data were pooled for all specimens (irrespective of genus) the Chao estimator predicted a total species richness of 278 species with a range of 253-370.

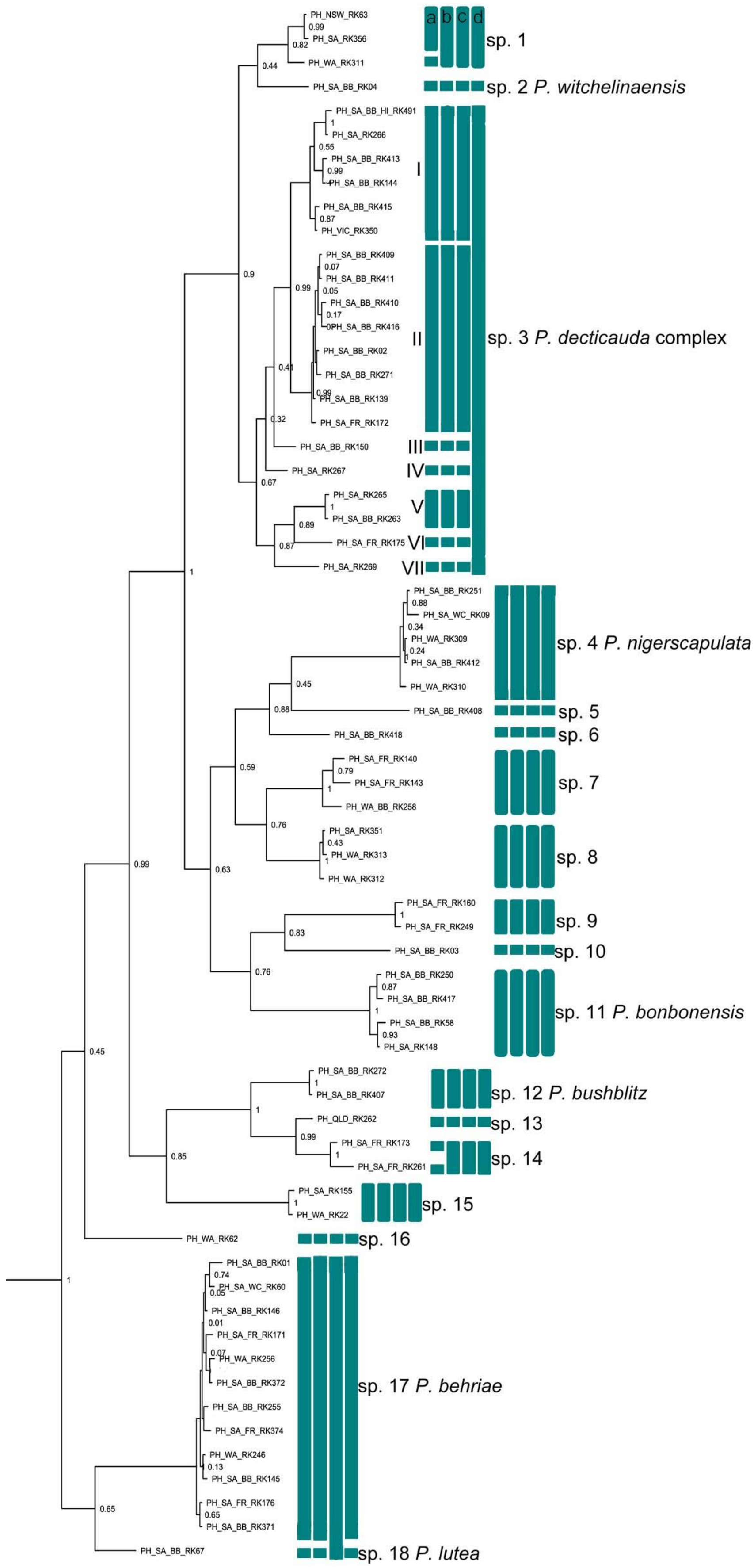

Figure 3. Resulting tree from the Bayesian phylogenetic analysis of the COI data for the genus *Phanerotoma*. Numbers on branches show posterior probabilities. Abbreviations: (a) PTP analysis, (b) GMYC (single), (c) GMYC (multi), (d) morphology.

The Chao estimator requires an unbiased collecting effort of an area which is clearly not the case for most terrestrial invertebrates, as indicated for Australian chelonines where the collection intensity has been far greater in eastern Australia, compared with the relative meagre collecting effort in the arid zone and western part of the continent. Also, a large number of morphospecies are represented by a single specimen, suggesting that collecting intensity in general, as well as geographically, needs to be significantly improved. In this respect, programs such as Bush Blitz can make a significant contribution and help ameliorate this situation. Although the accuracy of the Chao estimator is likely to be limited it still provide a useful starting point and indicates that there are possibly 60-170 chelonine species yet to be discovered on the Australian continent.

Table 2: Comparison of Australian chelonine species richness based on morphospecies delineation and the calculated species richness using a Chao estimator.

Genus	**Morphospecies**	**Chao estimated species richness**	**Ranges of Chao estimation**
Ascogaster	68	116	105-138
Austroascogaster	4	5	3-14
Chelonus	57	68	59-83
Phanerotoma	42	43	35-59
Phanaustrotoma	2	3	2-35
Phanerotomella	21	26	20-47
Wushenia	1	n/a (1)	n/a (1)
Total	**195**	**262**	**225-377**

Taxonomic treatment of species

Genus ***Ascogaster*** Wesmael, 1835

(Figures 2, 4-7, 15)

http://species-id.net/wiki/Ascogaster

Type. *Ascogaster instabilis* Wesmael, 1835: 227 (by subsequent designation: Förster, 1862: 244), IRSN [examined].

Ascogaster: Shenefelt 1973: 814, Shaw 1983: 7, Huddleston 1984: 348, Tang and Marsh 1994: 281.

For diagnosis of Australian taxa see (Kittel and Austin 2014).

Comments

Leptodrepana, described by Shaw (1983) from the new world, is accepted as a valid genus by some authors (Brajkovic et al. 2010), but others have treated it as a synonym of *Ascogaster* (van Achterberg 1990, Yu et al. 2005). Tang *et al.* (1994) followed van Achterberg's synonymy and treated his new species from China as *Ascogaster,* but also suggested that a comprehensive revision of the group was needed as some species showed intermediate characters between *Ascogaster* and *Leptodrepana*. Shaw (1997) discussed the difficult status of *Leptodrepana*, arguing for a separate genus since *Ascogaster* would otherwise be paraphyletic. However, no comprehensive analysiss has been untertaken to resolve this question. Thus we follow van Achterberg's synonymy, and point out that *Ascogaster brevivena* sp. nov. exhibits intermediate characters between these two genera, e.g. having equilateral ocelli like *Leptodrepana*.

Key to *Ascogaster* from the Australian arid zone

1 SR-1 not completely sclerotised, not extending to the margin of fore wing (Fig. 4e); female with 22 antennomeres; ocelli equilateral (Fig. 4c) ………………………… ……………………………………………………… ***Ascogaster brevivena* sp. nov.**

- SR-1 completely sclerotised, extending to the margin of fore wing (Fig. 5e); female with 19 antennomeres; ocelli isosceles (Fig. 5c) ……………………..…............... 2

2 Carapace elongate with extended tip, teeth on posterior end present (Fig. 6a) ………. ……………………………………………….… ***Ascogaster prolixogaster* sp. nov.**

- Carapace oval, but not elongated, without teeth on posterior end (Fig. 4a) ……….... 3

3 Carapace and legs orange (Fig 5a); notauli absent ………………………………..... ……………………………………………….. ***Ascogaster ferruginegaster* sp. nov.**

- Carapace black (Fig. 7a), legs brown with black coxa (Fig 7a); notauli present …... …………………………….………………….….. ***Ascogaster rubriscapa* sp. nov.**

Ascogaster brevivena sp. nov.

(Figures 4a-e, 15)

Description (female)

Body measurements. Length of body 2.3–2.5 mm; ratio of antenna to body 0.78–0.79 in females, 1.06 in males; ratio of length of fore wing to body 0.94–0.97 in females, 0.85 in males; ratio of length of metasoma to mesosoma 1.2.

Head. Antenna with 22 antennomeres in females, 24 antennomere in males; ratio of length of third antennomere to fourth 1.1 in females, 1.25 in males; ratio of length of third, fourth, penultimate, and terminal antennomere 3.5–3.8, 3.3–3.7, 0.9–1.2, and 1.3–1.6 in females, 3, 3, 1.3, and 1.7 in males their width, respectively; ratio of length of eye in dorsal view to length of temple 4.3 in females, 4.2 in males; ocelli equilateral; imaginary line between anterior margin of posterior ocelli is not touching the anterior ocellus; ratio of width of face in anterior view to its height 1.9–2.1 in females, 1.8 in males; ratio of width of clypeus to its height 1.0–1.1; clypeus without teeth; ratio of length of malar space to base of mandible 1.6–1.7 in females, 1.4 in males; face and frons punctuate; eyes with sparsely minute setae; ratio posterior ocelli:POL:LOL:OOL 1.0:1.0:0.7–0.8:2.2–2.6.

Mesosoma. Middle lobe of mesoscutum fine rugose; notauli absent; mesoscutellum shiny, fine punctate, weakly convex; mesopleuron shiny, smooth; precoxal sulcus present; ratio of height of mesosoma to its length 1.5 in females, 1.7 in males; hind coxa shiny, smooth; ratio of length of hind tibia to hind tarsus 1.0–1.1; ratio hind coxa, hind femur, hind tibia, and hind tarsus 1.8–2.2, 3.1–3.5, 5.2–5.5, and 13.0–18.0 in females, 2.1, 4.2, 4.8, and 12.5 in males their width, respectively; ratio of length of posterior spur to length of basal tarsus 0.55 in females, 0.48 in males; fore wing: 2-R1 absent; ratio of length of 1-R1 to length of pterostigma 0.9–1.0; ratio of width of pterostigma to its length 2.5–2.8; ratio r:3-SR:SR-1:r-m 1.0:1.0–1.3:1.1–2.2:0.7 in females, 1.0:0.9:5.5:0.8 in males; SR-1 only basally sclerotised; 1-SR+M emanating from base of parastigma; 2-SR+M antefurcal or interstitial.

Metasoma. Shape of metasoma oval in dorsal view; ratio of width of metasoma to its length 0.55; carapace broadens to posterior end in lateral view; ratio keel to metasomal length 0.1; carapace rugose.

Colour. Head brown, paler around eyes; anterior half of antenna light brown, posterior half dark brown; mesosoma black; wings with long brown hair given a smoky appearance of the wings, with a white band underneath the parastigma; legs white, with femur and apical end of tibia brown; anterior end of carapace white, extending dorsal into the posterior dark end.

Male. Head beige; antenna light brown; mesosoma black; legs as female but paler; wings infuscate; wing venation brown; metasoma anterior half white, posterior half black.

Diagnosis. Females differ from all other *Ascogaster* by having a reduced SR-1 vein (not extending to the margin of the fore wing).

Specimens examined. Holotype, Australia (South Australia): 1 ♀, “27 October 2010, Bon Bon Station 30°25'29"S, 135°28'41"E, Bush Blitz survey, R. Kittel, at light”

(SAM). **Paratypes, Australia (Queensland)**:1 ♀, Mt Glorious, Hiller property, 27°20'S, 152°46'E, 12 xiii 1998, N. Power, MT (WINC); 1 ♀, SEQ: Enogera Res., site 3, 27°27'S, 152°55'E, 27 i-15 iii 2000, C.J. Burwell, S.G. Evans, malaise 1000m 50274 (QM); 1 ♂, SEQ: East Woodmillar, 250m, 25°41'S, 151°36'E, 21 viii-10 x 1998, G.B. Monteith, vine scrub, FIT 7255 (WINC).

Biology. Unknown.

Etymology. The name ‘brevivena’ reflects the unusual short SR-1 vein in the fore wing of the females.

Distribution. Northern South Australia (Bon Bon Station), Queensland (Fig. 15).

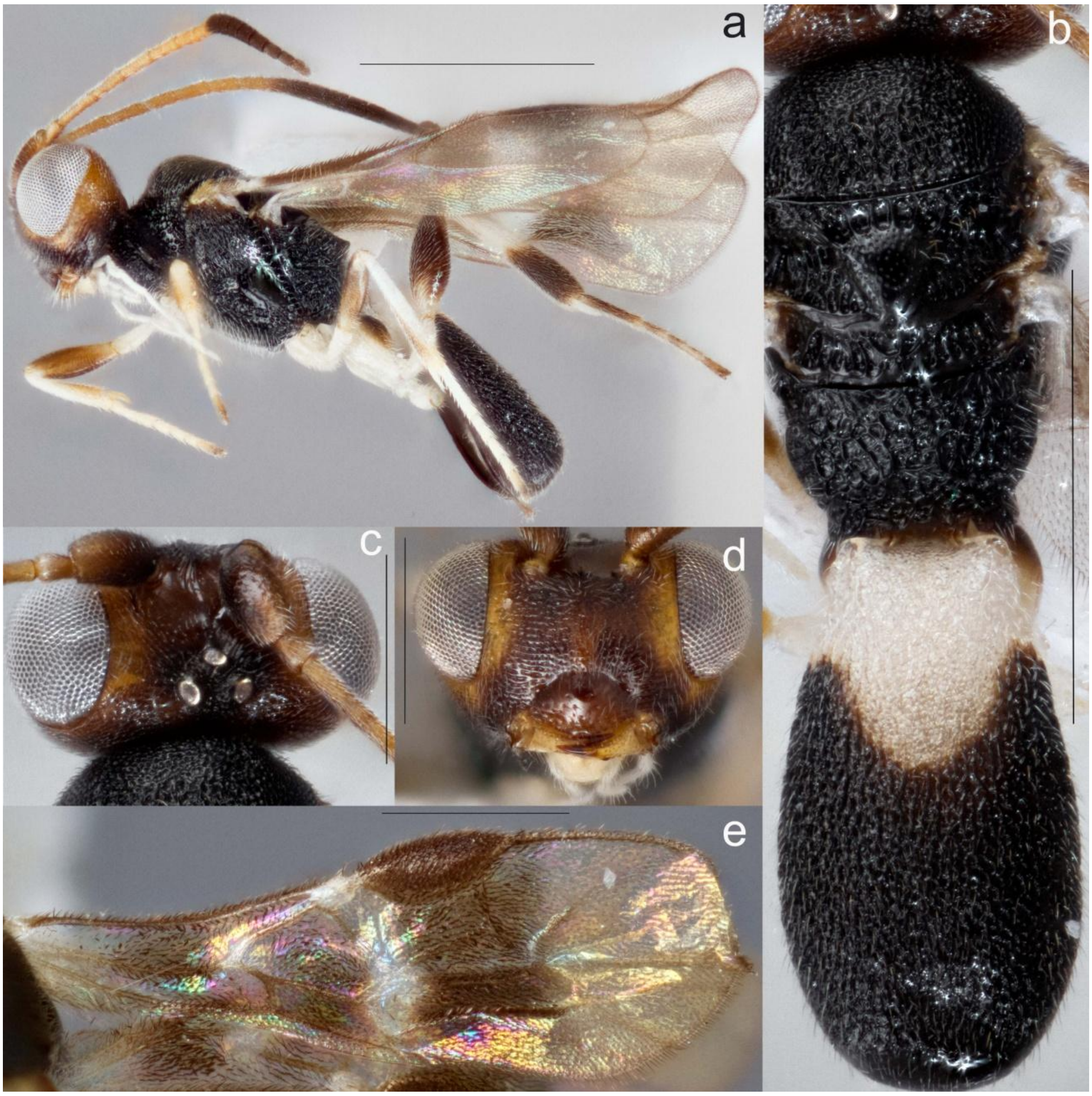

Figure 4. *Ascogaster brevivena* sp. nov.: (a) habitus, lateral, holotype, scale line = 1mm; (b) mesosoma and metasoma, dorsal view, holotype, scale line = 1 mm; (c) head, dorsal, holotype, scale line = 0.5 mm; (d) head, anterior, holotype, scale line = 0.5 mm; (e) fore wing, paratype, scale line = 0.5 mm.

Ascogaster ferruginegaster sp. nov.

(Figures 5a-e, 15)

Description (female)

Body measurements. Length of body 3.05–3.95 mm; ratio of antenna to body 0.7–0.9; ratio of length of fore wing to body 0.75–0.88; ratio of length of metasoma to mesosoma 1.1.

Head. Antenna with 19 antennomeres; ratio of length of third antennomere to fourth 0.9; ratio of length of third, fourth, penultimate, and terminal antennomere 4.0–6.0, 6.0, 2.0, and 2.0–3.0 their width, respectively; ratio of length of eye in dorsal view to length of temple 3.3–3.6; ocelli isosceles; imaginary line between anterior margin of posterior ocelli is not touching the anterior ocellus; ratio of width of face in anterior view to its height 2–2.4; ratio of width of clypeus to its height 1.0–1.3; clypeus without teeth; ratio of length of malar space to base of mandible 3.0; face fine punctuate; frons fine rugose; eyes glabrous; ratio posterior ocelli:POL:LOL:OOL 1.0:2.6–3.6:1.2–1.8:2.4–4.2.

Mesosoma. Middle lobe of mesoscutum punctuate; notauli absent; mesoscutellum shiny, fine punctuate, weakly convex; mesopleuron shiny, fine punctuate; precoxal sulcus present; ratio height of mesosoma to length 1.6–1.7; hind coxa shiny, smooth; ratio of length of hind tibia to hind tarsus 0.8–1.0; ratio hind coxa, hind femur, hind tibia, and hind tarsus 1.5–1.8, 3.7–4.2, 4.0–5.3, and 13.0–24.0 their width, respectively; ratio of length of posterior spur to length of basal tarsus 0.4–0.46; fore wing: 2-R1 present; ratio of length of 1-R1 to length of pterostigma 0.8–0.9; ratio of width of pterostigma to its length 2.0–4.0; ratio r:3-SR:SR-1:r-m 1.0:0.9–1.2:4.4:0.9–1.6; SR-1 completely sclerotised; 1-SR+M emanating from 1+M; 2-SR+M antefurcal or interstitial.

Metasoma. Shape of metasoma oval in dorsal view; ratio of width of metasoma to its length 0.5–0.6; carapace broadens to posterior end in lateral view; ratio keel to metasoma length 0.2–0.3; carapace fine rugose.

Colour. Head and metasoma black; antenna brown; legs and carapace red brown; wing venation, parastigma and pterostigma dark brown.

Diagnosis. The colour of the carapace distinguishes this species from all currently described species in Australia.

Specimens examined. Holotype, Australia (South Australia): 1 ♀, “18 October 2010 Witchelina Station 29°55'11"S, 137°56'13"E, S. Mantel, sweeping; Bush blitz Survey SM080, on *Pittosporum angustifolia*” (SAM). **Paratypes, Australia (Queensland)**: 1 ♀, 13 km E by S Weipa, 12.40S, 143.00W, 16 i-16 ii 1994, P. Zborowski, D Khalu, MT (ANIC); 1 ♀, 13 km E by S Weipa, 12.40S, 143.00W, 15 xi-16 xii 1993, P. Zborowski, MT (ANIC); 1

♀, 13 km E by S Weipa, 12.40S, 143.00W, 12 ix-24 x 1993, P. Zborowski & D. Rentz, MT (ANIC); 1 ♀, 13 km E by S Weipa, 12.40S, 143.00W, 15 xi-16 xii 1993, P. Zborowski, FIT (ANIC); **Northern Territory**: 1 ♀, 1 km E Baralil Ck nr Jabiru, 25 vi 1980, I.D. Naumann, LT, ex ethanol collection (ANIC); 1 ♀, Amadeus Basin, 30 vi 1962, P. Ranford, ex ethanol collection (ANIC).

Male. Unknown.

Biology. The holotype was collected from *Pittosporum angustifolia*.

Etymology. The name refers to the red brown carapace.

Distribution. Northern Territory, Queensland, South Australia (Witchelina Station) (Fig. 15).

Figure 5. *Ascogaster ferruginegaster* sp. nov.: (a) habitus, lateral, holotype, scale line = 1 mm; (b) head, anterior, holotype, scale line = 0.5 mm; (c) head, dorsal, holotype, scale line = 1 mm; (d) mesosoma dorsal, holotype, scale line = 1 mm; (e) fore wing, holotype, scale line = 1mm.

Ascogaster prolixogaster sp. nov.

(Figures 6a-d, 15)

Figure 6. *Ascogaster prolixogaster* sp. nov.: (a) habitus, lateral, holotype, scale line = 1 mm; (b) head, anterior, holotype, scale line = 0.5 mm; (c) metasoma, dorsal, holotype, scale line = 1 mm; (d) fore wing, paratype, scale line = 1 mm.

Description (female)

Body measurements. Length of body 3.65–5.8 mm; ratio of antenna to body 0.6–0.8; ratio of length of fore wing to body 0.7–0.8; ratio of length of metasoma to mesosoma 1.3–1.5.

Head. Antenna with 19 antennomeres; ratio of length of third antennomere to fourth 1.1–1.2; ratio of length of third, fourth, penultimate, and terminal antennomere 10.0, 8.0–10.0, 2.0, and 2–2.5 their width, respectively; ratio of length of eye in dorsal view to length of temple 2.5–3.2; ocelli isosceles; imaginary line between anterior margin of posterior ocelli is not touching the anterior ocellus; ratio of width of face in anterior view to its height 1.9–2.3; ratio of width of clypeus to its height 1.0–1.4; clypeus without teeth; ratio of length malar space to base of mandible 1.9–2.8; face punctuate; frons rugose; eyes glabrous; ratio posterior ocelli:POL:LOL:OOL 1.0:2.6–3.6:1.3–2.0:2.9–4.4.

Metasoma. Middle lobe of mesoscutum punctuate; notauli weakly present; mesoscutellum shiny, fine punctuate, convex; mesopleuron shiny, punctuate; precoxal sulcus present; ratio of height of mesosoma to its length 1.7–1.8; hind coxa shiny, fine punctuate; ratio of length of hind tibia to hind tarsus 0.9; ratio hind coxa, hind femur, hind tibia, and hind tarsus 2.0, 3.0–4.0, 4.0–5.0, and 14.0–16.0 their width, respectively; ratio of length of posterior spur to length of basal tarsus 0.3–0.5; fore wing: 2-R1 absent; ratio of length of 1-R1 to length of pterostigma 0.9; ratio of width of pterostigma to its length 2.7–3.0; ratio r:3-SR:SR-1:r-m 1.0:0.8–0.9:3.8–4.4:0.9–1.1; SR-1 completely sclerotised; 1-SR+M emanating from 1+M; 2-SR+M antefurcal.

Metasoma. Shape of metasoma long oval from dorsal view; ratio of width of metasoma to its length 0.4–0.5; carapace broadens to posterior end in lateral view and narrows down in dorsal view, with an extended tip for the ovipositor; ratio keel to metasoma length 0.03–0.04; carapace rugose.

Colour. Black; femur, tibia and tarsus dark brown to brown.

Diagnosis. The shape of the carapace with its elongated tip is unique among *Ascogaster*.

Specimens examined. **Holotype, Australia (South Australia)**: 1 ♀, “25-28 Oct 2010; Bon Bon Station 30°'37.56'S, 135°24.18'E, S. Mantel, F. Colombo, R. Kittel & G. Taylor, Malaise trap amongst *Senna artemisioides* , *Acacia tetragonophila*, *Acacia aneura* & *Acacia victoria*; Bush Blitz survey 367 Malaise 9” (SAM). **Paratypes, Australia (New South Wales)**:1 ♀, Pigeon House Ra. via Nerriga, 25 x 1979, I.D. Naumann, J.C. Cardale (ANIC); 2 ♀♀, Trangie, 21 x 1949, S.J. Paramonov (ANIC); 2 ♀♀, 1902, W.W. Frogatt Collection (ANIC); 3 ♀♀, Trangie, 20 x 1949, E.F. Riek (ANIC); **Queensland**:1 ♀, Bundaberg, 18 ix 1972, H. Frauca (ANIC); **South Australia**:1 ♀, Brookfield Con Pk, 34.19S, 139.30E, 2 xii 1991-2 i 1992, J. Steiman, S. Williams (ANIC); **Victoria**:1 ♀, 15 km S Yarrara, 34.33S, 141.25E, 18 x 1983, I.D. Naumann, J.C. Cardale (ANIC); **Western Australia**:1 ♀, 30W Coolgardie, 29 x 1958, E.F. Riek (ANIC); 1 ♀, 12 N Norseman, 25 xi 1958, E.F. Riek (ANIC), 1 ♀, 12mi WSW of Eucla Motel, 7 x 1968, Key, Upton, Balderson (ANIC); 1 ♀, 17.7 km S of Nerren Nerren HS, N of Galena, North-West Coast Hwy, 27 ix 1973, L.P. Kelsey (ANIC); 1 ♀, Broomehill, 33.51S, 117.38E, 11 xi 1978, R.P. Mcmillan (WAM); 1 ♀, Lake Cronin, 32°23'S, 119°46'E, 19-26 ix 1978, T.F. Houston *et al.* (WAM).

Other material, Australia (New South Wales): 1 ♀, 1902, W.W. Frogatt Collection (ANIC); mounted on the same cardboard with a specimen from another braconid subfamily.

Male. Unknown.

Biology. Unknown.

Etymology. The name reflects the elongated tip of the carapace.

Distribution. Widely spread across Australia (including Bon Bon Station in SA), except Northern Territory and Tasmania (Fig. 15).

Ascogaster rubriscapa sp. nov.

(Figures 7a-e, 15)

Description (female)

Body measurements. Length of body 4.4 mm; ratio of antenna to body 0.5; ratio of length of fore wing to body 0.7; ratio of length of metasoma to mesosoma 1.4.

Head. Antenna with 19 antennomeres; ratio of length of third antennomere to fourth 1.2; ratio of length of third, fourth, penultimate, and terminal antennomere 5.8, 4.8, 1.7, and 2.3 their width, respectively; ratio of length of eye in dorsal view to length of temple 5.8; ocelli isosceles; imaginary line between anterior margin of posterior ocelli is not touching the anterior ocellus; ratio of width of face in anterior view to its height 2.4; ratio of width of clypeus to its height 2.0; clypeus without teeth; ratio of length malar space to base of mandible 2.8; face punctuate; frons rugose; eyes glabrous; ratio posterior ocelli:LOL:POL:OOL 1.0:3.0:1.5:3.0.

Mesosoma. Middle lobe of mesoscutum punctuate; notauli present; mesoscutellum shiny, fine punctuate, weakly convex; mesopleuron shiny, punctuate; precoxal sulcus present; ratio of height of mesosoma to its length 1.5; hind coxa shiny, fine punctuate; ratio of length of hind tibia to hind tarsus 1.0; ratio hind coxa, hind femur, hind tibia, and hind tarsus 1.7, 5.6, 4.7, and 11.0 their width, respectively; ratio of length of posterior spur to length of basal tarsus 0.5; fore wing: 2-R1 absent; ratio of length of 1-R1 to length of pterostigma 1.0; ratio of width of pterostigma to its length 2.8; ratio r:3-SR:SR-1:r-m 1.0:0.7:4.2:0.8; SR-1 completely sclerotised; 1-SR+M emanating from 1+M; 2-SR+M antefurcal.

Metasoma. Shape of metasoma long oval in dorsal view; ratio of width of metasoma to its length 0.48; carapace broadens strongly to posterior end in lateral view; ratio keel to metasoma length 0.11; carapace rugose.

Colour. Black; except legs, pedicel, and wing venation brown.

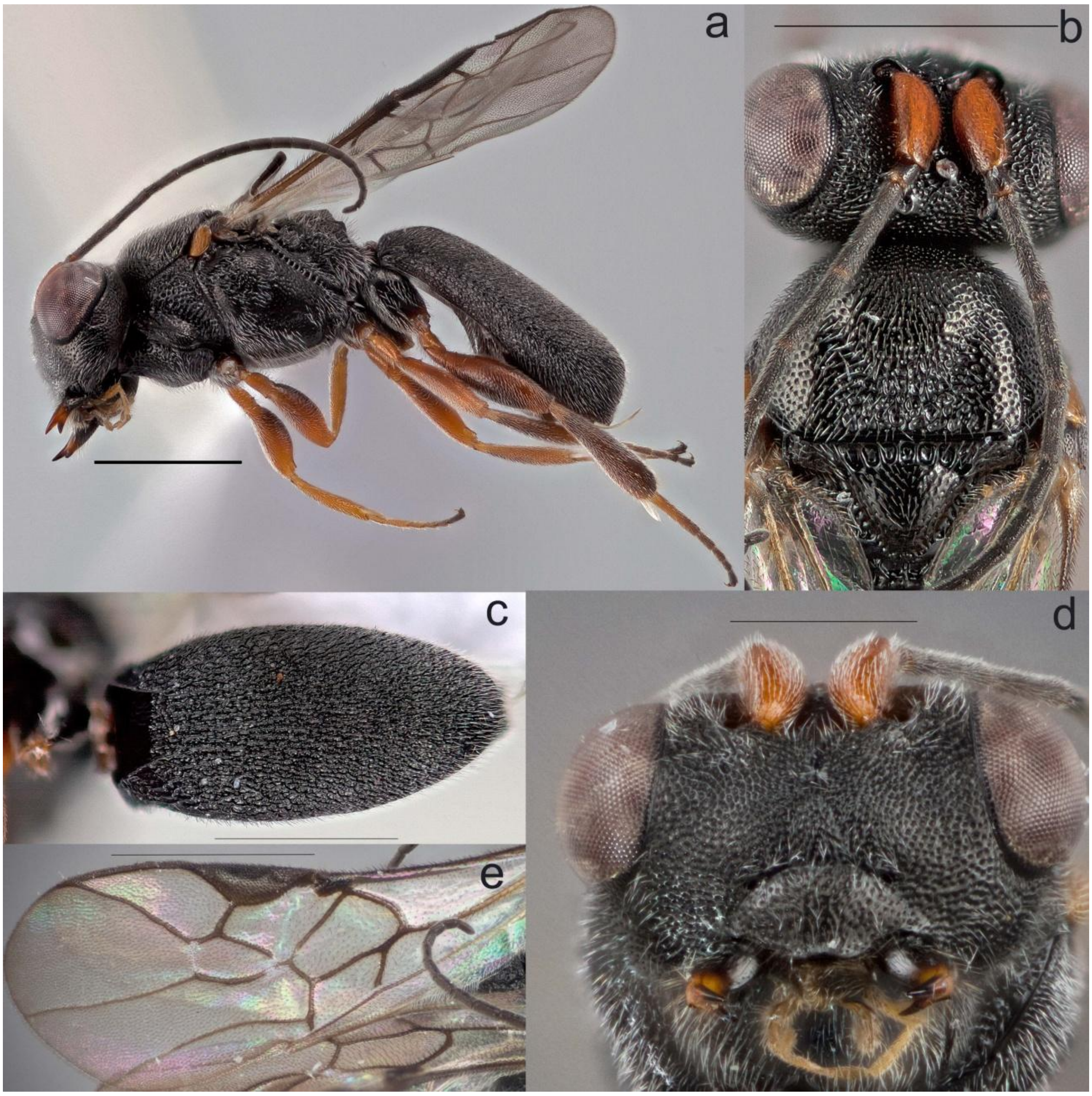

Figure 7. *Ascogaster rubriscapa* sp. nov.: (a) habitus, lateral, holotype, scale line = 1 mm; (b) mesosoma, dorsal, holotype, scale line = 1 mm; (c) metasoma, dorsal, holotype, scale line = 1 mm; (d) head, anterior view, holotype, scale line = 0.5 mm; (e) fore wing, holotype, scale line = 1 mm.

Diagnosis. Superficially similar to *A. prolixogaster*, but *A. rubriscapa* lacks the elongated tip of the carapace.

Specimens examined. Holotype, Australia (South Australia): 1 ♀, "25-28 Oct 2010, Bon Bon Station 30°37.56'S, 135°24.18'E, S. Mantel, F. Colombo, R. Kittel & G. Taylor, Malaise trap amongst *Senna artemisioides* , *Acacia tetragonophila*, *Acacia aneura*, and *Acacia victoria*; Bush Blitz survey 367 Malaise 9" (SAM).

Male. Unknown.

Biology. Unknown.

Etymology. The name refers to the red scape of the specimen.

Diagnosis. Superficially similar to *A. prolixogaster*, but *A. rubriscapa* lacks the elongated tip of the carapace.

Distribution. South Australia (Bon Bon Station) (Fig. 15).

Genus ***Phanerotoma*** Wesmael, 1838

(Figures 3, 8-14, 16-18)

http://species-id.net/wiki/Phanerotoma

Type *Chelonus dentata* Wesmael, 1838: 165 (designated by Haliday, 1840: 63) IRSN [examined].

Phanerotoma: Shenefelt 1973: 909, Zettel, 1988a: 216; Zettel 1988b: 199, 1989a: 318, 1989b: 528;van Achterberg, 1990: 10; Zettel 1990a: 4, 1990b: 147, 1990d: 1, 1990e: 153, 1990f: 336, 1991: 375, 1992a: 664, 1992b: 278; Kittel and Austin, 2014.

For diagnosis of Australian taxa see (Kittel and Austin 2014).

Comments

Van Achterberg (1990) stated in his diagnosis of *Phanerotoma* the presence of three distinctive clypeal teeth, although the number of teeth varies between two and three (Zettel 1990c). However, for Australia only a minority of species have three clypeal teeth and belong to a species group including *P. behriae, P. lutea* sp. nov., *P. novaguineensis* and *pacifica* which have a reduced r vein and a much longer 3-SR vein.

The subgenus *Bracotritoma* was discussed by van Achterberg (1990) and a detailed key was provided to distinguish it from the subgenus *Phanerotoma*, however, *Bracotritoma* was later synonymised by Zettel (1990c). The Australian *Phanerotoma* fauna consists of species which are not easily recognised as belonging to either subgenus and thus we follow Zettel's definition here.

Key to *Phanerotoma* from the Australian arid zone

1 Three teeth present on clypeus (Fig. 9b); r short (Fig. 9d) ……………………….…….. 2

- Two teeth present on clypeus (Fig. 8b); r long (Fig. 8e) …………………………….. 3

2 First and second metasomal tergites white, third orange (Fig.8d); face, vertex and frons finely rugose (Figs 7b-c) ………..…..……... ***Phanerotoma behriae* Zettel, 1988**

- All metasomal tergites completely yellow (Fig. 12c); face, vertex and frons strigose (Figs 12b) ……….………………………..…………... ***Phanerotoma lutea* sp. nov.**

3 Carapace narrowing to a pointed posterior tip, in dorsal view (Fig. 14d); ratio of first metasomal tergite to third >1.8; ……………... ***Phanerotoma witchelinaensis* sp. nov.**

- Posterior end of carapace rounded in dorsal view (Fig. 8d); ratio of first metasomal tergite to third <1.8; ……………………………………………………….……………… 4

4 Posterior end of carapace of female not indented (Fig. 13a) ...……………………..….. 5

- Posterior end of carapace of female deeply indented (Fig. 10c) ….…………………… 6

5 Carapace with tergites longitudinally strigose; face, vertex and frons finely rugose (Figs 7b-c) .... ***Phanerotoma nigerscapulata* sp. nov.**

- Carapace with tergites rugose (Fig. 11b); face, vertex and frons finely punctate (Fig. 11d) ……………………………….……..…… ***Phanerotoma decticauda* Zettel, 1988**

6 All tergites of carapace rugose (Fig. 10c); metasoma longer or equal in length to mesosoma (Fig. 10a)……….. ………………………. ***Phanerotoma bushblitz* sp. nov**.

- First and second tergites strigose, third tergite rugose (Fig. 9d); metasoma 1.1-1.3 x longer than mesosoma (Fig. 9a) ………………... ***Phanerotoma bonbonensis* sp. nov.**

Phanerotoma behriae Zettel, 1988

(Figures 8a-e, 18)

Phanerotoma behriae Zettel, 1988: 234. Holotype: BNHM [examined]. Type locality: Adelaide, SA. Host: *Etiella beherii* (Zeller, 1948) (Pyralidae).

Redescription

Body measurements. Length of body 2.5–5.6 mm; ratio of antenna to body 0.7–0.8; ratio of length of fore wing to body 0.8; ratio of length of metasoma to mesosoma 1.15.

Head. Ratio of length of third antennomere to fourth 0.9–1.1; ratio of length of third, fourth, penultimate, and terminal antennomere 2.4–3.3, 2.6–3.6, 2.3–2.6, and 2.0–3.3 their width, respectively; ratio of length of eye in dorsal view to length of temple 1.9–2.4; ratio of width of face in anterior view to its height 1.8–2.3; ratio of width of clypeus to its height 1.5–2.15; clypeus with two teeth; ratio of length of malar space to base of mandible 0.6–0.8; face, vertex and frons fine rugose; ratio posterior ocelli:LOL:POL:OOL 1.0:0.6–0.9:0.7:2.3–2.8.

Mesosoma. Middle lobe of mesoscutum rugose; notauli absent; mesoscutellum rugose; mesopleuron rugose; precoxal sulcus absent; ratio of height of mesosoma to its length 1.6; propodeal tubercles present; blister on mid tibia present; ratio of length of hind tibia to hind tarsus 1.0; ratio of length of posterior spur to length of basal tarsus 0.4–0.5; ratio hind coxa, hind femur, hind tibia, and hind tarsus 1.7, 3.0–3.8, 4.5–6.0, and 16.0–17.5 their width, respectively; fore wing: 2-R1 absent; ratio of length of 1-R1 to length of pterostigma 1.1–1.2;

ratio of width of pterostigma to its length 2.7–3.7; ratio r:3-SR:SR-1:r-m 1.0:5.0–5.8:12.3–14.8:1.1–2.0; 1-SR+M emanating from parastigma; 2-SR+M interstitial.

Metasoma. Shape of metasoma oval in dorsal view; ratio of width of metasoma to its length 0.6; carapace flat in lateral view; ratio of keel to length of metasoma 0.2–0.3; first and second metasomal tergite longitudinal strigose; third tergite rugose; posterior suture curved anteriorly; posterior end of carapace with a straight margin; ratio of the three metasomal tergites 1.0:0.9:1.4–1.5.

Colour. Head and mesosoma orange; antenna beige, gradually darker to tip; legs beige with posterior half of tibia orange; hind tibia black white black striped; wing venation brown, pterostigma and parastigma brown, white between them; wing hyaline; first and second metasomal tergite white, third orange.

Figure 8. *Phanerotoma behriae* Zettel, 1988: (a) habitus, lateral, holotype, scale line = 1 mm, inset type label; (b) head, anterior, holotype, scale line = 0.5 mm; (c) head, dorsal, holotype, scale line = 1 mm; (d) metasoma, dorsal, holotype, scale line = 1 mm; (e) fore wing, other material, scale line = 1 mm.

Diagnosis. Three teeth present on clypeus, distinct colour pattern: first and second metasomal tergites white, last tergite orange.

Specimens examined. Holotype, Australia (South Australia): ♀, *Phanerotoma behriae* Zettel, 1988, Adelaide. **Other material, Australia (New South Wales)**: 1♀, Evanslookout, Blue Mts NP, 4 xii 1971, G. Daniels, M.V. lamp (AMS, K358164); 1 unknown sex, Congo, 8 km SEbyE of Moruya, 35.58S, 150.09E, 15-16 v1980, M.S. Upton (ANIC); 1 ♂, 20mi SSW of Bourke on bank of Darling River, 25 xii 1973, G.F. Gross, LT (SAM); 1 ♂, Fowlers Gap Res Stn, 31.05S, 141.42E, 8-9 xii 1982, I.D. Naumann, ex ethanol (ANIC); 1 ♂, 32 km E of Warren, 8 xii 1976 E.M. Exley & T. Low on *Atalaya hemiglauca* (QM); **Northern Territory**: 1 ♂, 32 km WNW of Alice Springs, 23.36S, 133.35E, 8 x 1978, J.C. Cardale (ANIC); 8 ♂♂, 1♀, 39 km E Alice Springs, 23.41S, 134.15E, 25 ix 1978, J.C. Cardale, ex ethanol (ANIC); 4 ♂♂, 1♀, 39 km E Alice Springs, 23.41S, 134.15E, 5 x 1978, J.C. Cardale, ex ethanol (ANIC); 1 ♂, 53 km EbyN of Alice Springs, 23.43S, 134.22E, 6 x 1978, J.C. Cardale (ANIC); 3♀, 1 ♂, Roe Creek, 12 km SWbyW Alice springs, 23.46S, 133.47E, 9 x1978, J.C. Cardale, ex ethanol (ANIC); 1 ♂, 3 km SSW of Kathrine, 14.30S, 132.15E, 12 xi 1979, I.D. Naumann, collected LT, ex alcohol collection (ANIC); 1 ♂, Robin Falls, 13.21S, 131.08E, 8 vi 1993, E.D. Edwards (ANIC); 1 ♂, 1 ♀, Camfield River, 17.01S, 131.07E, 4 vi 1993, E.D. Edwards (ANIC); 1 ♀, 35 km S of The Granites Mine, Tanami Desert, 20.51S, 130.16E, 29 x-2 xi 1988, D.C.F. Rentz (ANIC); 1 ♂, Camfield HS 17.08S 131.21E, 17-18 viii 1982, I. Archibald, M.V. light (MAGNT); 1 ♀, Ruby NP, 23°28'50"S, 134°59'00"E, 20 iii 1993, J.A. Forrest & D. Hirst, MT (in ethanol) (SAM); 6 ♂♂, 8 ♀♀, 7 unknown sex, Darwin, G.F. Hill; Par on larvae of *Lygraphia clylusalis* Walk "Currajong Bag shelter moth" (in ethanol) (SAM); 1 unknown sex, 10mi NW of Yuenduni Creekbed, 20 ii1968, LT (SAM); 1 ♀, 10mi E of Daly River, 28 vi1972, B.K. Head, LT (SAM); 1 ♂, 2.8 mi S of Renner Springs, 8 iv 1966, N. McFarland, UV light (SAM); 1 ♂, Tennant Creek, 8 viii1990, R.P. McMillan (WAM 82895); 1 ♀, 10mi N Mid Br Gasgoyne Ranges, 11 vii 1958, R.P. McMillan (WAM 82811); 3 ♀♀, Kakadu NP, 3 km S Nourlangie Camp, 17 xi 1992, A.D. Austin & P.C. Dangerfield, LT, *Acacia* and *Pandanus* (WINC); 1 ♂, 195 km E of Ayers Rock, on Lassiter's Hwy, 5 xi 1992, P.C. Dangerfield, sweeping *Leptospermum* sp. (WINC); 1 ♀, Magela Ck ARR, 28 v 1991, Wells & Webber, MV, LT (WINC); 1 ♀, Darwin, Alawa, 18 v 1991, A. Wells, LT (WINC); 1 ♂, Devil's Marbles CP, 11 vi 1992, A.D. Austin & P.C. Dangerfield, LT (WINC); 1 ♀, 5 km NNW of Cahills Crossing (East Alligator River), 12.23S, 137.52E, 5 x 1975 A. Allwood & T. Angeles (QM); **Queensland:** 1 ♂, 7 km S Batavia Downs, 12.43S, 142.42E, 24 x-23 xi 1992, P. Zborowski & A. Calder, MT (ANIC); 1

♀, Mt. White, 13.58S, 143.11E, 12 i 1994, P. Zborowski & E.D. Edwards, LT (ANIC); 1 ♀, Mt Cook NP, 15.29S, 145.16E, 10-12 v 1981, I.D. Naumann, ex ethanol (ANIC); 1 ♂, Australia, Nth Qld, Black River, 9 xii 1990 T. Woodger (ANIC); 1 ♀, Bacusia, Nth Qld, Ken., 5 xi 2003, J. Sandery (ANIC); 2 ♂♂, 5 km EbyS Peak Hill, 10.44S, 142.29E, 20 vi 1993, P. Zborowski & I.D. Naumann (ANIC); 1 ♂, Heathlands, 11.45S, 142.35E, 12 viii 1993, P. Zborowski & J. Balderson (ANIC); 1 ♂, 1 ♀, Moreton HS, 12.27S, 142.38E, 21 viii 1992 I.D. Naumann & P. Zborowski, LT (ANIC); 1 ♂, 7 km S Batavia Downs, 12.43S, 142.42E, 23 xi-11 xii 1992, P. Zborowski & W. Dressler, MT (ANIC); 1 ♂, 1 km WbyN Bolt Head, 12.55S, 143.05E, 22 x 1992, P. Zborowski & T. Weir (ANIC); 3 ♀♀, Rokeby HS, 13.40S, 142.40E, 23 vi 1993, I.D. Naumann & P. Zborowski, LT (ANIC); 1 ♂, 3 km SbyE Coen, 13.55S, 143.11E, 24 vi 1993, I.D. Naumann & P. Zborowski, LT (ANIC); 1 ♂, The Bend, 3 km NbyW Coen, 13.56S, 143.12E, 25 vi 1989, I.D. Naumann, ex ethanol (ANIC); 1 ♂, Edwards River, 14.41S, 142.16E, 14 ix 1993, P. Zborowski & S. Shattuck, LT (ANIC); 1 ♂, Mt Webb NP, 15.04S, 145.07E, 27-20 iv 1981, I.D. Naumann, ex ethanol; collected LT (ANIC); 4 ♂♂, 2 ♀♀, Hann R, 73 km NWbyW Laura, 15.12E, 143.52E, 27 vi 1986, J.C. Cardale, at MV light (ANIC); 1 ♀, Battle Camp Range, 15.17S, 144.44E, 27 vi 1993, P. Zborowski, LT (ANIC); 1 ♂, 28 km NbyE Musselbrook Camp, Amphitheatre, 18.21S, 138.11E, 12 v 1995, I.D. Naumann, LT (ANIC); 1 ♂, 1 ♀, 8 km SEbyE Musselbrook Camp, 18.38S, 138.11E, 11 v 1995, I.D. Naumann, LT (ANIC); 1 ♀, 9 km SEbyE Musselbrook Camp, 18.38S, 138.12E, 20 v 1995, I.D. Naumann, LT (ANIC); 1 ♂, 10 km SE Musselbrook Camp, 18.39S, 138.12E, 13 v 1995, I.D. Naumann, LT (ANIC); 1 ♂, 1 ♀, 16 km SSE Musselbrook Camp, 18.44S, 138.12E, 18 v 1995, I.D. Naumann, LT (ANIC); 1 ♀, Musselbrook Resources Centre, Lawn Hill NP, nr monument, 160m, 18°35'52"S, 138°07'23"E, 19 iv 1995, G. Daniels & M.A. Schneider, mv lamp (QM); 1 ♂, Border Waterhole, 15 km W of Musselbrook Resources Centre Lawn Hill NP, 18°36'44"S, 137°59'30"E, 200m, 6 v 1995, G. Daniels & M.A. Schneider (QM); 1 ♂, Louie Ck Lawn Hill NP, 18.47S, 138.31E, 17-18 v 1995 I.D. Naumann (ANIC); 1 ♀, 70.23 km ENE (72°) Betoota, 25°34'31"S, 141°26'14"E, 5 iv 1994, G.V. Maynard & G. Davis, from *Grevillea sida cordifolia* GVM-AB040256 (ANIC); 3 ♀♀, Canobie Stn, 23-25 xi 1984, D.S. Gibson, light (ANIC); 1 ♀, Hughenden Stn, 19-21 xi 1984, D.S. Gibson, LT (ANIC); 1 ♂, 1.5 km WNW Riversleigh HS at Gregory River ford, 20 iv 1986, J.A. Forrest, blacklight (in ethanol) (SAM); 1 ♀, 2 km WNW Riversleigh HS, nr Gregory River, 28 iv 1986, J.A. Forrest, blacklight (in ethanol) (SAM); 3 ♀♀, 1 ♂, Normanton, 7 v 1963, P. Aitken & N.B. Tindale, LT (SAM); 1 ♂, Cairns, Turtle Ck Australia, 5-6 viii 1972, B. Hooking; (QM); 1 ♀, Bamaga

Capt Billy Ck Rd jnct 16 km NE Heathlands H.S., 11°41'S, 142° 42'E, 22 iii 1992, G. Daniels & M.A. Schneider, mv lamp (QM); 1 ♀, Cairns, Turtle Ck Australia, 6-7 viii 1972, B. Hooking (QM); 1 ♀, Lawn Hill NP, Qld, 18°42'08"S, 138°29'06"E, 140m, 26 iv 1995, G. Daniels & M.A. Schneider, mv lamp (QM); **South Australia**: 1 ♀, Brachina Creek, 31.20S 138.35E, 8 xi 1987, J.C. Cardale, LT (ANIC); 1 ♀, 1 ♂, Bon Bon Stn, 30°32'08"S, 135°35'37"E, 26 x 2010 S. Mantel, Bush Blitz svy SM140 sweeping on *Acacia aneura* (in ethanol) (SAM); 1 ♂, Bon Bon Stn, 30°25'26"S, 135°28'39"E, 28 x 2010, R. Kittel, Bush Blitz svy RK133, LT (SAM); 1 ♀, Bon Bon Stn, 30°28'22"S, 135°28'44"E, 24 x 2010, S. Mantel, Bush Blitz survey SM131 *Acacia aneura,* LT (SAM); 2 ♀♀, Bon Bon Stn, 30°25'29"S, 135°28'41"E, 27 x 2010, R. Kittel, Bush Blitz survey RK125 LT (in ethanol) (SAM); 3 ♀♀, Bon Bon Stn, 30°18'50"S, 135°32'50"E, 28 x 2010, R. Kittel; Bush Blitz survey RK129 sweeping on *Acacia victoriae* (in ethanol) (SAM); 1 ♀, Bon Bon Stn, 30°25'28"S, 135°28'40"E, 28 x 2010, S. Mantel, LT, Bush Blitz survey (SAM); 2 ♂♂, Bon Bon Stn, 30°23'41"S, 135°26'52"E, 25 x 2010, R. Kittel, LT (1 ♂ in ethanol) (SAM); 1 ♀, 1 ♂, Chillata Springs Lake Newland Eyre Pen., 29 xi 1986, J.A. Forrest, LT (in ethanol) (SAM); 22 ♀♀, Danggali CP 3 km N Tomahawk Dam, 33°19'39"S, 140°42'50"E, 25 xi 1996 J.A. Forrest, LT (in ethanol) (SAM); 1 ♂, Dingly Dell Camp, Oraparinna Ck 7, 31.21S 138.42E, xi 1987, I.D. Naumann, J.C. Cardale, ex ethanol (ANIC); 1 ♂, Flinders Ranges: Blinman, Rose Cottage, 31.095369'S, 138.678507'E, 7 iv 2011, R. Kittel & G. Taylor, LT (WINC); 2 ♀♀, Flinders Ranges: Road to Warraweena, 30°46.335'S, 138°29.040'E, 7 iv 2011, R. Kittel, Sweeping *E. camaldulensis* & *S. molle* (WINC); 1 ♀, Flinders Ranges: Wirreander 32°05.936'S, 138°17.802'E, 3 iv 201, R. Kittel & G. Taylor, Sweeping *Schinus molle* (WINC); 1 ♀, 3 ♂♂, Flinders Ranges: Blinman, Rose Cottage, 31.095369'S, 138.678507'E, 7 iv 2011, R. Kittel & G. Taylor, LT (in ethanol) (WINC); 2 ♂♂, Flinders Ranges, Blinman 31.095369'S 138.678507'E, 6 iv 2011, R. Kittel, LT (in ethanol) (WINC); 1 ♂, Yudnamutana Bore Arkaroola Stn, 30.10S, 139.07E, 22 x 1993, E.D. Edwards & E.S. Nielsen (ANIC); 1 ♂, 32 km NNE Cowell, 33.26S, 137.03E, 28 xi 1992, I.D. Naumann, J.C. Cardale (ANIC); 1 ♀, 21 km NW Renmark, 34.02S, 140.36E, 8 xi 1995, Cardale, Lee, Pullen & Domingues, LT (ANIC); 1 ♀, 9.6 km N of Hawker, 29 ii 1972, E.G. Matthews, LT (SAM); 1 ♂, Hiltaba Bush Blitz, 32.15581°S, 135.06989°E, 20 ix 2012, G. Taylor, sweeping (in ethanol) (SAM); 1 ♂, Hiltaba Bush Blitz, 32.24262°S, 135.05908°E, 12 ix 2012, R. Kittel sweeping (in ethanol) (SAM); 1 ♀, Hiltaba Bush Blitz, 32.24984°S, 135.05748°E, 13-21 ix 2012, R. Kittel, M. Cheng & G. Taylor, MT (in ethanol) (SAM); 1 ♀, Hiltaba Bush Blitz, 32.37032°S, 135.28946°E, 20 ix 2012, R. Kittel sweeping (in ethanol) (SAM); 1 ♀, 1 ♂, Alton Downs Stn 17 km NW Karrathunka WH, 26°06'07"S, 139°08'45"E, 23-27 iii 2001, pitfalls Sandy Des Surv KA00601; Dunefield *Zygochloa paradoxa*, *Salsola kali* and *Aristida holothera*, very open hummock grassland (in ethanol) (SAM); 1 ♂, Monarto approx 4 km E Callington, 35.07'S, 139.05'E, 6 xii 1984, Woods & Foresis, Ex *Euc brockwayi* (in ethanol) (SAM); 1 ♂, Moonaree Stn 8.2 km ESE Moonaree Hill, 31°57'09"S, 135°40'46"E, 15-20 x 2006, WHC Moonaree Svy; ACR camp, open shrub; *Ecualyptus socialis*, *Casuarina*, *Acacia*, *Dodonea*, red brown sandy-loam flat, LT (in ethanol) (SAM); 3 ♀♀, Mt. Lyndhurst Stn, 15 ix 1993, S. Donnellan, MT (in ethanol) (SAM); 1 ♀, 'Douglas Scrub' nr McLaren Flat, 4 iv 1985, L. Oveale, sweeping (in ethanol) (SAM); 1 ♀, Witchelina Stn, 30°07'27"S, 137°55'43"E, 19-22 x 2010, S. Mantel, F. Colombo, R. Kittel, MT dam floods with young *Eucalyptus* sp and flowering herbs Bush Blitz survey 363 (SAM); 1 ♂, Witchelina Stn, 30°09'13"S, 137°53'87"E, 18-22 x 2010, S. Mantel, F. Colombo, R. Kittel, MT well vegetated sand dune Bush Blitz survey 356 (SAM); 1 ♀, Witchelina Stn, 30°04'38"S, 137°45'13"E, 30 x 2010, R. Kittel, Bush Blitz survey RK067 sweeping on *Hakea leucoptera* (SAM); 3 ♂♂, Gawler Ranges 4 km SW Scrubby Peak, 12 xii 1989, J.A. Forrest, LT (in ethanol) (SAM); 3 ♀♀, Witchelina Stn, 30°08'06"S, 137°53'55"E, 19 x 2010, R. Kittel, Bush Blitz survey RK061, sweeping, sand dune (1 ♀ in ethanol) (SAM); 1 ♀, Witchelina Stn, 30°01'20"S, 138°02'46"E, 13 x 2010, R. Kittel, LT, Bush Blitz survey, RK 007 (SAM); 1 ♂, Witchelina Stn, 30°11'07"S, 137°58'38"E, 18-22 x 2010, S. Mantel, F. Colombo, R. Kittel, MT, Bush Blitz survey MT2 (SAM); 1 ♂, 1 km W Koolymilka, 30°58'14"S, 136°32'15"E, 23-24 iv 2007, Woomera PA svy, LT (SAM); 1 ♂, 32 km N Innamincka, 11 x 1987, J.A. Forrest, LT (SAM); 1 ♀, 9.6 km N of Hawker, 29 ii 1972, E.G. Matthews, LT (SAM); 1 ♀, Clifton Hills OS (ruin), 26°31'S, 139°26'E, 21 xi 1993, J.A. Forest & G. Hirst, LT (SAM); 1 ♂, Highgate, 20-27 ii 1957, H.A. Lindsay, LT (SAM); 1 unknown sex, Springbanks, i-iii 1960, R.V. Southcott, from light housing (SAM); 1 ♀, Sulphur Peninsula, Madigan Gulf, Lake Eyre North, 30 x 1966, G.F. Grossm (SAM); 1 ♂, Wirreandah Ck Crossing, 30 km S Hawker, 26 xi 1975, G.F. Gross & V. Potezny, LT (SAM); 1 ♀, Douglas Scrub, McLaren Flat, -35.185734,138.600231, 24 ix 2013, R. Kittel, LT (WINC); 2 ♂♂, Muloorina HS via Maree, nr bore lake, 29°14'S, 137°55'E, 9-10 ii 1989, A.D. Austin & P.C. Dangerfield, LT (WINC); 1 ♂, 5 km WNW Myrtle Springs HS, 30°27'S, 138°14'E, 8 ii 1989, A.D. Austin & P.C. Dangerfield, sweep (WINC); 1 ♂, Meningie, 25 i 1990, G. Howard, LT (WINC); 1 ♀, Yorke Peninsula, Curramulka, -34.66972, 137.72958, 19 x 2011, S. Mantel & H. De Graaf sweeping, in wheat crop (WINC); 1 ♀, Yorke Peninsula, Curramulka, -34.66972, 137.72958, 19 x 2011, S. Mantel & H. De Graaf sweeping, in wheat crop (WINC); **Victoria**: 1 ♀, Little

River Ripley Rd, 20 km N of Geelong, 37°52.709'S, 144°25.401'E, 9 xii 2011, R. Kittel & L. Krieger sweeping (WINC); 1 unknown sex, Birthday Tank, 50 km NE Cowangie, 10 v 1971, A.J. Coventay (MV); **Western Australia**: 2 ♀♀, 2 ♂♂, "The Crusher", CALM Site 9/1, 4 km SbyW Mining Camp Mitchell Plateau, 14.52S, 125.50E, 2-6 vi 1988, I.D. Naumann, closed forest and margin (ANIC); 1 ♀, "The Crusher", CALM Site 9/1, 4 km SbyW Mining Camp Mitchell Plateau, 14.52S, 125.50E, 2-6 vi 1988, I.D. Naumann, MT and closed forest (ANIC); 1 ♀, Kalumburu Mission Airfield, 14.71S, 126.38E, 23 v 1993, E.D. Edwards (ANIC); 1 ♀, CALM site 25/1, Synnot Ck, 16.31S, 125.16E, 17-20 vi 1988, T.A. Weir, LT, open forest (ANIC); 2 ♀♀, SSE of Fitzroy Crossing, 18.39S, 125.49, 10 v 1995, M. Horak &M. Matthews (ANIC); 1 ♀, 14 km ENE of Carnarvon, 24.50S, 113.46E, 21 x 1992, E.D. Edwards & E.S. Nielsen (ANIC); 4 ♀♀, Lookout on loop road, Kalibarri, 27.33S, 114.26E, 25 x 1992, E.D. Edwards & E.S. Nielsen (ANIC); 1 ♂, Millstream, 17-20 iv 1972, N.R. Mitchell (ANIC); 2 ♀♀, LTR 1 Barrow Island, WGS84: 337551, -7699293, 15 iii 2006, Callan & Graham LTR1 (WAM); 1 ♂, John Forrest NP, 8 km E of Midland, 16 xi 1978, Neboiss (MV); 1 ♂, Onslow, Nov 1955, E.T. Smith (MV); 1 ♂, CALM site 25/1, Synnot Ck, 16.31S, 125.16E, 17-20 vi 1988, T.A. Weir; LT, open forest (SAM); 1 ♀, 4 ♂♂, Yalgarup NP, White Hill Rd, 32°44.704'S, 115°39.360'E, 3 xi 2011, R. Kittel & L. Krieger, sweeping *Acacia* and *Eucalyptus* among others (in ethanol) (WAM SF008307-15, 20-23); 1 ♂, Cadjeput Rockhole 21°31'55"S, 119°08'57"E, 29 ix 1988 B.P. Hanich *et al.*, LT (UV) at night 6:00-8.45pm (in ethanol) (WAM 82903); 1 ♂, 11 km SE Eurardy HS, 27°39'17"S, 114°43'25"E, 25 x 2000, T.F. Houston & O. Mueller, TFH 1056-1 on flowers of *Persoonia bowgada* (Proteaceae) (WAM 82873); 1 ♂, Billy Well Creek, 20 km NE Mt Sandiman HS, 11-13 v 1981, B. Hanich & T.F. Houston, LT at night (WAM 82783); 2 ♂♂, Eneabba, 29°49'S, 115°16'E, 26 xii 1983, R.P. McMillan, LT (WAM 82814, 82815); 1 ♀, 10 km ESE Meedo HS, 25°40'S, 114°37'E, 7-8 v 1981, B. Hanich & T.F. Houston, LT at night (WAM 82804); 2 ♂♂, LTR6 Barrow Island, WGS84: 341230, -7707278, 6 v 2006, Callan & Graham (in ethanol) (ANIC); 2 ♀♀, LTR6 Barrow Island, WGS84: 328389, -7699655, 6 v 2006, Callan & Graham (in ethanol) (ANIC); 2 ♀♀, LTR4 Barrow Island, WGS84: 334071, -7691818, 6 v 2006, Callan & Graham (in ethanol) (ANIC); 1 ♀, LTR3 Barrow Island, WGS84: 338064, -769438, 6 v 2006, Callan & Graham (in ethanol) (ANIC); 1 ♂, LTR5 Barrow Island, WGS84: 332894, -7697016, 6 v 2006, Callan & Graham (in ethanol) (ANIC); 1 ♂, LTR6 SUC Barrow Island, WGS 84: 341230, -7707278, 6 v 2006, Callan & Graham (ANIC); 1 ♂, LTR5 SUC Barrow Island, WGS 84: 332894, -7697016, 6 v 2006, Callan & Graham (ANIC); 1 ♀, NO4 SUC Barrow Island, WGS 84: 340413, -7707558, 06 v 2006, Callan & Graham (ANIC); 1 ♀, NW Coastal Highway 5ml S of Karratha, 17 ii 1973, E.M. Exley (QM); 1 ♀, 7ml S of Port Hedland, 22 ii 1973, E.M. Exley, on *Acacia* sp (QM); 1 ♀, Karratha, 17 ii 1973, E.M. Exley, on *Eucalyptus* sp. (QM).

Biology. The type for this species was reared from *Etiella behrii* (Pyralidae). Some specimens have been reared from the 'Currajong Bag shelter moth' (*Lygraphia clylusalis*), but due to the bad conservation status of the specimens it is difficult to determine whether they actually belong to a separate species or not. One specimen has been reared from *Eucalyptus brockwayi*, and additional specimens have been collected from *Acacia aneura, Acacia victoriae, Grevillea sida cordifolia, Hakea leucoptera, Leptospermum* sp.*, Persoonia bowgada,* and *Schinus molle,* and in a wheat crop.

Distribution. Previously only recorded from South Australia, New South Wales and Northern Territory (Zettel 1988a), but additional material shows this species to be distributed widely across mainland Australia with new records from Queensland, Victoria and Western Australia. This species was also found at Bon Bon Station, Hiltaba Station and Witchelina Station (Fig. 18).

Phanerotoma bonbonensis sp. nov.

(Figures 9a-e, 16)

Description

Body measurements. Length of body 3.6–4.7 mm females, 3.3–4.2 mm males; ratio of antenna to body 0.7–0.87; ratio of length of fore wing to body 0.8; ratio of length of metasoma to mesosoma 1.1–1.3.

Head. Ratio of length of third antennomere to fourth 1.1; ratio of length of third, fourth, penultimate, and terminal antennomere 3.3–4.0, 3.2–3.5, 2.4–2.7, and 2.0–3.0 in females, 4.5–5.0 in males their width, respectively; ratio of length of eye in dorsal view to length of temple 3.0–4.0; ratio of width of face in anterior view to its height 1.6–1.8; ratio of width of clypeus to its height 1.5; clypeus with two teeth; ratio of length of malar space to base of mandible 0.5; face punctate; vertex and frons rugose; ratio posterior ocelli:LOL:POL:OOL 1.0:0.8:0.8–0.9:1.5–2.5.

Mesosoma. Middle lobe of mesoscutum rugose; notauli absent; mesoscutellum fine punctate; mesopleuron punctate; precoxal sulcus present; ratio of height of mesosoma to its length 1.7–1.9; propodeal tubercles absent in females, present in males; blister on mid tibia present; ratio of length of hind tibia to hind tarsus 1.0–1.2; ratio of length of posterior spur to length of basitarsus 0.3–0.5; ratio of hind coxa, hind femur, hind tibia, and hind tarsus 2.0–2.3, 3.3–3.8, 4.0–5.0, and 13.0–17.0 their width, respectively; fore wing: 2-R1 absent; ratio of length of 1-R1 to length of pterostigma 1.1–1.2; ratio of width of pterostigma to its length 2.7–3.3; ratio r:3-SR:SR-1:r-m 1.0:1.0–1.3:5.0–8.0:0.9–1.3; 1-SR+M emanating from base of parastigma; 2-SR+M interstitial or postfurcal.

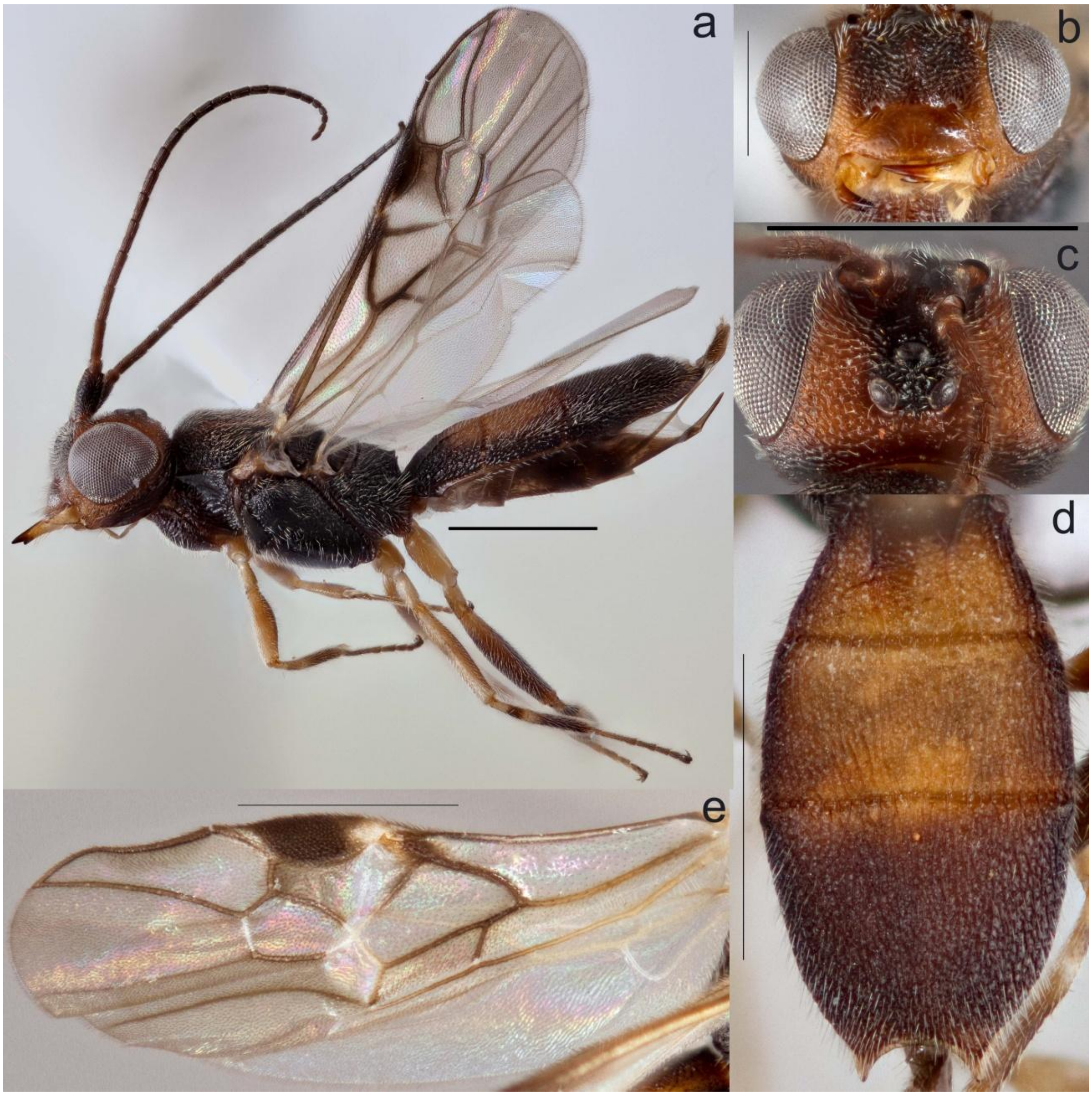

Figure 9. *Phanerotoma bonbonensis* sp. nov.: (a) habitus, lateral, paratype, scale line = 1 mm; (b) head, anterior view, holotype, scale line = 0.5 mm; (c) head, dorsal, holotype, scale line = 0.5 mm; (d) metasoma, dorsal, paratype, scale line = 1 mm; (e) fore wing, paratype, scale line = 1 mm.

Metasoma. Shape of metasoma oval from dorsal view; ratio of width of metasoma to its length 0.5–0.6; carapace flat in lateral view; ratio of keel to length of metasoma 0.16–0.21; first and second tergite longitudinal strigose; third tergite rugose; posterior end of carapace deeply indented; ratio of the three metasomal tergites 1.0:0.9:1.4–1.5.

Colour. Head orange, face and temple somewhat darker; metasoma dark reddish brown; lateral lobes of mesoscutum orange; wing venation, parastigma and pterostigma brown; carapace darker around the edges; third tergite completely dark.

Diagnosis. Propodeal tubercles present (in males); posterior end of carapace indented.

Specimens examined. Holotype, Australia (South Australia):1 ♀, “26 Oct 2010, Bon Bon Station 30°25'22"S, 135°28'41"E, D. A. Young, manual; Bush Blitz survey SM177” (SAM). **Paratypes, Australia (South Australia)**: 1 ♀, Bon Bon Stn, 30°24'41"S, 135°26'52"E, 25 Oct 2010, S. Mantel, Bush Blitz survey SM134 in swale with *Rutidosis helichrysoides,* LT (SAM); 1 ♂, Bon Bon Stn, 30°25'22"S, 135°28'41"E, 24 x 2010, R. Kittel, Bush Blitz svy RK093, LT (SAM); 9 ♀♀, 5 ♂♂, Bon Bon Stn, 30°25'29"S, 135°28'41"E, 26 x 2010, S. Mantel; Bush Blitz svy SM164 under *Acacia aneura,* LT (SAM); 4 ♀♀, 3 ♂♂, Bon Bon Stn, 30°28'22"S, 135°28'44"E, 24 x 2010, S. Mantel, Bush Blitz survey SM131 *Acacia aneura,* LT (SAM); 1 ♀, Bon Bon Stn, 30°25'28"S, 135°28'40"E, 28 x 2010, S. Mantel, Bush Blitz survey, LT (SAM); 8 ♀♀, 3 ♂♂, Bon Bon Stn, 30°25'28"S, 135°28'40"E, 28 x 2010, S. Mantel, Bush Blitz survey, LT (SAM); 1 ♀, Bon Bon Stn, 30°25'29"S, 135°28'41"E, 26 x 2010, S. Mantel, Bush Blitz survey, *Acacia aneura,* LT (SAM). **Other material, Australia (South Australia)**:1 ♂, Bon Bon Stn, 30°28'22"S, 135°28'44"E, 24 x 2010, S. Mantel, Bush Blitz survey SM131 *Acacia aneura,* LT (SAM); 1 ♂, Bon Bon Stn, 30°25'22"S, 135°28'41"E, 24 x 2010, R. Kittel, Bush Blitz svy RK093, LT (SAM); **Northern Territory**: 1 ♀, Ewaninga Rock, Engravings, 23.59S, 133,56E, 27 xi 1987, J. Archibald, M.B. light (MAGNT).

Biology. Collected in the proximity of *Rutidosis helichrysoides* or directly from *Acacia aneura*.

Etymology. Named after the type locality, Bon Bon Station.

Distribution. South Australia (Bon Bon Station) and Northern Territory (Fig. 16).

Phanerotoma bushblitz sp. nov.

(Figures 10a-d, 16)

Description

Body measurements. Length of body 3.25–3.5 mm females, 3.0 mm males; ratio of antenna to body 0.8–0.9; ratio of length of fore wing to body 0.83–0.86; ratio of length of metasoma to mesosoma 0.8 females, 1.0 males.

Head. Ratio of length of third antennomere to fourth 1.0–1.1; ratio of length of third, fourth, penultimate, and terminal antennomere 4.6, 4.2, 2.0, and 2.5 in females, 5.0, 5.0, 4.0, and 5.0 in males their width, respectively; ratio of length of eye in dorsal view to length of temple 2.9–3.3; ratio of width of face in anterior view to its height 1.7; ratio of width of clypeus to its height 1.4–1.5; clypeus with two teeth; ratio of length of malar space to base of mandible 0.64; face, vertex and frons rugose; ratio posterior ocelli:LOL:POL:OOL 1.0:0.8:0.8:1.8–2.7.

Figure 10. *Phanerotoma bushblitz* sp. nov.: (a) habitus, lateral, holotype, scale line = 1 mm; (b) head, anterior view, paratype, scale line = 0.5 mm; (c) metasoma, dorsal, paratype, scale line = 1 mm; (d) fore wing, paratype, scale line = 1 mm.

Mesosoma. Middle lobe of mesoscutum rugose; notauli weakly present; mesoscutellum fine punctate; mesopleuron fine punctate; precoxal sulcus weakly present; ratio of height of mesosoma to its length 2.1 in females, 1.8 in males; propodeal tubercles absent; blister on mid tibia present; ratio of length of hind tibia to hind tarsus 1.0; ratio of length of posterior spur to length of basal tarsus 0.38–0.42; ratio hind coxa, hind femur, hind tibia, and hind tarsus 2.1–2.3, 3.0–4.0, 4.5–4.8, and 15.0–16.0 their width, respectively; fore wing: 2-R1 present; ratio of length of 2-R1 to length of 1-R1 10.0–11.0; ratio of length of 1-R1 to length of pterostigma 1.0–1.2; ratio of width of pterostigma to its length 2.9–3.7; ratio r:3-SR:SR-1:r-m 1.0:2.6–3.0:12.0–15.0:2.0–2.2; 1-SR+M emanating from parastigma; 2-SR+M antefurcal or interstitial.

Metasoma. Shape of metasoma oval in dorsal view, ratio of width of metasoma to its length 0.6–0.7; carapace flat in lateral view; ratio of keel to length of metasoma 0.17–0.21; carapace rugose; sutures straight; posterior end of carapace indented; ratio of the three metasomal tergites 1.0:1.0:1.2–1.5.

Colour. Scape, pedicel and head orange; antenna brown; interocellar area dark; mesosoma reddish brown; fore and mid legs yellow; hind leg with brown tibia and femur; first two metasomal tergites beige; second tergite on the margin with a dark stripe; third tergite brown; wings golden infused; wing venation, parastigma and pterostigma brown.

Diagnosis. The wing venation 2-SR+M antefurcal makes this species unique among *Phanerotoma*.

Specimens examined. Holotype, Australia (South Australia): 1 ♀, “28 Oct 2010, Bon Bon Station 30°25'28"S, 135°28'40"E, S. Mantel, at light; Bush Blitz svy SM178 (SAM). **Paratypes, Australia (South Australia)**: 1 ♀ , 1 ♂, as holotype (SAM); 1 ♀, Bon Bon Stn, 30°25.48'S, 135°28.69'E, 24-30 x 2010, G. Taylor, LT, Bush Blitz survey (SAM). **Other material, Australia (South Australia)**: 1 ♀, Bon Bon Stn, 30°25'28"S, 135°28'39"E, 28 x 2010, R. Kittel, Bush Blitz svy RK133, LT (SAM).

Biology. Unknown.

Etymology. Species names refers to the Bush Blitz Program, during which this species was discovered.

Distribution. South Australia (Bon Bon Station) (Fig. 16).

Phanerotoma decticauda Zettel, 1988

(Figures 11a-e, 17)

Phanerotoma decticauda Zettel, 1988: 222. Holotype: NMNH [examined]. Type locality: Mt Molly, QLD.

Redescription

Body measurements. Length of body 2.5–5.55 mm females, 2.55–4.3 males; ratio of antenna to body 0.7–0.9; ratio of length of fore wing to body 0.8–0.9; ratio of length of metasoma to mesosoma 1.1–1.3.

Head. Ratio of length of third antennomere to fourth 1.0–1.4; ratio of length of third, fourth, penultimate, and terminal antennomere 3.0–3.8, 2.7–3.3, 1.3–3, and 1.7–2.8 in females, 3.2–3.8, 2.8–3.3, 2.0–2.5, and 3.3–4.2 in males their width, respectively; ratio of length of eye in dorsal view to length of temple 2.6–3.3; ratio of width of face in anterior view to its height 1.7–1.8; ratio of width of clypeus to its height 1.4–1.7; clypeus with two teeth; ratio of length malar space to base of mandible 0.7–1.0; face, vertex and frons punctate; ratio posterior ocelli:LOL:POL:OOL 1.0:0.8–0.9:0.7–0.8:1.9–2.3.

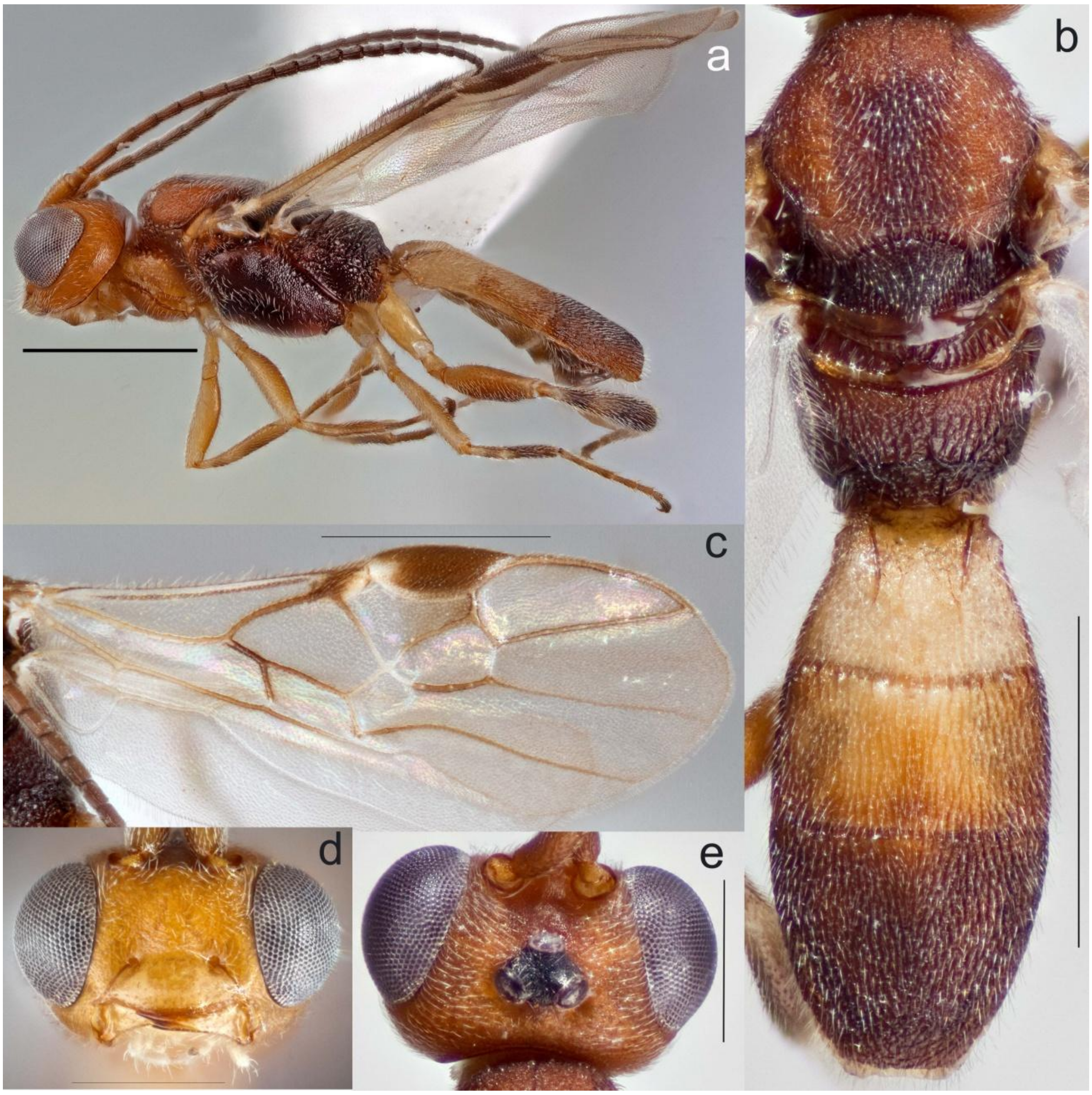

Figure 11. *Phanerotoma decticauda* Zettel, 1988: (a) habitus, lateral, other material, scale line = 1 mm; (b) mesosoma and metasoma, dorsal, other material, scale line = 1 mm; (c) fore wing, other material, scale line = 1 mm; (d) head, anterior view, other material, scale line = 0.5 mm; (e) head, dorsal, other material, scale line = 0.5 mm.

Mesosoma. Middle lobe of mesoscutum punctate; notauli absent; mesoscutellum punctate; mesopleuron punctate; precoxal sulcus weakly present; ratio of height of mesosoma to its length 1.7–2.0; propodeal tubercles absent; blister on mid tibia present; ratio of length of hind tibia to hind tarsus 1.0; ratio length of posterior spur to length of basal tarsus 0.33–0.47; ratio hind coxa, hind femur, hind tibia, and hind tarsus 1.9–2.3, 3.5–5.0, 4.0–5.0, and 13.0–20.0 their width, respectively; fore wing: 2-R1 absent; ratio of length of 1-R1 to length of pterostigma 1.0–1.2; ratio of width of pterostigma to its length 2.7–4; ratio r:3-SR:SR-1:r-m 1.0:1.0–1.8:5.0–9.0:1.1–1.7; 1-SR+M emanating from parastigma; 2-SR+M interstitial or postfurcal.

Metasoma. Shape of metasoma oval in dorsal view; ratio of width of metasoma to its length 0.46–0.59; carapace flat in lateral view; ratio of keel to length of metasoma 0.1–0.2; carapace rugose; sutures straight; posterior end of carapace not indented ratio of the three metasomal tergites 1.0:0.9–1.1:1.3–1.6.

Colour. Head orange; antenna brown; interocellar area dark; mesosoma mostly reddish brown; pronotum, mesoscutum and prosternum orange; first tergite beige to light brown, gradually from second tergite darker to posterior end; third tergite completely dark reddish brown.

Diagnosis. *Phanerotoma decticauda* can be recognised by the deeply indented carapace of the females and the presence of the propodeal tubercles of the males. Molecular evidence suggests that this species may well be a species complex (Fig 3). However, the specimens are extremely uniform morphologically which makes separation into potential new species very difficult. Due to the presence of cryptic species, it is not possible to assign *P. decticauda* to a specific clade/haplotype.

Specimens examined. Holotype, Australia (Queensland): ♀, *Phanerotoma decticauda* Zettel, 1988, Mt. Molly. **Other material, Australia (New South Wales)**: 1 ♀, 1 ♂, Australia, N. Sydney Narrabeen; 4 i 1981, Hangey & Vojnits No 46; *Phanerotoma decticauda* det. H. Zettel 1987 (WINC); 1 ♂, Eden, Bungastree, Exotic/Native garden blend + Eucalyptus forest, 21-27 xii 2005, C. Stephens, MT (WINC); 1 ♂, Grosse Riv Grosewold, 30 iii 1971, G. Daniels, mv Lamp (AMS K358147); 1 ♂, Warrumbungle NP, 23 iv 1973, G. Daniels, mv Lamp (AMS K358192); 1 ♀, Wilton Pear, 14 xii 1964 location & collector unknown (ANIC); 1 ♀, Wilton Pear, 8 ii 1965 location & collector unknown (ANIC); 1 ♂, Bogan Riv, 1935, J. Armstrong (QM); **Northern Territory**: 1 ♀, 3 km SSW of Katherine, 14.30S, 132.15E, 12 xi 1979, I.D. Naumann (ANIC); 6 ♀♀, 4 ♂♂, 30 km NWbyW of Alice Springs, 23.25S, 133.38E, 7 x 1978, J.C. Cardale, ex ethanol (ANIC); 2 ♀♀, 2 ♂♂, 30 km

NWbyW of Alice Springs, 23.32S, 133.38E, 7 x 1978, J.C. Cardale, ex ethanol (ANIC); 2 ♀♀, 2 ♂♂, 53 km EbyN Alice Springs, 23.35S, 134.22E, 6 x 1978, J.C. Cardale, ex ethanol (ANIC); 4 ♀♀, 4 ♂♂, 32 km WNW of Alice Springs, 23.36S, 133.35E, 8 x 1978, J.C. Cardale, ex ethanol (ANIC); 13 ♀♀, 8 ♂♂, 39 km E Alice Springs, 23.41S, 134.15E, 25 ix 1978, J.C. Cardale, ex ethanol (ANIC); 25 ♀♀, 8 ♂♂, 39 km E Alice Springs, 23.41S, 134.15E, 5 x 1978, J.C. Cardale, ex ethanol (ANIC); 1 ♀, Ellery Gorge, 85 km W of Alice Springs, 23.46S, 133.04E, 5 xi 1979, I.D. Naumann (ANIC); 1 ♀, 3 km SSW of Kathrine, 14.30S, 132.15E, 12 xi 1979, I.D. Naumann (ANIC); 1 ♀, 2 ♂♂, Roe Creek, 12 km SWbyW Alice Springs, 23.46S, 133.47E, 9 x 1978, J.C. Cardale, ex ethanol (ANIC); 1 ♀, 35 km S The Granite Mine Tanami Desert, 20.51S, 130.16E, 29 x-2 xi 1988, D.C.F. Rentz Stop T-9 (ANIC); 1 ♀, Daly River, 13.45S, 130.42E, 9-10 viii 1980, M.B. Malipatil, M.V. light (MAGNT); 1 ♀, Cannon Hill via Jim Jim, 18 viii 1971, T. Weir & A. Allwood (MAGNT); 1 ♀, Umbrawarra Gorge, 14.00S, 131.38E, 23 viii 1982, J. & I. Archibald, M.V. light (MAGNT); 1 ♀, U.D.P. Falls, 18-19 vii 1980, M.B. Malipatil, at mv light (MAGNT); 2 ♀♀, Howard River on Gunn Pt Rd, 27 ix 1978, Arilwood (MAGNT); 1 ♀, Koungarra, 9 iii 1973, M.S. Upton (SAM); 1 ♀, nr Centre of Aust marker, 29 iii 1993, J.A. Forrest & D. Hirst, LT (SAM); 3 ♀♀, Litchfield NP, around magnetic termite mounds, 14 xi 1992, P.C. Dangerfield, sweeping (WINC); 1 ♀, 195 km E of Ayers Rock, on Lassiter's Hwy, 5 xi 1992, P.C. Dangerfield, sweeping *Leptospermum* sp. (WINC); 1 ♀, Howard River on Gunn Pt Rd, 27 ix 1978 Arilwood (QM); **Queensland**: 2 ♀♀, 1 ♂, Pistol Gap, near Byfield, 23°10'S, 150°40'E, 10 i 1970, G.A. Holloway, MV lamp (AMS K358107, K358108, K358121); 3 ♀♀, Gunshot Creek Telegraph Xing, 11.44S, 142.29E, 4-5 iv 1992, M. Crossland (ANIC); 9 ♀♀, Heathlands, 11.45S, 142.35E, 15-26 i 1992, I.D. Naumann & T. Weir, LT (ANIC); 3 ♀♀, Heathlands, 11.45S, 142.35E, 17 vii 1992, J.C. Cardale & P. Zborowski, LT (ANIC); 2 ♀♀, Heathlands, 11.45S, 142.35E, 18 xi 1992, P. Zborowski & A. Calder, LT (ANIC); 1 ♀, Heathlands, 11.45S, 142.35E, 15 vii 1992, J.C. Cardale & P. Zborowski, LT (ANIC); 1 ♀, Heathlands, 11.45S, 142.35E, 7 xii 1992, P. Zborowski & W. Dressler, LT (ANIC); 1 ♀, Heathlands, 11.45S, 142.35E, 11-12 xi 1993, P. Zborowski & M. Horak, LT (ANIC); 1 ♂, Cockatoo Ck Xing, 17 km NW Heathlands, 11.39S, 142.27E, 15-26 i 1992, I.D. Naumann & T. Weir, LT (ANIC); 1 ♀, Heathlands, 11.45S, 142.35E, 15-26 i 1992, I.D. Naumann & T. Weir, night collecting (ANIC); 1 ♀, Heathlands, 11.45S, 142.35E, 20-22 vi 1992, T. Weir, LT (ANIC); 2 ♀♀, Heathlands, 11.45S, 142.35E, 18 viii 1992, J.C. Cardale & P. Zborowski, LT (ANIC); 2 ♀♀, Heathlands dump, 11.45S, 142.35E, 20 xi 1992, P. Zborowski & A. Calder, LT (ANIC); 1 ♀, 2 km NE Weipa, 12.37S, 141.54E, 14 xi 1993, P. Zborowski & M. Horak, LT (ANIC); 3 ♀♀, 3 km SbyE Coen, 13.55S, 143.11E, 24 vi 1993, I.D. Naumann & P. Zborowski, LT (ANIC); 1 ♂, Hann R 73 km NW by W of Laura, 15.12S, 143.52E, 27 vi 1986, T. Weir & A. Calder (ANIC); 1 ♀, Hann R 73 km NW by W of Laura, 15.12S, 143.52E, 27 vi 1986, J.C. Cardale, at MV light (ANIC); 1 ♀, 1 km N of Rounded Hill, 15.17S, 145.13E, 5-7 v 1981, I.D. Naumann, ex ethanol (ANIC); 2 ♀♀, 8 km W Dimbulah, 17.09S, 145.02E, 22 iii 1988, D.C. Rentz Stop A-36, collected LT (ANIC); 1 ♀, Holts Ck 8 km N Musselbrook Camp, 18.33S, 138.11E, 15 v 1995, I.D. Naumann, LT (ANIC); 1 ♀, Beerburrum St For., 26.58S, 152.58E, 28 xii 1991, J.A. Berry (ANIC); 1 ♂, Barakula, via Chinchilla, 4 x 1994, F.R. Wylie, J. King, M. De Baer (ANIC); 5 ♀♀, 8 ♂♂, Noondoo, 26 ii 1963, A.L. Dyce & M.D. Murray, ex ethanol (ANIC); 1 ♀, Cape York, 10.41S, 142.32E, 20 vi 1993, I.D. Naumann & P. Zborowski (ANIC); 1 ♀, Jardine R, 11.08S, 142.21E, 19 x 1992, P. Zborowski & T. Weir, night collecting (ANIC); 1 ♂, 4 km NE Batavia Downs, 12.39S, 142.42E, 11 xii 1992 -17 i 1993, P. Zborowski, MT (ANIC); 1 ♀, 2 km NNE Mt Tozer, 12.44S, 143.13E, 3 vii 1986, J.C. Cardale, at MV light (ANIC); 1 ♀, Battle Camp Range, 15.17S, 144.44E, 27 vi 1993, I.D. Naumann & P. Zborowski, LT (ANIC); 1 ♀, Hughenden Stn, 19-21 xi 1984, D.S. Gibson, LT (ANIC); 1 ♀, Mothar Mtn, 12 km SE of Gympie, 29 x 1980, A. Neboiss, MV-light (ANIC); 7 ♀♀, 2 ♂♂, Lake Broadwater, 19-21 xi 1985, G. & A. Daniels, LT (WINC); 1 ♀, 15 km W of Windorah, 24 ix 1983, S.R. Monteith, on *Eucal. terminalis* (QM); 1 ♀, 8.4 km CE Chillagoe NEQ on Rd to Mareeba, 17°12'45"S, 144°33'06"E, 31 iii 1992, E.C. Dahms & G. Sarnes (QM); 2 ♀♀, 9.7 km N Ellis Beach NEQ, 17 iv 1987, E.C. Dahms & G. Sarnes (QM); 1 ♀, Archer River x-ing, 13°25'S, 142°56'E, 5 iv 1989, G. & A. Daniels, mv lamp (QM); 1 ♀, Brisbane, 19 ii 1965, B. Cantrell (QM); 1 ♀, Lake Broadwater nr Dalby, site A, 27°21'S, 151°06'E, 24 x 1986 G. & A. Daniels, mv lamp (QM); 1 ♀, Lake Broadwater nr Dalby, site A, 27°21'S, 151°06'E, 27 ix 1986, G. & A. Daniels, mv lamp (QM); 2 ♀♀, MEQ, Boomer Ra, site 2 180m, 23°12'S, 149°45'E, 28-29 ix 1999, S. Evans & A. Ewart, at MV light open forest 7779 (QM); 1 ♀, Border Waterhole, 15 km W of Musselbrook Resources Centre Lawn Hill NP, 18°36'44"S, 137°59'30"E, 200m, 19 iv 1995, G. Daniels & M.A. Schneider (QM); 1 ♀, Border Waterhole, 15 km W of Musselbrook Resources Centre Lawn Hill NP, 18°36'44"S, 137°59'30"E, 6 v 1995, 200m, G. Daniels & M.A. Schneider (QM); 1 ♀, NEQ, 3 km NE Mareeba, 17°00'S, 145°24'E, 25-28 xi 1997, C.J. Burwell (QM); 1 ♀, Petrie, 5 ix 1965, A.E. May (QM); 1 ♂, 1 ♀, Blunder Cr., Brisbane 2-9 x 1979, A. Hook & H.E. & M.A. Evans (QM); 1 ♀, Blunder Cr., Brisbane, 30 xi 1979, H.E. & M.A. Evans & A. Hook (QM); 1 ♀, Wenlock River, 13°05'S, 142°56'E, 13 xii 1986. G. Daniels & M.A. Schneider, MT (QM); **South Australia**: 2 ♀♀, Arkaroola Stn, Petalinka Falls, 30.11S, 139.17E, 20 x 1993, E.D. Edwards & E.S. Nielsen (ANIC); 1 ♀, Arkaroola Stn, Petalinka Falls, 30.11S, 139.17E, 19 x 1993, E.D. Edwards &E.S. Nielsen (ANIC); 1 ♀, Brachina Creek, 31.20S, 138.35E, 8 xi 1987, J.C. Cardale, LT (ANIC); 1 ♀, Slippery Dip Camp, Brachina Creek, 31.20S, 138.36E, 9 xi 1987, J.C. Cardale, LT (ANIC); 2 ♀♀, Trezona Camp, Brachina Creek, 31.20S, 138.37E, 7 xi 1987, J.C. Cardale, LT (ANIC); 4 ♀♀, 2 ♂♂, Bucharinga Gorge c30 km NNW Quorn, 18 xii 1985, C. Reid, ex ethanol (ANIC); 1 ♂, Dingly Dell Camp, Oraparinna Ck, 31.21S, 138.42E, 7 xi 1987, I.D. Naumann, J.C. Cardale, ex ethanol (ANIC); 1 ♂, Lake Tungketta, 33.46S, 135.06E, 30 xi 1992, I.D. Naumann & J.C. Cardale (ANIC); 1 ♂, 8.5 km SbyW Calperum HS, 34.05S, 140.38E, 2 iii 1995, J.C. Cardale, LT (ANIC); 1 ♀, Brookfield CP, campsite, 34.21S, 139.29E, 30 iii-3 iv 1992, A. Calder & W. Dressler, LT (ANIC); 1 ♀, Arkaroola Stn, Petalinka Falls, 30.11S, 139.17E, 20 x 1993, E.D. Edwards & E.S. Nielsen (ANIC); 2 ♀♀, Trezona Camp, Brachina Creek, 31.20S, 138.37E, 7 xi 1987, J. C. Cardale, LT (ANIC); 1 ♀, 8.5 km SWbyW Calperum HS, 34.05S, 140.38E, 2 iii 1995, J.C. Cardale, LT (ANIC); 22 ♀♀ and 3 ♂♂, Boobook Hill Reserve, SE Kangaroo Is., various dates 2001-2011, R.V. Glatz (GKIC 3000, 12184, 5303, 2251, 3314, 2264, 9187, 2265, 8087, 3302, 1439, 10879, 3329, 2813, 8887, 3328, 10523, 8977, 12169, 12183, 4113, 2984, 2963); 1 ♀, Vivonne Bay 'Melaleuca Cottage' S Kangaroo Is, 35°58.691'S, 137°10.875'E, 4 i 2008, D.A. Young, to mercury vapour light (GKIC 12182); 1 ♂, Kimba, 4 i 1960, P. Aitken, LT (SAM); 1 ♀, 2 ♂♂, Bon Bon Stn, 30°37.56'S, 135°24.18'E, 25-28 x 2010, Bush blitz Survey 367 Malaise9 S. Mantel, F. Colombo, R. Kittel & G. Taylor, MT amongst *Senna artemisioides* , *Acacia tetragonophila* & *A. victoria*, BB svy SM367, MT9 (SAM); 2 ♀♀, Flinders Ranges, Blinman Rose Cottage, 31.095369'S, 138.678507'E, 7 iv 2011, R. Kittel & G. Taylor, LT (SAM); 1 ♀, Flinders Ranges, Blinman Rose Cottage, 31.095369'S, 138.678507'E, 8 iv 2011, R. Kittel, LT (WINC); 1 ♂, Bon Bon Stn, 30°23.68'S, 135°26.86'E, 25 x 2010, G. Taylor, LT (mercury vapour) (WINC); 1 ♀, Hiltaba Bush Blitz, 31.04235°S, 135.37053°E, 17 ix 2012, R. Kittel & M. Golebiowski, sweeping (SAM); 1 ♂, Hiltaba Bush Blitz, 32.15581°S, 135.06989°E, 19 ix 2012, R. Kittel, LT (SAM); 1 ♂, Hiltaba Bush Blitz, 32.23915°S, 135.06448°E, 14 ix 2012, R. Kittel, LT (SAM); 1 ♀, Danggali CP 2 km NW Mulga Dam, 33°11'35"S, 140°54'45"E, 23-24 iii 2001, J.A. Forrest & D. Hirst, mallee, *Triodia* sp., LT (SAM); 1 ♀, Musgrave Ra NG01 10 km NNE Mt Woodroofe, 26°14'55"S, 131°47'36"E, 13 x 1994, Pitjantjatjara Lands survey, LT (SAM); 1 ♀, Blue Hills Bore, 27°7'52"S, 132°51'58"E, 22 iii 1993, Pitjantjatjara Lands survey, pitfall (SAM); 1 ♀, Arkaroola Stn, Arkaroola shearers quarters, 30°20'02"S, 139°22'07"E, 20-23 x 1999, Flinders Ra survey, LT (SAM); 1 ♂, Witchelina Stn, 30°01'20"S, 138°02'46"E, 11 x 2010, S. Mantel, LT, Bush Blitz Survey SM102 (SAM); 4 ♀♀, Bon Bon Stn, 30°24'41"S, 135°26'52"E, 25 x 2010, S. Mantel, LT; Bush Blitz survey SM134 *Rutidosis heliochrysoides* (SAM); 8 ♀♀, 6 ♂♂, Bon Bon Stn, 30°25'22"S, 135°28'41"E, 24 x 2010, R. Kittel, LT; Bush Blitz svy RK093 (SAM); 2 ♀♀, 1 ♂, Bon Bon Stn, 30°25'26"S, 135°28'39"E, 28 x 2010, R. Kittel, LT; Bush Blitz svy RK133 (SAM); 6 ♀♀, 2 ♂♂, Bon Bon Stn, 30°25'28"S, 135°28'40"E, 28 x 2010, S. Mantel, LT; Bush Blitz svy SM178 (SAM); 8 ♀♀, 5 ♂♂, Bon Bon Stn, 30°25'29"S, 135°28'41"E, 26 x 2010, S. Mantel, LT; Bush Blitz svy SM164 under *Acacia aneura* (SAM); 5 ♀♀, 12 ♂♂, Bon Bon Stn, 30°28'22"S, 135°28'44"E, 24 x 2010, S. Mantel, LT; Bush Blitz survey SM131 *Acacia aneura* (SAM); 1 ♀, 1 ♂, Bon Bon Stn, 30°25.48'S, 135°28.69E, 26 x 2010, G. Taylor, LT (mercury vapour) (SAM); 2 ♀♀, Bon Bon Stn, 30°23'14"S, 135°26'52"E, 25 x 2010, R. Kittel, LT, BB svy RK100, in swale with *Rutidosis helichrysoides* (SAM); 2 ♀♀, Bon Bon Stn, 30°25'29"S, 135°28'41"E, 27 x 2010, R. Kittel, LT (SAM); 2 ♂♂, Bon Bon Stn, 30°25'22"S, 135°28'41"E, 24 x 2010, D.A. Young, LT, BB SM 145 *Acacia aneura* (SAM); 1 ♀, Balcanoona Ck, 23 xi 1975, G.F. Gross & V. Potezny, LT (SAM); 1 ♂, Witchelina Stn, 30°00'37"S, 137°46'35"E, 20 x 2010, F. Colombo, sweeping, BB svy FC060A (SAM); 2 ♀♀, 1 ♂, Witchelina Stn, 30°01'20"S, 138°02'46"E, 11 x 2010, D.A. Young, LT, Bush Blitz Survey SM023 (SAM);8 ♀♀, Witchelina Stn, 30°01'20"S, 138°02'46"E, 13 x 2010, R. Kittel, BB svy RK028, LT (SAM); 1 ♀, 10 km NW Emu Junc., Great Vict. Desert, 10 x 1976, G.F. Gross & J.A. Herridge, LT (SAM); 1 ♀, 10 km NW Emu Junc.Great Vict. Desert, 7 x 1976, G.F. Gross & J. Greenslade, at night (SAM); 2 ♀♀, 4.3 km NW Purple Downs HS, 30°50'48"S, 136°54'58"E, 24 iv 2007, Woomera PA Svy, LT (SAM); 1 ♀, Moonaree Stn, 8.2 km ESE Monaree Hill, 31°57'09"S, 135°40'46"E, 15-20 x 2006, WHC Moonaree Survey ACRcamp, open scrub, *Eucalyptus socialis*, *Casuarina*, *Acacia*, *Dodonea*, red brown sandy-loam flat (SAM); 1 ♂, Witchelina Stn, 30°01'20"S, 138°02'46"E, 11 x 2010, R. Kittel, Bush Blitz survey, RK 007, LT (SAM); 1 ♂, Flinders Ranges: Road east of Blinman, 30°59.100'S, 139°05.865'E, 8 iv 2011 R. Kittel, Sweeping *Eucalyptus* sp. (WINC); 1 ♀, Muloorina HS via Maree, nr bore lake, 29°14'S, 137°55'E, 9-10 ii 1989, A.D. Austin & P.C. Dangerfield, LT (WINC); 1 ♀, "Woorabinda" Stirling Linear Park, Mt Lofty Ranges, 8 ii-13 v 2001, N. Stevens, MT in remnant sclerophyll woodland (WINC); 1 ♂, Brachina Gorge, Flinders Ranges, 31°30'S, 139°05'E, 16 ii 1989, A.D. Austin & P.C. Dangerfield (WINC); 1 ♀, Belair NP Gate 11, 16-23 xii 2007, J.T. Jennings, MT (WINC); 1 ♀, Murray Bridge, xi 1985-i 1986, J. Hardy, LT (WINC); **Victoria**: 1 ♀, 12 km NNW Omeo, 28 ii 1980, I.D. Naumann & J.C. Cardale (ANIC); 1 ♀, Ned's Corner, Bush Blitz Survey, 1 xii 2011, Lillywhite, MT, BBNC site 14 (MV); 1 ♀, Wyperfield

NP, 25mi N Rainbow, 18-23 ii 1970, H.E. Evans & R.W. Matthews, MT (NMNH); **Western Australia**: 1 ♀, 14 km ENE of Carnavon, 24.50S, 113.46E, 21 x 1992, E.D. Edwards & E.S. Nielson (ANIC); 4 ♀♀, Kanjini NP Mt Bruce Rd Hamersley, 25 iv-14 v 2003, C. Lambkin & T. Weir, MT, dry rocky creekbed 757m Eucalyptus grassland ANIC 2056 22°34'14"S 118°17'52"E (ANIC); 1 ♀, Kimbolton iii-iv 1983, C. Sambell, ex ethanol (ANIC); 1 ♀, Porongurup NP, 34.40S, 117.52E, 16 iv 1983, E.S. Nielsen & E.D. Edwards (ANIC); 1 ♂, 63 km EbyN of Norseman, 32.04S, 122.25E, 6 v 1983, E.D. Edwards & E.S. Nielson (ANIC); 1 ♀, 1 ♂, Loch McNess, Yanchep NP, 31.33S, 115.15E, 20 iii 1996, E.D. Edwards & E.S. Nielson (ANIC); 1 ♀, 1 km S of Leeman, 29.58S, 114.59E, 30 x 1992, E.D. Edwards & E.S. Nielson (ANIC); 1 ♂, Onslow, xi 1955, E.T. Smith (MV); 2 ♀♀, 2.5 km N of Mt Linden, 29.19S, 122.25E, 17-23 iii 1979, T.F. Houston *et al.* 259-1 (WAM 82792, 82793); 2 ♀♀, 1 unknown sex, 37 km SW Youanmi, 28.45S, 118.31E, 13-14 iii 1982, T.F. Houston & B. Hanich 437-8; LT at night (WAM 82808, 82809, 82810); 1 ♀, 7.5 km NNW of Mt Linden, 29.19S, 122.25E, 17-23 iii 1979, T.F. Houston *et al.* 259-1 (WAM 82794) ; 1 ♂, 9.8 km SSE of Mt Linden, 29.19S, 122.25E, 17-23 iii 1979, T.F. Houston *et al.* 259-1 (WAM 82799); 2 ♀♀, 1 ♂, Buningonia Spring (Well), 31°26'S, 123°33'E, 18-25 xi 1978, T.F. Houston *et al.* 225/10 (WAM 82790, 82789, 82786); 1 ♀, Dyrandra State Forest 12.8 km SE of Cuballing, 4 iv 1984, R.P. McMillan (WAM 82812); 1 ♀, Koonong Pool Ashburton R 11 km E Ashburton Downs HS, xii 1982, H. Esler (WAM 82879); 1 ♀, 11 km ENE Anketell HS, 28.00S, 118.57E, 15-16 iii 1982, T.F. Houston & B. Hanich 439-8 (WAM 82784); 1 ♀, 12.5 km SSE of Banjiwarn HS, 27°42'S, 121°37'E, 22-28 ii 1980, WAM survey site BWR2 T.F. Houston *et al.* 316-10, LT at night (WAM 82803); 1 ♀, 7.5 km E of Yuinmery HS, 28°34'S, 118°01'E, 11-19 ii 1980 , WAM survey site yyeamb T.F. Houston *et al.* 310-1, LT at night (WAM 82802); 1 ♀, ca 9 km SE of Yuinmery HS, 28°34'S, 119°01'E, 25 iii 1980, T.F. Houston *et al.* 262, LT at night (WAM 82801); 2 ♀♀, Kings Park (Perth), 16 iv 1997, T.F. Houston 930-1, at MV light (WAM 82871, 82872).

Biology. Two specimens were reared from 'Wilton Pear' (*Pyrus* sp. probably in NSW). Additional specimens were collected from *Acacia aneura, Acacia leiophylla, Eucalyptus terminalis, Leptospermum* sp., and *Rutidosis heliochrysoides.*

Distribution. Previously known from New South Wales, Queensland and South Australia (Zettel 1988a), this study reveals a much wider distribution for the species including Northern Territory, Victoria and Western Australia. It was also found at Bon Bon Station, Hiltaba Station and Witchelina Station (Fig. 17).

Phanerotoma lutea sp. nov.

(Figures 12a-d, 16)

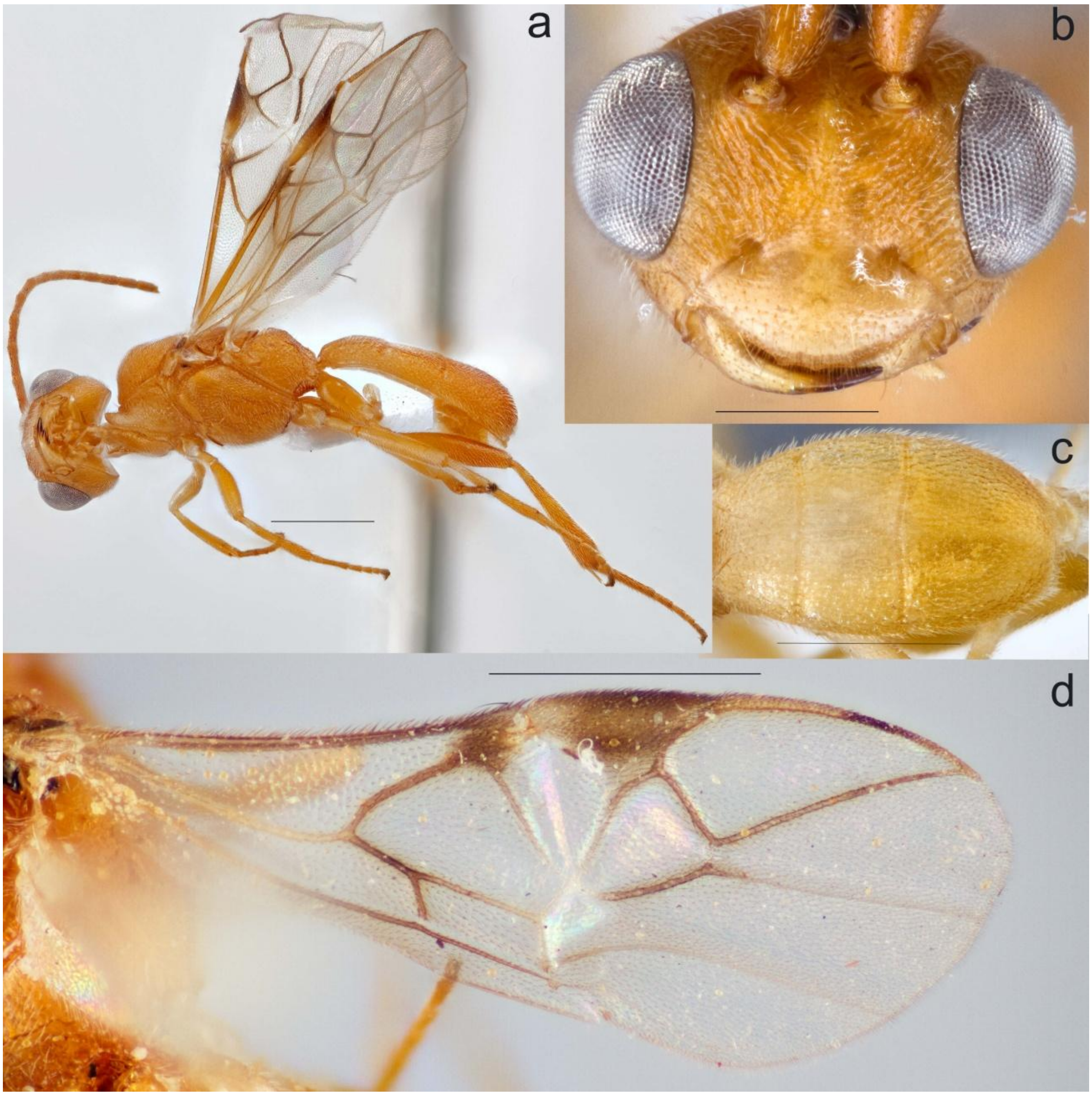

Figure 12. *Phanerotoma lutea* sp. nov.: (a) habitus, lateral, holotype, scale line = 1 mm; (b) head anterior, holotype, scale line = 0.5 mm; (c) metasoma, dorsal, paratype, scale line = 1 mm; (d) fore wing, other material, scale line = 1 mm.

Description

Body measurements. Length of body 3.7–5.45 mm females, 3.65–5.1 mm males; ratio of antenna to body 0.8 in females, 1.0 in males; ratio of length of fore wing to body 0.8; ratio of length of metasoma to mesosoma 1.1.

Head. Ratio of length of third antennomere to fourth 1.0; length of third, fourth, penultimate, and terminal antennomere 3.3–4.3, 3.2–4.7, 1.2–2.7, and 1.5–2.8 their width, respectively; ratio of length of eye in dorsal view to length of temple 1.7–2.1; ratio of width of face in anterior view to its height 1.9–2.3; ratio of width of clypeus to its height 1.7–2.2; clypeus with two teeth; ratio of length of malar space to base of mandible 0.4–0.9; face, vertex and frons traverse strigose; ratio posterior ocelli:LOL:POL:OOL 1.0:0.6:0.6:2.0 females 1.0:0.7:0.7:1.9 males.

Mesosoma. Middle lobe of mesoscutum rugose; notauli weakly present; mesoscutellum rugose; mesopleuron rugose; precoxal sulcus present; ratio of height of mesosoma to its length 1.6–1.7; propodeal tubercles present; blister on mid tibia present; ratio of length of hind tibia to hind tarsus 0.9–1.1; ratio of length of posterior spur to length of basal tarsus 0.35–0.48; ratio hind coxa, hind femur, hind tibia, and hind tarsus 2.2, 3.0–5.0, 4.0–5.0, and 14.0–23.0 their width, respectively; fore wing: 2-R1 absent; ratio of length of 1-R1 to length of pterostigma 1.3; ratio of width of pterostigma to its length 2.4–3.3; ratio r:3-SR:SR-1:r-m 1.0:4.0–6.0:13.0–16.0:1.6–2.2; 1-SR+M emanating from parastigma; 2-SR+M interstitial, antefurcal or postfurcal.

Metasoma. Shape of metasoma oval in dorsal view; ratio of width of metasoma to its length 0.55–0.6; carapace broadens to posterior end in lateral view; ratio of keel to length of metasoma 0.19–0.21; first and second tergite longitudinal strigose, third tergite rugose; curvature of second suture slightly towards anterior end; ratio of the three metasomal tergites 1.0:0.7–0.9:1.2–1.3.

Colour. Overall orange; interocellar area dark; wing venation, parastigma and pterostigma brown.

Diagnosis. Along with *Phanerotoma behriae*, this species has three teeth on the clypeus. It can be distinguished from the other species by its yellow colour.

Specimens examined. Holotype, Australia (South Australia): 1 ♀, “27 Oct 2010, Bon Bon Station 30°25'29"S, 135°28'41"E, R. Kittel, at light; Bush Blitz svy RK125 (SAM). **Paratypes, Australia (Queensland)**: 2 ♀♀, 2 km N Rokeby, 13.40S, 142.40E, 12 ix 1993, P. Zborowski & S. Shattuck, LT (ANIC); 1 ♀, Woobadda River, 15.58S, 145.22E, 25 viii 1992, J.C. Cardale & P. Zborowski, LT (ANIC); 1 ♀, Rockhampton, 24 km S, 23°37'S, 150°06'E, 28 xi 1990, T. Gush, on flowering tree, Tom Gush Collection 2567 (ANIC); 1 ♀, 11 km WbyN Bald Hill, McIlwraith Ra., 500m, 13.44S, 143.20E, 26 vi-13 vii 1989, I.D. Naumann, LT, search party campsite (ANIC). **Other material, Australia (New South Wales)**: 1 ♂, North Beach, Bellinger R, 21 ii 1965, D.K. McAlpine & R. Lossin (AMS 358175); 1 ♀, Pilliga Scrub, via Coonabarabran, 15 xii 1976, I.D. Naumann; beating and sweeping, dry sclerophyll forest (QM); **Northern Territory**: 1 ♀, Darwin, 17 vi 1962, R.V. Southcoll (SAM); **Queensland**: 1 ♀, 1 ♂, 10 km SSW Cape York, 10.46S, 142.30E, 15 x 1992, P. Zborowski & T. Weir, LT, rainforest (ANIC); 1 ♂, Captain Billy Landing, 11.38S, 142.51E, 21 i 1992, I.D. Naumann & T.A. Weir (ANIC); 1 ♀, Cockatoo Ck Xing 17 km NW

Heathlands, 11.39S, 142.27E, 15-26 i 1992, I.D. Naumann & T. Weir, LT (ANIC); 1 ♀, 14 km ENE Heathlands, 11.41S, 142.42E, 12 xi-14 xii 1993, P. Zborowski, MT (ANIC); 1 ♀, 14 km ENE Heathlands, 11.41S, 142.42E, 21 xi 1992, P. Zborowski & A. Calder, LT rainforest (ANIC); 1 ♂, Heathlands, 11.45S, 142.35E, 15-26 i 1992, I.D. Naumann & T. Weir, LT (ANIC); 1 ♀, Batavia Downs, 12.41S, 142.41E, 22-23 viii 1992, J.C. Cardale & P. Zborowski (ANIC); 1 ♀, 9 km NNW Lockhart River, 12.43S, 143.18E, 25 x 1992, P. Zborowski & T. Weir, LT rainforest (ANIC); 1 ♀, 2 km N Rockeby, 13.40S, 142.40E, 12 ix 1993, P. Zborowski & S. Shattuck, LT (ANIC); 1 ♀, WbyN Bald Hill McIlwraith Ra 500m, 13.44S, 143.20E, 11km, 26 vi-13 vii 1989, I.D. Naumann, LT search party campsite (ANIC); 1 ♀, Mt White, 13.58S, 143.11E, 12 i 1994, P. Zborowski & E.D. Edwards, LT (ANIC); 1 ♂, Turnoff to Captain Billy Landing, 11.41S, 142.42E, 20 viii 1992, J.C. Cardale & P. Zborowski, LT (ANIC); 1 ♀, Lizard Is, NNE of Cooktown, N. Qld, 16 xi 1974, M.S. & B.J. Moulds (AMS K 358191); 1 ♀, Tonga 20.7.57 D.J.P. (QM); 1 ♂, East Claudie Riv, 1 vii 1982, M.A. Schneider & G. Daniels, mv lamp (QM); 1 ♀, Lam. NP 25 v 1962 J. Cribb (QM); 1 ♀, Gatton 15 xii 1952 Prasai (QM); 1 ♂, ex *Cissus antarctica* (QM); 1 ♂, NEQ, "Kingfisher Park" 1 km N Julatten, 16°36'S, 145°20'E, 29 ix 1997 C.J. Burwell (QM); 1 ♂, NEQ, Wallaman Falls Rd Junction, 650m , 18°39'S, 145°52'E, 5-12 ii 1996, Monteith, Flight intercept, RF (QM); **South Australia**: 1 ♀, Kangaroo Isl., Flinders Chase NP, West Bay, coastal Mallee, i 1986 A.D. Austin (WINC); 1 ♀, 9.6 km N of Hawker, 29 ii 1972, E.G. Matthews, LT (SAM); 1 ♂, Marree, 3 xii 1964, P. Aitken & W. Head, LT (SAM); 4 ♂♂, 11 km SW by W Calperum HS, 34.06S, 140.37E, 28 ii 1995, Cardale, Colloff, Pullen, LT; Calperum Station/Bookmark Biosphere Reserve Invertebrate Survey (ANIC).

Biology. One specimen reared from *Cissus antarctica (*Kangaroo Treebine).

Etymology. The name ‘lutea’ refers to the overall yellow appearance of the species.

Distribution. New South Wales, Queensland and South Australia (including Bon Bon Station) (Fig. 16).

Phanerotoma nigerscapulata sp. nov.

(Figures 13a-d, 16)

Description

Body measurements. Length of body 2.15–4.0 mm females, 2.4–4.1 mm males; ratio of antenna to body 0.6 in females, 0.76–0.86 in males; ratio of length of fore wing to body 0.9 in females, 0.8 in males,; ratio of length of metasoma to mesosoma 1.0–1.2.

Head. Ratio of length of third antennomere to fourth 1.0–1.4; ratio of length of third, fourth, penultimate, and terminal antennomere 2.5–3.6, 2.0–3.2, 1.3–2.0, and 2.0–2.7 their width, respectively; ratio of length of eye in dorsal view to length of temple 2.5–2.7; ratio of width of face in anterior view to its height 1.6–1.8; ratio of width of clypeus to its height 1.5–1.9; clypeus with two teeth; ratio of length of malar space to base of mandible 0.8–1.4 in females, 0.5–0.8 in males; face, vertex and frons rugose; ratio posterior ocelli:LOL:POL:OOL 1.0:0.6–1.3:0.6–1.2:2.0–3.0.

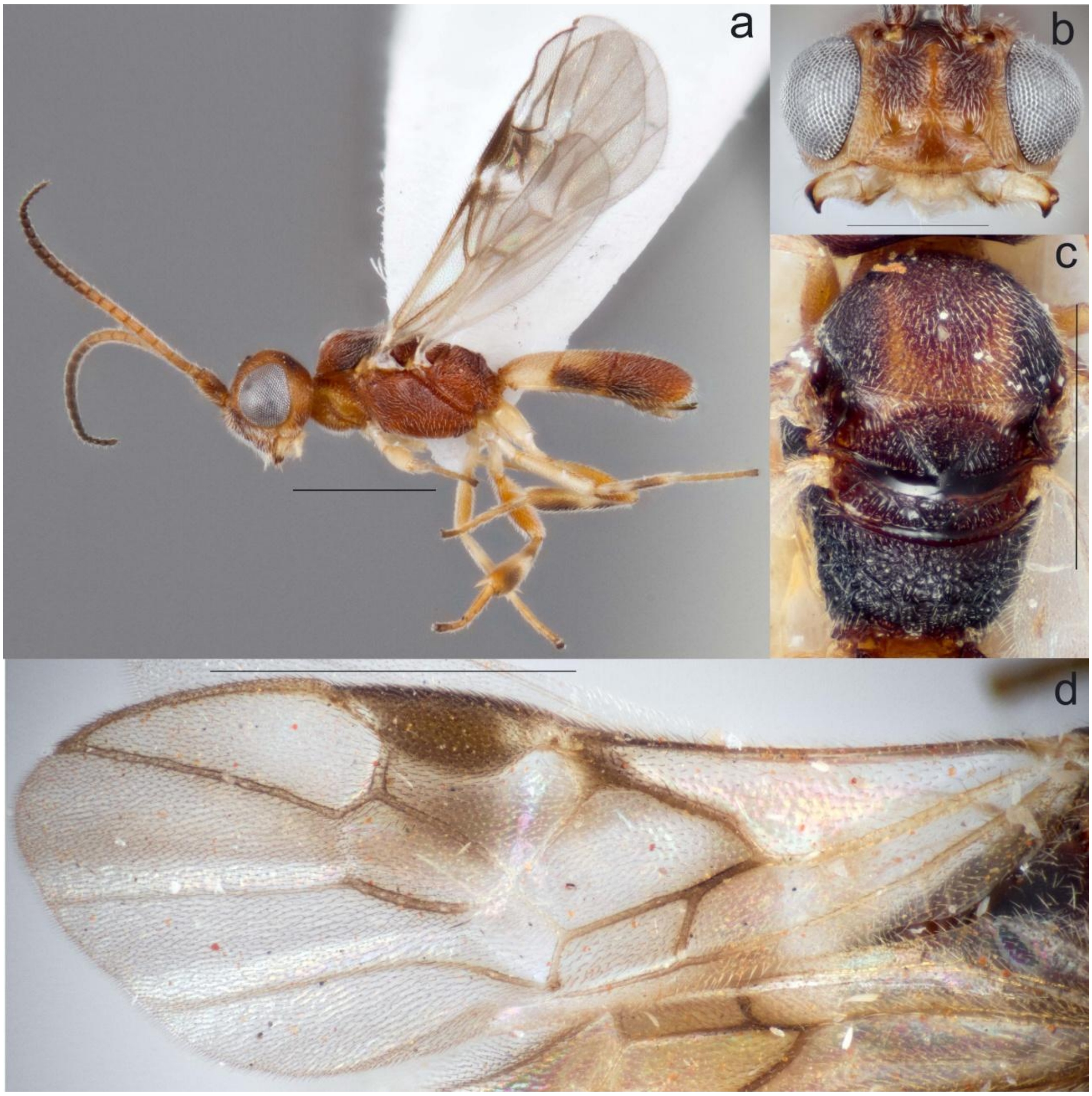

Figure 13. *Phanerotoma nigerscapulata* sp. nov.: (a) habitus, lateral, paratype, scale line = 1 mm; (b) head, anterior, holotype, scale line = 0.5 mm; (c) mesosoma, dorsal, paratype, scale line = 1 mm; (d) fore wing, paratype, scale line = 1 mm.

Mesosoma. Middle lobe of mesoscutum rugose; notauli absent; mesoscutellum rugose; mesopleuron rugose; precoxal sulcus present; ratio of height of mesosoma to its length 1.8–2.0; propodeal tubercles present but small; blister on mid tibia present; ratio of length of hind tibia to hind tarsus 1.0–1.1; ratio of length of posterior spur to length of basal tarsus 0.4–0.5;

ratio of hind coxa, hind femur, hind tibia, and hind tarsus 2.4–2.5, 3.3–4.4, 4.0–5.0, and 13.0–18.0 their width, respectively; fore wing: 2-R1 absent; ratio of length of 1-R1 to length of pterostigma 1.0–1.2; ratio of width of pterostigma to its length 3.0–3.6; ratio r:3-SR:SR-1:r-m 1.0:0.6–1.4:5.5:0.8–1.3; 1-SR+M emanating from base of parastigma; 2-SR+M interstitial or postfurcal.

Metasoma. Shape of metasoma oval in dorsal view; ratio of width of metasoma to its length 0.6; carapace flat in lateral view; ratio of keel to length of metasoma 0.15–0.2; carapace longitudinal sculptured; both sutures straight; posterior end of carapace not indented; ratio of the three metasomal tergites 1.0:0.9–1.0:1.2.

Colour. Head orange with reddish brown face and temple; antenna brown; interocellar area dark; metasoma dark reddish brown; with middle lobe of mesoscutum dark orange; first tergite of carapace beige, second and third gradually darker, reddish brown; wing venation, parastigma and pterostigma brown.

Diagnosis. This species differs from most other species by not having an indented carapace on the posterior end. It can be recognised by the black scapula and the much lighter brown mesoscutum.

Specimens examined. Holotype, Australia (South Australia): 1 ♀, “27 Oct 2010, Bon Bon Station, 30°25'29"S, 135°28'41"E, R. Kittel, LT” (SAM). **Paratypes, Australia (Northern Territory)**: 1 ♂, 30 km NWbyW of Alice Springs, 23.35S, 133.38E, 7 x 1978, J.C. Cardale, ex ethanol (ANIC); 1 ♀, Mt Weht, Soudan, Narkly Tableland , 17 viii 1960, E.M. Exley (QM); **South Australia**: 1 ♀, Waite Campus, Arboretum, UofA, Urrbrae, 1-20.iii 2002, N. Stevens (WINC); 1 ♀, Bon Bon Stn, 30°25'29"S, 135°28'41"E, 26 x 2010, S. Mantel, LT; Bush Blitz svy SM164 under *Acacia aneura* (SAM); **Western Australia**: 1 ♀, Capel, Bussell Hwy, 33°33.323'S, 115°33.073'E, 31 x 2011, G. Taylor (WINC); 1 ♀, 60 km W Esperance, South Coast Hwy, Lort River Bridge, 33°44.630'S, 121°15.375'E, 6 xi 2011, G. Taylor, Swept *Acacia* sp. (WINC); 2 ♀♀, 5 km SE of Tambellup, Toolbrunup Rd, 34°04.301'S, 117°40.789'E, 10 xi 2011, R. Kittel & L. Krieger sweeping (WAM SF 008307-11). **Other material, Australia (Australian Capital Territory)**: 1 ♂, Canberra, 15 i 1979, N.J. Short, MT (ANIC); **New South Wales**: 1 ♂, 5 mi S Mendooran, 17 iii 1972, G. Daniels, mv lamp (AMS K358071); 2 ♂♂, Nyngan dist, 1-9 ii 1960, T.E. Woodward (QM); 1 ♀, Rainforest Iluka Clarence R, 24 xi 1970, D.K. McAlpine, MV lamp (AMS K351901); **Northern Territory**: 6 ♀♀, 30 km NWbyW of Alice Springs, 23.32S, 133.38E, 7 x 1978, J.C. Cardale, ex ethanol (ANIC); 1 ♀, 35 km S The Granite Mine Tanami Desert, 20.51S, 130.16E, 29 x-2 xi 1988, D.C.F. Rentz Stop T-9 (ANIC); 1 ♀, East Point, 13 v 1981, D.P.A.

Sands, ex *Hibiscus tilaceus* (ANIC); 1 ♂, Yuendumu, ii 1968 (ANIC); **Queensland**: 1 ♀, Cockatoo Ck Xing, 17 km NW Heathlands, 11.39S, 142.27E, 15-26 i 1992, I.D. Naumann & T. Weir, LT (ANIC); 1 ♀, Bertie Ck Xing, 12 km SW Heathlands, 11.50S, 142.30E, 15-26 i 1992, I.D. Naumann & T. Weir, LT (ANIC); 1 ♀, Batavia Downs, 12.41S, 142.41E, 22-23 vii 1992, J.C. Cardale & P. Zborowski, LT (ANIC); 1 ♀, Wenlock R Crossing, Portland Roads Road, 13.06S, 142.56E, 17 vii 1986, J.C. Cardale, at MV light (ANIC); 1 ♀, 1 km N of Rounded Hill, 15.17S, 145.13E, 5-7 v 1981, I.D. Naumann, ex ethanol (ANIC); 1 ♀, 1 ♂, 8 km SEbyE Musselbrook Camp, 18.38S, 138.11E, 11 v 1995, I.D. Naumann, LT (ANIC); 3 ♀♀, 10 km SE Musselbrook Camp, 18.39S, 138.12E, 13 v 1995, I.D. Naumann, LT (ANIC); 1 ♂, 16 km SEE Musselbrook Camp, 18.44S, 138.12E, 18 v 1995, I.D. Naumann, LT (ANIC); 1 ♂, Barakula, via Chinchilla, 4 x 1994, F.R. Wylie, J. King, M. De Baer (ANIC); 1 ♂, Noondoo, 26 ii 1963, A.L. Dyce & M.D. Murray, ex ethanol (ANIC); 1 ♀, Mudjimba Beach, E of Nambour, 29 xi 1985, G. Cassis (ANIC); 1 ♀, 1 km N of Rounded Hill, 15.17S, 145.13E, 5-7 v 1981, I.D. Naumann, ex ethanol (ANIC); 2 ♂♂, Corallie R. Bruce Highway, NW Fladstone N. Qld, 23 i 1970, G.A. Holloway, MV light (AMS K358159); 1 ♀, Lake Broadwater nr Dalby, site A, 27°21'S, 151°06'E, 24 x 1986, G. & A. Daniels, mv lamp (QM); 1 ♀, Eurimbula Ck., via Round Hill Head, 3-5 v 1975, I.D. Naumann; sweeping low vegetation, open forest/subtropical rainforest boundary (QM); **South Australia**: 1 ♀, Brookfield CP, 34.19S, 139.31E, 24 xi 1992, I.D. Naumann, J.C. Cardale (ANIC); 1 ♀, Brookfield CP, 34.21S, 139.29E, 17-20 ii 1992, J.C. Cardale, LT (ANIC); 1 ♂, Brookfield CP, 34.21S, 139.29E, Campsite, 30 iii-3 iv 1992, A. Calder & W. Dressler, LT (ANIC); 1 ♂, 5 km NNE Prices Bore, 30°20'41"S, 136°11'46"E, 18 iv 2007, Woomera PA Svy, LT (SAM); 1 ♀, Belair NP, Gate 11, 1-8 iii 2008, J. T. Jennings, MT (WINC); 1 ♀, Flinders ranges, Brachina Gorge, 31°19.954'S, 138°35.916'E, 5 iv 2011, G. Taylor, *Acacia lingulata* (WINC); 1 ♂, Flinders ranges, Brachina Gorge, 31°20.630'S, 138°33.635'E, 5 iv 2011, R. Kittel & G. Taylor, Sweeping *Eucalyptus socialis* (WINC); **Tasmania**: 2 ♀♀, Cambridge, 21 ii 1967, A. Neboiss (MV); **Victoria**: 1 ♀, Abbeyard, 27 i 1960, A. Neboiss (MV); 1 ♀, Latrobe R. Survey St 8 U7/s, 17 ii 1973, R. Morwell, LT (MV); 2 ♀♀, Meredith, 12-13 ii 1959, A. Neboiss (MV); 1 ♀, Meredith, 13 ii 1959, A. Neboiss (MV); 1 ♀, Myrtleford, 23 vi 1973, A. Neboiss, *Eucalyptus* spp., MV-trap (MV); 1 ♀, Nunawading, 1 iii 1960, A. Neboiss (MV); 4 ♀♀, Porepunkah, 26 i 1960, A. Neboiss (MV); 1 ♂, Mt Langi Ghiran, 17 xii 1966, A. Neboiss (MV); **Western Australia**: 1 ♀, 18 mi E Pingelly, 2 i 1971, G.A. Holloway & H. Huges, mv lamp (AMS K351888); 1 ♀, 1 ♂, Miaboolya Beach, N of Carnarvon, 24.48S, 113.38E, 22 x 1992, E.D. Edwards & E.S. Nielson (ANIC); 2 ♀♀, Loop Road, 30 km NE by

E of Kalbarri, 27.34S, 114.26E, 17 x 1984, Kalbarri NP, D.C.F. Rentz Stop 48 (ANIC); 8 ♀♀, Kalbarri, 27.43S, 114.10E, 15 x 1992, E.D. Edwards & E.S. Nielson (ANIC); 3 ♀♀,1 ♂, Kalbarri, 27.43S, 114.10E, 24 x 1992, E.D. Edwards & E.S. Nielson (ANIC); 2 ♀♀, Augustus Island, CALM Site 26/1, 15.25S, 124.38E, 11-16 vi 1989, I.D. Naumann (ANIC); 1 ♀, 1 km W of Wave Rock, 32.27S, 118.53E, 31 i 1993, E.D. Edwards & E.S. Nielsen (ANIC); 1 ♂, Gill Pinnacle, Mural Crescent, 2 xi 1963, P. Aitken & N.B. Tindale, LT (SAM); 1 ♀, Gill Pinnacle, Mural Crescent, 10 xi 1963, P. Aitken & N.B. Tindale, LT (SAM); 1 ♀, 3.8 km NE of Comet Vale Siding, 29.57S, 121.07E, 7-15 iii 1979, T.F. Houston *et al.* 256-8 (WAM 82791); 1 ♀, Nullagine, 19-20 i 1974, A.M. & M.J. Douglas (WAM 82875); 3 ♂♂, Buningonia Spring (Well), 31°26'S, 123°33'E, 18-25 xi 1978, T.F. Houston *et al.* 225/10 (WAM 82785, 82787, 82788); 1 ♀, 9.8 km SSE of Mt Linden, 29.19S, 122.25E, 17-23 iii 1979, T.F. Houston *et al.* 259-1 (WAM 82800); 1 ♂, Spectacles Yargan, 32°12.893'S, 115°49.758'E, 2 xi 2011, R. Kittel & L. Krieger, sweeping *Eucalyptus* and *Banksia* (WAM SF 008307-17); 1 ♂, Credo Station, 30°04.476'S, 120°36.910'E, 7 ix 2011, R. Kittel Sweeping *Senna*, Bush Blitz survey (WAM).

Biology. One specimen has been reared from *Hibiscus tilaceus*. Additional specimens were collected from *Acacia lingulata* and *Eucalyptus socialis.*

Etymology. The species is named after the dark scapula area as opposed to the orange light brown mesoscutum.

Distribution. Recorded from across Australia, but it is not as abundant as *P. decticauda* or *P. behriae*. It is known from the Australian Capital Territory, New South Wales, Northern Territory, Queensland, South Australia (including Bon Bon Station), Tasmania, Victoria and Western Australia (Fig. 16).

Phanerotoma witchelinaensis sp. nov.

(Figures 14a-d, 16)

Description

Body measurements. Length of body 2.9–3.5 mm females, 3.0–3.5 mm males; ratio of length of fore wing to body 0.88; ratio of length of metasoma to mesosoma 1.2.

Head. Ratio of length of third antennomere to fourth 1.2; ratio of length of third and fourth antennomere 2.4 and 2 their width, respectively; ratio of length of eye in dorsal view to length of temple 2.2; ratio of width of face in anterior view to its height 1.7; ratio of width of clypeus to height 1.3; clypeus with two teeth, ratio of length malar space to base of mandible

0.6; face fine rugose; vertex and frons rugose; ratio posterior ocelli:LOL:POL:OOL 1.0:1:0.8:2.4

Mesosoma. Middle lobe of mesoscutum rugose; notauli present; mesoscutellum fine punctate; mesopleuron punctate; precoxal sulcus present; ratio of height of mesosoma to length 1.9; propodeal tubercles absent; blister on mid tibia present; ratio length of hind tibia to hind tarsus 1.0; ratio of length of posterior spur to length of basal tarsus 0.4; ratio hind coxa, hind femur, hind tibia, and hind tarsus 1.7, 4.3, 5.7, and 20.0 their width, respectively; fore wing: 2-R1 absent; ratio of length of 1-R1 to length of pterostigma 1.4; ratio of width of pterostigma to its length 2.6; ratio r:3-SR:SR-1:r-m 1.0:1.3:7.7:1.15; 1-SR+M emanating from parastigma; 2-SR+M postfurcal.

Figure 14. *Phanerotoma witchelinaensis* sp. nov.: (a) habitus lateral, scale line = 1 mm; (b) head dorsal, scale line = 0.5 mm; (c) head, anterior, scale line = 0.5mm; d metasoma dorsal, scale line = 1 mm; all holotype.

Metasoma. Shape of metasoma oval in dorsal view, narrows down to posterior end; ratio of width of metasoma to its length 0.5; carapace flat in lateral view; ratio of keel to length of metasoma 0.17; carapace longitudinal strigose; both sutures straight; third tergite without lobes or teeth; ratio of the three metasomal tergites 1.0:1.2:1.9.

Colour. Head orange; antenna light brown; mesosoma reddish brown except mesoscutum and mesosternum orange; legs light brown; first and second tergites beige, gradually darker (reddish brown) towards posterior end; wing venation dark brown.

Diagnosis. This species differs from all other species by the shape of the carapace. The last tergite of the carapace has a long triangular shape.

Specimens examined. Holotype, Australia (South Australia): 1 ♀, "14 Oct 2010, Witchelina Station 30°05'44"S, 138°08'09"E, R. Kittel, sweeping; Bush Blitz survey RK035 on *Acacia* sp." (SAM). **Other material, Australia (Queensland)**: 1 ♀, Eurimbula, Miriam Vale distr. Site 4, 27 iii 1975, D.K. McAlpine, M.V. light (AMS K358188); 1 ♀, S.E. QLD Beerwak, 26.51S, 152.57E, 28 ix-29 x 86, B.K. Cantrell, M.T. (WINC); 1 ♂, Bertiehaugh Creek, 12.12S, 142.22E, 13 viii 1993, P. Zborowski & J. Balderson, LT (ANIC); 1 ♂, Heathlands, 11.45S, 142.35E, 15-26 i 1992, I.D. Naumann & T. Weir, LT (ANIC); **Western Australia**: 1 ♀, Pilganoova Well, 25 v 1953, T.B. Tindale (SAM); 1 ♀, Kanjini NP, Mt Bruce Rd, Hamersley, 22°37'27"S, 118°20'47"E, 25 iv-1 v 2003 Lambkin & Weir, MT, 755m, dry rocky creekbed (ANIC); 2 ♀♀, Leeuwin Naturaliste NP, Gnarabug Cave, 34°03.014'S, 115°01.501'E, 5 xi 2011, Kittel & Krieger, sweep (WAM SF008307-18, 19).

Biology. Unknown.

Etymology. Named after the type locality Witchelina Station.

Distribution. Found in South Australia (Witchelina Station), Queensland and Western Australia (Fig. 16).

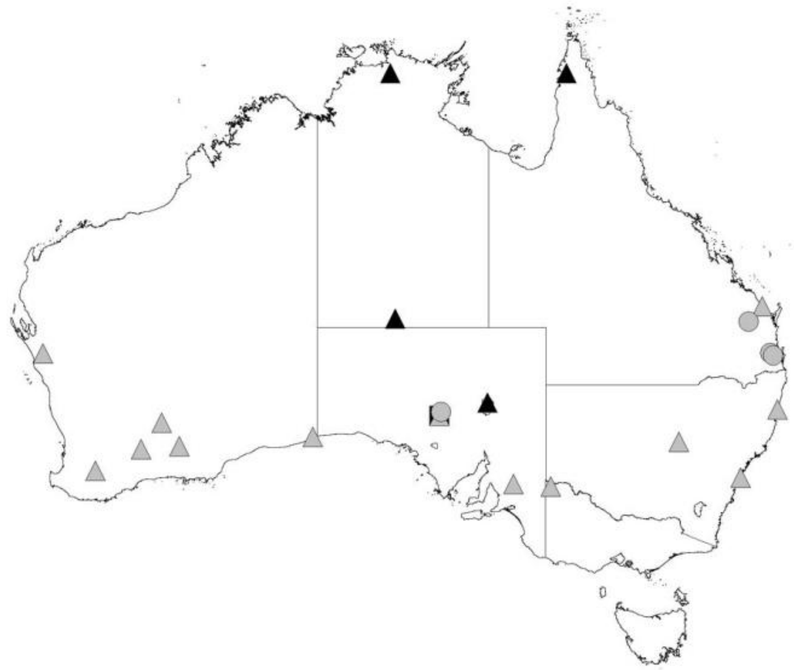

Figure 15. Distribution map: *Ascogaster brevivena* sp. nov. grey circle, *Ascogaster ferruginegaster* sp. nov. black triangle, *Ascogaster prolixogaster* sp. nov. grey triangle, *Ascogaster rubriscapa* sp. nov. black square.

Figure 16. Distribution map: *Phanerotoma bushblitz* sp. nov. black diamond, *Phanerotoma lutea* sp. nov.grey square, *Phanerotoma witchelinaensis* sp. nov. black square, *Phanerotoma nigerscapulata* sp. nov. grey circle, *Phanerotoma bonbonensis* sp. nov. black circle.

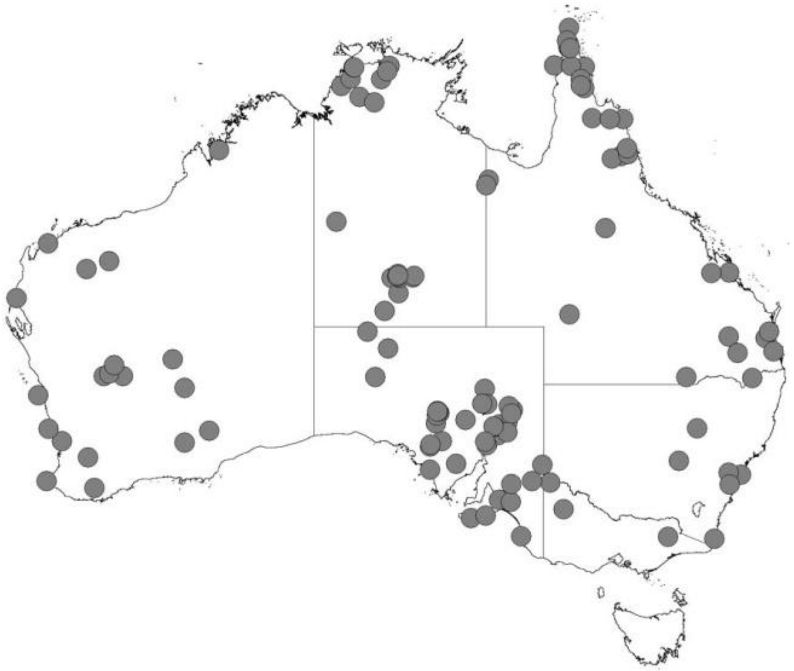

Figure 17. Distribution map: *Phanerotoma decticauda* Zettel, grey circle, incl. holotype.

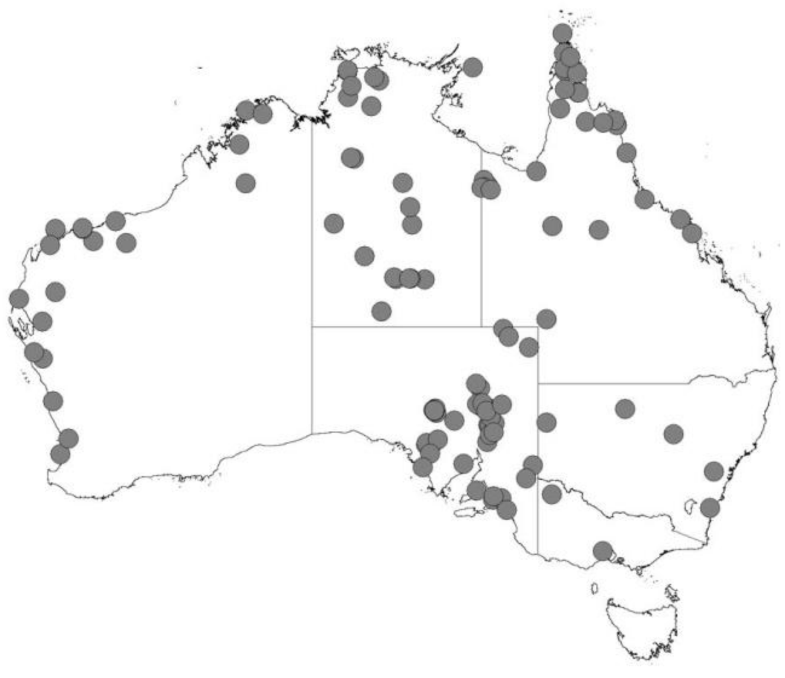

Figure 18. Distribution map: *Phanerotoma behriae* Zettel, grey circle, incl. holotype.

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Chapter 7: General Discussion

This study provides new insights into the systematics of the world genera of the subfamily Cheloninae and the diversity of the Australian chelonine fauna. The first comprehensive phylogenetic analysis of the subfamily has been undertaken in order to elucidate the relationships among genera. The aims were to test the phylogenetic status of the Adeliinae in regards to the Cheloninae, and to test the monophyly of genera, in particular the phylogenetic status of *Chelonus* and *Microchelonus* as well as *Ascogaster* and *Leptodrepana*. A further aim was to revise the Australian species, redescribe existing species with consistent morphological characters, to describe new species for specific genera, and to develop keys for their identification. Significantly, these revisions in conjunction with the DNA barcoding of specimens, have formed the bases for estimating the species richness of the Australian chelonine fauna.

7.1 Phylogenetic Analyses

The phylogenetic analyses in **chapter 2** were undertaken by examining a large number of genera from all biogeographical regions and using a dataset of 84 species and a total of 1454 bp of sequence data. The results show that the subfamily Adeliinae is indeed nested within the Cheloninae and thus does not form a separate subfamily, thus corroborating the work of Dowton & Austin (1998) and Dowton et al. (2002). Although the Adeliinae do form a monophyletic group, their position in the phylogeny precludes them from being recognised as a tribe within the chelonines. The sister clade to the adeliine genera was either *Dentigaster* or *Phanerotomella,* which varied in their support values among analyses, suggesting that the status of the clade is not well established. Thus, including additional adeliine genera and species may change the results of the phylogenetic analysis significantly. Also I was unable to include all extant genera, mostly due to their monotypic status, and unavailability of samples. However, it was possible to include specimens representing rare genera, e.g. *Dentigaster, Huseyinia, Odontosphaeropyx, Pseudophanerotoma,* and *Megascogaster*. Additionally, due to the age of some of the specimens, especially *Megascogaster* and *Phanaustrotoma,* I was not able to amplify the full gene fragment, which could be the reason for the paraphyletic status of *Phanerotoma*, as discussed in **chapter 2**. Adding all genera and having a complete molecular dataset may influence the outcomes of future phylogenetic analysis, for example the position of adeliine genera among the Phanerotomini. This being said, the monophyly of several genera and relationships among them was highly supported and thus they are unlikely to change with additional data.

7.2 Taxonomic revisions and species richness

Taxonomic revisions of genera are often done years to decades after a genus has been established. Often additional species are discovered from new areas, which sometimes requires taxonomic reinterpretation of the genus or species group. Revisionary studies often increase the number of known species significantly, by four- to eightfold in the case of parasitic Hymenoptera. For instance, Austin (1990) discovered a fourfold increase during the revision of the Australasian genus *Miropotes* and an eightfold increase was discovered in Wharton's revision of the Australian Alysiini (Wharton 2002). By revising the genus *Phanerotomella* (**chapter 5**) I found a sevenfold increase in species for Australia. Based on material available in collections for all chelonines, I recognised approximately 200 morphospecies, which equates to a fourfold increase for the subfamily for Australia, while a species-richness estimation gave an overall sixfold increase in species (**chapter 6**). These figures are congruent with the revisions by Austin and Wharton (above), but they are much higher than the 1.4-1.87% increase predicted by Jones et al. (2009) for the Cheloninae on a global scale. Jones et al. (2009) discussed that the majority of new species are expected to be found in South America and Africa, based on past taxonomic descriptions and revisions. It is very likely that Australia and south-east Asia have equally diverse faunas given the rate at which new species are being uncovered for these biogeographic areas. Furthermore, the Ichneumonoidea represent 28% of all described Hymenoptera on a world-wide basis (Aguiar et al. 2013), but only 10 % of the described Australian fauna (ABRS 2013), thus the superfamily represents a much smaller proportion of species for a continent the size of Australia which has such a diverse array of habitats. It is unclear whether this is a real phenomenon or simply a result of scant collecting over the last 100+ years compared with other regions.

7.3 Taxon sampling

Many new but as yet undescribed chelonine species have been found in Australia (**chapter 3, 4, 5** and **6)**. Although a large number of specimens were available from Australian collections (more than 5000), many morphospecies are represented by just a single individual (see also **chapter 5**: *Phanerotomella*). This indicates a significant undersampling of the Australias's fauna, which can cause problems in species richness estimation (Coddington et al. 2009). Although singletons are a common finding in arthropod surveys, e.g. Butcher et al. (2012), they can be reduced to some degree with an increase in collecting effort (Coddington et al. 2009), not a trivial exercise for a landmass the size of Australia. This undersampling can have a significant impact (overestimation) on species richness estimation using available algorithms. Another factor that impacts on species richness estimations is the need for an unbiased survey of an area (underestimating the species richness). By plotting all chelonine specimens on a map (Fig. 1), a clear bias in collecting effort is visible towards the east coast. Thus, a robust estimation of species richness cannot be obtained until Australia has been more thoroughly and evenly surveyed. The species richness estimations undertaken as part of this study (**chapter 6**) are limited in their accuracy due to the biases outlined above. The absence of Adeliinae in the calculations may not have much of an effect on the total estimation, although a few more undescribed species would be expected.

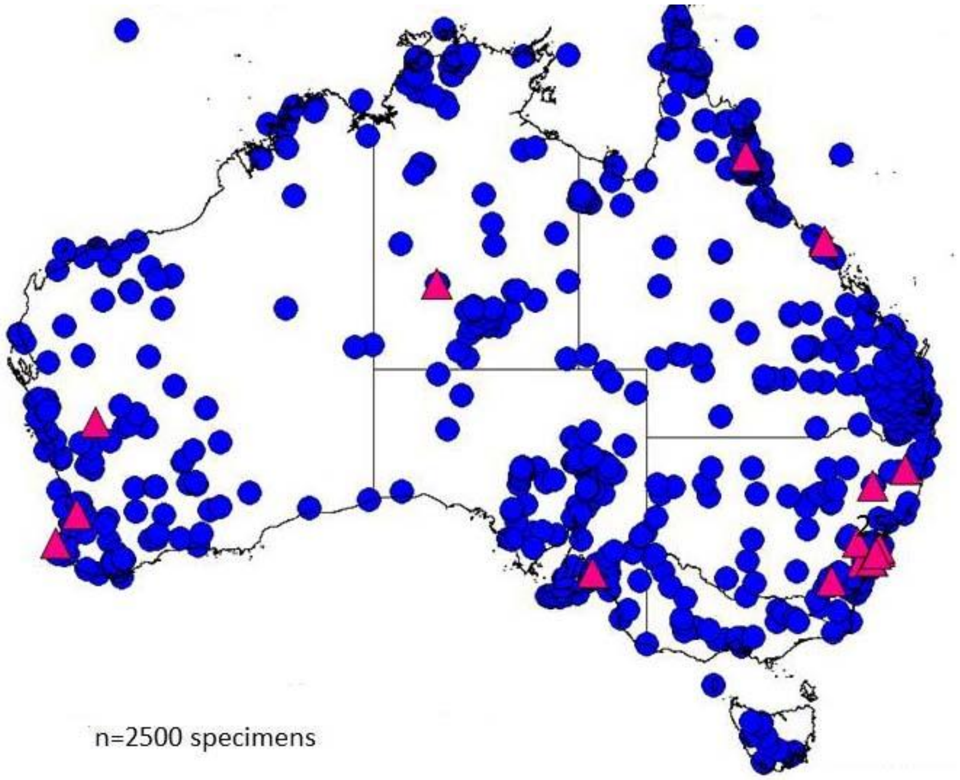

Figure 1: The localities of 2500 examined chelonine specimens for Australia. The blue circles indicate specimens for species' descriptions in preparation (incl. current study), and red triangles the type localities of species described prior to the current study.

7.4 Delimitating genera

I expanded the diagnosis of *Wushenia* (**chapter 4**) and *Phanerotomella* (**chapter 5**) in order to accommodate the morphological variation encountered in species from Australia. This approach seems valid for the genus *Phanerotomella,* which contains many described species from most biogeographic regions. However, it raises some issues for the genus *Wushenia,* as this taxon was previously monotypic. Given the morphological differences involved, the major issue is whether the Australian species is closely related to the *Wushenia* type-species from Taiwan, or whether it should be placed in an entirely different genus. Until phylogenetic data are available that indicate otherwise, the morphological differences of the second species from Australia appear not to be significant enough at the genus level (see characters discussed in **chapter 2**), thus I felt confident placing it in *Wushenia*.

The phylogenetic analyses indicate that *Ascogaster* is paraphyletic (**chapter 2**), with one clade mainly from North America, and another containing species from Australia and New Caledonia. However, I have not found any morphological differences between these two clades. Possibly host information or dissecting genitalia would help to better delimit these two *Ascogaster* clades. Until more compelling information is available that justifies them being recognised as separate monophyletic genera, I describe all relevant Australian species as belonging to *Ascogaster* (**chapter 6**).

7.5 Future research directions

This PhD thesis provides a strong framework for future phylogenetic studies on the subfamily using morphological and molecular data. For robust phylogenetic relationships it is crucial to employ multiple genes (Cunningham 1997), which I have done in this study. However, not all clades received high support values. Thus with next generation sequencing and genomic approaches the phylogenetic relationships are likely to be fully resolved. Next generation sequencing will also improve the ability to amplify shorter fragments of DNA extracted from old specimens of rare taxa and by so doing, more species can be added and therefore the phylogenetic analysis can be significantly improved (Strutzenberger et al. 2012).

The hosts of only a few species are known (Yu et al. 2012), mostly for chelonine wasps that have been reared from agriculture pests over the years. In order to separate morphologically similar species (e.g. cryptic species, **chapter 6**) or determine how species/genera have evolved with their spectrum of hosts (with host shifts being a possibility, **chapter 2**), a substantial amount of additional biological information will be required for these parasitoid wasps.

Host information can also increase our understanding of the polydnavirus-chelonine association. Many studies have aimed at understanding how polydnaviruses have evolved and why only the microgastroid complex is associated with them (Whitfield 1990, 1997, 2000, 2002; Murphy et al. 2008). However, the majority of studies focus on the more derived Microgastrinae, and very little is known about polydnaviruses associated chelonine wasps. Increased research on the polydnavirus-chelonine association might provide a better understanding of the co-evolution between the two groups and insights into the dynamics of this remarkable virus association.

This study has also provided an important contribution to our knowledge of the Australian Cheloninae by increasing the number of described species significantly. But, given the rate at which additional species are being recognised, there are still many more new species to be discovered, especially when taking the adeliine genera into account.

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Appendix

Publications derived from this study.

Chapter 2

Kittel, R. N., Jennings, J. T., Austin, A. D.:11th Invertebrate Biodiversity and Conservation Conference, Sydney, Australia, 1 - 4 December 2013, oral presentation: Phylogenetics of chelonine wasps (Hymenoptera: Braconidae); with an assessment of the Australian species richness

Kittel, R. N., Jennings, J. T., Austin, A. D.: 61st Entomological Society of America Annual Meeting, Austin, Texas, USA, 10 - 13 November 2013, oral presentation: Phylogenetics of chelonine wasps (Hymenoptera: Braconidae) with special reference to the Australian fauna

Kittel, R. N., Jennings, J. T., Austin, A. D.: 44th Conference of the Australian Entomology Society, Adelaide, Australia, 29 September - 2 October 2013, oral presentation: Phylogenetics of chelonine wasps (Hymenoptera: Braconidae) with special reference to the Australian diversity

Chapter 3

Kittel, R. N., & Austin, A. D. (2014). Synopsis of Australian chelonine wasps (Hymenoptera: Braconidae: Cheloninae) with description of two new genera. *Austral Entomology,* 53(2), 183-202.

Chapter 4

Kittel, R. N., & Austin, A. D. (2013). Remarkable range extension of the previously monotypic braconid genus *Wushenia* Zettel (Hymenoptera: Braconidae: Cheloninae), with description of a second species from Australia. *Zootaxa, 3694*(5), 486-492.

Chapter 5

Kittel, R. N., Jennings, J. T., & Austin, A. D. Revision of Australian *Phanerotomella* Szépligeti (Hymenoptera: Braconidae), with descriptions of 18 new species [submitted to Insects Systematics & Evolution].

Chapter 6

Kittel, R. N. & Austin, A. D. New species of chelonine wasps (Hymenoptera: Braconidae) from the Australian arid zone [submitted to the Journal of Natural History].

Kittel, R. (2012). Diversity of chelonine wasps (Insecta: Hymenoptera) in South Australia. *The South Australian Naturalist, 86*(1), 9-13.

Kittel, R. N., Jennings, J. T., Austin, A. D.: 3rd Combined Australian and New Zealand Entomological Societies Conference, Christchurch, New Zealand, 28 August – 1 September 2011, poster presentation: Diversity and phylogeny of Australian chelonine wasps (Hymenoptera: Braconidae); parasitoids of lepidopteran eggs

Kittel, R. N., Jennings, J. T., Austin, A. D.: 4th International Barcode of Life Conference, Adelaide, Australia, 28 November - 3 December 2011, Oral presentation: DNA based species delineation: diversity and phylogeny of Australian chelonine wasps (Hymenoptera: Braconidae); parasitoids of lepidopteran eggs

Kittel, R. N., Jennings, J. T., Austin, A. D.: 10th Invertebrate Biodiversity and Conservation Conference, Melbourne Australia, 4 - 8 December 2011, Oral presentation: The phylogeny and species diversity of Australian chelonine wasps (Hymenoptera: Braconidae)

Kittel, R. N., Jennings, J. T., Austin, A. D.: 43rd Conference of the Australian Entomology Society, Hobart, Australia, 25 - 28 November 2012, oral presentation: Systematics of Australian chelonine wasps facilitated through support from Bush Blitz

Kittel, R. N., Jennings, J. T., Austin, A. D.: 43rd Conference of the Australian Entomology Society, Hobart, Australia, 25 - 28 November 2012, poster presentation: Molecular phylogenetics of chelonine wasps (Hymenoptera: Braconidae): parasitoids of lepidopteran larvae

Kittel, R. N., Jennings, J. T., Austin, A. D.: XXIV International Congress of Entomology, Daegu, South Korea, 19 - 24 August 2012, oral presentation: The phylogeny of chelonine wasps (Hymenoptera: Braconidae) with special reference to the species diversity of the Australian fauna