

# Behaviour of the Australian 'fire-beetle' *Merimna atrata* (Coleoptera: Buprestidae) on burnt areas after bushfires

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**ABSTRACT** – The Australian 'fire-beetle' *Merimna atrata* can be found in large numbers directly after a fire in eucalyptus forests in the smoky burnt area. The main reasons for this so-called pyrophilous behaviour are reproduction and foraging. Beetles of both sexes are most probably attracted by the smell of burning eucalyptus trees and invade a freshly burnt area as early as possible. Nearly the entire cycle of reproduction, including mate finding, copulation and oviposition takes place, and the beetles are most likely protected from predators by heat and smoke. This is possible because *M. atrata* has developed special infrared receptors on the abdomen which serve for the detection of hot spots. As the burnt area gets cooler and the smell of burning declines, beetles disappear within about 3 days. Observations on burnt areas over a period of 12 years also have revealed that *M. atrata* is a diurnal sun-loving beetle which prefers high body temperatures above 40°C.

**KEYWORDS:** pyrophilous insect, forest fire, fire detection, infrared reception, Western Australia

## INTRODUCTION

The Australian 'fire-beetle' *Merimna atrata* (Gory & Laporte, 1837) (Buprestidae) bears its name because this so-called pyrophilous beetle heads for forest fires (Poulton 1915; Schmitz and Schmitz 2002). *M. atrata* is the only species of the genus *Merimna* and is distributed all over Australia (Hawkeswood 2007), but has not been found outside the Australian mainland. The first report dealing with the pyrophilous behaviour of *M. atrata* was published more than 120 years ago (Tepper 1887). Tepper noted that under normal conditions this beetle is hard to find and could never be found on flowers (Tepper 1887). Accordingly Poulton (1915) wrote that *M. atrata* is only seen when a bushfire is raging. In contrast to these older reports, however, Williams and Williams (1983) described the "Dwarf Apple" *Angophora hispida* as an adult host plant, implying that *M. atrata* visits flowers during the day. During a bushfire, *M. atrata* adults seem to approach the fire from all directions, flying straight into it (Poulton 1915). Tepper (1887) reported that thousands of beetles were in flight one or two hours after a bushfire in localities where searches for beetles had previously been fruitless. Having arrived on the freshly burnt area beetles become very agile and have been seen running over hot steaming branches and sometimes even over parts that are glowing red but

without damage to the tarsi (Poulton 1915). Although not specifically stated in these older reports, it is probable that these observations were made during the day. However, it has also been noted that *M. atrata* is nocturnal (Moore and Brown 1985). The reason for this assessment may be that *M. atrata* has been reported to be attracted to artificial lights at night (Williams 1982; Hawkeswood 1992).

It has been hypothesised that the beetles were stimulated by the scent of the fire to seek a place where their larvae can feed upon wood from which volatile protective substances have been removed by the heat (Poulton 1915). In general the larvae of *M. atrata* are most probably associated with fire-damaged eucalyptus trees (Hawkeswood 2007). Until now, however, only fire-killed *Eucalyptus* (currently genus *Corymbia*) *calophylla* (Hawkeswood and Peterson 1982) and burnt stumps of *Baeckea frutescens* (Myrtaceae) (Kitchin 2009) have been described as potential food plants for the larvae (cf. Table 1).

In contrast to nearly all other members of the otherwise brightly coloured family Buprestidae, adults of *M. atrata* are uniformly black (Figures 1A, D, E). This can be interpreted as a special adaptation as *M. atrata* is hard to discover when resting on the bark of a burnt tree (Figures 1A, 2B). Another adaptation to

TABLE 1 Larval food plants of *M. atrata*.

Name	Common name	Family	Described by
<i>Eucalyptus = Corymbia calophylla</i>	Marri	Myrtaceae	Hawkswood and Petersen 1982
<i>Baeckea frutescens</i>		Myrtaceae	Kitchin 2009
<i>Eucalyptus gomphocephala</i>	Tuart	Myrtaceae	This paper
<i>Eucalyptus marginata</i>	Jarrah	Myrtaceae	This paper
<i>Melaleuca raphiophylla</i>	Swamp paperbark	Myrtaceae	This paper

the pyrophilous lifecycle are its infrared (IR) sensing capabilities. One to three pairs of IR receptor organs occur on the abdomen (Schmitz et al. 2000; Mainz et al. 2004).

What is still missing in the literature is a comprehensive description of the behaviour of *M. atrata* on a freshly burnt area after a fire. Of special interest are the first three days when most of the reproductive cycle of the species occurs. In view of the very special habitat it is postulated that *M. atrata* shows specific adaptations to cope with the threats on a smoky burnt area. In this paper we describe the behaviour of *M. atrata* on burnt areas after wildfires in Western Australia (WA). An attempt is made to provide detailed insight into the biology and ecology of this highly pyrophilous beetle which is perfectly adapted to bushfires and to resolve some of the contradictory information currently existing in the literature.

## METHODS

### STUDY SITES

Observations of the behaviour of *M. atrata* after fires were made in forests in south-western WA located within a radius of roughly 100 km around the city of Perth. Thus our study sites extended from forests near Gingin and Bindoon in the north to the eastern forests of the Darling Range and extended down to Mandurah and Dwellingup in the south. Beginning in 2002, beetles were observed every year with the exception of 2010 during three-week field trips always lasting from mid-January to early February. Thus more than 35 freshly burnt areas were inspected, most of them more than once. The sizes of the burnt areas, however, varied considerably from less than one (e.g. a traffic island in Perth) to several thousand hectares in extensive forests outside towns.

### OBSERVATIONS OF GENERAL BEHAVIOURAL PATTERNS

Due to our collaboration with the bushfire brigade of the Western Australian Department of Parks and Wildlife (DPaW, formerly Department of Environment and Conservation) based in Wanneroo, we often arrived

at a freshly burnt area while the fire-fighters were still on the ground extinguishing pockets of embers and mopping up. Thus in larger burnt areas many hot spots were still active, mostly also emitting smoke. Even if only small numbers of eucalypt trees were affected by the fire adults of *M. atrata* could be easily observed flying over the burnt area and resting or running around on burnt trees and shrubs.

### RECORDING THE NUMBER OF BEETLES ON BURNT TREES

In January/February 2013 we counted the number of beetles on burnt trees every five minutes for two hours or at fixed times up to four days after a fire. This was done on four different burnt areas (exact locations provided in the captions of Figures 4–7). Because in the mallee woodlands typical of southern WA, eucalyptus trees frequently consist of several trunks arising from the ground (cf. Figures 6, 7), it was not possible to define a simple two-dimensional area of defined size in which beetles could be counted. Therefore we only defined an upper boundary of our observation area at a height of about 2 m. The lower boundary was the field of ash with a radius of about 1 m around the stem bases. A given tree was observed with a pair of binoculars from a fixed observation point at least five meters away from the tree.

At the first two observation sites we erected a black canvas sheet of 1.5 x 2 m as camouflage in front of our observation point. However, it turned out that the erection of the canvas chased away most beetles. On the other hand it was possible to slowly access an observation point without camouflage located next to a larger tree from behind without disturbing the beetles. Thus we omitted the canvas on the following days. All beetles visible within the observation area were counted.

### STATISTICS

Data on the number of beetles counted at different locations and on consecutive days were analyzed using a Friedman test for repeated measures. Level of significance was set at  $p < 0.05$  (\*\* $\triangleq p < 0.01$ ; \* $\triangleq 0.01 \leq p < 0.05$ ; n.s.  $\triangleq 0.05 \leq p$ ).

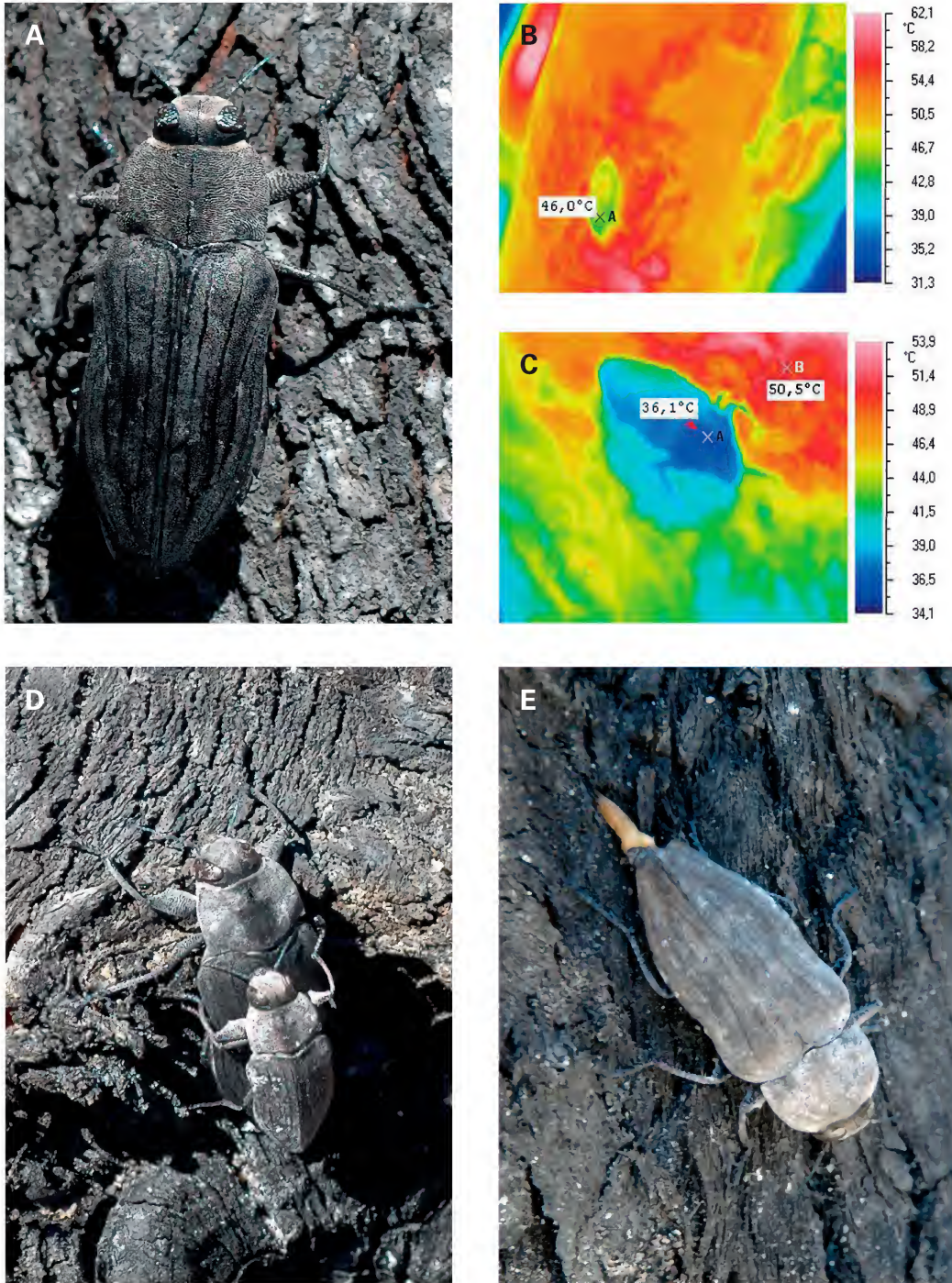


FIGURE 1 A, *M. atrata* sun basking on burnt bark; B, thermal image of a sun basking beetle; head oriented downwards; thoracic surface temperature 46°C; C, thermal image of a beetle resting at the border between the sunny and shaded region of a burnt stem; thoracic surface temperature 36°C; D, copulating beetles resting on the sun exposed side of a burnt eucalyptus tree; E, ovipositing female. Body lengths of beetles between 15 and 20 mm.

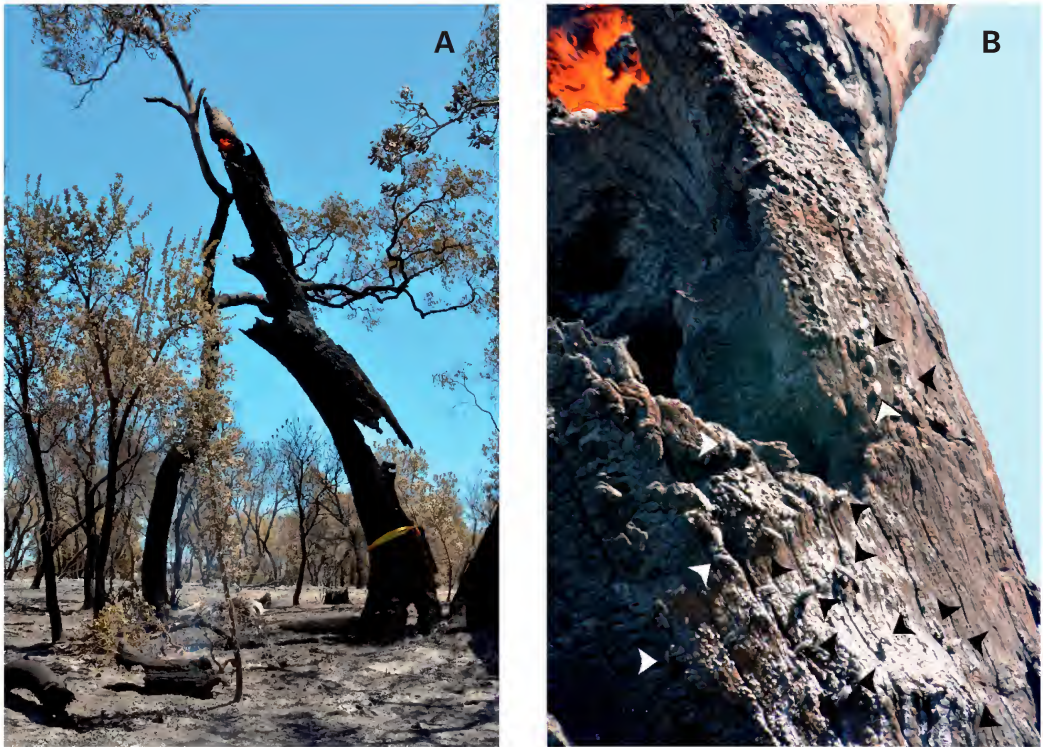


FIGURE 2 A, one day after the fire a tall burnt eucalyptus tree (height about 8 m) was still burning and glowing at its top; B, dozens of *M. atrata* (arrowheads) had aggregated directly under the apical glowing zone at a height of about 7 meters.

## IR THERMOGRAPHY

IR thermograms of resting beetles and their surroundings were taken with an IR FlexCam T IR camera (Goratec Inc.). The radiometric camera is equipped with a 160 x 120 pixel vanadium oxide focal plane array and a 20 mm germanium lens. Thermograms were visualised and analysed with GTS Thermography Studio V. 5.1. software (Goratec Inc.). The accuracy of the camera was checked against a blackbody radiator heated to 100, 200, and 300°C (CS 500, DIAS Infrared, Dresden, Germany). Deviations from respective temperatures set at the blackbody radiator were always smaller than 1°K.

## RESULTS

### BEHAVIOUR ON FRESHLY BURNT AREAS

Driven by the prevailing wind the flame front of a forest fire leaves a smoky burnt area. At this early time after the fire, the burnt area is characterised by many hot spots consisting of burning or glowing wood (e.g. fallen trees or broken off branches) and fields of hot

ashes. Thus smoke and – especially near larger hot spots – radiant heat is typical for the burnt areas in the first hours after the fire. Initially beetles arrive at the border of the freshly burnt area where they can be observed resting or running around on the vegetation. However, at the earliest time when a human is able to enter the burnt area the beetles also start to invade the scorched terrain.

Adults of *M. atrata* rapidly spread over the burnt area and can be easily observed flying around relatively close to the ground or running over the ground, trees and shrubs. However, if a beetle rests motionless on burnt bark it is difficult to observe as both sexes are coloured black (Figures 1A, D, E, 2B). Males primarily search for females and often show a stereotypical behaviour: at a height of roughly 1 to 3 m a male beetle lands on the bark of a burnt eucalyptus tree, immediately turns around and quickly runs down the stem in intermittent running sequences. On their way down to the ground male beetles look for two things: females and food. The beetles often carefully inspect crevices and holes in the bark in search for edible material. As will be described in more detail below, *M. atrata* is omnivorous.

Therefore, beetles try to exploit all vegetable and animal food sources (e.g. scorched arthropods). As soon as a male *M. atrata* becomes aware of a female beetle, it vigorously tries to copulate. It jumps onto the back of the other beetle, eventually turns around and tries to insert its aedeagus into the genital chamber of the female (Figure 1D). Often the other beetle also is a male which lugs around the upper male for some time until it tries to shake it off, using its hind legs to kick the upper male away. While doing so the lower male usually bends its abdomen away from the stem up to an angle of 45° to prevent the upper male from adhering to the bark. The violent kicks eventually causes the upper male to lose its footing; it then falls off and flies away. The rapid reflex to ride another beetle is apparently triggered by the sight of another beetle-like object especially when it is moving. This behaviour was observed on a burnt area south of Perth near Anketell Road in 2002, where some clerid beetles (*Trogodendron fasciculatum* (Schriebers, 1802)) were also present. All male *M. atrata* which came close to the dissimilar species immediately tried to copulate with it.

If a female is encountered, a male copulates within a few seconds. However, if the female is already mating it tries to remove the males in the same manner as males do if bothered by another male. The copula lasts for a longer period (not determined so far) and after copulation the females start to deposit their eggs under the bark of the burnt eucalyptus trees by inserting their ovipositor in small crevices (Figure 1E).

During the many years observing *M. atrata* on burnt areas we have learnt that locations where eggs are deposited are very variable. Generally the eggs are laid in trunks and branches of burnt eucalyptus species (Table 1). We have never observed eggs that were deposited in unburnt parts of a tree (e.g. at the border of the burnt area). Severe damage to the region of the tree where the eggs are deposited seems to be important. In most cases eggs are deposited relatively close to the ground (up to about 2 m) where the heat of the ground fire has most probably heavily damaged the cambium layer. In this area, and especially older damage of the bark caused by previous fires, seems to be of interest. At those spots the bark is partially broken open by the ground fire and the edges are usually scarred. The deposition of eggs is preferred around the bulging edges of bark. Another surprising behaviour is that females sometimes completely dive into the ash with the tip of the abdomen first. This behaviour was frequently observed even some meters away from the base of a tree. Females stay hidden in the ash for some minutes until they re-emerge and fly away. These ash-covered females look remarkably white for some time (Figure 3A). Although we never were able to verify oviposition under the ash we are convinced that females deposit their eggs in or near roots smothered in ash.

As mentioned above, there is strong evidence that *M. atrata* also intensely uses the opportunity to forage on the burnt area. All potentially edible material is investigated and if palatable, eaten. We have frequently fed beetles with fruit, peanuts, resins, cheese and meat, among others, and everything was eaten by the beetles. Occasionally we have observed *M. atrata* to feed on dead conspecifics. Also carcasses of small fire-killed vertebrates are devoured (Figure 3B).

#### THERMOREGULATION

Like most buprestid beetles, *M. atrata* is a thermophilic species preferring high body temperatures (Evans et al. 2007). Thus the whole behaviour displayed on the freshly burnt area is strongly influenced by thermoregulatory needs. The highest level of activity occurs during the hottest hours of the day. In the hours around noon beetles fly around in the bright sunshine and prefer to land on the sun-exposed sides of tree trunks. Shaded stems and branches are clearly avoided as landing sites. A striking phenomenon which can

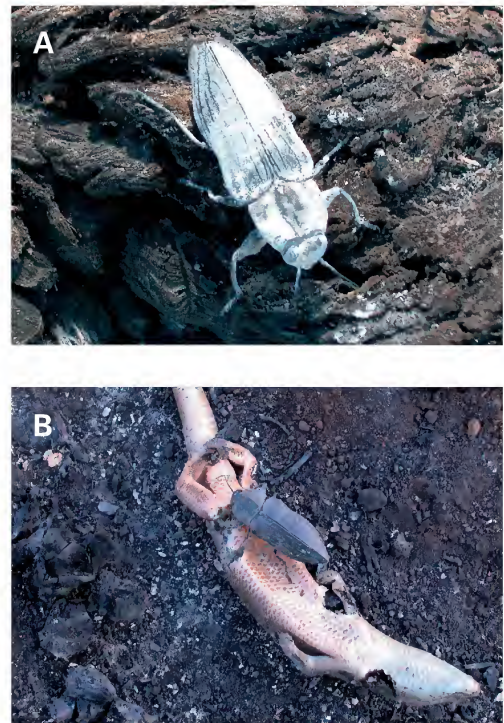


FIGURE 3 A, Female *M. atrata* powdered with white ash resting on a burnt log after oviposition in the ash; B, *M. atrata* feeding on a scorched lizard; several pieces had already been bitten out by conspecifics.

be frequently observed is that the black beetles rest motionless on the jet-black bark of a burnt tree for many minutes in full sunshine (Figure 1A). Because ambient temperatures on hot summer days often already exceed 30°C, the body temperatures of sun basking beetles can quickly reach temperatures of 40°C or more (Figure 1B), suggesting that *M. atrata* is extremely thermophilic. At these high body temperatures beetles are extremely agile and can avoid overheating in different ways by: (i) raising the body away from the bark by extending the legs to maximal lengths under the body thereby facilitating convective cooling along the entire body; (ii) by moving to shaded regions of the stem with characteristic sharp sudden movements (Figure 1C); or (iii) by flying away. Based on our current thermographic measurements on about 30 *M. atrata*, a beetle will not tolerate an increase of its body temperature beyond 46°C.

#### PROGRESSION OF BEETLE ACTIVITY AFTER THE FIRE

In the first hours after a fire, many beetles can be found on the burnt area. As long as the running fire is burning and hot spots on the freshly burnt area emit heat and smoke, further beetles will be attracted. This can be observed at the boundary of smaller burnt areas when beetles fly in from unburnt terrain.

On the first day after the fire, the number of beetles on a given burnt area shows a distinct peak. Even if the firefighters had extinguished all hot spots on smaller burnt areas (cf. Figure 4), beetles stay on the scorched site and display the entire behaviour described above.

Although not so far supported by quantitative investigations it is quite evident that hot spots – even very small ones – increase the numbers of beetles in their immediate vicinity (Figure 2A, B). For example on the third day after a fire, several beetles could still be observed on a broken tree stump with small hot spots at its base (Figure 5). At this spot it was conspicuous that some beetles rested for many minutes at sheltered sites near the base of the trunk.

However, especially when ambient temperatures are high and the tree is sun exposed, the behaviour is very dynamic which is mirrored by the permanently changing numbers of beetles (cf. Figures 4, 5). A continual coming and going can be observed: new beetles arrive eventually chasing away others when landing. Beetles which had run down the stem frequently took off after having crawled a few dozen seconds in the ash on the ground. Another reason that beetles suddenly disappear were attempts by males to copulate with other males. If the lower male finally got rid of the upper one the unsuccessful aggressor frequently flew away.

A continuous decrease in the number of beetles continues over the next days (Figure 6). On the first day

at the Gngangara-Moore River State Forest, a smoking hot spot at the base of a tree and another one a few meters away on the broken branch of a fallen tree most probably increased the attractiveness of this spot. On the second day both hot spots were extinguished. However, beetles could still be observed for another two days in significantly declining numbers.

Most probably, hot spots are not the predominant factors defining the general attractiveness of a tree. This is shown in Figure 7 where three neighbouring trees on a small burnt area had been observed. The 2 ha burnt area close to houses was completely extinguished by the firefighters just after the fire had been noticed. Nevertheless the fire attracted great numbers of beetles which stayed on the clear area for three days. As usual, beetle numbers declined over three days and on the fourth day all beetles had disappeared, most probably already searching for new fires.

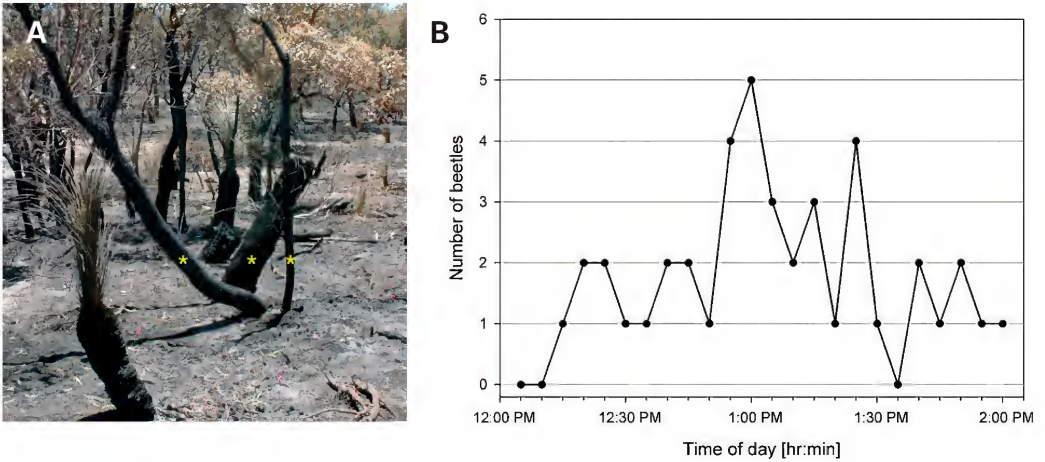
Observations on larger burnt areas outside inhabited areas often yielded the result that beetles aggregate around larger hot spots. If a large hot spot (e.g. a fallen tree) was burning or glowing for more than three days, beetles usually could be found around it.

## DISCUSSION

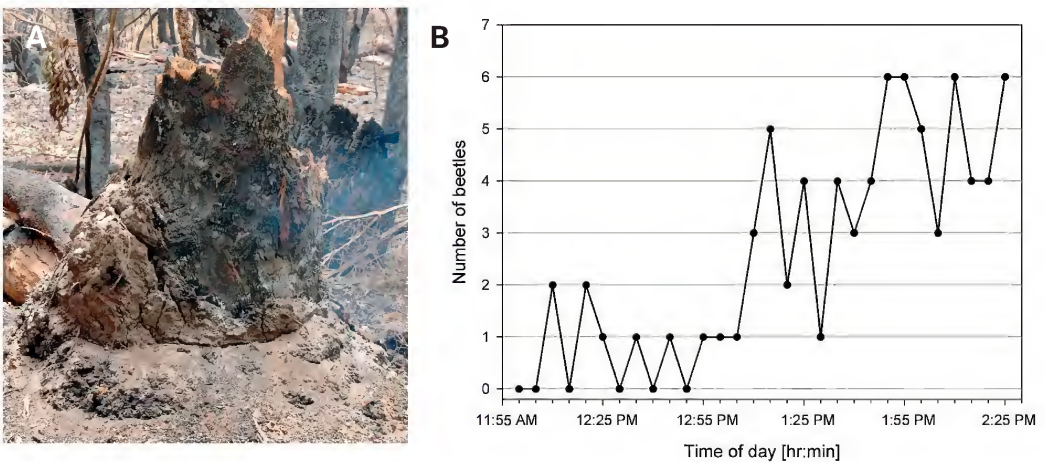
#### THE FRESHLY BURNT AREA AS A VALUABLE ECOLOGICAL NICHE

Although not evident at first glance, a freshly burnt area can be regarded as an interesting ecological niche for a wood-boring insect like *M. atrata*. If equipped with the appropriate sensory systems to prevent injuries by flames and hot surfaces, smoke and heat offer a good shelter against predators. As long as the burnt area is "active" (i.e. characterised by smoking hot spots), mating, foraging and oviposition can take place safely. As the burnt area cools down we have frequently observed that birds such as Australian Magpies (*Cracticus tibicen*) start to prey on *M. atrata*. As long as there is heat and smoke, however, birds stay away from those locations. This may be the reason that *M. atrata* gathers around hot spots.

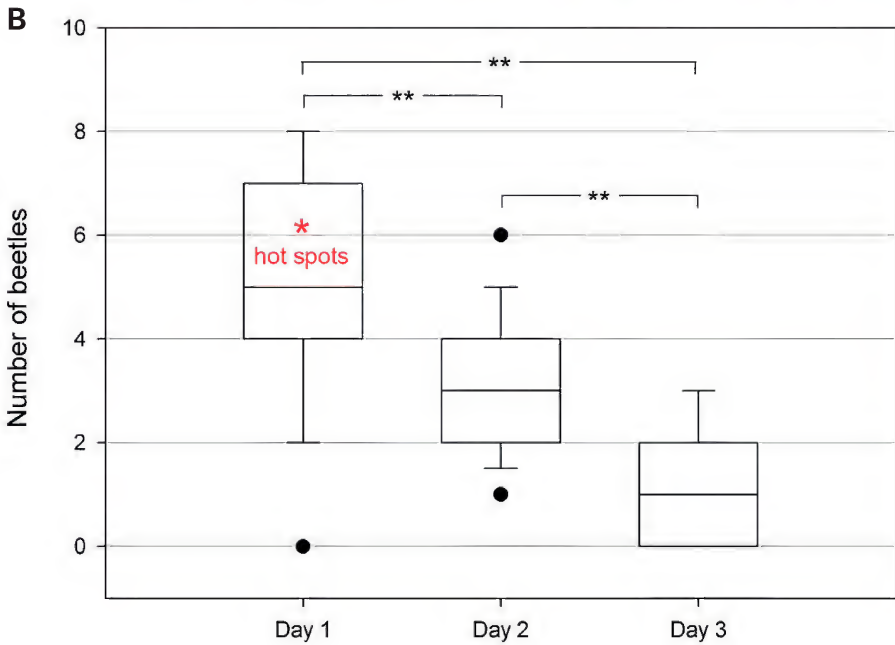
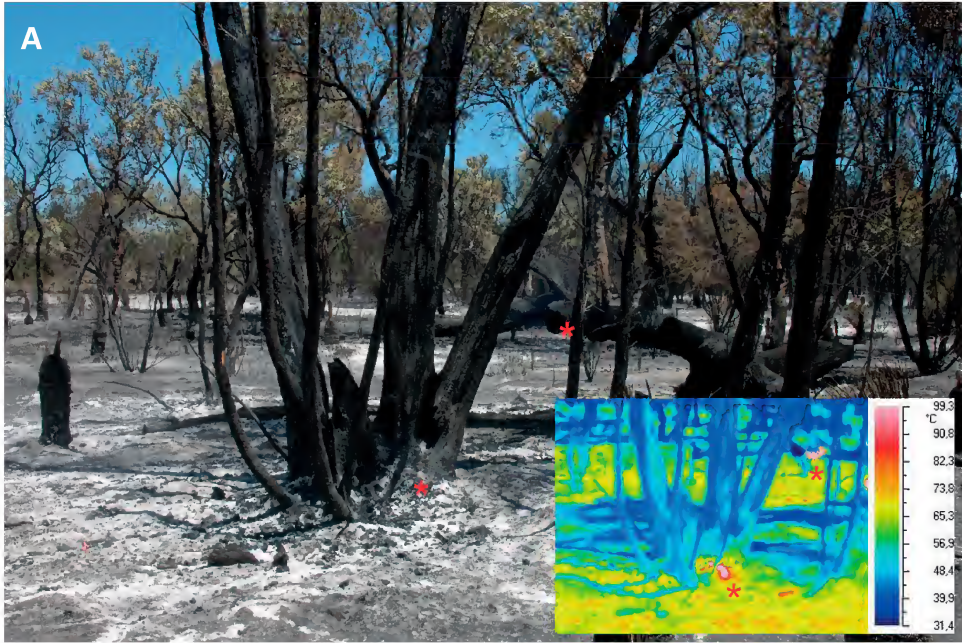
The second and obviously most important reason is that the wood of the burnt trees is an ideal source of food for the wood-boring larvae. Especially closer to the ground the cambium layer has been killed by the intense heat preventing any further protective mechanisms like increased cell divisions around the tiny first larvae in order to squash the unwelcome intruder. Additionally, as already proposed by Poulton (1915), harmful volatile protective substances have been evaporated by the heat. As a result, a freshly burnt area is a kind of "land of plenty" for a woodborer like *M. atrata*. However, in order to profit from all advantages (protection and larval



**FIGURE 4** Beetle activity on an extinguished burnt area close to Farrington Road, North Lake, Western Australia (32°04'52"S, 115°50'49"E): A, small group of three burnt stems of different diameter (see asterisks) one day after a fire on 20 January 2013; no hot spots could be identified; B, Number of beetles visible from the viewpoint during two hours of observation; the decrease in beetle numbers during the first hour was caused by the setting up of the black canvas. Although erection of the canvas took only about 10 minutes it took one hour before the initial number of beetles observed before the disturbance (approximately 3 to 4 beetles) was reached.



**FIGURE 5** Beetle activity on a burnt area close to Reid / Roe Highway, Middle Swan, Western Australia at 31°51'49"S, 116°00'56"E: A, broken stump of a large eucalyptus tree; some smaller hot spots near the base of the stump still emitted smoke; B, number of beetles counted on the bark of the stump visible from the viewpoint three days after the fire on 16 January 2013. As in Figure 4 the decrease in numbers of beetles during the first hour was caused by setting up the canvas. Although erection took only about 10 minutes it took nearly one hour until the initial number observed before the disturbance (approximately 3 to 4 beetles) was reached.



**FIGURE 6** Progression of beetle activity on a single tree over a period of three days: A, eucalyptus tree with many basal side branches on a burnt area in the Gngara-Moore River State Forest, Pinjar, Western Australia, near Higgins Road at 31°37'42"S, 115°52'07"E. On day 1 after the fire two hot spots were still active (see red asterisks) and emitted some smoke. Inset shows IR image; B, number of beetles counted every five minutes over a period of two hours in the early afternoon on three consecutive days (21–23 January 2013). Symbol '\*\*' indicates highly significant differences with a p-value set at  $p < 0.01$  (Friedman test).

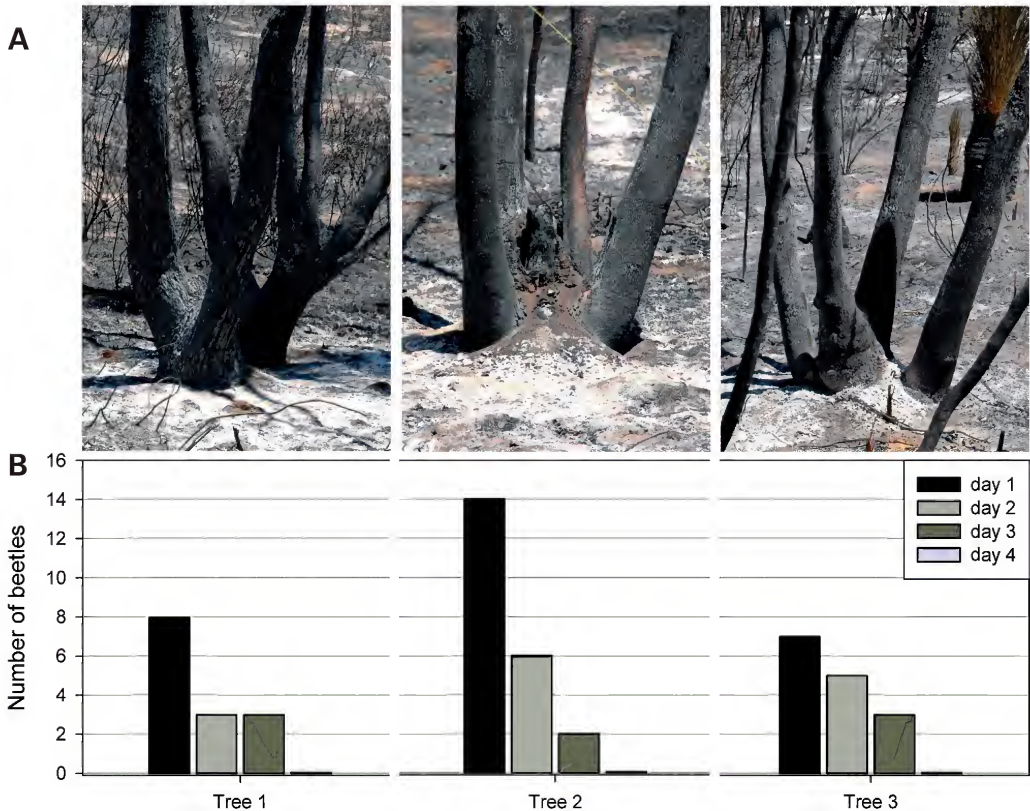


food still untouched by competitors), the burnt area has to be found as early as possible.

A further feature of a burnt area advantageous for a thermophilic beetle like *M. atrata* is the opening of the canopy caused by burning of the leaves and small branches so that the sunbeams can more readily reach the stems of the black tree trunks and the ground. Beetles can bask efficiently to quickly reach the high body temperatures necessary to become highly active. The sun-exposed burnt tree trunk, therefore, can be regarded as an ideal meeting place for males and females. This is in line with our observations that shaded trunks are clearly avoided. We also speculate that the smell of smoke may serve as a kind of pheromone substitute. This may be another reason that beetles are attracted to smouldering wood and gather around smoking hot spots. Beetles have been observed after sunset around

street lights (Williams 1982; Hawkeswood 1992), which can most probably be interpreted as a misdirection by beetles which may have emerged on a nearby burnt area and have approached the bright streetlights as many other diurnal insects do during warm summer nights.

The value of a freshly burnt area as a favourable place to start reproduction is additionally demonstrated by the immediate arrival of other highly pyrophilous insects like the "Little Ash Beetle" *Acanthocnemus nigricans* (Hope, 1843) (Acanthocnemidae) and the flat bugs *Aradus albicornis* (Walker, 1873) and *A. fuscicornis* (Kormilev, 1966) (Aradidae) which all are also equipped with IR receptors (Champion 1922; Kreiss et al. 2005; Schmitz et al. 2010). However, these IR receptors are totally different from the abdominal receptors in *M. atrata* and, therefore, must have developed independently.



**FIGURE 7** Progression of beetle activity over four days on three different trees (28-31 January 2013); observations started one day after the fire had been extinguished: A, pictures of the three trees. All trees were located on the same burnt area of only 2 ha close to Pipidinny Road, Eglinton, Western Australia, 31°35'06"S, 115°40'59"E; no hot spots were active; B, beetles were always counted at 2:00 pm; on a given day beetle numbers did not differ significantly between trees (Friedman test; p-value p<0.05).

## PREREQUISITES FOR EXPLOITING A BURNT AREA

Even on a fire-prone continent like Australia that is characterised by frequent forest fires the outbreak of a fire in a given forest is unpredictable. Therefore it can be proposed that a strong evolutionary pressure has acted on sensors used by *M. atrata* to detect fires. While it is possible that receptors for visual, olfactory, acoustic, and thermal stimuli could be used, there is no information that *M. atrata* can hear a fire such as has been described, for example, in certain reed frogs of the West African savannah (Grafe et al. 2002). It is speculated that beetles performing a search flight could be able to see a huge smoke plume against the horizon. The view of a smoke plume may give the beetles their first hint that a bushfire is burning even if the wind does not blow the smoke into the direction of the beetle. Nevertheless, olfaction is certainly also very important for fire detection. It has been shown that *M. atrata* can smell several fire-specific compounds (Eßinger et al. 2010). An important group of marker volatiles are specific host plant terpenoids. Terpenes are released at low to moderate temperatures before ignition of the wood. It has been shown by electrophysiological experiments that *M. atrata* is able to smell  $\alpha$  pinen and especially cineol, the main component of eucalyptus oil (Stefan Schütz, Göttingen, pers. communication). In the pre-combustion stage (at temperatures between 150–200°C) thermal decomposition products of hemicellulose like furfural are emitted. If the wood finally burns (temperatures 200–250°C and above), guaiacol and its derivatives (e.g. 2-methoxyphenol) from the oxidation of lignin are emitted. All these key components can be detected by *M. atrata* with high sensitivity (Eßinger et al. 2010; Paczkowski et al. 2011).

So there is considerable evidence that *M. atrata* approaches a fire mainly guided by olfactory cues. Our observations demonstrate that *M. atrata* can only be found if at least a few burnt eucalyptus trees are available on the burnt area. This has been observed some years ago after a very small fire on a traffic island in Innaloo, a northern suburb of Perth. On this little island a few small eucalyptus trees were scorched by the fire and about a dozen *M. atrata* were found on the trees just after the fire has been extinguished. Small campfires made with eucalyptus twigs and leaves also attract *M. atrata*. In contrast, fires in pure *Banksia* woodlands or in pine plantations do not attract *M. atrata* at all. Thus a burnt area is only of interest for *M. atrata* if the typical eucalyptus specific smell (e.g. of cineol) can be perceived.

Particularly with regard to special receptors, fire adaptations are extensive in *M. atrata*. As a unique feature, *M. atrata* has developed IR receptors on the abdomen. A pair of circular IR receptors is situated on the second, third, and sometimes also on the fourth abdominal sternite (Schmitz et al. 2000, 2001; Mainz et al. 2004). A single IR receptor is located close to the lateral edge of the curved sternite and is characterised

by a yellowish IR absorbing area (diameter of about 0.5 mm) slightly sunken into the dark cuticle (Schmitz et al. 2001). In a flying beetle the organs are directed to the ground in an angle of roughly 45°. The receptor is innervated internally by a so-called sensory complex consisting of one large thermoreceptive neuron and a small chordotonal organ consisting of two mechanosensitive scolopidia (Schneider and Schmitz 2013). So far electrophysiological recordings have only been obtained from the thermoreceptive neuron. Results had shown that the neuron responds to an increase in temperature in a phasic-tonic way. Sensitivity, however, seems not to be high. A threshold of 400 W/m<sup>2</sup> has been determined (Schmitz and Trenner 2003). This rather low sensitivity does not point to a function of the IR receptors as detector for remote fires. Accordingly, beetles most probably make use of their IR receptors on a burnt area in order to prevent landing on a hot spot. We have never observed beetles running over glowing surfaces as reported by Poulton (1915). Additionally, there is no indication that *M. atrata* can tolerate high temperatures beyond 46°C. Therefore, the IR receptors are used as an early warning system enabling the beetle to detect a hot spot before it becomes injured by a hot surface. However, the mechanosensitive chordotonal organ eventually could extend the measuring range thereby increasing the sensitivity of the organ which may allow detection of fires from greater distances (Schneider and Schmitz 2013).

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# Taxonomic resolution of the *Aprasia repens* species-group (Squamata: Pygopodidae) from the Geraldton Sandplains: a description of a new species and additional mainland records of *A. clairae*

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**ABSTRACT** – The Australian pygopodid genus *Aprasia* is a group of morphologically conservative, worm-like fossorial lizards. Combined allozyme and morphological analyses revealed a previously unrecognised species, named herein as *A. wicherina* sp. nov., known from a small number of specimens from an area of elevated, ancient sandplains on the central west coast of Western Australia. The new species is a member of the *Aprasia repens* species-group, but it is genetically divergent and morphologically distinguishable from all other previously described members of this group, including the geographically proximate *A. clairae*, *A. haroldi*, *A. repens* and *A. smithi*. We also report additional specimens of *A. clairae* from the central west coastal mainland and we provide new information that supplements our original description of this species. Finally, we present preliminary allozyme evidence for additional candidate species in *A. repens*, thus highlighting the need for greater geographic sampling of this widespread taxon. Addition of *A. wicherina* sp. nov. to the Western Australian endemic *A. repens* species-group brings the known diversity to eight species, with the highest diversity on the Geraldton Sandplains. The discovery of yet another new and potentially rare vertebrate species from southwestern Australia underlines our lack of knowledge of the most developed part of the state.

**KEYWORDS:** worm lizard, taxonomy, *Aprasia wicherina* sp. nov., conservation, allozyme electrophoresis

## INTRODUCTION

*Aprasia* Gray, 1839 is a genus of small, worm-like fossorial pygopodids, which currently includes 10 species in Western Australia. Preliminary investigations of the endemic *A. repens* species-group (which includes all Western Australian species other than *A. inaurita*, *A. pulchella* and *A. striolata*) suggested that species diversity had been significantly underestimated, especially along the west coast between Geraldton and the North West Cape (Aplin and Smith 2001: 70). These previous investigations initiated a combined molecular and morphological appraisal of taxa within the *A. repens* species-group as proposed by Storr et

al. (1990). The first outcome of this work was the description of *A. clairae* from single localities on the Houtman Abrolhos islands and the adjacent mainland near Dongara (Maryan et al. 2013a). A second outcome was the description of *A. litorea* from the Lake MacLeod region, and the synonymising of *A. fusca* with *A. rostrata* (Maryan et al. 2013b). During these studies several other unresolved taxonomic issues were noted within the *A. repens* species-group, including the identity of morphologically distinctive specimens from localities at the northern edge of the range of *A. repens* (Maryan et al. 2013a). Previous treatments of *A. repens* have included specimens from as far north as Kalbarri (Storr et al. 1990; Wilson and Swan 2013), however the

northernmost record is based on a single specimen of uncertain identity (Aplin and Smith 2001: 70).

In this contribution, our third on the *A. repens* species-group, we focus on the taxonomic identity of four distinctive specimens from an area of ancient, elevated sandplains on the central west coast of Western Australia. In general aspects of morphology, including the elongate body and protrusive rostral ‘beak’, these specimens resemble *A. rostrata* (*sensu* Maryan et al. 2013b); the most northerly distributed member of the *A. repens* species-group. However, the southern sandplains population differs from *A. rostrata* and all other members of the *A. repens* species-group on both molecular and morphological criteria. We herein diagnose this population as the eighth species in the *A. repens* species-group. Our expanded analyses also resulted in the recognition of additional mainland populations of the recently described *A. clairae* (Maryan et al. 2013a), and allow for an expanded account of the morphology, distribution and habitat associations of this geographically restricted species. Finally, our results provide further evidence for as yet unresolved taxonomic complexity within *A. repens sensu stricto*.

## MATERIAL AND METHODS

### ALLOZYME ANALYSIS

Liver samples of those specimens with tissues extracted are stored at -70°C at the Western Australian Museum, Perth (WAM) or Evolutionary Biology Unit, South Australian Museum, Adelaide (SAMA), including tissues from three of the four specimens of the putative new species (WAM R121129, WAM R146587, WAM R173106). These tissues were incorporated into an extended allozyme study that also included all previous analysed *Aprasia* tissues (Maryan et al. 2013a, 2013b) as well as some previously uncharacterised samples of the *A. repens* species-group tissues from the central west coast of Western Australia. The allozyme study also included exemplars of all other species of *Aprasia*, some of which were not included in previous studies. Notable among the latter was the only available tissue of *A. picturata*. Details of the 83 specimens used for the allozyme study are presented in the Appendix. Figure 1 shows the geographic origin of the *A. repens* species-group specimens used in the allozyme study.

Allozyme electrophoresis of liver homogenates was undertaken as described in Richardson et al. (1986) for the same suite of enzymes as previously employed (Maryan et al. 2013a, 2013b). As in our earlier studies, we first used an individual-based analytical procedure (stepwise Principal Coordinates Analysis: PCO), before subsequently undertaking taxon-based assessments of genetic affinities (Neighbour-joining tree). All

procedural details for implementing these analyses are presented in these studies and discussed in more detail elsewhere (Hammer et al. 2007; Adams et al. 2014).

### MORPHOLOGICAL ANALYSIS

The four individuals of the putative new species were compared to 17 specimens of the morphologically similar species, *A. rostrata*, from the North West Cape peninsula and offshore islands, and to the nearest geographical congeners comprising 7 specimens of *A. clairae* and 29 *A. repens* from between Perth and Geraldton (Appendix and type lists in Taxonomy section). All specimens are from the collections of the Western Australian Museum, Perth (WAM). Sex of individuals was determined by visual inspection of everted hemipenes and postcloacal spurs in males, presence of eggs in heavily gravid females or internal examination of gonads. Head scale definitions follow those used by Storr et al. (1990), and methods of scale counting and morphometric measurements follow those used by Maryan et al. (2013a, 2013b), with two additional measures: body width and body depth.

For the purpose of this study the following linear measurements reported in millimetres (mm) were taken with digital calipers or plastic ruler: snout-vent length measured from tip of snout to vent (SVL), head depth measured from a point immediately behind eyes (HD), head length measured from tip of snout to posterior margin of frontal scale (HL), head width measured from a point between eyes (HW), rostral length measured between anterior and posterior point of scale (RL), rostral width measured between lateral extremes of scale (RW), snout length measured from tip of snout to anterior margin of eye (SL), body width measured half way on body between lateral surfaces (BW) and body depth measured half way on body between dorsal and ventral surfaces (BD). Three meristic counts were taken: number of midbody scale rows counted half way around body (Mbs), number of ventrals counted from immediately behind mental scale to vent including precloacal scale (Vent) and number of vertebrae counted from immediately behind frontal scale to above vent (Vert). Specimens preserved in a circular or twisted position were straightened on a flat surface when measured for snout-vent length. We excluded tail length from our linear measurements and multivariate analysis of morphological variation, as the majority of tails in specimens were recently broken or obviously regenerated, as indicated by a clear break in colouration. In any case, x-rays are necessary to reliably distinguish between original and fully regenerated tails in pygopodid lizards (G. Shea, pers. comm.) and these were not taken during this study. In this study, we provide only tail length measured from tip of tail to vent in the designated holotype of the putative new species

for descriptive purposes only (type lists in Taxonomy section).

An index of body robustness (IBR) was calculated by dividing the SVL by the average of body width (BW) and body depth (BD), as follows:  $IBR = (SVL / (BW + BD)) / 2$ .

For the two better represented taxa, we used T-tests ( $\alpha = 0.05$ ) to test for sexual dimorphism in each measurement and meristic scale count; these were calculated without prior assumption of equal variances. Statistical operations were implemented in Prism version 6.05. We also used T-tests to determine the statistical validity of observed interspecific contrasts in measurements and meristic values.

## RESULTS

### ALLOZYME ANALYSIS

The primary dataset resulting from the allozyme study comprised the genotypes of 83 *Aprasia* specimens at 38 presumptive allozyme loci. These data are summarised in Table 1 as allozyme frequencies by locus for each of the taxa as ultimately identified by stepwise PCO. Since a preliminary PCO of all specimens (not presented) clearly indicated a primary genetic dichotomy between members of the *A. repens* species-group (*sensu* Storr et al. 1990; Maryan et al. 2013a, 2013b) and all other outgroup species (i.e. *A. aurita*, *A. inaurita*, *A. parapulchella*, *A. pseudopulchella*, *A. pulchella*, and *A. striolata*), all subsequent PCOs were restricted to the 53 individuals representing the *A. repens* species-group.

Stepwise PCO of these 53 individuals (Figure 2) demonstrated the presence of nine genetic clusters that were diagnosable from one another by fixed differences (FDs) at multiple allozyme loci (range 2–12; mean 7.5; Table 2). Individually, these clusters were referable to *A. clairae*, *A. haroldi*, *A. litorea*, *A. picturata*, two diagnosable lineages within *A. repens* (one ‘coast’ and the others with discrete ‘south’ and ‘north’ populations; Figure 1), *A. rostrata*, *A. smithi*, and lastly the three *A. sp.* individuals that prompted this study (referred to in Figure 1 and hereinafter as *A. wicherina* sp. nov.). Importantly, there are several instances where diagnosable taxa were collected either in near sympatry (*A. clairae* and *A. repens* ‘north’; *A. repens* ‘coast’ and *A. repens* ‘south’; Figure 1) or parapatry (*A. clairae*, *A. repens* ‘north’, and *A. wicherina* sp. nov.; Figure 1).

*Aprasia wicherina* sp. nov. shows multiple FDs with each of the geographically proximate species of the *A. repens* species-group (Table 2), as follows: four FDs with *A. clairae*, five FDs with *A. haroldi*, four FDs with *A. repens* ‘north’ (six and five FDs with the *A. repens* ‘coast’ and ‘south’, respectively), ten FDs with *A. smithi*. It shows six FDs with *A. rostrata*. This finding effectively rules out the possibility that *A. wicherina* sp. nov. is of recent hybrid origin, although it does not

deny the possibility of some genetic interaction with one or more of the regionally sympatric species, leading to limited introgression.

A neighbour-joining tree assessing the genetic affinities of all *Aprasia* species and lineages is presented in Figure 3. The key outcomes of this analysis are: (1) modest support for the monophyly of all species currently assigned to the *A. repens* species-group (Storr et al. 1990; Maryan et al. 2013a, 2013b) (2) the placement of *A. wicherina* sp. nov. in this group as a possible sister species to *A. rostrata* (3) support for the two diagnosable lineages within *A. repens* being sister taxa (4) no allozyme evidence of any close phylogenetic relationship between *A. picturata* and *A. pulchella* (contra suggestions by Jennings et al. 2003 from analysis of mtDNA sequence data), and (5) reasonable concordance between the allozyme and mtDNA trees for all other jointly included species (note that *A. fusca* has now been synonymised with *A. rostrata*; Maryan et al. 2013b).

### MORPHOLOGICAL ANALYSIS

Mensural and meristic data are summarised in Table 3 for each of *A. wicherina* sp. nov., *A. rostrata*, *A. clairae* and a sample of *A. repens* that includes representatives of all of the genetic sub-groups of this species. Data is presented separately for each sex in light of the fact that many pygopodids are sexually dimorphic in both metric and meristic attributes (e.g. Maryan et al. 2007).

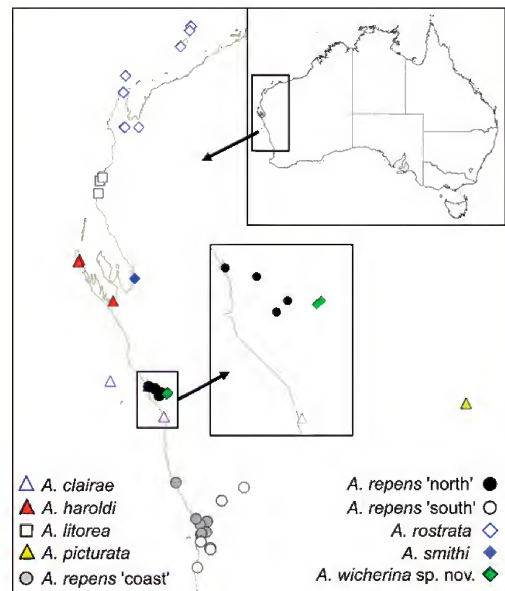
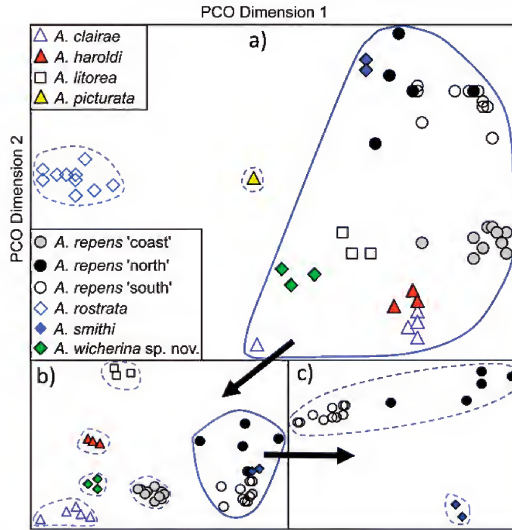
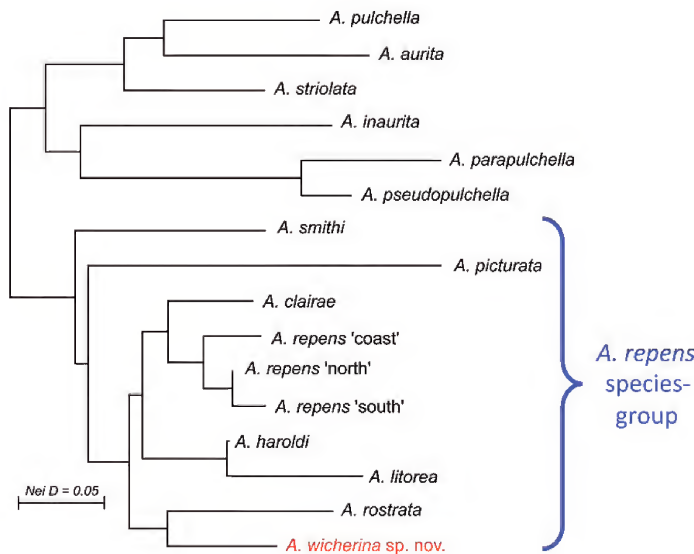


FIGURE 1 Map showing the location of the 53 *A. repens* species-group specimens included in the allozyme study.



**FIGURE 2** Stepwise Principal Coordinates analysis of the 53 specimens of the *A. repens* species-group included in the allozyme study. Each individual is identified by a symbol depicting its morphotype. PCO clusters that were ultimately diagnosable from all others by at least two fixed differences are encircled with a dotted line, while PCO clusters representing multiple taxa are encircled in a solid line. (a) Initial PCO of all 53 specimens. Relative PCO scores have been plotted for the first and second dimensions, which individually explained 29% and 13% respectively of the total multivariate variation present. (b) Follow up PCO of 41 individuals within the composite cluster comprising all species except *A. rostrata* and *A. picturata*. These dimensions accounted for 21% and 16% respectively of the total multivariate variation present. (c) Follow up PCO of individuals within a second composite cluster comprising the 'north' and 'south' lineages of *A. repens* (as defined in Figure 1) plus *A. smithi*. These dimensions accounted for 25% and 24% respectively of the total multivariate variation present.



**FIGURE 3** Neighbour-joining tree among 16 species and/or lineages of *Aprasia*, based on the pairwise unbiased Nei Distances (Table 2).

TABLE 1

Allozyme frequencies at all variable loci for 13 *Aprasia* species plus the three OTUs identified in *A. repens*. Species are labelled using the first two letters of their name. For polymorphic loci, the frequencies of all but the rarest allele is expressed as a percentage and shown as a superscript. Sample sizes are given in brackets. A dash (-) indicates there was insufficient enzyme activity to assign genotypes. The following loci were monomorphic: *Gapd*, *Ldh*, and *Mdh*.

Locus	AU (2)	IN (5)	PA (4)	PS (6)	PU (4)	ST (9)	CL (5)	HA (3)	LI (3)	PI (1)	RE coast (10)	RE north (5)	RE south (10)	RO (11)	SM (2)	WI (3)
<i>Acon1</i>	a	b	d	d	b	b <sup>83</sup> ,c	d	d	b	f	d	b <sup>80</sup> ,d	d	b <sup>90</sup> ,c	f	d <sup>83</sup> ,e
<i>Acon2</i>	f <sup>75</sup> ,d	a <sup>90</sup> ,f	f <sup>87</sup> ,e	f	f	b <sup>38</sup> ,k <sup>27</sup> , f <sup>22</sup> ,h <sup>17</sup> ,c	i	i	m	m	f <sup>80</sup> , I <sup>15</sup> ,f	f <sup>80</sup> ,i	f <sup>60</sup> ,e <sup>25</sup> ,f <sup>10</sup> ,d	m	j <sup>50</sup> ,n	i
<i>Acp</i>	a	a	a	a	a <sup>75</sup> ,b	a	a	a	a	a	a	a	a	a	a	a
<i>Acyc</i>	c	c	c	c	c	c	b	b	b	a <sup>50</sup> ,b	b	b	b <sup>95</sup> ,a	b	b	b
<i>Akl</i>	a	a	a	a	a	a	a	a	a	b	a	a	a	a	a	a
<i>Ak2</i>	b	b	b	c <sup>88</sup> ,b	b	b	b	b	b	b	b <sup>85</sup> ,a	b <sup>80</sup> ,d	b	b <sup>95</sup> ,c	b	b
<i>Dia</i>	c <sup>90</sup> ,d	b	g	g	d	a <sup>63</sup> ,e	-	f <sup>90</sup> ,g	-	g	-	e	e	-	-	-
<i>Enol</i>	b	b	b	b	c	b	b	a	a	c	a	c	c	c	c	b
<i>Est</i>	b	b	b	b	b	b <sup>86</sup> ,d	b	b	b	b	b <sup>75</sup> , a <sup>15</sup> ,c	b	b	b	b	b <sup>83</sup> ,c
<i>Fum</i>	c	c	d	c	c <sup>60</sup> , b <sup>38</sup> ,e	c	c <sup>90</sup> ,f	c	c	c	c <sup>70</sup> ,f	c <sup>90</sup> ,a	f <sup>60</sup> ,c	c	c	c
<i>Gda</i>	b	b	b	b	b	b	b	b	b	b	b	b <sup>67</sup> ,c	b	a <sup>83</sup> ,b	b	b <sup>83</sup> ,a
<i>Glo</i>	c	d <sup>70</sup> , e <sup>20</sup> ,c	c	c	d	d <sup>94</sup> ,b	d	d	d	d	d	c <sup>70</sup> ,d	c <sup>90</sup> ,a	d	c	d
<i>Got1</i>	c	c	a	a	c	c	c	b <sup>83</sup> ,c	b	c	c	c <sup>60</sup> ,d	c	c <sup>75</sup> ,e	c	c
<i>Got2</i>	a	a <sup>90</sup> ,c	a	a	a	a	a	a	a	b	a	a	a	a	a	a
<i>Gpi</i>	c	c <sup>90</sup> ,b	c	c	c <sup>90</sup> ,d	c <sup>78</sup> ,b	a	a <sup>83</sup> ,c	a	c	a	a	a	a	c	a
<i>Gsr</i>	d	b <sup>90</sup> ,d	a	b	d	d	b <sup>10</sup> , d <sup>10</sup> ,c	b	b	d	b	b	b	c <sup>91</sup> ,b	b	d <sup>67</sup> ,e



Locus	AU (2)	IN (5)	PA (4)	PS (6)	PU (4)	ST (9)	CL (5)	HA (3)	LI (3)	PI (1)	RE coast (10)	RE north (5)	RE south (10)	RO (11)	SM (2)	WI (3)
<i>Guk</i>	c	c	c	c	c	b <sup>69</sup> <sub>i</sub> c <sup>25</sup> <sub>a</sub>	c	c	c	c	c	b <sup>83</sup> <sub>c</sub>	c	c	c	b <sup>83</sup> <sub>c</sub>
<i>Idh1</i>	b	b	b	b	a <sup>63</sup> <sub>b</sub>	b	b	b	b	b	b	b	b	b	b	b
<i>Idh2</i>	d <sup>75</sup> <sub>b</sub>	d <sup>90</sup> <sub>a</sub>	e	d	d	d	d	f <sup>75</sup> <sub>d</sub>	d	d	d	d <sup>80</sup> <sub>b</sub> b <sup>10</sup> <sub>f</sub>	d	g <sup>55</sup> d <sup>36</sup> <sub>f</sub>	c <sup>50</sup> <sub>d</sub>	d
<i>Lap</i>	a	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
<i>Me</i>	d <sup>80</sup> c <sup>25</sup> <sub>e</sub>	a <sup>50</sup> <sub>d</sub> <sup>30</sup> <sub>c</sub> <sup>10</sup> <sub>f</sub>	d <sup>63</sup> <sub>e</sub>	e <sup>92</sup> <sub>d</sub>	f	c <sup>50</sup> <sub>e</sub> <sup>33</sup> <sub>b</sub>	e <sup>50</sup> <sub>f</sub>	b <sup>50</sup> <sub>d</sub>	d	d	a <sup>85</sup> <sub>e</sub>	d	d <sup>80</sup> <sub>a</sub>	e <sup>91</sup> <sub>g</sub>	b	d
<i>Mpi</i>	d	b <sup>90</sup> <sub>d</sub>	e	e <sup>83</sup> <sub>c</sub>	b	e <sup>94</sup> <sub>b</sub>	g	f	f	d	f	f	f <sup>95</sup> <sub>a</sub>	f	f	f
<i>Ndpk</i>	a	a	a	a	a	a	a	a <sup>83</sup> <sub>b</sub>	a	a	a	a	a	a	a	a
<i>PepA1</i>	h <sup>75</sup> <sub>f</sub>	g <sup>90</sup> <sub>b</sub>	g	g	d	e	c	c <sup>75</sup> <sub>a</sub>	a	c	c	c	c	c	c	c
<i>PepA2</i>	f	b	a	a	f	f <sup>94</sup> <sub>g</sub>	f <sup>80</sup> <sub>e</sub>	f	f	-	f	f	f <sup>75</sup> <sub>d</sub> <sup>20</sup> <sub>e</sub>	c	f	c
<i>PepB</i>	f	a <sup>50</sup> <sub>e</sub>	f	f <sup>92</sup> <sub>d</sub>	f	f <sup>89</sup> <sub>g</sub>	f <sup>87</sup> <sub>d</sub>	f	f <sup>97</sup> <sub>b</sub>	h	g <sup>80</sup> <sub>f</sub> g <sup>85</sup> f <sup>90</sup> <sub>c</sub>	g <sup>80</sup> <sub>f</sub> g <sup>85</sup> f <sup>90</sup> <sub>c</sub>	b <sup>68</sup> <sub>f</sub>	g	f	
<i>PepC</i>	c	b	b	b	c	c <sup>89</sup> <sub>b</sub>	c	c	c	c	c	c	c <sup>72</sup> <sub>a</sub>	a	b	a
<i>6Pgd</i>	b	b	c	c	b	b	b	b <sup>83</sup> <sub>c</sub>	c	a	b	b	b	b	b	b
<i>Pgk</i>	b	b	b	b	b	b	b <sup>50</sup> <sub>c</sub>	b	b	b	b	b	b <sup>95</sup> <sub>a</sub>	b	b	b
<i>Pgm</i>	b	a	b	b	b	b <sup>94</sup> <sub>d</sub>	c	c	c	c	c <sup>95</sup> <sub>e</sub>	c	c <sup>95</sup> <sub>e</sub>	c	c	
<i>Pk</i>	b	a	a	a	b	a	a	a	a	c	a	a	a	a	a	a
<i>Sod</i>	d	a	a	a <sup>92</sup> <sub>b</sub>	c	c	a	a	a	a	a	a	a	a	a	a
<i>Sordh</i>	c <sup>75</sup> <sub>d</sub>	d <sup>80</sup> <sub>c</sub>	d	d	d	b <sup>81</sup> <sub>e</sub> <sup>13</sup> <sub>d</sub>	d	b	d	-	d	d	d <sup>94</sup> <sub>f</sub>	a	a <sup>30</sup> <sub>d</sub>	d
<i>Tpi</i>	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
<i>Ugpp</i>	a	b	a	a	a	a	a	a	a	-	a	a	a	a	a	a

TABLE 2 Pairwise genetic distance values among 16 species and lineages of *Aprasia*, based on the allozyme data. Lower left-hand triangle = number of loci displaying a fixed allozyme difference; upper right-hand triangle = unbiased Nei distance.

Taxon	AU	IN	PA	PS	PU	ST	CL	HA	LI	PI	RE coast	RE north	RE south	RO	SM	WI
AU	-	0.49	0.47	0.42	0.29	0.29	0.42	0.52	0.56	0.54	0.53	0.48	0.49	0.67	0.48	0.50
IN	15	-	0.46	0.36	0.45	0.39	0.39	0.52	0.45	0.54	0.41	0.45	0.46	0.51	0.38	0.43
PA	14	14	-	0.11	0.58	0.47	0.49	0.54	0.53	0.72	0.59	0.58	0.52	0.69	0.50	0.52
PS	12	11	4	-	0.52	0.40	0.42	0.47	0.45	0.66	0.48	0.49	0.45	0.65	0.41	0.48
PU	8	13	16	14	-	0.26	0.38	0.53	0.47	0.56	0.46	0.43	0.48	0.55	0.50	0.50
ST	9	12	12	10	7	-	0.33	0.40	0.45	0.56	0.42	0.39	0.47	0.50	0.45	0.37
CL	11	12	14	12	10	9	-	0.16	0.26	0.42	0.12	0.20	0.15	0.30	0.30	0.14
HA	14	13	14	12	13	10	4	-	0.15	0.46	0.12	0.22	0.20	0.32	0.27	0.22
LI	15	13	15	13	13	13	8	3	-	0.44	0.20	0.20	0.24	0.32	0.36	0.30
PI	15	15	18	17	14	15	11	10	12	-	0.45	0.44	0.44	0.44	0.40	0.44
RE coast	14	12	16	14	13	11	3	3	7	12	-	0.13	0.08	0.30	0.22	0.20
RE north	12	12	14	12	10	10	3	3	5	11	2	-	0.07	0.27	0.17	0.19
RE south	13	14	16	14	14	13	5	5	8	12	2	0	-	0.28	0.15	0.19
RO	16	14	17	16	13	12	7	8	9	11	8	6	8	-	0.31	0.23
SM	14	12	15	12	13	11	9	7	11	11	7	5	5	9	-	0.34
WI	13	12	14	13	13	12	4	5	9	11	6	4	5	6	10	-

Sexual dimorphism can only be examined statistically in each of *A. repens* and *A. rostrata* (see Table 4). Our sample of *A. repens* was not significantly sexually dimorphic in body size or proportions, or in any measurement or meristic count. However, the two longitudinal scale counts Vent and Vert both come close to attaining statistical significance, with females having higher mean values as well as higher minima and maxima for both parameters. By contrast, *A. rostrata* is significantly sexually dimorphic in SVL, in Vent and Vert, and in two head measurements (HL and HD, nearly so in HW). By contrast, it is monomorphic in rostral dimensions, snout length and in body robustness (IBR).

In *A. wicherina* sp. nov. the single available female has a larger SVL than any of the three males (92 v 59–82 mm); however, the female meristic counts fall within the male range (Vent: 154 v 146–162; Vert: 150 v 142–156). As in *A. repens*, sexual dimorphism in *A. wicherina* sp. nov. is either absent or subtly expressed. By contrast, *A. clairae* appears to be strongly sexually dimorphic in ventral and vertebral scale counts, and potentially also in overall body size, with the two available females being slightly larger (93–103 mm) than any of the five recorded

males (64–90 mm) and having appreciably higher Vent and Vert counts (182–188 v 152–164 and 168 v 138–156, respectively). Unfortunately, too few individuals are available to support statistical testing; however, at least for Vent and Vert counts, the degree of distinction exceeds that observed in other pygopodid populations without sexual dimorphism.

The IBR values distinguish three elongate, slender-bodied taxa, *A. wicherina* sp. nov. (IBR = 38.6–41.7; mean 40.5), *A. rostrata* (35.4–42.1; mean 39.6), and *A. clairae* (31.9–46.2; mean 37.7) from the stockier-bodied *A. repens* (26.8–39.6; mean 32.5).

Midbody scale row counts appear to be invariant within each species but they differ between them. *Aprasia repens* has 12 scale rows at midbody while each of *A. rostrata*, *A. clairae* and *A. wicherina* sp. nov. have 14 scale rows. All four taxa have four preanal scales.

Head form varies noticeably within the group. *Aprasia wicherina* sp. nov. and *A. rostrata* share a protrusive rostral 'beak' and a strongly angular snout in lateral profile (Figure 5 B). By contrast, *A. clairae* and *A. repens* share a less protrusive, rounded rostral and a moderately angular snout in lateral profile (Figure 9 B).

**TABLE 3** Descriptive statistics of the measurements and counts for the four main *Aprasia* species discussed in this paper. See material and methods for abbreviations of measurements and counts. Values are mean ± standard deviation (*S.D.*) and range. Sample sizes are shown at the head of each column; where this varies the secondary value is identified by an asterisk.

	<i>A. repens</i>		<i>A. rostrata</i>		<i>A. clairae</i>		<i>A. wicherina</i> sp. nov.	
SEX	♂, N: 16, 15*	♀, N: 13, 11*	♂, N: 13, 12*	♀, N: 4	♂, N: 5	♀, N: 2	♂, N: 3	♀, N: 1
SVL	86.1±9.3 (63–104)	87.6±17.1 (50–103)	94.1±9.9 (72–108)	107±3 (104–112)	79.6±8.8 (64–90)	98 (93–103)	72±9.6 (59–82)	92
HD	2±0.2 (1.6–2.4)	1.9±0.2 (1.4–2.4)	1.8±0.1 (1.6–2.1)	2.1±0.2 (1.9–2.4)	1.7±0.1 (1.4–1.9)	1.8 (1.8–1.8)	1.7±0.2 (1.4–2)	1.8
HL	3±0.3 (2.2–3.4)	3.1±0.3 (2.2–3.5)	2.6±0.1 (2.4–2.9)	2.9±0.1 (2.8–3.1)	2.5±0.5 (2.4–2.6)	2.6 (2.6–2.7)	2.6±0.2 (2.3–2.8)	2.6
HW	2.2±0.2 (1.7–2.6)	2.1±0.2 (1.6–2.6)	1.9±0.1 (1.5–2.1)	2±0.1 (1.9–2.2)	1.8±0.5 (1.6–1.9)	1.8 (1.6–1.9)	1.6±0.1 (1.3–1.7)	1.7
RL	0.6±0.1* (0.4–0.9)	0.6±0 (0.5–0.8)	0.7±0.1 (0.6–1.2)	0.8±0.1 (0.7–1.0)	0.6±0.5 (0.5–0.7)	0.6 (0.5–0.8)	0.7±0 (0.6–0.8)	0.7
RW	0.7±0.1* (0.5–0.9)	0.7±0.1 (0.5–1)	0.6±0 (0.5–0.7)	0.7±0 (0.6–0.7)	0.7±0.5 (0.5–0.7)	0.7 (0.7–0.8)	0.7±0 (0.6–0.8)	0.8
SL	1.7±0.1 (1.3–2)	1.8±0.2 (1.2–2.1)	1.6±0.1* (1.3–2)	1.8±0.1 (1.6–1.9)	1.5±0.5 (1.5–1.7)	1.5 (1.5–1.5)	1.4±0.1 (1.3–1.6)	1.6
BW	2.6±0.3 (2.1–3.6)	2.7±0.4* (2–3.5)	2.3±0.4 (1.7–3.2)	2.6±0.2 (2.3–2.9)	2.3±0.2 (1.8–2.5)	2.3 (2–2.5)	1.8±0.2 (1.5–2.1)	2.1
BD	2.6±0.3 (1.8–3.2)	2.8±0.6* (1.5–3.8)	2.4±0.2 (2.1–2.8)	2.8±0.2 (2.5–3.1)	2.1±0.3 (1.4–2.5)	2.2 (1.9–2.5)	1.7±0.1 (1.5–1.9)	2.3
Vent	143.8±7.6 (125–162)	149.6±8.4 (134–164)	180.3±6.2 (172–194)	188.5±2.1 (186–192)	156.4±4.8 (152–164)	185 (182–188)	153.3±6.6 (146–162)	154
Vert	143.5±9.3 (120–158)	149.8±9.4 (136–164)	175±4.8 (168–184)	183.5±2.1 (180–186)	146.4±5.8 (138–156)	168 (168–168)	148.6±5.7 (142–156)	150
IBR	32.6±3.1 (27.7–39.6)	32.2±2.9* (26.8–37.6)	39.7±3.9 (34.9–47.8)	39±2 (36.1–41.4)	36±2.8 (31.9–39.2)	43.4 (40.7–46.2)	40.1±1.2 (38.6–41.7)	41.3

**TABLE 4** Results of t-tests for sexual dimorphism in each of *A. rostrata* and *A. repens* and for interspecific differences between *A. wicherina* sp. nov. (pooled sexes) and each of *A. rostrata* (males only) and *A. repens* (pooled sexes) for selected variables only. See material and methods for abbreviations of measurements and counts. Results that satisfy the  $p < 0.05$  criterion for statistical significance are in bold.

	<i>A. rostrata</i> male v female	<i>A. repens</i> male v female	<i>A. wicherina</i> sp. nov. v male <i>A. rostrata</i>	<i>A. wicherina</i> sp. nov. v <i>A. repens</i>
SVL	<b>t = 2.381, d.f. = 15</b> <b>p = 0.028</b>	t = 0.274, d.f. = 27 p = 0. 788	<b>t = 2.683, d.f. = 15</b> <b>p = 0.017</b>	t = 1.352, d.f. = 31 p = 0.186
HD	<b>t = 2. 819, d.f. = 15</b> <b>p = 0.013</b>	t = 0.582, d.f. = 27 p = 0. 566	-	-
HL	<b>t = 2.973, d.f. = 15</b> <b>p = 0.010</b>	t = 0.217, d.f. = 27 p = 0. 833	-	-
HW	t = 1.909, d.f. = 15 p = 0.076	t = 0.390, d.f. = 27 p = 0. 700	-	-
RL	t = 0.635, d.f. = 15 p = 0.535	t = 0.101, d.f. = 27 p = 0. 920	-	-
RW	t = 0.801, d.f. = 15 p = 0.436	t = 0.426, d.f. = 27 p = 0. 674	-	-
SL	t = 1.539, d.f. = 15 p = 0.146	t = 0.780, d.f. = 27 p = 0. 445	-	-
Vent	<b>t = 2.429, d.f. = 15</b> <b>p = 0.028</b>	t = 1.857, d.f. = 27 p = 0. 074	<b>t = 7.213, d.f. = 15</b> <b>p &lt; 0.0001</b>	t = 1.563, d.f. = 31 p = 0.128
Vert	<b>t = 3.151, d.f. = 15</b> <b>p = 0.007</b>	t = 1.751, d.f. = 27 p = 0. 091	<b>t = 8.735, d.f. = 15</b> <b>p &lt; 0.0001</b>	t = 0.512, d.f. = 31 p = 0.612
IBR	t = 0.326, d.f. = 15 p = 0.749	t = 0.272, d.f. = 27 p = 0. 788	t = 0.467, d.f. = 19 p = 0.566	<b>t = 5.003, d.f. = 29</b> <b>p &lt; 0.0001</b>

The generally conservative morphology and low number of head scales in *Aprasia* tends to preclude high levels of intraspecific variation. All examined specimens of *A. repens*, *A. rostrata*, *A. clairae* and *A. wicherina* sp. nov. have five supralabial scales with the third positioned below the eye. By contrast, *A. haroldi* has only four supralabial scales with the second below the eye. *Aprasia haroldi* is also unusual in having the postocular fused to the third upper labial rather than to the fourth as in the other members of the *A. repens* species-group. In *A. wicherina* sp. nov. the posterior margin of the mental scale intercepts the oral margin posterior to the suture between the first and second supralabial scales. This condition is also observed in some *A. repens*; however, most *A. repens* and all *A. clairae*, *A. rostrata* and *A.*

*litorea* have the posterior margin of the mental scale aligned with the suture between the first and second supralabial scales.

Another variable feature concerns the relations of the nasal suture. This feature shows interspecific variation within *Aprasia* (Kluge, 1974; Storr et al. 1990) as well as intraspecific variation among members of the *A. repens* species-group (Maryan et al. 2013a, 2013b) and it is similarly variable in *A. wicherina* sp. nov., with the following observed conditions: suture contacts the prefrontal bilaterally in WAM R173106, R146587 and R121132; contacts the second upper labial bilaterally in WAM R121129.

Body colouration and patterning displays subtle but consistent variation within the *A. repens* species-

group (Maryan et al. 2013a, 2013b). *Aprasia wicherina* sp. nov. and *A. rostrata* share the characteristic of four broken lines of dashes on the dorsal surface, with the laterodorsal line more pronounced than the paravertebral line, and a well-developed series of lateral lines, each consisting of broken dashes. By contrast, *A. clirae* has only two laterodorsal series of dashes. *Aprasia wicherina* sp. nov. and *A. clirae* have dark flecking under the head and along the ventral surface (Figures 5 C; 9 C), while *A. rostrata* typically has more intense ventral patterning ranging to almost entirely dark (Maryan et al. 2013b). The venter in *A. repens* is paler overall, sometimes with diffuse lines of short dashes. The head colouration of these species is strikingly different to the two black-headed members of the *A. repens* species group, *A. picturata* and *A. smithi*.

**TAXONOMIC CONCLUSIONS**

The case for recognition of the Wicherina *Aprasia* population as a distinct species is strong, with robust support from both genetic and morphological evidence. Both datasets identify the Wicherina species as a member of the *A. repens* species-group. However, beyond this, they fail to identify an immediate sibling species. Rather, they identify to a number of

approximately equally-distinct affinities, namely *A. rostrata*, *A. clirae*, *A. haroldi*, *A. litorea*, and *A. repens* with its various genetic sub-groups. Despite their overt morphological conservatism, all species of this group are strongly differentiated genetically, with multiple fixed allozymic differences observed between each pair of species.

Morphological comparisons of the Wicherina *Aprasia* also demonstrate that this population is distinguishable from all other described species within the *A. repens* species-group. The overall closest resemblance is with *A. rostrata* but the two species are clearly distinguished by longitudinal meristic counts which are considerably higher in *A. rostrata* than in the Wicherina species, and additionally in body size.

In the following section we begin with a revised characterisation of the genus *Aprasia* and of the *A. repens* species-group. We then describe *A. wicherina* sp. nov. as a new member of the *A. repens* species-group, and document new material of *A. clirae* that provides additional information on its colouration, morphometric features, habitat associations, and geographic distribution on the Western Australian mainland.

**TABLE 5** Measurements in mm and meristic counts for the type series of *A. wicherina* sp. nov. and seven available specimens of *A. clirae*. See material and methods for abbreviations of measurements and counts.

WAM #	SEX	SVL	HD	HL	HW	RL	RW	SL	BW	BD	Mbs	Vent	Vert
<i>Aprasia wicherina</i> sp. nov.													
121129		82	1.6	2.8	1.7	0.8	0.8	1.4	2.1	1.9	14	152	148
121132		59	1.4	2.3	1.3	0.6	0.6	1.3	1.5	1.5	14	146	142
146587		75	2.0	2.7	1.6	0.7	0.7	1.6	1.7	1.8	14	162	156
173106		92	1.8	2.6	1.7	0.7	0.8	1.6	2.1	2.3	14	154	150
<i>Aprasia clirae</i>													
127527		64	1.4	2.4	1.6	0.6	0.5	1.5	1.8	1.6	14	152	138
156892		80	1.8	2.6	1.8	0.6	0.7	1.5	2.4	1.9	14	152	146
156901		90	1.9	2.5	1.9	0.5	0.7	1.7	2.3	2.2	14	154	144
165699		93	1.8	2.6	1.6	0.5	0.7	1.5	2.0	1.9	14	188	168
166868		78	1.7	2.5	1.9	0.6	0.7	1.5	2.5	2.3	14	160	148
173107		103	1.8	2.7	1.9	0.8	0.8	1.5	2.5	2.5	14	182	168
173108		86	1.8	2.5	1.8	0.7	0.7	1.5	2.5	2.5	14	164	156

## TAXONOMY

### Genus *Aprasia* Gray, 1839

*Aprasia* Gray, 1839: 331.

#### TYPE SPECIES

*Aprasia pulchella* Gray, 1839, by monotypy.

#### DIAGNOSIS

*Aprasia* differs from all other pygopodid genera in possessing the following combination of character states: head scales very large, few in number; parietal scales absent; ring of ocular tissue not completely separated into distinct scales; external auditory meatus reduced (small opening present beneath scale in *A. aurita*) or absent (all other species); scales smooth; precloacal pores absent; almost always one hind limb scale; snout very short; body diameter small relative to body length; tail very short.

#### INCLUDED SPECIES

*Aprasia aurita* Kluge, 1974, *A. clairae* Maryan, How and Adams, 2013, *A. haroldi* Storr, 1978, *A. inaurita* Kluge, 1974, *A. litorea* Maryan, Bush and Adams, 2013, *A. parapulchella* Kluge, 1974, *A. picturata* Smith and Henry, 1999, *A. pseudopulchella* Kluge, 1974, *A. pulchella* Gray, 1839, *A. repens* (Fry, 1914), *A. rostrata* Parker, 1956, *A. smithi* Storr, 1970, *A. striolata* L. tken, 1863, *A. wicherina* sp. nov.

#### *Aprasia repens* species-group

#### DIAGNOSIS

This group, originally proposed by Storr et al. (1990), now contains eight species, all endemic to Western Australia: *A. clairae*, *A. haroldi*, *A. litorea*, *A. picturata*, *A. repens*, *A. rostrata*, *A. smithi* and *A. wicherina* sp. nov.. Members of this group differ from all other *Aprasia* spp. in having a more slender body, a longer, more angular snout profile, and a postocular that is almost always fused to the fourth upper labial.

#### *Aprasia wicherina* sp. nov.

#### Wicherina Worm Lizard

Figures 4–6

<http://zoobank.org/NomenclaturalActs/72C52442-FD0F-4B44-805B-210AD19B0D71>

#### MATERIAL EXAMINED

##### *Holotype*

**Australia: Western Australia:** WAM R173106, female collected by R. Lloyd and B. Maryan on 1 August 2013, from Wicherina Water Reserve (28°43'02"S, 115°01'11"E).

##### *Paratypes*

**Australia: Western Australia:** WAM R121129, WAM R121132, WAM R146587, males, all from Wicherina Water Reserve (28°44'S, 115°00'E).

##### *Referred specimen*

**Australia: Western Australia:** BMNH 1955.1.4.28, male, Eradu (28°42'S, 115°02'E). This specimen was collected in 1934 and is held in the Natural History Museum, London.

#### DIAGNOSIS

A small (SVL to 92 mm) and very slender, elongate-bodied member of the *A. repens* species-group that lacks overt sexual dimorphism and has 14 midbody scale rows; 146–162 ventral scales; 142–156 vertebral scales; five upper labials with first anteriorly fused to nasal; nasal suture variably contacting prefrontal or second upper labial; postocular fused with fourth upper labial; and simple colouration of longitudinal lines of brownish streaks on a yellowish-brown dorsum with a densely flecked ventral surface.

#### DESCRIPTION

##### *Holotype*

Head elongate, gradually narrowing anteriorly and of equal width as body posteriorly; no obvious tympanic aperture, snout long and rounded in dorsal profile with strongly protrusive rostral 'beak' forming a weak 'trilobed' appearance, strongly angular in lateral profile, but not sharp-edged, forming very distinct undershot lower jaw; eyes noticeably large and positioned above third upper labial; nostril positioned anteriorly in nasal; body and tail very slender of equal width and round in cross-section; hindlimb remnants visible as very small rounded scales at lateral extremes of vent; tail short, tapering very gradually distally to a round tip.

Head scales smooth, shiny, non-imbricate and heterogeneous; large rostral scale rounded anteriorly, slightly wider than long, visible from above with posterior point projecting between nasals; nasals large and in broad contact, angled posteromedially behind rostral; nasal fused anteriorly and forming suture posteriorly with first upper labial; nasal suture originates from anterior border of prefrontal bilaterally, angled downwards anteroventrally to terminate at centre of nostril, forming short contact with first upper labial, nostril and nasal suture visible from below; prefrontals large, and in broad contact medially, and in narrow contact with first upper labial and broad contact with second upper labial; large frontal, longer than wide, triangular anteriorly and rounded posteriorly; a single large supraocular extending across full width of eyes, in contact with preocular; a small preocular, much higher than wide, in broad contact with second upper labial and in short contact with third upper labial; five upper labials, second slightly higher than third, but of equal width, fourth fused to postocular and fifth the smallest; mental large, wider than long, rounded posteriorly

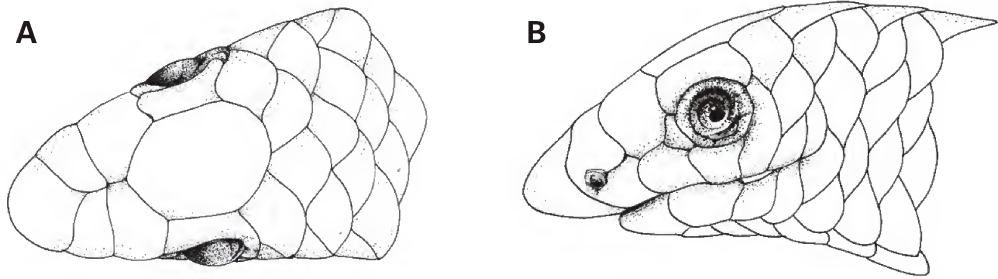


FIGURE 4 Head scalation of *Aprasia wicherina* sp. nov. holotype (WAM R173106) in (A) dorsal and (B) lateral views.

and suture with first lower labial and postmental aligned with suture between first and second upper labials. General form of head and details of scalation is illustrated in Figure 4.

Body scales, smooth and shiny, non-imbricate, homogeneous, and arranged in parallel longitudinal rows; ventral scales not noticeably wider than the adjacent body scales. Tail length measured 69 mm (75% of SVL).

#### Colouration

In life (Figure 5), head yellowish-brown anterior to level of eyes, variegated with dark brown, labials and base of rostrum distinctly light yellow. Light yellowish-brown from behind head to level of vent on dorsal surface. Two vague, longitudinal lines of brownish smudges (passing through centres of paravertebral scales) extend from behind head to vent. Two outermost lines of laterodorsal streaks are more continuous and clearly demarcated from a white to silvery-grey lateral surface, each lateral scale centrally streaked with dark brown to black. All dorsal and lateral lines of smudges and streaks become more continuous, forming multiple (10) brownish lines on dorsal surface of light yellow tail and indistinct smudges laterally towards tail-tip. Ventral surface silvery-grey moderately flecked with black from behind head to vent, without flecks on ventral surface of tail.

In preservative after several months (Figure 6), head becomes light grey turning in to creamy white on dorsal surface. Dark pigment on lateral and ventral surfaces, including lines of streaks along tail, is more prominent. The light yellow wash on some head scales and tail is retained. Ventral surface becomes light grey with light brown flecks.

#### VARIATION

Individual measurements in mm and meristic values of the type series of *A. wicherina* sp. nov. are presented in Table 5.

#### Colouration

WAM R146587 was similarly coloured to the holotype in life and subsequently in preservative. After 10 years in preservative, WAM R121129 and WAM R121132 have a light grey dorsal and ventral surface, with dark pigment on lateral and ventral surfaces, including lines of streaks along tail, fading to light brown.

#### Scalation

Variation in the relations of the nasal suture was noted above. The posterior border of the mental scale intercepts the oral margin posterior to the suture between the first and second supralabial scales in all four specimens; in WAM R121132 the point of intercept is further behind the supralabial suture than in the remaining specimens.

#### REMARKS

The referred specimen BMNH 1955.1.4.28 (formerly WAM R5064) from Eradu was listed by Parker (1956: 383), Kluge (1974: 63) and Smith and Henry (1999: 75) as *A. repens*. It is more slender bodied than typical *A. repens* and has a prominent rostral 'beak' and 14 midbody scales. Despite the desiccated and faded condition of the specimen, examination by J. Turpin at the Natural History Museum, London confirmed its identity as *A. wicherina* sp. nov..

#### ETYMOLOGY

The species name refers to the area of Wicherina, where all the type material is known from, and a local indigenous word meaning water hole (S. Heriot, pers. comm.). The epithet is to be used as a noun in apposition.

#### DISTRIBUTION AND SYMPATRY

*Aprasia wicherina* sp. nov. is currently known only from the Wicherina Water Reserve (2246ha), approximately 40 km east of Geraldton (Figure 7) but it is likely to occur in the adjoining Eradu Nature



FIGURE 5 Holotype (WAM R173106) of (A) *Aprasia wicherina* sp. nov. (B) lateral view of head and (C) ventral surface, photographed in life. [Images by B. Maryan (A); R. Lloyd (B, C)].



FIGURE 6 Preserved holotype of *Aprasia wicherina* sp. nov. (WAM R173106).



Reserve (2,275 ha). Management of these areas is vested with the Water Corporation (Wicherina) and Department of Parks and Wildlife (Eradu). The Wicherina Water Reserve has been recognised as having high conservation and eco-recreational value, including the presence of declared flora (Water Corporation 2004). Outside these areas the entire region is heavily developed for agriculture, with very few areas set aside for the conservation of flora and fauna. Further surveys are required at favourable times for capture in other nature reserves and remnant bushland with similar habitat to determine whether this species is distributed more widely in the area. The referred specimen from the Eradu area is in the same vicinity as Wicherina; therefore it is possible this specimen could also have come from the Water Reserve.

To date, there are no recorded instances of interspecific syntopy of *A. wicherina* sp. nov. with other *Aprasia* species. However, *A. repens* is known to occur in the vicinity of the Wicherina Water Reserve, based on specimens WAM R1730 from Newmarracarra and WAM R165951–52 from Kojarena. These recent collections of *A. repens* from the Kojarena area are approximately 12 km west of the Wicherina Water Reserve (Figure 7).

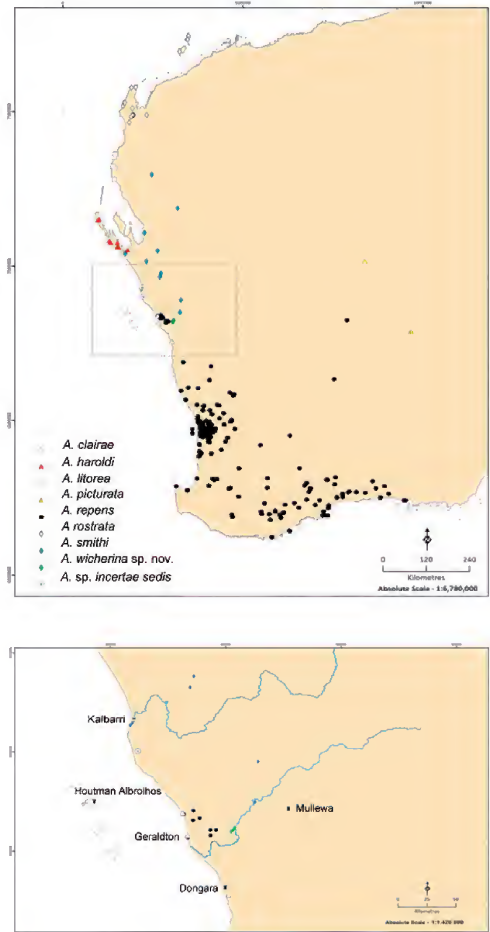
*Aprasia haroldi* and *A. litorea* are both allopatric to *A. wicherina* sp. nov. (Figure 7). *Aprasia wicherina* sp. nov. and *A. rostrata* are widely allopatric with a minimum separation distance > 800 km (Figure 7).

**HABITAT**

The holotype was captured after it was raked (using a 3-prong cultivator) from within a sand embankment beside a firebreak on sandplain (Figure 8). The Wicherina area is located on ancient, elevated sandplains dissected by the Greenough River and Wicherina Brook. The habitat in the adjoining Eradu Nature Reserve is comparable to the Wicherina Water Reserve, comprising Mallee heath of *Actinostrobis arenarius*, *Allocasuarina campestris*, *Banksia*, *Eucalyptus jucunda* and *Xylomelum* over a very diverse shrub layer and ground cover understorey. The paratypes were pit-trapped in this habitat. There is no habitat information associated with the referred specimen from Eradu.

**COMPARISONS WITH OTHER SPECIES**

*Aprasia wicherina* sp. nov. is compared first with *A. rostrata*, the species that it is most similar to in general aspects of morphology, colouration and scalation. It is then compared with the geographically nearest congeners, *A. clairae* and *A. repens*, and finally with each of the other members of the *A. repens* species-group.



**FIGURE 7** Map of Western Australia showing distribution of species of the *A. repens* species-group. Inset shows the detailed distribution of species on the central west coast including the two specimens from Kalbarri and 32 km S of Kalbarri regarded as *A. sp. incertae sedis* pending further field survey and analysis.

*Aprasia wicherina* sp. nov. and *A. rostrata* share a protrusive rostral ‘beak’, strongly angular snout and typically the presence of four lines of streaks on the dorsal surface. However, *A. wicherina* sp. nov. differs from *A. rostrata* in averaging significantly smaller in SVL and in both Vent and Vert counts, even when comparison is made only to males of *A. rostrata* in which these values are lower than females (Table 4) and in lacking overt sexual dimorphism in body size, ventral and vertebral scale counts, and head dimensions.



FIGURE 8 Mallee heath on sandplains at Wicherina Water Reserve, Western Australia, the type locality for *Aprasia wicherina* sp. nov. (Image by B. Maryan).

*Aprasia wicherina* sp. nov. and *A. clairae* are similar in body size (Table 3) and agree in most details of head and body scalation. *Aprasia wicherina* sp. nov. differs from *A. clairae* in having a longer head featuring a more protrusive rostral ‘beak’ and a snout that is strongly angular in lateral profile (Table 3; Figure 5 B). In *A. clairae* the rostral is less protrusive, more rounded in dorsal view, and the snout is moderately angular in lateral profile (Figure 9 B). Ventral and vertebral counts in both sexes of *A. wicherina* sp. nov. broadly overlap the values recorded in male *A. clairae* (Table 3) but fall well below those of the two available female *A. clairae*. The presence of overt sexual dimorphism in *A. clairae* represents an important point of distinction between this species and the essentially monomorphic *A. wicherina* sp. nov..

Body pattern and colouration also distinguish *A. wicherina* sp. nov. and *A. clairae*. Most conspicuously, in *A. wicherina* sp. nov. the dorsal surface bears four rather than two weakly-developed longitudinal streaks. Another subtle but consistent difference concerns the relationship between the outermost lines of the dorsal streaks and the lateral pattern. In *A. wicherina* sp. nov. there is a clear gap between the outermost of the four dorsal streaks and the uppermost of the well-defined longitudinal lines that comprise the lateral pattern; by contrast, in *A. clairae* the single (outer) dorsal streak on each side is closely approximated to the uppermost of the lateral lines. *Aprasia wicherina* sp. nov. also differs

from *A. clairae* in its overall paler colouration on the head, dorsum and ventral surface (Figures 5 A–C; 9 A–C).

*Aprasia wicherina* sp. nov. differs from *A. repens* in having 14 midbody scale rows (v 12), having a more protrusive rostral ‘beak’ (v rounded rostral), a smaller recorded maximum SVL (to 92 mm v to 126 mm; Storr et al. 1990), and a consistently more slender body form (IBR 38.6–41.7 v 26.8–39.6; Tables 3, 4). They also differ in aspects of colouration, the most obvious being the flecking under the head and along the ventral surface in *A. wicherina* sp. nov., contrasting with a typically paler ventral surface in *A. repens*, occasionally with lines of short dashes. *Aprasia wicherina* sp. nov. differs from *A. haroldi* in having 5 upper labials (v 4) and from *A. litorea* in having 14 midbody scale rows (v 12). *Aprasia wicherina* sp. nov. differs from the remaining members of the *A. repens* species-group, *A. picturata* and *A. smithi*, by not having a black head.

#### REMARKS

Bush et al. (2007: 4) illustrate the male *A. wicherina* sp. nov. WAM R146587, paratype collected in October. This specimen has enlarged testes, with clearly visible tubules and highly convoluted efferent ducts (K. Aplin, pers. comm.), a condition that is consistent with the timing of reproduction recorded in *A. repens* (Webb and Shine 1994).

***Aprasia clirae* Maryan, How and Adams, 2013****Batavia Coast Worm Lizard**

Figure 9

*Aprasia clirae* Maryan et al. 2013: 30–43.**MATERIAL EXAMINED**

**Australia: Western Australia:** WAM R165699, female, Geraldton (28°46'S, 114°37'E); WAM R166868, male, Oakajee (28°33'43"S, 114°34'49"E); WAM \*R173107–08, female, male, Coronation Beach, Oakajee (28°33'43"S, 114°34'49"E). \*Also included in the allozyme study.

**REVISED DIAGNOSIS**

A small (SVL of males to 90 mm; of females to 103 mm), slender-bodied (IBR 31.9–46.2; of males (n = 5) 31.9–39.2; of females (n = 2) 40.7–46.2), sexually dimorphic member of the *A. repens* species-group with 14 midbody scale rows, 152–188 ventral scales (of males 152–164; of females 182–188), 138–168 vertebral scales (of males 138–156; of females 168), five upper

labials with first anteriorly fused to nasal, condition of nasal suture variably contacting prefrontal or second upper labial, postocular fused with fourth upper labial, and simple colouration of longitudinal lines of brown to black streaks on a yellowish-brown to light brown dorsum with a densely flecked greyish ventral surface.

**VARIATION**

Individual measurements in mm and meristic values of all available specimens of *A. clirae* are presented in Table 5.

*Aprasia clirae* is now known from seven specimens with an updated recorded maximum SVL to 103 mm, due to the collection of the adult female specimens WAM R165699 and WAM R173107. Female *Aprasia* are known to attain larger body sizes than conspecific males in *Aprasia* species (Webb and Shine 1994). The smallest recorded male specimen (WAM R127527, with a SVL of 64 mm) has mature, developed testes.

**Colouration**

The single previously available specimen from the mainland (WAM R127527) was considerably darker than the specimens from East Wallabi Island in the



**FIGURE 9** Specimen (WAM R173108) of (A) *Aprasia clirae* (B) lateral view of head and (C) ventral surface, photographed in life. [Images by B. Maryan (A); R. Lloyd (B, C)].

Houtman Abrolhos. The additional mainland material reported here confirms this distinction between the two populations. A revised description of colouration and patterning in the mainland population of *A. clairae* follows, based on the expanded sample.

In life, head light brown with darker brown variegations on rostrum and crown with light grey smudges on sides including labial scales; in general appearance the head is almost uniform dark brown (see Figure 9 and Maryan et al. 2013a: Figure 5). Dorsal surface yellowish to light brown with two vague to distinct, longitudinal lines of brownish streaks or spots (passing through paravertebral series) extending from behind head (sometimes forming continuous lines on nape) to vent, becoming more continuous and, forming multiple blackish lines on dorsal surface of tail. Uppermost laterodorsal line of continuous brown streaks is not clearly demarcated from a dark brown lateral surface (more silvery-grey on tail), each lateral scale with a light grey streak. Ventral surface, including under head, light grey with dense dark brown to black flecks, and with a light yellow wash under tail.

In preservative, the yellowish to light brown colouration on dorsal surface becomes a light to silvery-grey. Dark pigment on dorsum, flanks and ventral surface remains prominent as does the yellow wash on both original and regenerated tails.

#### Scalation

Maryan et al. (2013a) recorded the nature of the nasal suture originating from the second upper labial in WAM R127527 and WAM R156901, and from the suture between the first and second upper labials in WAM R156892. Contact with the second upper labial bilaterally is also present in WAM R165699 and WAM R166868, while WAM R173107–08 have the suture contacting the second upper labial and prefrontal scales on opposite sides of the head.

#### DISTRIBUTION AND SYMPATRY

*Aprasia clairae* is known from Turtle Bay on East Wallabi Island in the Houtman Abrolhos, and on the mainland extending north to Geraldton and Coronation Beach at Oakajee, and south to near Dongara (Figure 7).

The additional mainland specimens reported here substantially enlarge the known geographic range of *A. clairae*. However, unlike the Houtman Abrolhos islands, which are 'A'-class Nature Reserves, none of the known mainland populations are protected in areas set aside for the conservation of flora and fauna. Further surveys are required at favourable times to the north and south of the known collection sites to determine whether this species is distributed more widely in the area. The collection sites for this species indicate a coastal distribution, which is comparable to some other members of the *A. repens* species-group that occupy other biogeographical regions in Western Australia (Figure 7; see Discussion).

Two specimens from coastal localities further north of the known *A. clairae* records, one identified by Storr

et al. (1990: 110) as *A. repens*, warrant special mention. Specimens WAM R86892 from Kalbarri and WAM R130495 from 32 km S of Kalbarri (Figure 7) are confirmed here as members of the *A. repens* species-group due to their shared presence of a slender body with an elongate, angular snout, and a postocular that is fused to the fourth upper labial. They differ from *A. repens* and resemble *A. clairae* in having 14 midbody scales and in general appearance including aspects of colouration. However, until the identity of these populations can be confirmed with genetic analysis, we hesitate to include them within this species. We note that northern Geraldton Sandplains, including the iconic Kalbarri National Park (Maryan 2005; Department of Parks and Wildlife 2014), have not been subject to comprehensive fauna surveys. For the present, we recommend that the Kalbarri populations be treated as *Aprasia* sp. *incertae sedis*.

To date, there are no recorded instances of interspecific syntopy of *A. clairae* with other *Aprasia* species. However, *A. repens* has been collected in near sympatry with the Coronation Beach population of *A. clairae*, the nearest records coming from Bella Vista Nature Reserve (approximately 15 km east of Coronation Beach; WAM R134308, WAM R137160) and from 5 km N of White Peak (approximately 5 km south of Coronation Beach; WAM R144049). These specimens represent the most northerly records for *A. repens* (Figure 7).

#### HABITAT

The mainland paratype of *A. clairae* (WAM R127527) was collected in a broad interdune adjacent to near-coastal dunes, with low scrub and dense thickets of *Acacia rostellifera* (Maryan et al. 2013a). The newly collected specimens all come from similar habitats. WAM R165699 was found inside a house situated adjacent to *A. rostellifera* scrub in coastal dunes. WAM R166868 and WAM R173107–08 came from a ridge parallel to the ocean and adjacent to near coastal dunes. The dominant vegetation at this site is *Melaleuca cardiophylla* and *Grevillea argyrophylla* scrub with emergent mallee *Eucalyptus dolichocera*, and the habitat includes numerous limestone outcrops (Ecologia Environment 2010; see Figure 10). WAM R166868 was found beneath a limestone slab in a gully and WAM R173107–08 (a female and male, respectively) were raked out together from beneath a small, embedded stump.

By comparison to the insular habitat (Maryan et al. 2013a: Figure 8), the soils at these mainland localities are generally darker through humic enrichment. This probably accounts for the slightly darker overall colouration of the mainland population of *A. clairae*; substrate matching appears to be a common phenomenon among these highly fossorial lizards, with other examples noted by Maryan et al. (2013b) in *A. rostrata* and *A. smithi*.



FIGURE 10 The mainland habitat of *Aprasia clirae*, thickets of *Melaleuca* and *Grevillea* with emergent Mallee on low ridge with limestone outcrops at Coronation Beach, Oakajee, Western Australia (Image by B. Maryan).

## DISCUSSION

### DIVERSITY AND UNRESOLVED ISSUES

The present study has defined another new species of the *A. repens* species-group and provided additional information on mainland Western Australian populations of the recently described *A. clirae* (Maryan et al. 2013a). *Aprasia wicherina* sp. nov. is currently known from a small area of ancient, elevated sandplain habitat in the Wicherina/Eradu area, while *A. clirae* occurs in coastal sand dune habitats, often associated with limestone outcrops. *Aprasia wicherina* sp. nov. is most similar morphologically to *A. rostrata* of the North West Cape peninsula with outlying populations on Barrow Island and the Monte Bello Islands (Maryan et al. 2013b). However, *A. rostrata* and *A. wicherina* sp. nov. are strongly differentiated genetically and are also distinguishable on body size and meristic variables.

Despite recent progress on taxonomic diversity within the *A. repens* species-group, knowledge of the group remains incomplete. In particular, our genetic analyses have demonstrated that there are at least two allozymically diagnosable lineages within the widespread taxon *A. repens* as currently defined. Preliminary morphological studies of genotyped

specimens suggest that these lineages may be morphologically diagnosable and further studies of this widespread and historically well-collected (> 500 specimens) taxon are currently underway. In addition, we suspect that additional fieldwork in poorly surveyed areas of southwestern Australia will turn up additional species of *Aprasia*, including other members of the *A. repens* species-group.

### BIOGEOGRAPHY

The *A. repens* species-group is endemic to Western Australia and includes 8 of the 13 known members of the genus (Maryan et al. 2013a, 2013b; this study). The species-group is particularly diverse in habitats on coastal sands and adjacent sandplains between Perth and the North West Cape, with a local ‘hotspot’ in the Geraldton Sandplains bioregion (Thackway and Cresswell 1995) located on the central west coast.

Based on current knowledge, four species of the *A. repens* species-group occur in the Geraldton Sandplains bioregion. *Aprasia clirae* and *A. wicherina* sp. nov. appear to have near-parapatric distributions, the former confined to the coast, and the latter found on inland sandplains; the nearest records are separated by only a short distance (40 km) of intervening country. Both

species are also regionally sympatric with *A. repens* (sensu lato) which occurs throughout southwestern Western Australia in a variety of habitats (Bush et al. 2007) and which reaches its northernmost geographic extent in the Geraldton Sandplains bioregion. In addition to this, another member of the *A. repens* species-group, the uniquely coloured *A. smithi*, also occurs in the same general area on both soft and hard soils (Wilson and Swan 2013). All of these species are very similar in body proportions, meristics and in relative head shape and they may be weakly differentiated ecologically and subject to mutual competitive exclusion.

The morphologically similar *A. wicherina* sp. nov. and *A. rostrata* are widely allopatric with a distributional gap of > 800 km. In this case, the intervening area is occupied by other members of the *A. repens* species-group (e.g. *A. haroldi*, *A. litorea*). The complex biogeographic history involving a combination of geological activity and changes in sea level has played a major role in shaping the extensive sandy areas along the west coast of the continent (e.g. Hocking et al. 1987; Rabosky et al. 2004). The significant levels of genetic divergence among members of the *A. repens* species-group could be related to habitat specialisation, which has formed patterns of isolation and subsequent genetic differences. This hypothesis seems plausible in light of the parallel divergence seen in other frogs and reptiles inhabiting sandy habitats along the west coast (e.g. *Lerista* skinks: Storr et al. 1999; *Arenophryne* frogs: Doughty and Edwards 2008; *Ctenophorus* dragons Melville et al. 2008).

## CONSERVATION STATUS

For rare or secretive reptiles such as small fossorial species, it often requires a considerable length of time conducting trapping programs simply to reveal their presence (How and Shine 1999). Without substantial sampling effort, it is difficult to establish exact distributions and life histories, and virtually impossible to estimate population size and trends. These difficulties clearly hinder effective wildlife conservation and the development of appropriate protective legislation (Ehmann and Cogger 1985; Harvey 2002).

It is now abundantly clear that Australia harbours an exceedingly high number of narrowly distributed small frog and reptile species (Cogger 2014; Wilson and Swan 2013). For example, 24 of the 91 species of *Lerista* occupy areas of less than 5,000 km<sup>2</sup>, which constitutes one of the IUCN criteria for recognition as an endangered species (Amey and Worthington Wilmer 2014). These species and others would also qualify as 'short range endemics' based on their naturally small ranges of less than 10, 000 km<sup>2</sup> (Harvey 2002).

Each of *A. clairae* and *A. wicherina* sp. nov. are restricted to parts of the Geraldton Sandplains that are subject to heavy anthropogenic disturbance, most notably clearing for winter cereal crop and pasture production (Gibson et al. 2004). The linear distance between the known northern and southern most locality records for *A. clairae* on the mainland is approximately 100 km in an area that also encompasses the densely populated and growing City of Geraldton. In addition to this, the unique population of *A. clairae* on East Wallabi Island is under threat from considerations for a major resort development. Interestingly, this development is supported by the Conservation Council of Western Australia due to the preferred location, ideal sandy substrates for construction and space for infrastructure to be built to manage wildlife (<http://www.abc.net.au/news/conservation-council-backs-resort-move-plan>). These plans will need to take into account the potentially unique requirements of the fossorial worm lizard *A. clairae*.

Based on current knowledge, *A. wicherina* sp. nov. has one of the smallest distributions of any Australian pygopodid, with only two locations known within small patches of remnant sandplain habitat surrounded by extensive agricultural lands. Despite the proclamation of the Wicherina Water Reserve for the purpose of protecting the public drinking water source for Geraldton, no priority classification areas for source protection have been assigned to the reserve (Water Corporation 2004).

Our studies along with those of others (e.g. Melville et al. 2008; Kay and Keogh 2012) on cryptic vertebrate groups in southwestern Australia, provide awareness of the high levels of endemism in these vanishing habitats, and highlight the importance of assessing the conservation status of these poorly known species.

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APPENDIX Additional material examined. All localities are in Western Australia unless otherwise indicated: SA = South Australia, VIC = Victoria, ACT = Australia Capital Territory. Legend for museum registration numbers: WAM = Western Australian Museum, SAMA = South Australian Museum, MV: Museum Victoria (R and D prefixes have been omitted for all specimens). \*Also included in the allozyme study. ^Allozyme study only.

*Aprasia aurita* SAMA: ^43054 Wathe Fauna Reserve VIC (35°33'S, 142°25'E); ^49602 16.9 km N of Millicent SA (37°26'12"S, 140°19'03"E).

*Aprasia clairae* WAM: \*127527 paratype (male), 10 km SSE of Dongara (29°19'S, 114°58'E); \*156892 paratype, \*156901 holotype (males), Turtle Bay, East Wallabi Island (28°25'55"S, 113°44'08"E).

*Aprasia haroldi* WAM: ^135496 11 km NE of Tamala Homestead (26°37'S, 113°47'E); ^163614 Dirk Hartog Island (25°43'51"S, 112°59'34"E); ^163615 Dirk Hartog Island (25°41'17"S, 113°00'41"E).

*Aprasia inaurita* SAMA: ^43055 Wathe Fauna Reserve VIC (35°33'S, 142°25'E); ^45254 Karte Conservation Park SA (35°07'32"S, 140°43'28"E); ^47087 Saint Peter Island SA (32°15'S, 133°35'E); ^49132 1 km W of Iron Duchess South SA (33°16'12"S, 137°06'08"E); ^54697 14 km ENE of Gluepot Homestead SA (33°45'04"S, 140°16'29"E).

*Aprasia litorea* WAM: ^116614 9 km NE of Cape Cuvier (24°11'S, 113°27'E); ^116656 0.5 km S of Gnaraloo Homestead (23°49'S, 113°32'E); ^116660 7 km SSW of Gnaraloo Homestead (23°54'S, 113°29'E).

*Aprasia parapulchella* SAMA: ^39799–00 Shepherds Lookout ACT (35°15'S, 148°57'E); MV: ^66569, ^66573 Bendigo Whipstick Forest VIC (36°46'S, 144°17'E).

*Aprasia picturata* WAM: ^131647 3.5 km S of Minara Homestead (28°27'S, 121°48'E).

*Aprasia pseudopulchella* SAMA: ^41116–17 3.2 km SSE of Old Belcunda Homestead SA (33°05'S, 139°01'E); ^42592 Cobbler Creek Reserve SA (34°47'S, 138°42'E); ^43085 Para Wirra Conservation Park SA (34°40'S, 138°50'E); ^44657, ^44663 Mount Brown Conservation Park SA (32°28'S, 138°01'E).

*Aprasia pulchella* WAM: ^80000 Jarrahdale (32°20'S, 116°04'E); ^132803 Chittering (31°28'S, 116°06'E); ^135130–31 Mundijong (32°18'S, 115°59'E).

*Aprasia repens* WAM: \*113330 (female), Bold Park (31°55'S, 115°47'E); \*115079 (male), Bold Park (31°56'S, 115°46'E); \*119919 (male), Wembley Downs (31°54'S, 115°47'E); \*125986 (female), 20 km E of Geraldton (28°46'S, 114°49'E); \*126079 5 km S of Byford (32°16'02"S, 116°00'44"E); \*127681 Cardup (32°16'08"S, 116°00'44"E); \*127685 Cardup Reserve (32°14'53"S, 115°59'08"E); \*127686 Brickwood Reserve (32°14'02"S, 116°00'07"E); \*129543 Lake Mealup (32°41'S, 115°42'E); \*133179 (male), Bold Park (31°56'28"S, 115°46'00"E); 134308 (male), Bella Vista Nature Reserve (28°32'15"S, 114°40'14"E); \*135145–46 Manning Lake (32°06'S, 115°46'E); 137160 (female), Bella Vista Nature Reserve (28°32'15"S, 114°40'14"E); \*137457 (male), Cervantes area (30°45'04"S, 115°12'10"E); \*141972 (female), Morley (31°53'S, 115°54'E); \*144049 (female), 5 km N of White

Peak, Oakajee (28°34'S, 114°35'E); \*144612 (female), Burns Beach (31°42'57"S, 115°45'57"E); \*151695 (female), Muchea Air Weapons Range (31°38'29"S, 115°55'03"E); \*151696 (male), Muchea Air Weapons Range (31°38'32"S, 115°55'03"E); \*153967–68 Bindoon Military Training Area (31°10'14"S, 116°15'38"E); \*157835 5 km NE of Wongan Hills (30°52'S, 116°45'E); \*165951–52 (male, female), Kojarena (28°43'S, 114°52'E); \*165961 (male), Eglinton (31°34'56"S, 115°40'29"E); \*168645 (male), Yetna (28°36'24"S, 114°43'29"E); 173503–04 (female, male), Moresby Conservation Park (28°37'37"S, 114°39'55"E).

*Aprasia rostrata* WAM: 13861 (male), Hermite Island (20°29'S, 115°31'E); 61077 (male), 3 km NW of Bullara (22°40'S, 114°02'E); 74951 (female), Bullara Homestead (22°41'S, 114°02'E); 110662 (male), Learmonth Air Weapons Range (22°25'04"S, 113°45'50"E); ^116651 (female), 1 km NW of Bullara Homestead (22°41'S, 114°03'E); ^116672 (female), 2 km W of Bullara Homestead (22°41'S, 114°01'E); ^116882 (female), 21 km N of Bullara Homestead (22°29'S, 114°01'E); ^116914 (female), 2 km W of Bullara Homestead (22°41'S, 114°01'E); 141583 (male), 2 km W of Bullara Homestead (22°40'20"S, 114°00'52"E); 151725–27 (female, male, male), 1.5 km W of Bullara Homestead (22°41'S, 114°01'E); \*153827–28 (male, female), 2 km NW of Yardie Homestead Caravan Park (21°52'57"S, 114°00'16"E); 153829 (female), Bullara Station (22°53'26"S, 113°55'25"E); 153830 (male), Bullara Station (22°43'35"S, 113°58'32"E); \*165984–85 (males), Trimouille Island (20°23'12"S, 115°33'04"E); \*165986–87 (males), Hermite Island (20°29'36"S, 115°31'40"E); \*173456 (male), Barrow Island (20°50'18"S, 115°18'44"E).

*Aprasia smithi* WAM: ^116574, ^116657 11 km NE of Carbla Homestead (26°07'S, 114°16'E).

*Aprasia striolata* WAM: ^127524 10 km E of Ravensthorpe (33°35'25"S, 120°09'00"E); ^127528 10 km E of Ravensthorpe (33°35'20"S, 120°09'15"E); SAMA: ^39790 Flinders Chase National Park SA (35°58'S, 136°40'E); ^45106 Venus Bay Conservation Park SA (33°13'S, 134°36'E); ^45137 12.8 km ENE of Salt Creek SA (36°04'24"S, 139°45'46"E); ^45921 Wedge Island SA (35°11'20"S, 136°28'40"E); ^49598 16.7 km W of Snuggery SA (37°39'58"S, 140°14'29"E); ^49618 11.6 km ENE of Mount Benson SA (37°00'19"S, 139°56'10"E).

*Aprasia* sp. *incertae sedis* WAM: 86892 (male), Kalbarri (27°43'S, 114°10'E); 130495 (male), 32 km S of Kalbarri (27°59'26"S, 114°11'35"E).



# Two new species of stygobitic *Anzyclops* (Copepoda: Cyclopoida: Cyclopidae) from Australia

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**ABSTRACT** – Two new, small subterranean species of the genus *Anzyclops* Karanovic, Eberhard & Murdoch, 2011 are described from the Pilbara region in Western Australia. Both *Anzyclops trotteri* sp. nov. and *Anzyclops pearsoni* sp. nov. have small known ranges. Both species are distinguished from all other described species of *Anzyclops* by the highly ornamented hyaline fringe of the urosomal segments and the postero-lateral expansion of the genital somite dorsally. *Anzyclops trotteri* sp. nov. can be distinguished from *Anzyclops pearsoni* sp. nov. by its serrated (rather than smooth) W-shaped projection in the medial dorsal hyaline fringe of the genital double-somite of both sexes and more jagged serrations of the dorsal hyaline fringe of posterior urosomites, as well as by subtle differences in body shape and in segmentation of the antennule. A key to all known species of *Anzyclops* is provided.

**KEYWORDS:** stygobite, stygofauna, Pilbara, taxonomy, biodiversity, short range endemic

## INTRODUCTION

The genus *Anzyclops* Karanovic, Eberhard & Murdoch, 2011 was erected to contain five species that mostly share the following combination of characters: dorsoventrally compressed body shape, reticulated integument, and reduced armature of the antennule, antenna and swimming legs (with a spine formula of 2.3.3.2 or 2.3.2.2). Three of the existing species of *Anzyclops* occur in the Pilbara region of northern Western Australia (Figure 1), one species is found in Queensland and one species is from New Zealand. In this paper, we describe a further two species of *Anzyclops* from the Pilbara region. An eighth species is currently being described from India (Totakura & Ranga Reddy, in press). It is not discussed further in this paper.

It is not surprising that three of the described species of *Anzyclops* are known from the Pilbara. This region has been relatively well surveyed for stygofauna during the past 15 years, at least in the context of the Southern Hemisphere, and possibly about half the stygobitic species present have been formally described (Eberhard et al. 2009; Halse et al. 2014). With 86 named ostracod and 50 named copepod species, the ostracod and

copepod faunas of the Pilbara are both rich and better known than other elements of the region's stygofauna (see Karanovic 2007; Karanovic and McKay 2010 for ostracods; Karanovic 2006, 2010; Karanovic and Hancock 2009; Karanovic and Krajicek 2012; Tang et al. 2008; Karanovic et al. 2011; Karanovic and McRae 2013 for copepods).

Threats to the conservation of stygofauna in the Pilbara are significant. Mining, principally for iron ore, is the main economic activity in the region and extensive de-watering of mine pits is often required to access ore (Johnson and Wright 2001; Sheppard et al. 2009). This de-watering may potentially threaten species with small ranges, which many species of stygofauna have. While some stygobitic copepod species are widely distributed (Karanovic and Krajicek 2012; Halse et al. 2014), others appear to have linear ranges of only a few kilometres (e.g. Karanovic and Cooper 2011). Threats such as de-watering highlight the importance of documenting species distributions so that species with small ranges may be recognised and their conservation planned. Documenting distributions is much easier when species are formally described.

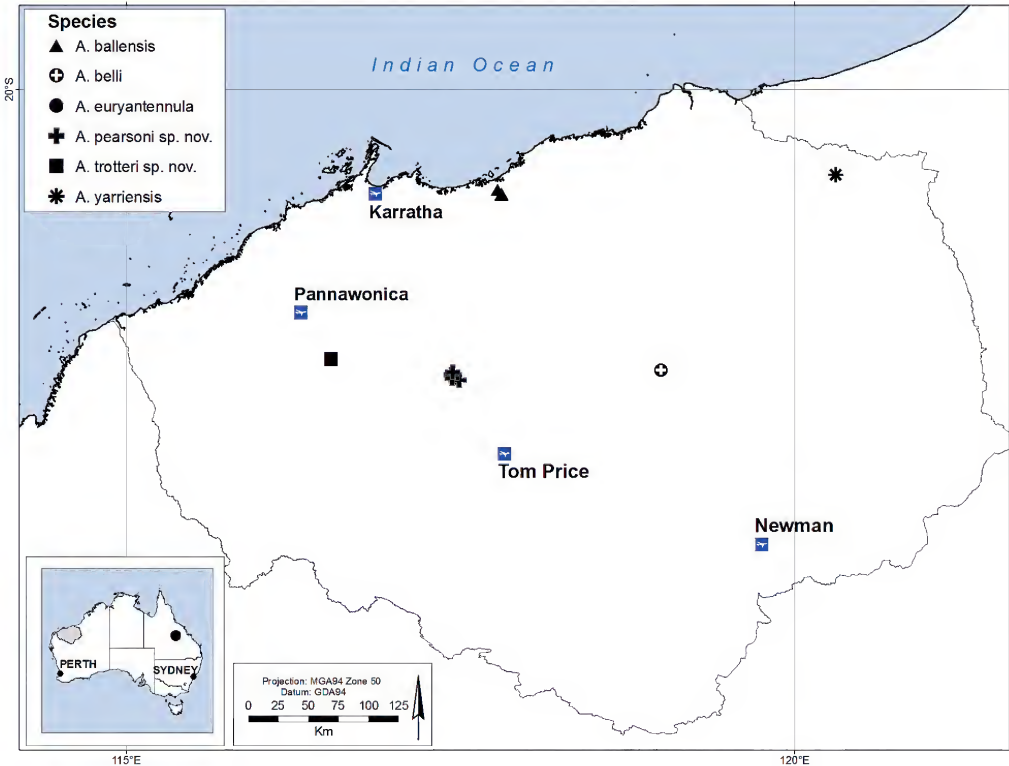


FIGURE 1 Known locations of Australian specimens of *Anzyclops*.

## MATERIAL AND METHODS

Both new species were collected from uncased holes drilled for geological exploration. These holes were sampled using a weighted haul net (mesh size 50 or 150 m) that was lowered on cord to the bottom of the hole, jiggled to stir up the substrate and then retrieved through the water column and back to the surface (Eberhard et al. 2005). Most specimens were collected while sampling for stygofauna, although some were collected as bycatch when the watertable was intercepted while collecting troglofauna using a netting technique known as scraping (Halse and Pearson 2014). Nets were sterilised after use to prevent transfer of animals.

Samples were preserved in the field in 100% ethanol and returned to the laboratory for sorting. Appropriate specimens of the two species were dissected and mounted on microscope slides in Faure's medium (Stock and Von Vaupel Klein 1996) and dissected appendages were then sealed by a coverslip.

All drawings were prepared using a camera lucida attached to a Leica DM2500 differential interference compound microscope with N-PLAN objectives. Specimens that were drawn whole were examined in a mixture of equal parts of distilled water and glycerol and, after examination, were again preserved in 100% ethanol.

Specimens examined by scanning electron microscopy were dehydrated in progressive ethanol concentrations, transferred into pure isoamyl-acetate, critical-point dried, mounted on stubs, coated in gold and observed under a Hitachi S-4700 scanning electron microscope on the in-lens detector, with working distances of 12.7–13.2 mm and an accelerating voltage of 10 kV.

The morphological terminology used in this paper follows Huys and Boxshall (1991). All listed material is deposited in the Western Australian Museum (WAM), Perth.

TABLE 1 Habitat data for Pilbara *Anzycyclops* species. *N* = number of drill holes in which recorded.  
<sup>1</sup> Depth to groundwater; <sup>2</sup> Karanovic et al. (2012), <sup>3</sup> Detrital iron deposit; <sup>4</sup> Channel iron deposit.

Species	<i>N</i>	EC ( $\mu\text{S}/\text{cm}$ )	pH	Depth <sup>1</sup> (m)	Aquifers intersected
<i>A. ballensis</i> <sup>1,2</sup>	3	-	-	-	Alluvium, fractured basalt
<i>A. belli</i> <sup>2</sup>	1	820	6.9	12.5	Jointed basalt
<i>A. pearsoni</i> sp. nov.	6	203–879	6–6.7	26–33	Alluvium, DID <sup>3</sup> , CID <sup>4</sup>
<i>A. trotteri</i> sp. nov.	1	300	6.4	25	Alluvium, DID, CID
<i>A. yarriensis</i> <sup>2</sup>	1	427	5.8	40.1	Hematite, fractured basalt

## SYSTEMATICS

### Family Cyclopidae Burmeister, 1834

#### Genus *Anzycyclops* Karanovic, Eberhard & Murdoch, 2011

#### *Anzycyclops trotteri* sp. nov.

(Figures 2–6)

<http://www.zoobank.org/urn:lsid:zoobank.org:act:77309487-733A-4F37-B626-12EFF5C4D75F>

### MATERIAL EXAMINED

#### *Holotype*

**Australia: Western Australia:** female, Pilbara region, Robe River catchment, drill hole BH209, 22°00'57"S 116°31'58.6"E, S. Bennett & G. Pearson, 19 July 2012 (WAM C55886, dissected on slide). Depth to watertable 25 m, water temperature 26.4 °C, pH 6.42, electrical conductivity 300  $\mu\text{S}/\text{cm}$  (Table 1).

#### *Allotype*

**Australia: Western Australia:** male, Pilbara region, Robe River catchment, drill hole BH209, 22°00'57"S 116°31'58.6"E, S. Bennett & G. Pearson, 19 July 2012 (WAM C55887, dissected on slide).

#### *Paratypes*

**Australia: Western Australia:** Pilbara region, Robe River catchment, drill hole BH209, 22°00'57"S 116°31'58.6"E, S. Bennett & G. Pearson, 19 July 2012, 41 males and females in alcohol (WAM C55888); 1 female (WAM C55889, dissected on slide); 1 female (WAM C57230, dissected on slide); 2 males and 3 females (WAM C55891) on one SEM stub; G. Pearson & J. Quartermaine, 5 October 2012 (WAM C55901), 1 female in alcohol; 1 male and 1 female (WAM C55890, dissected on slide); 3 males and 11 females in alcohol (WAM C60015).

### DIAGNOSIS

*Anzycyclops trotteri* sp. nov. differs from previously described species of *Anzycyclops* in the pronounced ornamentation of the somites (all other described species have smooth somites) and large spine-like postero-lateral projections of the dorsal side of the genital double-somite, the triangular operculum (other species have a rounded operculum), the lack of the apical spine on the second endopodal segment of the fourth swimming leg (instead there is an apical secondary seta) that is characteristic of other species except for *A. belli* Karanovic, Eberhard & Murdoch, 2011 and *A. pearsoni* sp. nov. The serrated W-shaped projection in the medial dorsal hyaline fringe of the genital double-somite of both sexes, and more jagged serrations of the dorsal hyaline fringe of posterior urosomites, distinguish *A. trotteri* sp. nov. from *A. pearsoni* sp. nov.

### DESCRIPTION

#### *Female*

Total body length of females from tip of rostrum to end of the caudal rami ranges from 282–320  $\mu\text{m}$  (mean 301  $\mu\text{m}$ ; *n* = 9). Habitus robust, dorsoventrally compressed, with prosome/urosome ratio 1.7 and greatest width at posterior end of cephalothorax (Figures 2A, B, 5A). Body length/width ratio about 2.1 (dorsal view); cephalothorax 1.4 times as wide as genital double-somite. Free pedigerous somites with slight lateral expansions but an overall form that is typical of the genus. Nauplius eye visible. Rostrum large, membranous, broadly rounded, and furnished with 2 large sensilla (Figure 5B). Cephalothorax slightly longer than greatest width (dorsal view), representing 50% of total body length. Surface of cephalothoracic shield and pleurotergites of free pedigerous prosomites (except for second) with many large sensilla; integumental reticular pattern present on all somites but absent from appendages; hyaline fringes of somites narrow and smooth (Figure 2A). Fifth pedigerous somite ornamented with 2 dorsal sensilla; lateral edges of the somite with rounded tips or weakly recurved (Figure 2D).

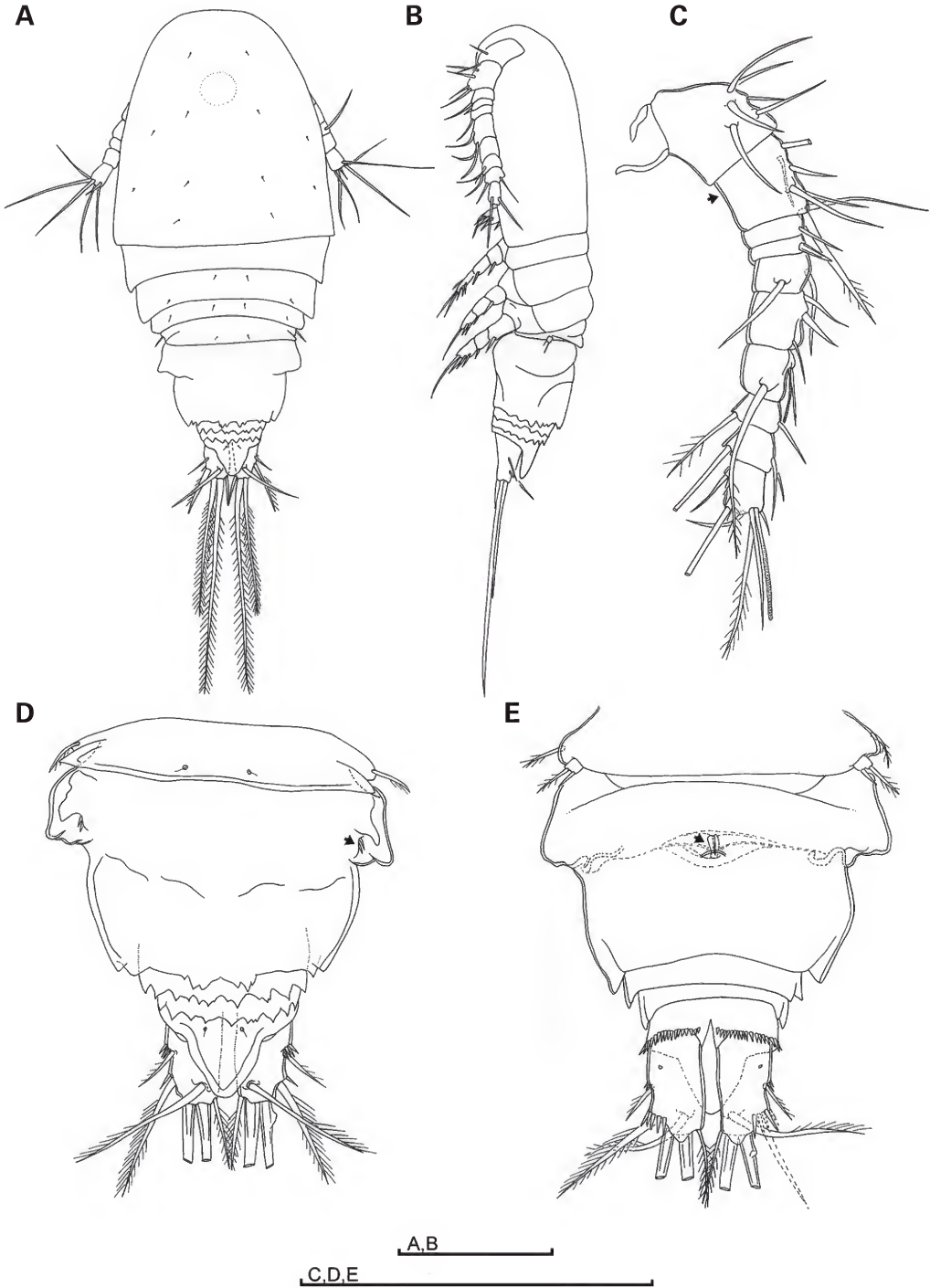


FIGURE 2 *Anzyclops trotteri* sp. nov. Holotype female. A, habitus, dorsal; B, habitus, lateral; C, antennule, ventral; D, urosome, dorsal; E, urosome, ventral. Scale bars 0.1 mm.

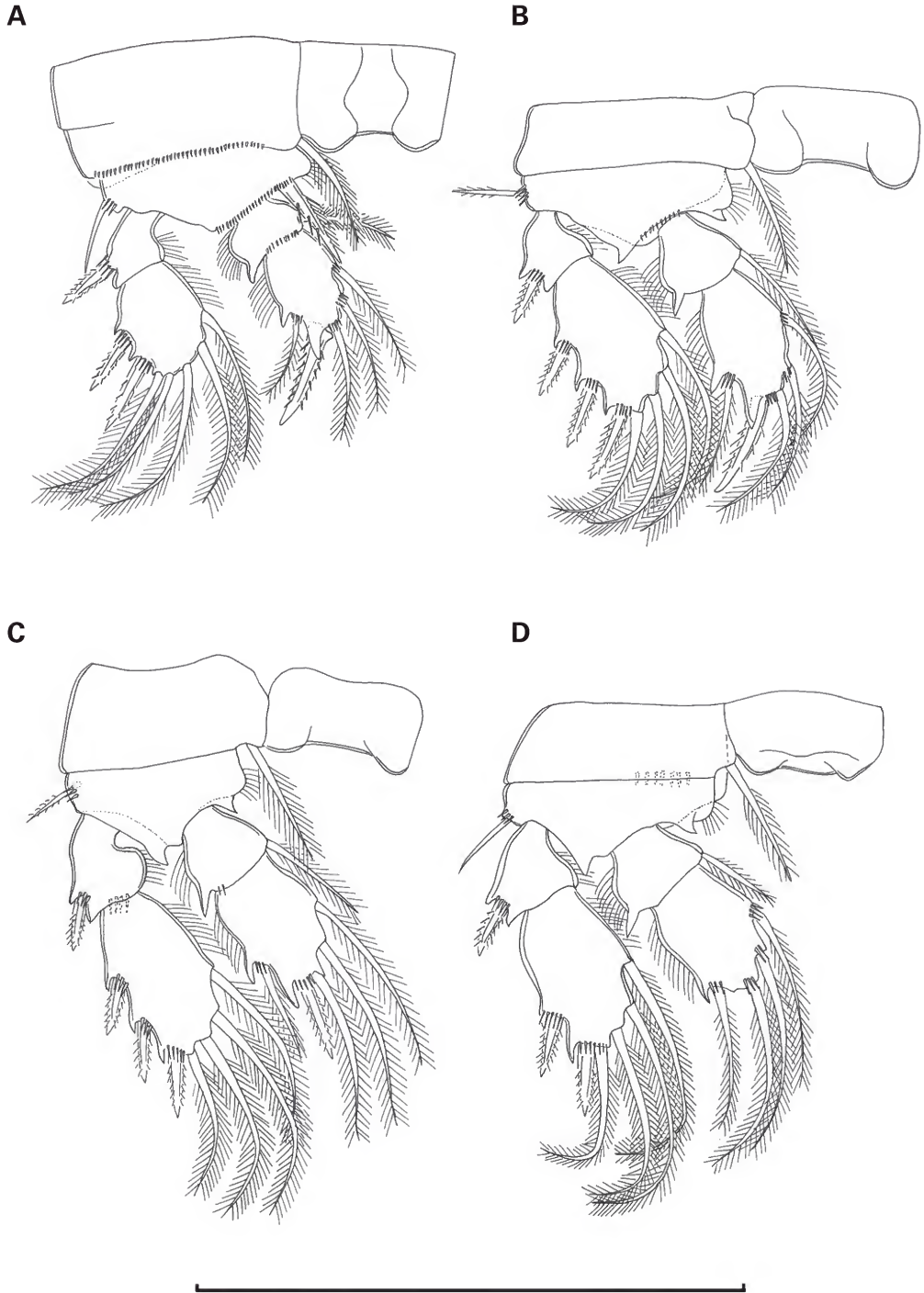


FIGURE 3 *Anzyclops trotteri* sp. nov. A, first swimming leg, anterior, holotype female; B, second swimming leg, anterior, paratype (WAM C55890); C, third swimming leg, anterior, paratype (WAM C55890); D, fourth swimming leg, anterior, paratype (WAM C55889). Scale bar 0.1 mm.

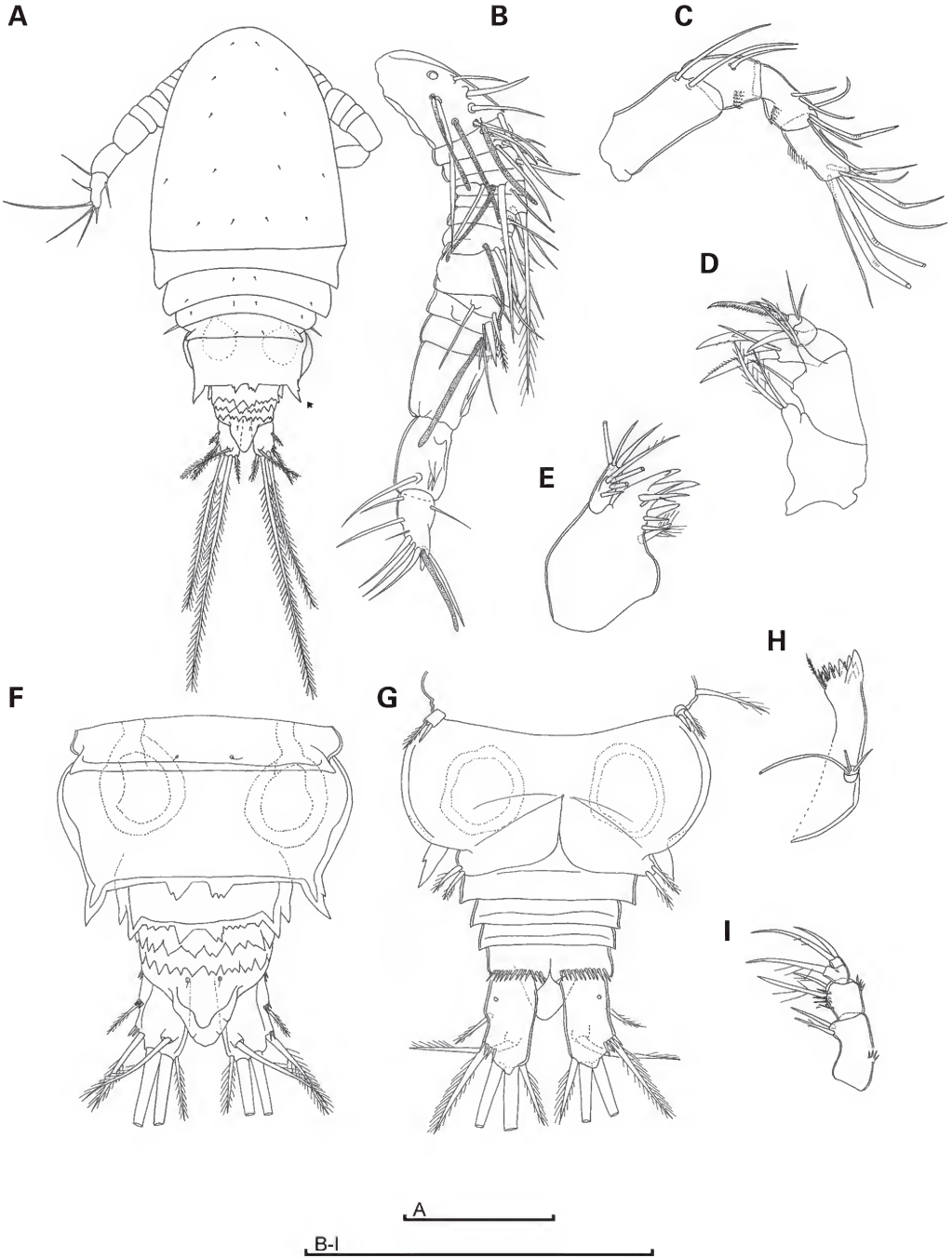
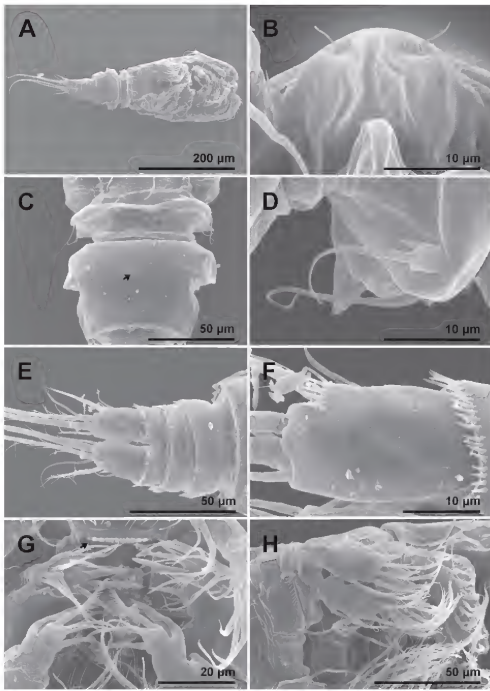
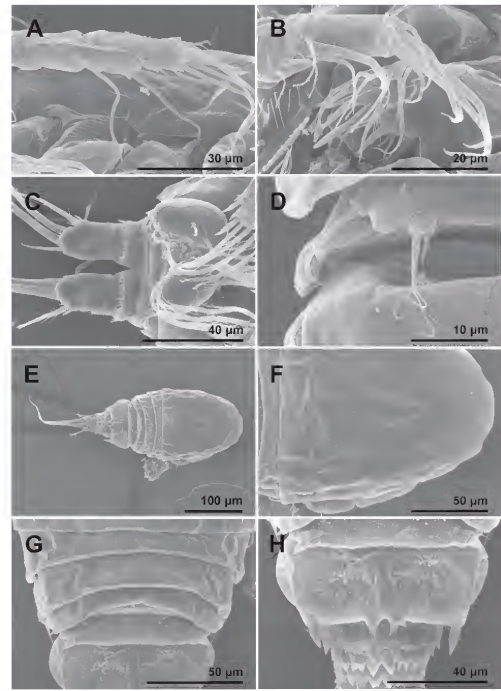


FIGURE 4 *Anzyclops trotteri* sp. nov. A, B, F, G allotype male. A, habitus, dorsal; B, antennule, dorsal; C, antenna, caudal, paratype (WAM C55889); D, maxilla, posterior, paratype (WAM C57230); E, maxillule, anterior, holotype female; F, urosome, dorsal; G, urosome, ventral; H, mandible, posterior, paratype female (WAM C55889); I, maxilliped, anterior, paratype female (WAM C55890). Scale bars 0.1 mm.



**FIGURE 5** *Anzyclops trotteri* sp. nov. SEM micrographs (WAM C55891), paratype female 7: A, habitus, ventral; B, rostrum, ventral; C, fifth pedigerous somite and genital double-somite, ventral; D, fifth leg, ventral; E, last three urosomites and caudal rami, ventral; F, right caudal ramus, ventral; G, distal tips of mouth appendages, ventral; H, fourth swimming leg, posterior.



**FIGURE 6** *Anzyclops trotteri* sp. nov., SEM micrographs (WAM C55891), A, B, E-H paratype female 7; C, paratype female 8, D, paratype female 9; E-H, paratype male 1. A, distal part of antennula, ventral; B, distal part of antenna, ventral; C, urosome with spermatophores attached, ventral, paratype female 2; D, fifth leg, ventro-lateral, paratype female 3; E, habitus, dorsal; F, cephalothorax, dorsal; G, tergites of free pedigerous somites, dorsal; H, anterior part of urosome, dorsal.

Genital double-somite 1.84 times as wide as long (dorsal view) with expanded anterior part and deep lateral recesses at level of sixth legs, ornamented with 2 cuticular pores ventrocaudally, hyaline fringe with dorsal median irregularly serrated W-shaped lobe and smooth ventral margin (Figures 2D, E, 5C). Copulatory pore small, ovoid, situated at 1/3 of somite length; copulatory duct narrow, siphon-shaped, well sclerotised (arrowed in Figures 2E, 5C). Seminal receptacle not visible; oviducts broad and sclerotised. Ovipores situated somewhat dorsolaterally, covered with reduced sixth legs (arrowed in Figure 2D).

Distal margin of third and fourth urosomite with dorsal hyaline fringe of irregular teeth, ventrally smooth (Figures 2D, E, 5C). Third urosomite about 1.4 times as long as fourth, both without any ornamentation. Anal somite ornamented with 2 large dorsal sensilla, and ventral and

lateral transverse row of minute spinules along posterior margin (Figures 2D, E, 5E). Anal sinus smooth. Anal operculum very large, triangular, smooth, representing 62% of anal somite width. Caudal rami (Figures 2D, E, 5E, F) cylindrical, parallel, closely spaced, and about 2 times as long as wide; ornamented with a pore on ventral side in anterior lateral position and several spinules at base of the 2 lateral setae. Dorsal seta 1.2 times longer than ramus, inserted at 3/4 of ramus length, biarticulate at base and plumose at distal part. Anterolateral seta arising dorsolaterally at about 1/2 length of ramus, 1/3 as long as dorsal seta. Posterolateral seta stout, spiniform, about the same length as ramus, bipinnate. Terminal accessory seta (innermost 1) also bipinnate but not spiniform, 0.5 times as long as posterolateral seta. Terminal setae without breaking planes and plumose; inner seta 1.5 times as long as outer seta and 0.47 times as long as body length.

Antennule (Figures 2C, 6A) reaching 5/6 of cephalothoracic shield in length, 10-segmented, with ancestral second and third segments joined (arrowed in Figure 2C), with armature formula (ae = aesthetasc): 6.7.1.1.2.3.2+ae.2.3.6+ae. Armature elements with 1 pinnate setae on the second, seventh, eighth and terminal segments, all other setae smooth. Apical aesthetasc somewhat longer than ultimate and penultimate segments combined. Length ratio of segments: 1.0 : 1.0 : 0.3 : 0.2 : 0.5 : 0.9 : 0.8 : 0.5 : 0.7 : 0.9.

Antenna 4-segmented, comprising coxobasis and 3-segmented endopod (Figures 4C, 6B). Coxobasis large, cylindrical, more than twice as long as wide, unornamented, armed with 2 smooth distomedial setae; seta representing exopod is absent. First endopodal segment ovoid, 1.4 times as long as wide, with inner smooth seta at 2/3 and patch of spinules along lateral margin. Second endopodal segment more slender, 1.8 times as long as wide, with proximal part bearing 6 medial setae and 1 spinular row on lateral margin. Third endopodal segment cylindrical, twice as long as wide, with 1 spinular row on lateral margin and armed with 7 smooth apical setae (3 of them strong and geniculate). Length ratio of antennal segments from proximal end: 1.0 : 0.6 : 0.6 : 0.6.

Labrum (arrowed in Figure 5G) small trapezoidal plate, ornamented with 2 diagonal, short rows of 9 long spinules on anterior surface. Cutting edge slightly concave, with 9 large and sharp teeth, 2 smaller outer teeth between produced rounded lateral corners.

Mandible composed of coxa and small palp (Figure 4H). Coxal gnathobase cutting edge with 2 spinules on anterior surface and 5 apical teeth (ventralmost tooth strongest and quadridentate; second, third and fifth teeth bidentate), and 2 setae on dorsal corner (dorsalmost seta bipinnate, 1.7 times as long as other unipinnate seta). Palp 1.2 times as wide as long, unornamented but armed with 3 apical setae: 2 long and plumose (broken in holotype) and 1 short and smooth.

Maxillule (Figure 4E) robust, composed of praecoxa and 2-segmented palp. Praecoxal arthrite bearing 4 very strong distal spines (2 fused at base, 1 smooth, 1 bidentate; 2 distinct at base, 1 sharp, and 1 spinulate), and 3 medial elements (proximal longest and plumose). Palp composed of coxobasis and endopod. Coxobasis with 1 proximal (exopodal) seta and 3 medial setae; endopod with 3 setae.

Maxilla (Figure 4D) 5-segmented, slender. Endite of praecoxa with 2 pinnate setae. Coxa unornamented; proximal endite represented by a knob with 1 smooth seta; distal endite elongate with 2 apical bipinnate setae. Basis expanded into robust claw, ornamented with 2 sub apical teeth and row of spinules; 2 setae at base of claw with strong seta as long as claw. Endopod 2-segmented; proximal segment armed with 1 robust, smooth seta; distal segment with 2 apical setae, 1 robust, with row or

setules, other slender and smooth, 2 slender and smooth subapical setae.

Maxilliped (Figure 4I) 4 segmented, composed of syncoxa, basis, and 2-segmented endopod. Ornamentation consisting of 1 row of large spinules on syncoxa close to outer margin. Basis with 2 rows of spinules. Armature formula: 2.2.1.2.

Intercoxal sclerites of all swimming legs with concave distal margins and without any surface ornamentation. Praecoxae short and unornamented. Coxae of first leg ornamented with long distal row of minute spinules on anterior surface, coxa of fourth leg with short spinule row on posterior surface. Inner distal corner of basis of all legs ornamented with long setules and a few spinules at base of outer seta; median edge and inner distal corner of basis of second, third, and fourth legs with small sharp process. Basis of first leg with large inner spine reaching midway along second endopodal segment (Figure 3A), with a long row of minute spinules near the spine insertion.

Swimming legs with 2-segmented exopods and endopods (Figures 3A-D). Second exopodal segment spine formula 2.3.3.2 and setal formula 5.4.4.4. The complete armature formula is:

	Coxa	Basis	Exopod	Endopod
Leg 1	0-1	1-1	I-0; I, I+1, 4	0-1; 1, I+1, 2
Leg 2	0-1	1-0	I-0; II, I+1, 3	0-1; 1, I+1, 2
Leg 3	0-1	1-0	I-0; II, I+1, 3	0-1; 1, I+1, 2
Leg 4	0-1	1-0	I-0; I, I+1, 3	0-1; 1, 1, 2

All setae on endopods and exopods slender and plumose; no modified setae observed. All spines strong and bipinnate. Exopods with long hairlike setules on inner margin; endopods with setules on outer margin; both rami additionally ornamented with minute spinules at base of each armature element. Second (Figure 3B) and third (Figure 3C) swimming legs very similar, except second exopodal segment of third leg somewhat larger than that of second leg and apical spine smaller. Endopod of fourth swimming leg (Figures 3D, 5H) as wide as exopod; second endopodal segment about 1.4 times as long as wide; apical spine absent.

Fifth leg held ventrolaterally, composed of protopod completely fused to somite and free exopod (Figures 2E, 6D). Protopodal seta slender, visible in dorsal view, without prominent setophore, unisetulate along outer margin. Exopod small and quadriform, about as wide as long, armed apically with outer bipinnate seta and inner smooth spine; seta about twice as long as adjacent spine, 3 times as long as segment and almost as long as protopodal seta.

Sixth leg positioned dorsolaterally (arrowed in Figure 2D), consists of a small, semicircular cuticular plate, armed with 2 short spines.



*Male*

Body length of males ranges from 275–294  $\mu$ m (mean 285  $\mu$ m;  $n = 9$ ). Habitus (Figures 4A, 6E) smaller and more slender than in female, prosome/ urosome ratio about 2.0 and greatest width at posterior end of cephalothorax. Body length/width ratio 2.2; cephalothorax (Figure 6F) about 1.5 times as wide as genital somite. Cephalothorax 1.1 times as long as wide (dorsal view), representing 51% of total body length. Ornamentation of prosomites and colour similar to female.

Genital somite (Figures 4F, G; 6H) almost twice as wide as long, hyaline fringe medially with an irregularly serrated medial W-shaped lobe as in the female, but produced into large spine-like, posterolateral caudal projections. Next three urosomites without any ornamentation, all with hyaline fringe sharply irregularly serrated, ventrally smooth; serrations on third urosome fringe larger medially and laterally.

Anal somite (Figures 4F, G) ornamented as in female; anal operculum somewhat narrower. Caudal rami (Figures 4F, G) with ventral cuticular pore proximally; remaining ornamentation same as in female. Terminal setae as in female except inner seta longer, being 0.55 times as long as body length.

Antennule (Figure 4B) digeniculate, 15-segmented, with spine-shaped cuticular structures on thirteenth and fourteenth elements (distal geniculation). Armature formula: 6 + 3ae.4.1.2 + ae.1.2.2.3 + ae.2.2.2.2+ ae.0.1.8 + ae. One pinnate setae on the sixth and tenth segment, all other setae smooth. Asthetasc on 12<sup>th</sup> segment relatively large and extending almost to midway on 14<sup>th</sup> segment.

Antenna, labrum, mandible, maxillule, maxilla, maxilliped, swimming legs, and fifth leg similar to those of female.

Sixth leg (Figure 4G) large, unornamented cuticular plate, armed with 2 bipinnate and subequal setae on outer distal corner (inner spine and outer seta on outer distal corner; both bipinnate and subequal).

## ETYMOLOGY

The species is named after Andrew Trotter of Bennelongia Environmental Consultants in recognition of his valuable work in helping to understand subterranean fauna in Western Australia. Specific epithet in singular masculine genitive.

## VARIABILITY

The cuticular ornamentation is very variable and may be more or less obvious according to the preservation of the animal. The characters of the genital double-somite may also be variable and the accessory tooth present on the left spine of the male allotype (arrowed in Figure 4A) is not seen in all animals.

*Anzyclops pearsoni* sp. nov.

(Figures 7–12)

<http://www.zoobank.org/urn:lsid:zoobank.org:act:DFA82FDC-8C2B-44D1-8B16-7765E75D96CB>

## MATERIAL EXAMINED

*Holotype*

**Australia: Western Australia:** female, Pilbara region, Fortescue River catchment, bore HPRC4121, 22°09'23.1"S 117°26'22.5"E, G. Pearson and S. Bennett, 21 August 2011 (WAM C55893, dissected on slide). Depth to watertable 26 m, temperature 27.8 °C, pH 6.74, electrical conductivity 879 S/cm (Table 1).

*Allotype*

**Australia: Western Australia:** male, Pilbara region, Fortescue River catchment, bore HPRC4121, 22°09'23.1"S 117°26'22.5"E, G. Pearson and S. Bennett, 21 August 2011 (WAM C55894, dissected on slide).

*Paratypes*

**Australia: Western Australia:** Pilbara region, Fortescue River catchment, bore HPRC4121, 22°09'23.1"S 117°26'22.5"E, G. Pearson and S. Bennett, 21 August 2011, female (WAM C55895, dissected on slide); female (WAM C55896, dissected on slide); male (WAM C55897, dissected on slide); 1 female in alcohol (WAM C55898); 1 male in alcohol (WAM C55899); 1 male in alcohol (WAM C55900); 4 males, 7 females in alcohol (WAM C60014); 2 males and 5 females (WAM C55892) on one SEM stub; J. Cocking & J. Quartermaine, 26 July 2011, 1 male and 3 females in alcohol (WAM C55902).

*Other material*

**Australia: Western Australia:** Pilbara region, Fortescue River catchment, bore HPRC0096, 22°09'23.0"S 117°27'24.0"E; D. Main & J. Quartermaine, 15 April 2011, male in alcohol (WAM C55903); bore HPRC4254, 22°10'30.3"S 117°29'19.5"E; M. Curran & J. Cocking, 16 April 2011, 5 males and 3 females in alcohol (WAM C55904); bore HPRC0379, 22°08'07.2"S 117°25'55.7"E; J. Cocking & J. Quartermaine, 31 July 2011, 1 female and 2 males in alcohol (WAM C55905); bore HPRC4119, 22°09'29.0"S 117°26'18.8"E; G. Pearson & S. Bennett, 21 August 2011, 2 males in alcohol (WAM C55906); bore HPRC0504, 22°06'52.8"S 117°26'31.8"E; G. Pearson & S. Bennett, 19 August 2011, 4 males and 1 female in alcohol (WAM C55907); 1 female dissected on slide (WAM C57231).

## DIAGNOSIS

*Anzyclops pearsoni* sp. nov. differs from previously described species of *Anzyclops*, other than *A. trotteri* sp. nov., by having pronounced ornamentation of the somites (all other described species have smooth somites), a large spine-like posterolateral projection of

the dorsal side of the genital double-somite, a triangular operculum (other species have a rounded operculum), the lack of an apical spine on the second endopodal segment of fourth swimming leg (a secondary apical seta is present but other species have an apical spine instead, except for *A. belli* Karanovic, Eberhard & Murdoch, 2011 and *A. trotter* sp. nov.). *A. pearsoni* sp. nov. is distinguished from *A. trotteri* sp. nov. by possessing a simple W-shaped projection in the medial dorsal hyaline fringe of the genital double-somite of both sexes and by smoother scalloping of the dorsal hyaline fringe of posterior urosomites.

## DESCRIPTION

### Female

Total body length from tip of rostrum to end of the caudal rami ranges from 279–350  $\mu$ m (mean 302  $\mu$ m  $n=9$ ). Body robust, wide, strongly dorsoventrally compressed (Figures 7A, B, 11A, G), with prosome/urosome ratio 1.9 and greatest width at posterior end of cephalothorax. Body length/width ratio approximately 2.0 (dorsal view); cephalothorax 1.5 times as wide as genital double-somite. Free pedigerous somites with slight lateral expansions but an overall outline typical of the genus. Nauplius eye visible. Rostrum large, broadly rounded, and furnished with 2 large sensilla. Cephalothorax large, as long as wide (dorsal view); representing approximately 40% of total body length (Figure 11A). Surface of cephalothoracic shield and pleurotergites of free pedigerous somites ornamented with several sensilla and with irregular reticulum of pits; integumental reticular pattern present as in other described species of *Anzyclops* on all somites, but absent from all appendages (Figure 11C). Hyaline fringes of prosomites narrow and smooth. Fifth pedigerous somite ornamented with 2 dorsal (1 on each side) large sensilla; lateral edges produced into recurved spine dorsally, hyaline fringe smooth on all sides (Figures 7C, D, 11D).

Genital double-somite large, with expanded anterior part and deep lateral recesses at level of the sixth legs, 1.9 times as wide as long (dorsal view), ornamented with pits but without sensilla; hyaline fringe of genital double-somite with median W-shaped lobe dorsally (Figures 7C, D, 11D). Copulatory pore ovoid, situated at 1/3 of somite length; copulatory duct narrow, siphon-shaped, well sclerotised. Seminal receptacle with small anterior expansion and larger posterior expansion, representing 71% of double-somite's length; oviducts broad and strongly sclerotised. Ovipores situated dorsolaterally.

Third and fourth urosomites without any pores or sensilla, ornamented only with cuticular pits; hyaline

fringe scalloped dorsally, ventrally smooth (Figures 7C, D, 11F). Third urosomite 1.2 times as long as fourth.

Anal somite ornamented with 2 large sensilla dorsally and transverse row of spinules along posterior margin ventrally and laterally (Figures 7C, D). Anal sinus smooth and completely covered by very large triangular anal operculum (Figure 11F), produced posteriorly well beyond somite margin to about 1/2 of the length of the caudal rami and representing 50% of anal somite width.

Caudal rami (Figures 7C, D, 11F) cylindrical, almost parallel, closely inserted (with space between them about 1/5 of ramus width) and about 1.6 times as long as wide; ornamented with several spinules at base of 2 lateral setae. Dorsal seta strong, about 1.3 times as long as ramus, inserted at 3/4 of ramus length, biarticulate at base and plumose. Anterolateral seta arising somewhat dorsolaterally at middle of ramus length, 0.5 times as long as dorsal seta. Posterolateral seta stout, spiniform and bipinnate, about as long as ramus. Terminal accessory seta also bipinnate, 0.6 times as long as posterolateral seta but not as strong. Terminal setae with breaking planes, bipinnate. Inner terminal seta about 1.5 times as long as outer 1 and half as long as body length.

Antennule (Figure 9A) 11-segmented, reaching 3/4 of cephalothoracic shield in length, unornamented. Armature formula as follows: 5.1.5.2.1.2.3.2+ae.2.2.7+ae. No setae biarticulating on basal part, 2 setae on the eighth segment pinnate, all other setae smooth. Both aesthetascs slender, apical aesthetasc as long as terminal 3 segments combined. Length ratio of segments: 1 : 0.5 : 0.6 : 0.3 : 0.3 : 0.4 : 1 : 0.8 : 0.5 : 0.8 : 1.

Antenna (Figure 9E) 4-segmented, comprising coxobasis and 3-segmented endopod. Coxobasis large, cylindrical, twice as long as wide, unornamented, armed with 2 smooth distomedial setae; seta representing exopod absent; original segmentation of coxa marked by partial transverse surface suture. First endopodal segment 1.3 times as long as wide, with inner smooth seta at 2/3 and patch of spinules along lateral margin. Second endopodal segment more slender, about 1.7 times as long as wide, with distal part bearing 6 medial setae (2 sub-distal) and 1 spinular row on lateral margin. Third endopodal segment cylindrical, twice as long as wide, with 2 spinular rows on lateral margin and armed with 7 smooth apical setae (3 of them strong and geniculate). Length ratio of antennal segments from proximal end: 1 : 0.7 : 0.6 : 0.7.

Labrum, not figured, small trapezoidal plate, ornamented with 2 diagonal, short rows of long spinules on anterior surface. Cutting edge slightly concave, with 14 large and sharp teeth between produced rounded lateral corners.

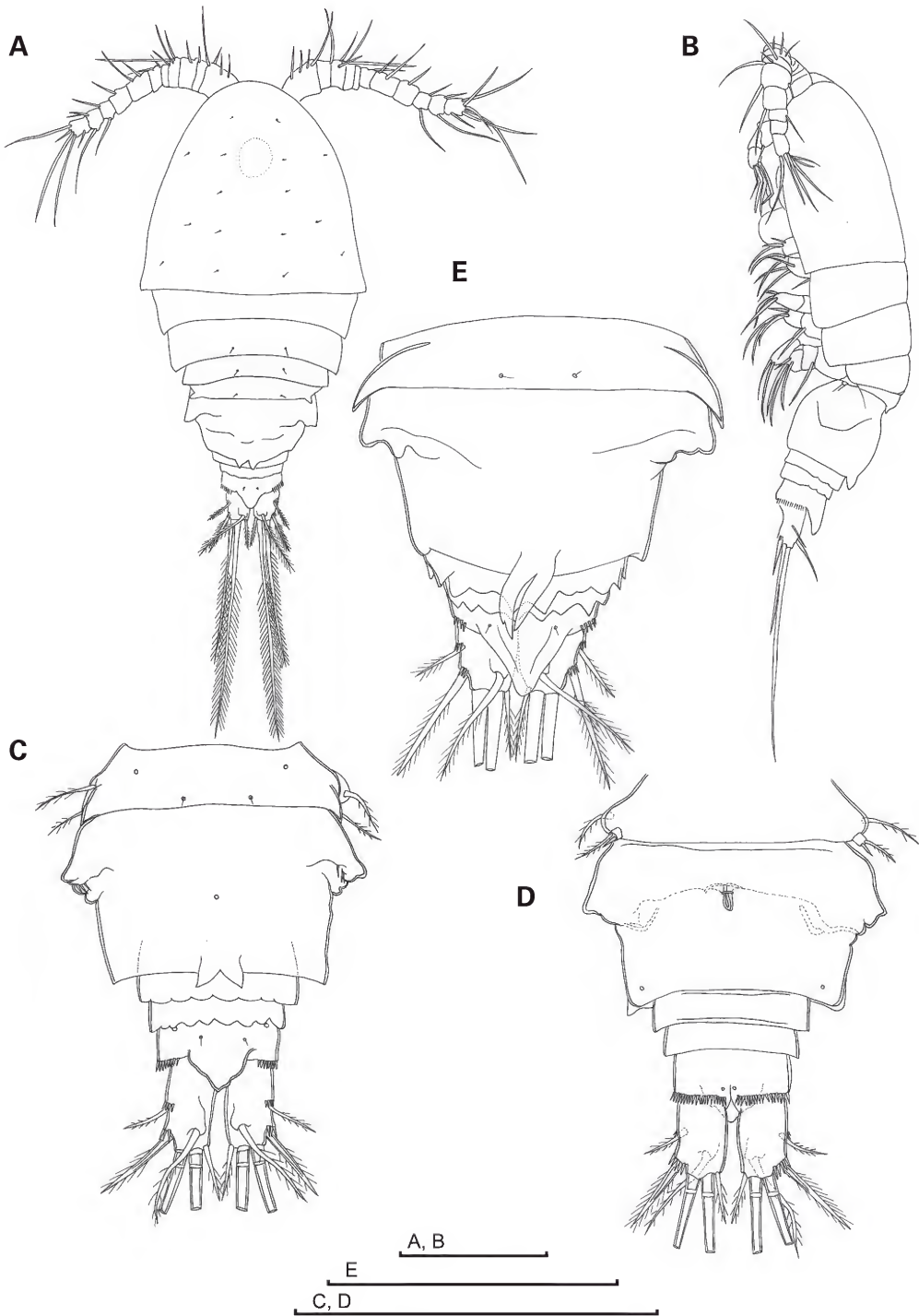
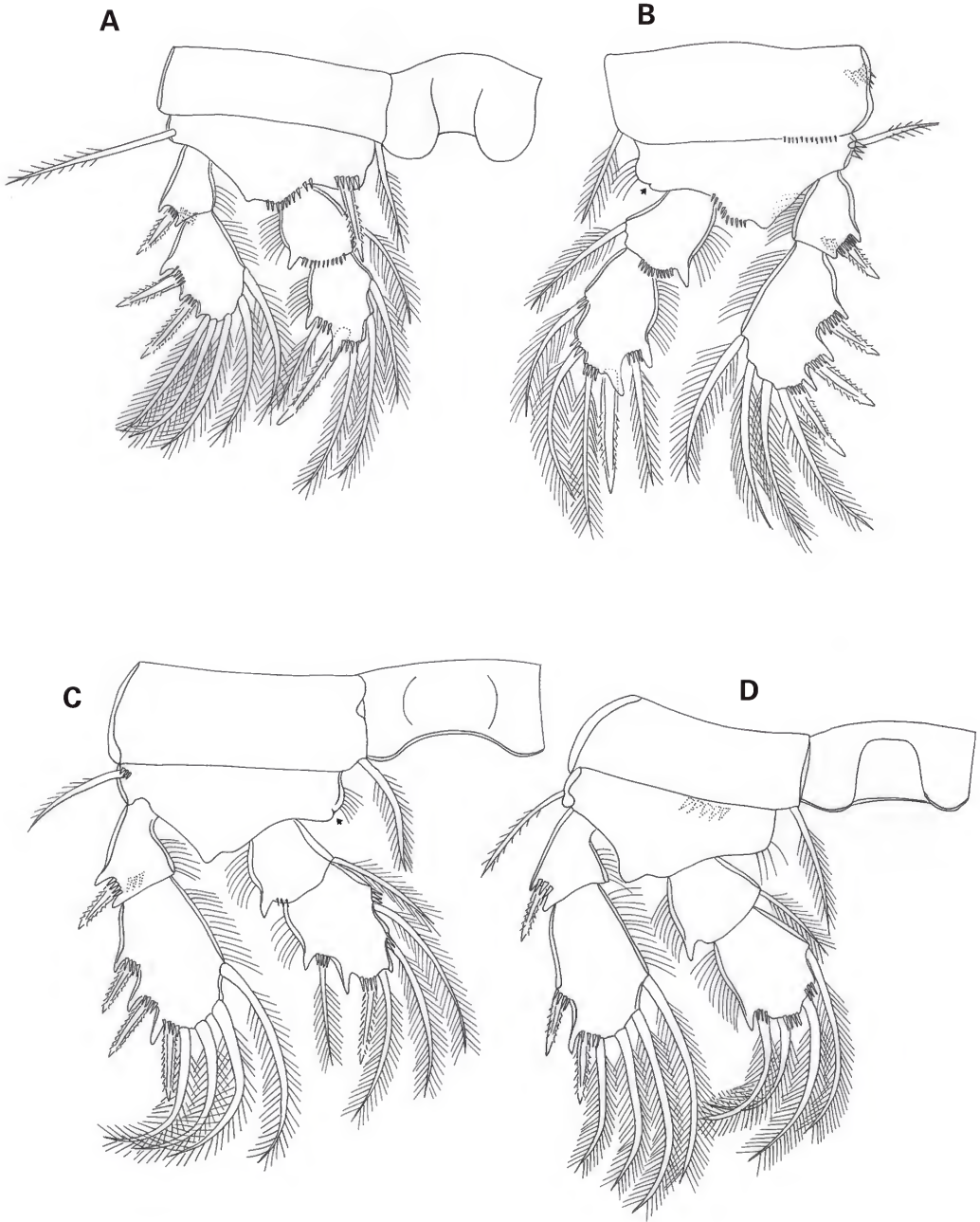
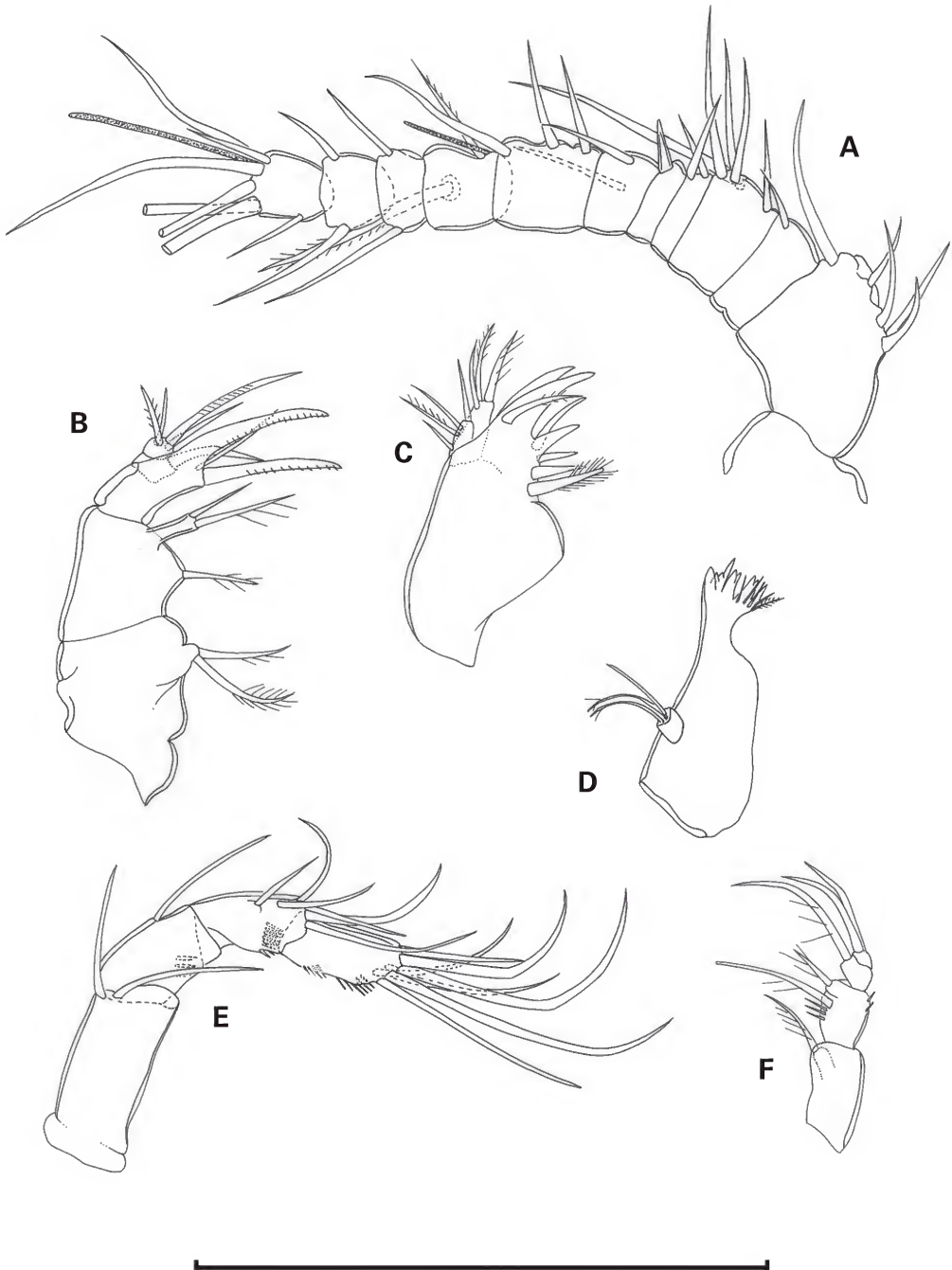


FIGURE 7 *Anzyclops pearsoni* sp. nov. A, habitus, dorsal, paratype, female (WAM C55898); B, habitus, lateral, paratype, female 1; C, urosome, dorsal, holotype female 4; D, urosome, holotype female; E, urosome, dorsal, animal variant (WAM C57231). Scale bar 0.1 mm.



**FIGURE 8** *Anzyclops pearsoni* sp. nov. A, B holotype female; C, D paratype female (WAM C55900). A, first swimming leg, anterior; B, second swimming leg, anterior; C, third swimming leg, anterior; D, fourth swimming leg, anterior. Scale bar 0.1 mm.



**FIGURE 9** *Anzyclops pearsoni* sp. nov. B, C, E, F paratype female 3. A, antennula, dorsal, holotype animal; B, maxilla, posterior; C, maxillula, posterior; D, mandibula, posterior paratype female (WAM C55895); E, antenna, caudal; F, maxilliped, posterior.

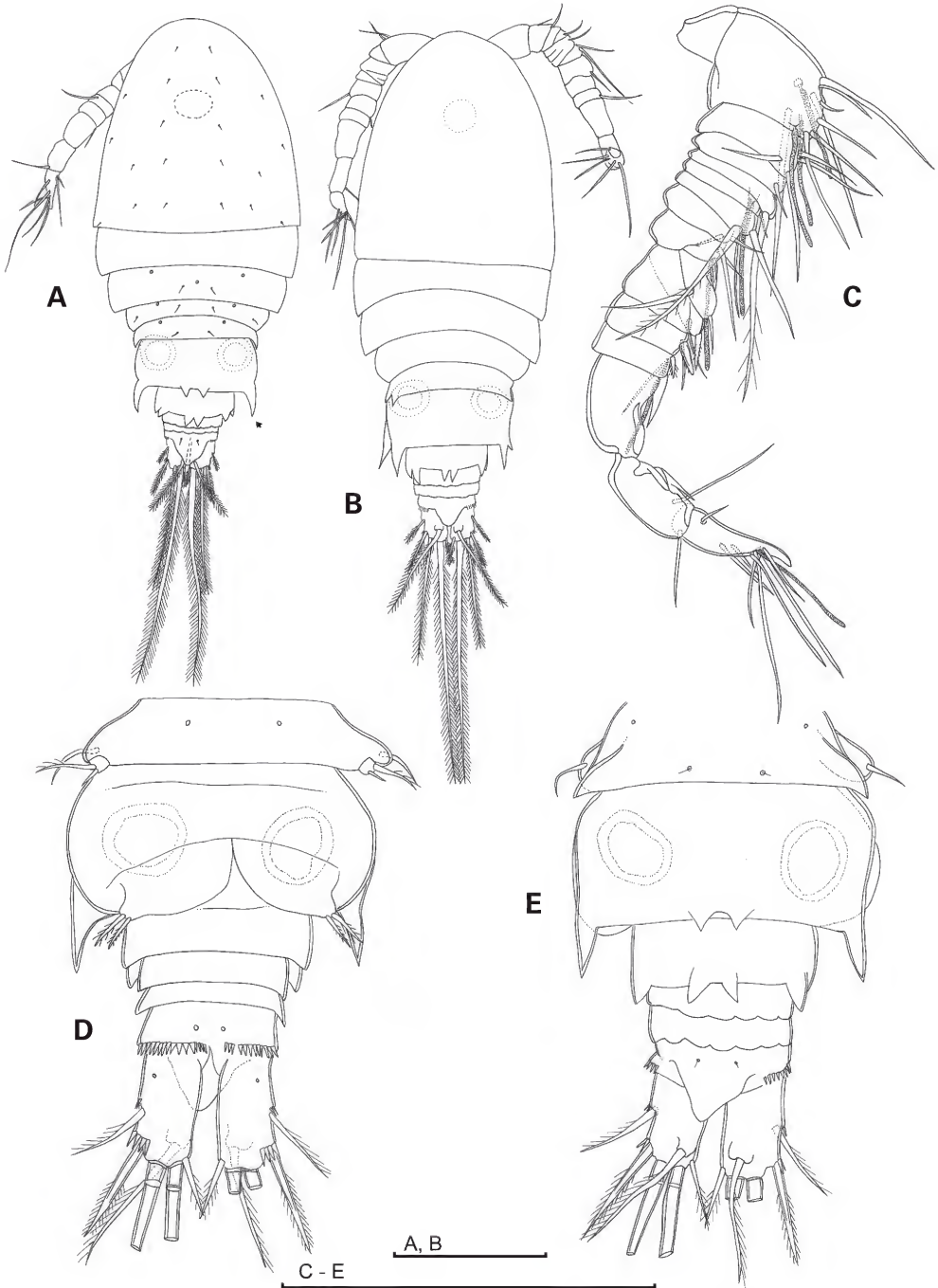
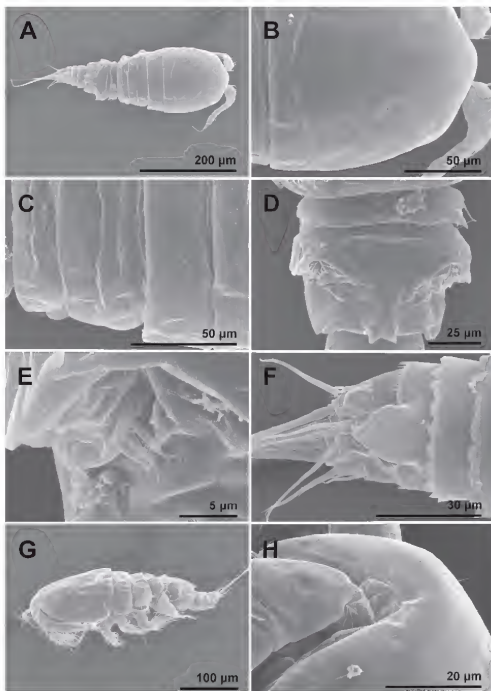


FIGURE 10 *Anzyclops pearsoni* sp. nov. C, D, E allotype male. A, habitus, dorsal paratype male (WAM C55896); B, habitus, dorsal, paratype male (WAM C55899); C, antennula, ventral; D, urosome, ventral; E, urosome, dorsal.

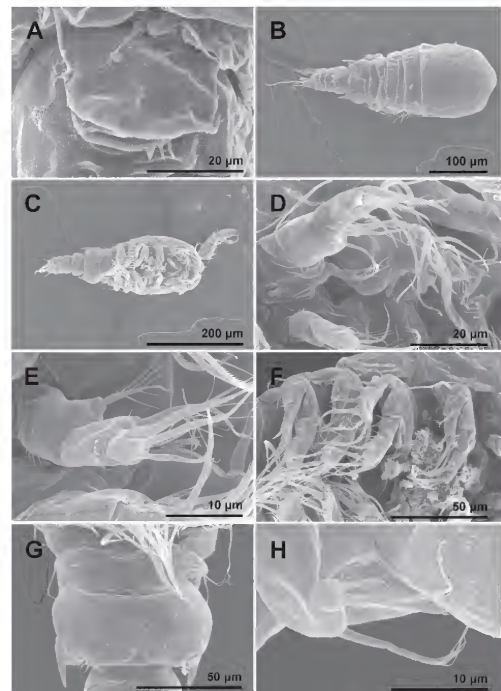


**FIGURE 11** *Anzyclops pearsoni* sp. nov. SEM micrographs (WAM C55892), A-F paratype female 1, G, H, paratype female 2: A, habitus, dorsal; B, cephalothorax, dorsal; C, tergites of free pedigerous somites, dorsal; D, fifth pedigerous somite and genital double-somite, dorsal; E, sixth leg, dorsal; F, last three urosomites and caudal rami, dorsal; G, habitus, lateral; H, rostrum and first antennular segment, lateral.

Mandible (Figure 9D) composed of coxa and small palp. Coxal gnathobase cutting edge with 3 spinules on anterior surface and 4 apical teeth (ventral most tooth strongest and complex, quadridentate; second and third tooth bidentate), and 2 setae on dorsal corner. Palp, unornamented but armed with 3 apical setae: 2 long and 1 short and smooth.

Maxillule (Figure 9C) composed of praecoxa and 2 segmented palp. Praecoxal arthrite bearing 3 very strong distal spines, smooth, blunt, and fused at base, plus 1 sharp, and 1 spinulate setae; and 3 medial elements (proximal longest and plumose, others smooth). Palp composed of coxobasis and endopod. Coxobasis with smooth proximal (exopodal) seta and 3 medial setae (1 smooth and slender, 2 bipinnate); endopod with 1 smooth and 2 pinnate setae.

Maxilla (Figure 9B) 5-segmented, but praecoxa partly



**FIGURE 12** *Anzyclops pearsoni* sp. nov. SEM micrographs (WAM C55892), C-H paratype female (WAM C55000); B, habitus, dorsal, paratype male (WAM C55000); C, habitus, ventral; D, maxillula and maxilla, ventral; E, maxilliped, ventral; F, swimming legs, ventral; G, first two urosomites, ventral; H, fifth leg, ventral.

fused to coxa on posterior surface. Endite of praecoxa robust, armed with 2 subequal, pinnate setae. Proximal endite of coxa reduced to a knob with 1 bipinnate seta; distal endite highly mobile, elongate, and armed apically with 2 setae, 1 of which is pinnate; coxa unornamented. Basis expanded into robust claw, ornamented with 2 longitudinal rows of spinules, and armed with 1 seta and a second seta transformed into a large claw. Endopod 2-segmented; proximal segment armed with 1 robust, unipinnate seta; distal segment with 1 robust, unipinnate, apical seta, 2 slender and smooth subapical setae and 1 bipinnate setae. All strong setae, as well as basal claw, prehensile.

Maxilliped (Figure 9F) 4-segmented, composed of syncoxa, basis, and 2 segmented endopod. Ornamentation consisting of several longitudinal rows of spinules on basis. Syncoxa appears to be armed with only 1 strong seta. Armature formula: 1.2.1.2.

Inner spine on basis of first swimming leg short, reaching slightly beyond distal margin of first endopodal segment (Figure 8A). Outer seta on basis of first swimming leg very long and bipinnate; those on other legs shorter. Inner distal corners of basis of second and third legs notched (arrowed in Figures 8B, C). Basis of fourth swimming leg with round inner distal corners, ornamented with long setules. Intercoxal sclerites of all swimming legs with concave distal margins and without any surface ornamentation. Praecoxae short and unornamented. Coxa of first swimming leg unornamented, coxa of second swimming leg ornamented with short distal row of minute spinules on anterior margin; and a larger spinule patch on posterior surface close to outer margin.

All swimming legs with sub-equal 2-segmented exopods and endopods (Figures 8A-D). Second exopodal segment spine formula 2.3.3.2 and setal formula 5.4.4.4. The complete armature formula is:

	Coxa	Basis	Exopod	Endopod
Leg 1	0-1	1-I	I-0; I,I + 1,4	0-I; 1,I + 1,2
Leg 2	0-1	1-0	I-0; II,I + 1,3	0-1; 1,I + 1,2
Leg 3	0-1	1-0	I-0; II,I + 1,3	0-1; 1,I + 1,2
Leg 4	0-1	1-0	I-0; I,I + 1,3	0-1; 1,1,2

All setae on endopods and exopods slender and plumose; all spines strong and bipinnate.

Long setules on inner margin of exopods and outer margin of endopods; both rami additionally ornamented with minute spinules at base of each armature element and the base of each segment except fourth leg. Second (Figure 8B) and third (Figure 8C) swimming legs very similar, except apical spine on second leg endopod somewhat larger. Endopod of fourth swimming leg (Figure 8D) as wide as exopod but slightly shorter; second endopodal segment about as long as wide and without apical spine.

Fifth leg (Figures 7D, 12A) held ventrolaterally, composed of protopod completely fused to somite and free exopod. Protopodal seta small and slender but visible in dorsal view, without prominent setophore, smooth. Exopod quadriform and very small, about as long as wide, armed apically with outer bipinnate seta and inner smooth spine; seta about 3 times as long as adjacent spine.

Sixth leg (Figures 11E, 12A) small, semicircular cuticular plate, armed with 3 short spines; inner spine thick, fused to plate, outer spines articulated.

#### Male

Total body length ranges from 268–331  $\mu$ m (mean 288  $\mu$ m; n=9). Body (Figures 10A, 12B, C) much more

slender than in female, prosome/urosome ratio about 1.9 and greatest width at posterior end of cephalothorax. Body length/width ratio 2.2; cephalothorax about 1.7 times as wide as genital somite. Cephalothorax about as long as wide (dorsal view), representing 47% of total body length. Ornamentation of prosomites similar to female. Hyaline fringe of fifth pedigerous somite (Figures 10D, E) smooth ventrally and dorsally; somite ornamented as in female but lateral edges produced into larger recurved spines (arrowed in Figure 10A).

Genital somite (Figures 10D, E, 12G) more than twice as wide as long, hyaline fringe with median W-shaped lobe dorsally as in the female; posterolateral edges produced into a large caudally directed spine-like lobe; 2 ovoid spermatophores visible inside.

Third urosomite with hyaline fringe smooth ventrally; dorsally with large median W-shaped lobe, 2 times longer than lobe on genital somite; anterior-lateral edges produced into a small posteriorly directed spine like lobe, about 1/3 of size of lobe on genital somite (Figure 10E); next 2 urosomites without any ornamentation; all urosomites with hyaline fringes dorsally scalloped and ventrally smooth.

Anal somite ornamented as in female but anal operculum (Figure 10E) larger, reaching 2/3 length of caudal rami. Caudal rami (Figure 10D, E) with ornamentation, as well as armature and proportions same as in female.

Antennule (Figures 10C, 12H) digeniculate, 15-segmented, with spine-shaped cuticular structures on thirteenth and fourteenth elements (distal geniculation). Armature formula: 8 + 3ae.4.1.2 + ae.1.2.2.3 + ae.2.2.2.2 + ae.0.1.9+ ae.

Antenna, labrum, mandible, maxillule, maxilla, maxilliped, swimming legs, and fifth leg similar to those of female. Sixth leg (Figure 10D) large, unornamented cuticular plate, armed with inner spine and outer seta on outer distal corner; both bipinnate and seta just longer than spine.

#### ETYMOLOGY

The species is named after Grant Pearson, formerly of the Department of Parks and Wildlife and then Bennelongia Environmental Consultants, in recognition of his valuable work collecting subterranean fauna, including the type material of this species, across Western Australia.

#### VARIABILITY

The cuticular ornamentation is very variable and may be more or less visible due to the preservation of the specimen. The W-shaped lobe on the genital double-somite is variable in shape and the scalloping on the hyaline fringe of urosomites is also variable. The dorso-



lateral edges of the fifth pedigerous somite are variously produced and are more rounded in some specimens. The operculum may vary in size.

One male paratype (Figure 10B) shows many variations in morphology with the genital double-somite lacking a median W-shaped lobe dorsally and having two asymmetrical posteriorly directed spine like lobes. The anterior-lateral edges of the third urosomite are produced into two small posteriorly directed spine like lobes. The two female specimens collected from drill hole HPRC0504 have an extremely elongated median lobe on the genital double-somite, larger operculum, more serrated hyaline fringe on dorsal urosomites and the dorsolateral edges of fifth pedigerous somite are markedly produced and recurved (Figure 7E); the four males from this site have the normal form of the W-shaped lobe on the third urosomite but the W-shaped lobe is absent from the genital double-somite. This population may be a different species.

## DISCUSSION

### Distributions

The eight known species of *Anzycyclops* are amongst the smallest known cyclopoid copepods. All seven described species have total lengths (excluding caudal setae) <0.5 mm, with most species being about 0.3 mm long. Six of the species occur in Australia, one is found in New Zealand, while an eighth species from India is currently being described. Five of the Australian species are known only from the Pilbara region.

Three of the Pilbara species (*A. belli* Karanovic, Eberhard & Murdoch, 2011, *A. trotteri* sp. nov., *A. yarriensis* Karanovic, Eberhard & Murdoch, 2011) are known from single sites, despite sampling being quite intensive in the local areas where they were collected. *Anzycyclops ballensis* Karanovic, Eberhard & Murdoch, 2011 is known from three sites within a distance of 5 km and *A. pearsoni* sp. nov. from six sites within a distance of 8 km (Figure 1). Each species occurs within a different river catchment (*A. trotteri* in the Robe, *A. pearsoni* in the Fortescue). The small ranges of both species suggest that *Anzycyclops* species in the Pilbara are most definitely short range endemics as defined by either Harvey's (2002) criterion of range <10,000 km<sup>2</sup> or Eberhard et al.'s (2009) tighter criterion of range <1000 km<sup>2</sup>.

Despite being in different catchments, the known ranges of both new species lie in the Fortescue River basin and, not surprisingly, these two species have the greatest number of shared morphological characters of all *Anzycyclops* species. The known range of *A. belli* is just north of the Fortescue River basin and it is the species geographically closest to *A. trotteri* sp. nov. and *A. pearsoni* sp. nov. *Anzycyclops belli* shares a significant number of morphological characters with *A. trotteri* sp.

nov. and *A. pearsoni* sp. nov. (see below).

The richness of *Anzycyclops* species in the Pilbara and their small ranges reflect the importance of the Pilbara region for subterranean fauna (Halse et al. 2014; Halse and Pearson 2014) and the high levels of endemism present in its copepod fauna (Karanovic 2006; Karanovic et al. 2011). However, it should be recognised that while the Pilbara and adjacent Yilgarn regions in Western Australia appear to support substantially richer stygofauna communities than other parts of Australia (Guzik et al. 2010), there has been comparatively little study of stygobitic copepods elsewhere in Australia and the number of described species in Queensland and New South Wales considerably underestimates known stygobitic copepod biodiversity in those states (e.g. Hancock and Boulton 2008; Karanovic and Hancock 2009).

### Ecology

Studies of copepods in Australian groundwater are still in their infancy, with the primary focus being identifying new species and unravelling species complexes (e.g. Karanovic and Cooper 2011, 2012). There has been little study of the ecology and life history of different species. The limited information available suggests that four of the Pilbara species (no information is available for *A. ballensis* from the coastal part of the Sherlock River catchment) and the Queensland species occur in fresh groundwater of neutral to slightly acidic pH (Table 1). Known depths to groundwater vary from 5 to 40 m. Of the species in the Pilbara, *A. ballensis*, *A. belli* and *A. yarriensis* have been collected in groundwater in fractured rock basalts (Karanovic et al. 2011), which Halse et al. (2014) identified as a geology likely to yield stygofauna. *Anzycyclops pearsoni* sp. nov. and *A. trotteri* sp. nov. were collected from areas containing alluvial and channel iron deposit aquifers (Table 1). Alluvium is widely recognised as an important habitat for stygofauna (e.g. Hahn and Matzke 2005; Halse et al. 2014) but *A. trotteri* sp. nov. and *A. pearsoni* sp. nov. appear to utilise detrital and channel iron deposits as well.

### Taxonomy

The two new species, *Anzycyclops pearsoni* sp. nov. and *A. trotteri* sp. nov., share the same armature formula of the swimming legs, pronounced spiniform processes on the urosomites, very long and triangular anal operculum, and similar shape and armature of the caudal rami. Their known distributions are also in the same broad drainage basin (Fortescue, see above) and it appears likely they originated from a common recent ancestor. They can be chiefly distinguished by the subtle differences in body shape, number and size of spiniform processes on urosomites, and segmentation of the antennule. The latter character is probably of little phylogenetic significance. *Anzycyclops ballensis* shares the characteristic of a 10-segmented antennule with *A.*

*trotteri* sp. nov, although it shares few other characters (others than those that are diagnostic of the genus) with either *A. trotteri* sp. nov. or *A. pearsoni* sp. nov.

The 10-segmented state of the antennule recorded in *A. ballensis* and *A. trotteri* sp. nov. may be the result of convergence, even though in both cases the reduction in segmentation is a consequence of absence of articulation between the ancestral second and third segments. Differences between *A. ballensis* and the two new species include, but are not limited to: body shape (not dorsoventrally compressed in *A. ballensis*), lateral protrusions of the genital double-somite (absent in *A. ballensis*), sculpturing of the hyaline membrane on urosomites (finely serrated in *A. ballensis*), shape and length of the anal operculum (shorter and linguiform in *A. ballensis*), length of the caudal rami (longer in *A. ballensis*), proportions of armature elements on the caudal rami (innermost apical setae longer than outermost apical setae in *A. ballensis*), armature of the mandible (only two setae in *A. ballensis*), armature of the maxilliped (no setae on the first segment in *A. ballensis*), and armature of the fourth leg endopod (apical spine present and outer seta absent in *A. ballensis*).

The new species share the greatest number of morphological characters with *A. belli*, which also is closest to them geographically (see above). These three species all have a similar body shape, pronounced lateral protrusions on the genital double-somite, long anal operculum, caudal ramus of similar proportions with the innermost apical seta significantly shorter than the outermost, very similar shape and armature of cephalic appendages, exactly the same armature formula of all swimming legs, and a similar fifth leg. Females of *A. belli* differ from females of the two new species by absence of pronounced spiniform processes on urosomites (although the hyaline in *A. belli* is very roughly serrated), linguiform shape of the anal operculum, and in having longer dorsal setae on the caudal rami. Unfortunately, the males of *A. belli* are as yet unknown, so the male characters could not be compared.

Excluding *A. belli*, *A. trotteri* sp. nov. and *A. pearsoni* sp. nov. from the central Pilbara, the remaining four species of the genus *Anzyclops* appear to form a rather heterogeneous group. The occurrence of *Anzyclops* species in the highly disjunct areas of Western Australia, Queensland, New Zealand and India suggests the possibility of a long evolutionary history. As the survey of subterranean diversity in Australia and Asia is still in its infancy, it is expected that more species of *Anzyclops* will be discovered and that these species may provide missing links between the currently known species of *Anzyclops*.

A key to the described species of *Anzyclops*, based on female characters, is provided below.

## KEY TO SPECIES OF ANZCYCLOPS

(see Karanovic et al. 2011)

1. Endopod segment 2 of fourth leg with outer seta ..... 3  
Endopod segment 2 of fourth leg lacking outer seta ..... 2
2. Body shape dorsoventrally depressed.....  
.....*A. silvestris* (Harding, 1958)  
Body shape of typical cycloform pattern. ....  
.....*A. ballensis* Karanovic, Eberhard & Murdoch, 2011
3. Endopod segment 2 of fourth leg with apical spine ..... 4  
Endopod segment 2 of fourth leg without apical spine ..... 5
4. Endopod of fourth leg with 3 inner setae on second segment.....  
.....*A. yariensis* Karanovic, Eberhard & Murdoch, 2011  
Endopod of fourth leg with 2 inner setae on second segment.....  
.....*A. euryantennula* Karanovic, Eberhard & Murdoch, 2011
5. Dorsal hyaline fringe of genital double-somite with W-shaped medial lobe; anal operculum triangular ..... 6  
Dorsal hyaline fringe of genital double-somite without medial lobe; anal operculum linguiform. ....  
.....*A. belli* Karanovic, Eberhard & Murdoch, 2011
6. Dorsal hyaline fringe of genital double-somite with simple W-shaped medial lobe; dorsal hyaline fringe of third and fourth urosomites with moderately smooth scalloping.....  
.....*A. pearsoni* sp. nov.  
Dorsal hyaline fringe of genital double-somite with serrated W- shaped; third and fourth urosomites with strong irregular serrations.....  
.....*A. trotteri* sp. nov.

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# An annotated type catalogue of the turtles (Testudines: Pleurodira: Chelidae) in the collection of the Western Australian Museum.

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**ABSTRACT** – An annotated catalogue is provided for the type specimens of turtles (Testudines: Chelidae) in the herpetological collection of the Western Australian Museum. The collection currently holds eight type specimens representing five named taxa from Australia and Timor-Leste, two of which are currently considered as valid at the specific or subspecific level. We also take into consideration the taxonomic status of some species and synonymise *Chelodina kuchlingi* with *C. oblonga* and *Macrochelodina walloyarrina* with *C. burrungandjii*.

**KEYWORDS** – type specimens, Testudines, Chelidae, Western Australian Museum

## INTRODUCTION

The herpetofaunal collection of the Western Australian Museum (WAM) is one of the largest collections in Australia, containing over 160,000 specimens, representing the long history of the collection and the special interest in this faunal group by current and previous curators and research staff. From the year of the museum's foundation (1891) to 1912, amphibians and reptiles were accessioned in a series of six general registers, the last of which was the Zoological Register 1907–1912 which included all other museum collections and materials obtained, including all terrestrial and aquatic zoology, history, anthropology and archaeology department collections.

In 1912 a separate register was established specifically for herpetological specimens. Specimens accessioned into the herpetological register obtained a number prefixed with 'R'. This prefix is still in use to denote registration numbers and specimens associated with the herpetological collection. Where specimens could be matched to registration numbers, the specimens from the pre-departmental registers were re-registered into the new system and given 'R' numbers. It is unknown if this was completed for the entire collection; however, upon review of historic registers, it seems evident that re-registration of specimens accessed prior to the current herpetology register (pre-1912) was completed in stages by numerous museum staff over a number of years.

Many historic specimens have notations indicating a specimen has been re-registered in the new system along with the date completed, sometimes signed by the person responsible. A large number of early register entries are not accompanied with notations of re-registration and no specimen can be located, indicating specimens were gifted to other institutions, discarded or lost.

Since the first specimen to be accessioned into the herpetological register in 1912 (WAM R1; *Moloch horridus*, previously registered as 12957 in the original Catalogue of the Museum), the collection has continued to grow steadily, particularly in the past 50 years, during which more than 80% of the specimens have been accumulated (see How and Cowan 2006). The collection primarily comprises Western Australian species, but does contain significant comparative material from other Australian states and territories and some overseas regions, particularly Indonesia and Timor Leste. The collection includes over 7,850 primary and secondary type specimens.

Testudines are represented by 1,248 specimens within the collection, including whole preserved (fluid and dry), and skeletal (whole skeletons and carapace only) specimens and eggs. The testudine types comprise only ten specimens representing five taxa, of which two are currently considered as valid species or subspecies. Of these ten specimens, one specimen is currently considered lost. The validity of two species

(*Chelodina kuchlingi* and *Chelodina walloyarrina*) is still in question and requires further investigation (see TTWG 2014).

WAM published a list of types annually in the Annual Report from 1960 to 1969. A total of 10 parts of the type list were presented, of which all but part 1 (1959–60) and part 3 (1961–62) included herpetological type material (Anonymous 1961, 1963, 1964, 1965, 1966, 1967, 1968, 1969). The herpetological lists, compiled by Glen Storr, only presented primary type specimens within the collection (holotypes, syntypes, lectotypes and neotypes). Two chelid type specimens were listed in the 1960–61 annual report, namely *Chelodina milly-millyensis* Glauert, 1923 and *Emydura inspectata* Glauert, 1954 (Anonymous 1961). Owing to the limited distribution of the annual reports, it is unlikely that these type lists reached their target audience, evident by the designation of a lectotype for *C. milly-millyensis* by Cogger et al. (1983) despite holotype information being presented, even though incorrectly, in the 1960–1961 annual report (Anonymous 1961). A decision to discontinue publishing the type list in annual reports was published in the 1969–1970 Annual Report. This was, to be replaced by publication of a consolidated and revised type list, incorporating previous published type information and projected to appear as a WAM special publication (Anonymous 1970). No such publication of type lists or material has occurred for the herpetological collection.

WAM in addition to the Australian National Wildlife Collection (ANWC), Canberra and Tasmanian Museum and Art Gallery (TMAG), Hobart are the only Australian institutions not to have published a comprehensive list of herpetological type material held within their collections. In accordance with Recommendation 72F of the Code, we aim to give an account of the herpetofaunal type material held in the collection of WAM. This paper is the first part of a series aimed at listing all type material of amphibians and reptiles held by WAM.

## METHODS

Information on type specimens was obtained from the original description and compared with information retrieved from accession data, jar labels, personal communications and subsequent publications relating to relevant type material. All type specimens in the collection of WAM were examined in addition to any respective label information and notations. This catalogue also includes type specimens of species that have subsequent to their description been synonymised and/or resurrected from synonymy with other taxa. Currently valid names are in accordance with the most recent the Turtle Taxonomic Working Group (TTWG) 7<sup>th</sup> edition of Turtles of the World checklist (2014), unless otherwise stated. This catalogue was prepared in accordance with the rules and recommendations of the

Code (ICZN 1999). In accordance with the Code, the following ‘name-bearing’ and ‘other’ type specimens terminology is used here:

*Holotype*: single specimen upon which new nominal species-group taxon is based in the original publication (Article 73.1).

*Paratype*: each specimen of a type series other than the holotype (Article 72.4.5.; Recommendation 73D).

*Syntypes*: specimens of a type series that collectively constitute the name-bearing type (Article 73.2).

*Lectotype*: may be designated from the syntypes to become the unique name bearer of the name of a nominal species-group taxon and the standard for its application (Article 74.1).

*Paralectotype*: following the designation of a lectotype, all remaining syntypes become paralectotypes (Article 74.1.3; Recommendation 74F).

## FORMAT

### ORIGINAL BINOMEN

***Genus species subspecies* Author, year.**

#### Referenced figures

##### *Original type species citation*

Author, year, title, journal, page(s), [page of description].

##### *Primary type (Holotype/Lectotype/Syntypes)*

Registration number, locality (latitude/longitude), collector(s) and collection date.

##### *Secondary type(s) (Paratypes/Paralectotype)*

Registration number, locality.

##### *Current nomenclature*

Current generic and specific recognition of the species, if different from original description.

##### *Current status*

Current status and validity of the species, synonymies, if different from original description.

##### *Remarks*

Additional information provided on subjects including the history and status of types, location of additional type specimens and information regarding the synonymy or resurrection of a species or subspecies if necessary and available.

Each taxon is presented by the name provided by the original author(s), followed by the author's name, and year of publication. Species names are given in the exact format in which they were first published, some of which do not correspond with the current provisions of the ICZN Code for Zoological Nomenclature (1999). The original type species publication citation follows next displaying the author(s), year, title (of article or book), journal (unless otherwise), page(s) and the page the description of the species commences in square brackets ([x]). Primary type (holotype or lectotype) information includes the WAM registration number, locality, latitude and longitude (in degrees minutes seconds) as presented in the description, collector(s) name and collection date. Type localities shown in quotes are those derived from the original published descriptions and are presented exactly as presented in original descriptions. Where latitude and longitude were not provided in the original description, location was obtained from accession data or subsequent designation by WAM staff, presented in square brackets ([x]). All dates are presented as day, month, year, or month, year or year where information is not provided in the original description or relevant information sources. On the next line secondary types (paratypes, paralectotypes and syntypes) are displayed showing WAM registration number and locality. Specific locality (latitude and longitude) and collection details (collector and date) are not provided for non-name-bearing type specimens. Specimens marked with an asterisk (\*) indicate specimen no longer held in the collection of WAM, either due to gifting or loan to other institutions or loss of specimen. Details of specimens no longer held in the collection are discussed further in the Remarks section of each species where information was available.

Current nomenclature and status are only presented where change from the original binomen or trinomen has occurred such as generic changes, specific amendments, changes to species or subspecies status and synonymy or resurrection from synonymy. Remarks include relevant information on issues and errors from original description, specimens, historical remarks or subsequent publications referring to the species or specimens as well as information relating to the synonymy or resurrection of the species or information pertaining to lost or destroyed specimens. Square brackets ([x]) indicate corrections or additions of information presented in the original description or subsequent publications. The prefix R is used to denote that the registration number corresponds with the herpetofaunal collection of WAM.

## ACCOUNT OF TYPE SPECIMENS

### Family Chelidae

#### *Chelodina kuchlingi* Cann, 1997

##### Figure 1

Cann, J. (1997). Kuchling's long-necked turtle. *Monitor* 9(1): 41–44 [41]

##### *Holotype*

R29411, 'Kalumburu', Western Australia [14°18'S, 126°38'E], presented by W.H. Butler in 1966 (Figure 1).

##### *Current status*

Junior synonym of *Chelodina oblonga* (Gray, 1841), synonymy of this paper.

##### *Remarks*

Also described in the book *Australian Freshwater Turtles* by Cann (1998), where it states '*Chelodina kuchlingi* sp. nov.' and 'A new species of long-necked turtle is described here, from the Kimberley region of north-west Australia' (p. 97) implying the description of a new species, in error. The description appearing in the 1998 publication does not differ from the text or images of the original 1997 publication other than a few minor edits and inclusion of acknowledgements. Cann originally intended for the formal description of the species to appear in the book; however, due to printing delays while the book was in press the description was published in *Monitor* to prevent the new taxa being described by others who were aware of it (G. Shea, pers. comm.). The validity of the species was questioned following preliminary morphological analysis by Georges and Thomson (2006) based on the species description from a single specimen of uncertain origin; however, it was not formally listed as a junior synonym of *Chelodina rugosa* (now *C. oblonga*, see ICZN 2013) until a later publication (Georges and Thomson 2010), a synonymy supported by TTWG (2010). The species was raised from synonymy of *C. rugosa* by TTWG (2014) based on additional unpublished information provided by G. Kuchling who challenged the status of the species as a synonym of *C. oblonga*, see TTWG (2014).

Damage to and condition of the holotype specimen described by Cann (1997) is consistent with a captive containment, having a worn plastron and very worn down or cut nails. The locality and other information for the holotype specimen are possibly in error. Cann (1997) detailed 'H. Butler' as the collector and 'Kalumburu, Western Australia' as the locality; however, the origin of the specimen is unknown. The holotype was given to H. Butler by another person who collected and held it in captivity for an unknown length of time before it was given to the University of Western Australia where it

was held for a short period before donation to WAM (S. Thomson, pers. comm.). Specimen accession registration states the collection date as 'x-xii-1965-i-i-1966' with accession date '30:viii:67'.

The validity of the species is still in question and requires further investigation; see TTWG (2014). Until further supporting evidence for the species to be recognised as a distinct taxon is published, we maintain it as a junior synonym of *Chelodina oblonga* following Georges and Thomson (2010). The species was described from a single specimen of questionable origin. The species morphology is consistent with *C. oblonga* and, in the lack of supporting evidence for recognition as a valid taxonomic unit and for the resurrection from synonymy by the TTWG (2014), the species is considered a junior synonym. Molecular analysis and morphological examination of additional specimens are likely to resolve the taxonomic status of the species. Molecular and morphological data provide evidence of only two *Chelodina* lineages occurring in the Kimberley, representing *C. burrungandjii* and *C. oblonga* (Georges et al. 2002; Georges and Thomson 2006; 2010; Georges and Merrin 2008).

***Chelodina mccordi timorlestensis* Kuchling, Rhodin, Ibarrodo & Trainor, 2007**

Figure 2

Kuchling, G., Rhodin, A.G.J., Ibarrodo, B.R. and Trainor, C.R. (2007). A new subspecies of the snakeskin turtle *Chelodina mccordi* from Timor-Leste (East Timor) (Testudines: Chelidae). *Chelonian Conservation and Biology* 6(2): 213–222 [213].

**Holotype**

R165888, 'area of Lake Iralalero, Timor-Leste' [08°31'26"S, 126°59'50"E], collected by A.B.F. Ly and donated to G. Kuchling 23 May 2006, presented to WAM by G. Kuchling (Figure 2).

**Current status**

Junior synonym of *C. mccordi timorensis* (formerly *C. timorensis* McCord, Joseph-Ouni and Hagen, 2007), *vide* Rhodin et al. (2008) and TTWG (2014).

**Remarks**

The species *Chelodina timorensis* McCord et al., 2007 was described in the hobbyist periodical *Reptilia* only months prior to the description of *C. mccordi*



FIGURE 1 *Chelodina kuchlingi*, holotype (R29411).



FIGURE 2 *Chelodina mccordi timorlestensis*, holotype (R165888).

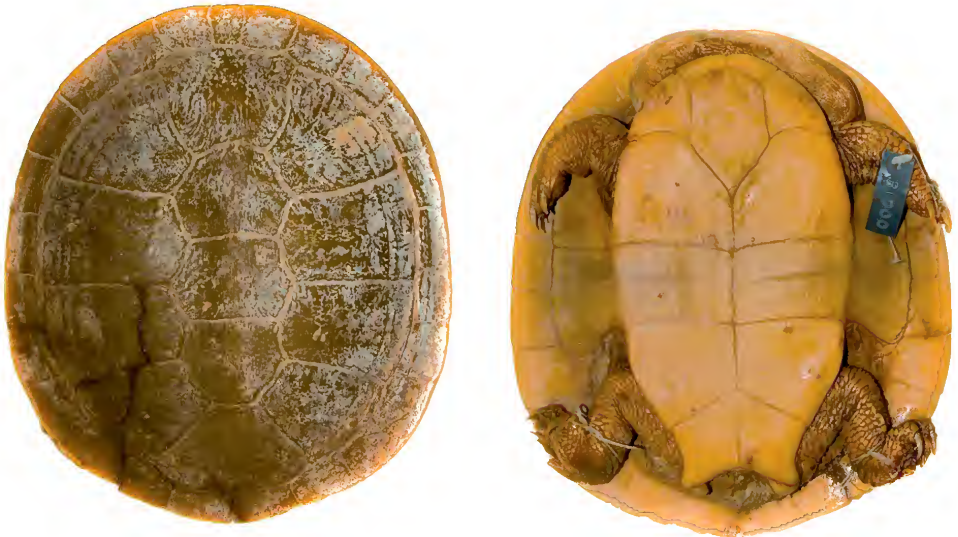


FIGURE 3 *Chelodina milly-millyensis*, lectotype (R1000).



*timorlestensis*, see notes added in proof in Kuchling et al. (2007) and Rhodin et al. (2008). The latter description by Kuchling et al. (2007) identified the taxon as a subspecies, therefore by inference reducing the species described by McCord et al. (2007) to subspecific status; see also Georges and Thomson (2010).

### ***Chelodina milly-millyensis* Glauert, 1923**

#### Figure 3

Glauert, L. (1923). Contributions to the Fauna of Western Australia No. 2. A new freshwater tortoise from the Murchison River. *Journal of the Royal Society of Western Australia* 9: 53–56 [53].

#### *Lectotype*

R1000, ‘Milly Milly Station, Murchison River’, Western Australia [26°05’S, 116°41’E], collected by J.E. Scully, accessed 19 October 1922, designated by H.G. Cogger (Cogger et al. 1983) (Figure 3).

#### *Paralectotypes*

R911, R912, R1106\*, Milly Milly Station, Western Australia.

#### *Current status*

Junior synonym of *Chelodina steindachneri* (Siebenrock, 1914), *vide* Cogger et al. (1983) and supported by TTWG (2014).

#### *Remarks*

Glauert described the species based on four available specimens; however, a holotype was not formally designated. R1000 was described in detail in the original description due to its larger size and better condition relative to other specimens. In the type list presented in the WAM 1960–1961 annual report, the specimen R1000 was listed as a holotype (Anonymous, 1961); however, this is in error. As Glauert presented registration numbers for four specimens but did not nominate a holotype, all specimens are considered syntypes. The nomination of R1000 as a holotype in the annual report was in error and should have been listed as a lectotype or all four specimens presented as syntypes. Due to the limited circulation of annual reports the identification of this specimen as holotype remained unnoticed. Cogger et al. (1983) correctly designated R1000 as the lectotype of the four syntypes resulting in the remaining three specimens becoming paralectotypes. Of the four type specimens, the lectotype (R1000) and one paralectotype (R1106) are whole wet specimens. The remaining paralectotypes (R911 and R912) are carapace only specimens. Paralectotype R1106 could not be located within the WAM collection

during the chelid type specimen audit for this paper and subsequent searches. The specimen was not recorded in previous audits in 1999 and 2008–2010 that included chelid specimens and is presumed lost.

### ***Emydura inspectata* Glauert, 1954**

#### Figure 4

Glauert, L. (1954). Herpetological miscellanea IV. – A new swamp tortoise from the Swan River district. *Western Australian Naturalist* 4(6): 125–127 [125].

#### *Holotype*

R11092, ‘Warbrook, about 24 miles N of Perth’, Western Australia [31°43’15”S, 116°00’55”E], collected by A. Gates in July 1953 (Figure 4).

#### *Paratype*

R11093\*, Warbrook, Perth, Western Australia.

#### *Current status*

Junior synonym of *Pseudemydura umbrina* (Siebenrock, 1901), *vide* Williams (1958), supported for synonymy by Cogger et al. (1983) and TTWG (2014).

#### *Remarks*

In the description, Glauert refers to R11092 as ‘the type’ while R11093 is referred to as ‘the second specimen’. The type specimens were presented to the museum on 27 April 1954 by R. Boyd after they were kept in captivity for nine months following their collection by A. Gates in 1953.

The paratype specimen (R11093) was loaned to the late J.M. Legler, visiting professor at the University of New England, New South Wales on 27 June 1974 with four additional *P. umbrina* specimens. The specimens were taken back to Utah, United States where they were held in Legler’s private collection at the University of Utah. The specimen loan form states ‘Permission granted to study in USA and to skeletonize one of the females listed, per. Telephone conversation between J.M. Legler and G. Storr 11 July 1974’; however, it is unknown if R11093 was the specimen selected to be skeletonized, Glauert did not state the sex of the specimen in the original description. All specimens are now held at the Natural History Museum of Utah, Utah, United States (NHMU) following Legler’s death in March 2014. The paratype and other specimens loaned in addition to Australian specimens collected by and held in Legler’s private collection are currently awaiting return to respective institutions of the states from which specimens were loaned or collected. The current condition and status of the specimen is not known.

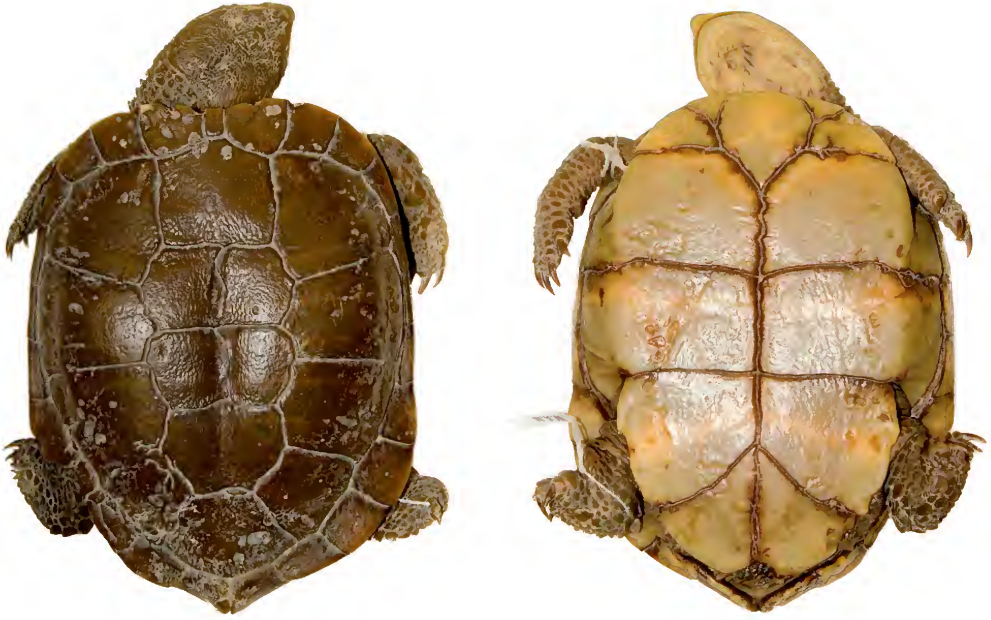


FIGURE 4 *Emydura inspectata*, holotype (R11092).



FIGURE 5 *Macrochelodina walloyarrina*, holotype (R164345).

***Macrochelodina walloyarrina***  
**McCord & Ouni, 2007**

Figure 5

McCord, W.P. and Ouni, M.J. (2007). A new genus of Australian longneck turtle (Testudines: Chelidae) and a new species of *Macrochelodina* from the Kimberley region of Western Australia (Australia). *Reptilia* **31**: 56–64 [59].

**Holotype**

R164345, 'Fitzroy River Crossing, Fitzroy River', Western Australia [18°10'50"S, 125°35'50"E], collected by D. Wedd, G. Erikson, J. Cover and J. Seyjagat on 20 July 2004 (Figure 5).

**Paratype**

R164346, Carson River, Western Australia.

**Current status**

Junior synonym of *Chelodina burrungandjii* Thompson, Kennett and Georges, 2000, synonymy of this paper.

**Remarks**

Listed as a junior synonym of *Chelodina burrungandjii* by Georges and Thomson (2010) based on a lack of evidence to support the specific recognition, further complicated by issues of hybridisation and introgression between *C. burrungandjii* and *C. rugosa* (now *C. oblonga*, see ICZN 2013) in the Kimberley region (see Georges and Thomson 2010). TTWG noted the synonymy by Georges and Thomson but chose to resurrect the species stating 'we provisionally retain *walloyarrina* as distinct [species] until published molecular data resolves the issue' (TTWG 2010, p 000.141). The validity of the species is still in question and requires further investigation (see TTWG, 2014). In the lack of supporting evidence for the resurrection of the species from synonymy with *C. burrungandjii* by TTWG (2014) we follow Georges and Thomson (2010) and consider the species a junior synonym of *C. burrungandjii*, noting no subsequent work has identified any supporting evidence for the species. Molecular and morphological data show evidence for only two *Chelodina* lineages in the Kimberley region, representing *C. burrungandjii* and *C. oblonga* (Georges et al. 2002; Georges and Thomson 2006, 2010; Georges and Merrin 2008). Further molecular analysis and morphological examination of additional specimens are likely to resolve the taxonomic status of the species.

Of the type specimens, the holotype (R164345) is an entire wet specimen while the paratype (R164346) is a carapace and skeleton only. Six eggs belonging to the paratype specimen are registered separately as R150324. The holotype was one of six individuals

collected north of Fitzroy Crossing on the Fitzroy River during a collecting expedition by members of the National Aquarium (Baltimore, USA) and Territory Wildlife Park (Darwin, NT) in July 2004. It was freighted to the US and was housed at the National Aquarium where it subsequently died on 8 May 2004, eight days after arriving (J. Seyjagat, pers. comm). Death was attributed to aggression from other enclosure inhabitants.

The specimen was then made available to McCord for use in the species description with the support of additional specimens from Australia. The WAM paratype was imported into the US by McCord through the University of Canberra to aid the description. In the description the paratype was described as skeletonized, although at the time of publication the specimen was frozen. It was subsequently skeletonised at the American Museum of Natural History (AMNH) as its poor condition made it unsuitable for whole preservation in liquid. All specimens were sent to the AMNH in 2009 for preparation and preservation before being returned to Australia and deposited at WAM in 2009 in accordance with conditions of the permit issued to the collectors of the specimens. Western Australian Department of Parks and Wildlife (DPaW; formerly Dept. Environment and Conservation, DEC; Dept. Conservation and Land Management, CALM) collecting permits, Regulation 17 license to take fauna for scientific purposes conditions state 'All holotypes and syntypes and a half share of paratypes of species or subspecies permitted to be permanently taken under this license shall be donated to the Western Australian Museum'. Three additional paratypes are held in the Australian Museum (AM) (R136058, R136063, R136150) and a single specimen in the AMNH (AMNH R159947).

**ACKNOWLEDGEMENTS**

The authors are grateful to Paul Doughty (WAM), Aaron Bauer (Villanova University) and Glenn Shea (University of Sydney and Australian Museum) for technical discussions and comments on earlier drafts of the catalogue, John Seyjagat (National Aquarium, Baltimore), William McCord (East Fishkill Animal Hospital, New York) and Scott Thomson (Museum of Zoology, University of São Paulo) for providing additional information on the history of *C. walloyarrina* type specimens, Don Bradshaw (University of Western Australia) and Scott Thomson for information on the holotype of *C. kuchlingi*. Earlier versions of the manuscript were greatly improved by two reviewers, A. Bauer and G. Shea who provided useful comments and suggestions for improvement.

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SHORT COMMUNICATION

# Corrections of the type specimens of *Liasis olivaceus barroni* Smith, 1981 (Serpentes: Pythonidae)

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**KEYWORDS** – Nomenclature, ICZN, holotype, paratype, olive pythons, Pilbara, Gascoyne.

## INTRODUCTION

In the description of *Liasis olivaceus barroni* Smith, 1981, the author incorrectly listed the registration numbers for the holotype and one paratype specimen. These errors inadvertently designated two other species, *Ctenophorus caudicinctus macropus* (holotype) and *Underwoodisaurus milii* (paratype) as type specimens, technically resulting in the placement of *L. o. barroni* into synonymy with *C. caudicinctus macropus*. Here the correct holotype and paratype specimens for *L. olivaceus barroni* are identified and the erroneous registration numbers and associated specimen data corrected.

*Liasis olivaceus barroni* or the Pilbara olive pythons are large uniformly coloured pythons endemic to the Pilbara and northern parts of the Gascoyne bioregions in Western Australia (Bush & Maryan 2011). The subspecies was described in 1981 by Laurie A. Smith, in a revision of the *Liasis olivaceus* species-group in Western Australia. The description of *L. o. barroni* was based on eight specimens of the subspecies in addition to comparative material of other species examined by Smith. In the description Smith designated type specimens for the new subspecies in accordance with the International Code of Zoological Nomenclature (ICZN), then third edition (1964). The information provided for the holotype specimens was ‘R55384, a juvenile collected at Tambrey, Western Australia, in 21°35’S, 117°34’E by W.H. Butler on 7 July 1964’. Paratypes listed included ‘Bamboo Creek (33420); Woodstock (54378); Marandoo (60708); 16 km from Nanutarra (24920); Paraburdoo (58935); Pipe Springs, 16 km W of Newman (54617); Prairie Downs (17694)’. All type specimens are held in the collection of the Western Australian Museum (WAM).

Following a review of the original description and associated specimens for a type specimen audit of the

collection of the Western Australian Museum, two inconsistencies were identified between the registration numbers of the type series listed in the description, Smith’s unpublished morphological and meristic data and the specimens associated with those numbers held in the WAM collection. The registration number listed by Smith for the *Liasis olivaceus barroni* holotype, R55384, refers to a specimen of the agamid lizard *Ctenophorus caudicinctus macropus* Storr, 1967 from 62 km east of Mount Isa, Queensland (20°49’S, 140°00’) and one paratype specimen, R54617, a specimen of the carphodactylid gecko *Underwoodisaurus milii* (Bory de Saint-Vincent, 1823) from Steep Point, Western Australia (26°09’S, 113°10’E).

Examination of specimens held in the type collection at the WAM, Smith’s unpublished data, historical specimen registers and accession data revealed the correct holotype and paratypes examined for the original description and identified the derivation of the two errors. Smith’s original specimen data collected during examination of specimens for the description presents morphological and meristic data for a total of ten specimens, one of which is crossed out (R2760, Cue, WA), later identified as a specimen of *L. olivaceus olivaceus* (Smith 1981a). Of the remaining nine specimens, one entry is annotated with ‘Type’, although paratype specimens are not identified. Smith (1981a) stated eight specimens of *L. olivaceus barroni* were examined; however, Smith’s unpublished data indicate nine specimens of the subspecies were examined, of which all but the holotype were destined to become paratypes (L.A. Smith, pers. comm.).

Examination of Smith’s unpublished specimen data collected for the species description states ‘R55383’ with the locality ‘Pindrunna, Tambrey’ with a notation of ‘Type’ next to the specimen’s registration number and locality. The registration number of the *L. o.*

*barroni* specimen contained in the type collection with holotype labels is R55383. The location and collection information associated with this specimen matches those and the morphology of the specimen, and is comparable to that provided in the description. The erroneous holotype registration R55384 compared to the correct holotype registration R55383 vary only by a single digit (4 *versus* 3). Thus, it is clear which specimen was the desired holotype for the subspecies based on the matching type localities and minor numerical error. It is likely the error was a minor typographical error that occurred during the preparation of the manuscript on Smith's part.

In regards to the erroneous paratype specimen registration number, there are inconsistencies with the number of specimens examined presented in the description to Smith's unpublished data of morphology and meristic data of specimens examined. The data for the erroneous paratype presented in the description is associated with two remaining specimens examined by Smith. The specimen associated with the registration R45617 is a *L. olivaceus barroni* from Rhodes Ridge, 56 km west of Mount Newman, WA (23°05'S, 119°17'E). Despite the locality not matching the erroneous registration number presented in the description (R54617), the error of a reversal of the first two digits of the registration number (45 *versus* 54) can be easily identified. The specimen is also listed in error in Smith's unpublished data of examined specimens as R54617, locality '35 mi. W of Mt Newman' where it is likely to have been accidentally carried on through to the description. This specimen is currently held in the type collection and labelled with a paratype tag. The locality for the erroneous paratype presented by Smith of 'Pipe Spring, 16 km W of Newman' is only associated with one other *L. o. barroni* specimen which is not listed as a type, R31143 from Pipe Spring, 10 miles (16 km) west of Mount Newman, WA (23°20'S, 119°33'E). This specimen is correctly listed in Smith's list of examined specimens; however, it is not presented as a paratype in the description.

Following examination of the type specimens and Smith's unpublished data from specimens examined for the description it is apparent that the two specimens, R45617 and R31143 were both examined for the description of *L. olivaceus barroni* and should both have been listed as paratypes. It is not clear where the error originated in regards to the paratype. It appears, however, that the typographical error of the registration number of R45617 has resulted in the erroneous paratype listing of only one specimen with data from both. All specimens examined by Smith, excluding the holotype were to be designated as paratypes and all should have been listed as such (L.A. Smith, pers. comm.).

Other *L. o. barroni* specimens have been held in the collection historically which are not listed as material examined by Smith: R548, Marble Bar; R868, Pilbara Goldfield; R2248, Tambrey District and R8101, Tambrey

(all from WA). Of these specimens, only one can be located within the WAM collection: R8101, a juvenile in poor condition. Of the remaining three specimens, one was disposed (R2248) and two others could not be located (R548 and R868) and are presumed lost or disposed. Until about 1950, it was common practice at the WAM to discard large sized specimens, particularly pythons that could be easily identified and not confused with other species once they had been identified and catalogued (Smith 1981b).

The correct registration numbers and associated localities for *L. o. barroni* type specimens are presented below with collector and date of collection as presented on accession forms. All specimens held in the WAM collection.

**Holotype:** R55383, Pindrunna, 32 km north-west of Tambrey, WA (21°38'S, 117°36'E), W.H. Butler, 7 July 1964.

**Paratypes:** R17694, Prairie Downs, 8 km south of Mount Robinson, WA (23°07'S, 118°55'E), C. Snell, November 1962; R24920, Ashburton River, 16 km upstream from Nanutarra, WA (22°37'S, 115°37'E), C.R. Barrett-Lennard, 1 May 1965; R31143, Pipe Springs, 10 mi [16 km] W Mt Newman, WA (23°20'S, 119°33'E), C. Snell, December 1967; R33420, Bamboo Creek, WA (20°54'S, 120°12'E) collected by A.M. Douglas, January 1969; R45617, Rhodes Ridge, 56 km west of Mount Newman, WA (23°05'S, 119°17'E), collected by mining personnel, January 1974; R54378, Woodstock Station, WA (21°37'S, 118°57'E), W.H. Butler, 6 May 1965; R58935, Paraburdoo, WA (23°12'S, 117°40'E), collected by first aid officer, 1977; R60708, Marandoo (22°38'S, 118°07'E), J.S. Burt, 1 September 1978.

The corrections for the erroneous registration numbers were identifiable by review of information provided in the description and associated accession data in addition to Smith's unpublished data and notes. Further examination of specimens held in the collection of the WAM including those with identifiable holotype and paratype tags attached allowed confirmation of correct type specimens. These errors have not been identified earlier and have subsequently been incorrectly listed in the National Zoological Catalogue for Amphibia and Reptilia by Cogger et al. (1983). In the most recently published catalogue of snake species, Wallach et al. (2014) listed *L. o. barroni* as a synonym of *Liasis olivaceus* and did not provide any additional type specimen information for the *L. o. barroni* subspecies. Correction of the erroneous holotype and paratype registration numbers maintains nomenclatural stability without the need to nominate a neotype specimen as the error and correct holotype were easily identified. This minor error with considerable implications identifies the need for collection audits to take place, particularly for historic type specimens which are most likely to be missing or in error to maintain taxonomic and nomenclatural stability.

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## SHORT COMMUNICATION

# Freshwater fishes of three tributaries of the Pentecost River, Kimberley, Western Australia

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**KEYWORDS:** Durack, Karunjie, Northern Province, Durack River, Bindoola Creek, Salmond River

## INTRODUCTION

Freshwater fish diversity in Australia increases dramatically in the tropical north when compared to southern parts of the continent (Unmack 2001; Allen et al. 2002) and there is still much to be documented in terms of species diversity, distributions, systematics and ecology. New, novel forms continue to be recorded from remote regions of Australia (e.g. Pusey and Kennard 2001; Morgan et al. 2013, 2014a; Raadik 2014), and recent research using genetic techniques suggest that there may be two to three times the number of species actually present than is currently recognised (Adams et al. 2013; Hammer et al. 2013; Raadik 2014). Hence, detailed surveys and taxonomic reviews of local fish faunas are likely to provide important and exciting biodiversity updates, as well as contribute to natural resource management and conservation.

From an ichthyological perspective, Western Australia's Kimberley region encompasses the entire Kimberley Province as well as the western portion of the Northern Province (Unmack 2013; Morgan et al. 2014b). Several biodiversity surveys have examined Kimberley freshwater fishes (e.g. Allen 1975; Hutchins 1981; Allen and Leggett 1990; Morgan et al. 2004a) and have identified 49 species. The Kimberley supports considerable endemism among freshwater fishes (30–40%; Unmack 2001, 2013; Allen et al. 2002; Morgan et al. 2011), including two endemic genera. The remaining species range across northern Australia, with varying distributions. However, due to the relatively inaccessible landscape of much of the region, many waterways remain poorly surveyed, or not surveyed at all, particularly in the Northern Province, and the eastern parts of the Kimberley Province (Morgan et al. 2011). A complex geological and landscape history of the region has likely been responsible for high endemism and deep genetic divergences (Unmack 2001; Pepper and Keogh 2014).

Here we report on a recent survey of tributaries of the Pentecost River catchment in the east Kimberley that flow through Karunjie and Durack River stations. The only published survey of freshwater fishes in these tributaries is that of Allen and Leggett (1990), whose collections included only six species from two sites (50, 51) in the Durack River on Karunjie Station. Ten species were collected from Durack River and Bindoola Creek by G.R. Allen in 1977 (seven of which were additional to Allen and Leggett 1990) and are held in the collection of the Western Australian Museum (WAM). Given that other, well studied river systems of the Kimberley have much higher biodiversity (Morgan et al. 2011), we predicted this total of 13 species likely reflects a low sampling effort rather than a depauperate fauna.

## METHODS

The survey included three main tributaries of the Pentecost River that feed into the west arm of Cambridge Gulf; from north to south, these are the Durack River, Bindoola Creek and the Salmond River (Figure 1). This is part of the extensive Northern Province, near the transition into the Kimberley Province (Unmack 2001, 2013). The main branches of the Chamberlain and Pentecost rivers continue further south through El Questro Station and are not included in this study (but see Allen and Leggett 1990; Morgan et al. 2011 for species lists). Durack Falls is the highest waterfall on the Durack River, which is a multi-tiered cascade that is submerged during most wet seasons (Figure 2). On Bindoola Creek, both Bindoola Falls and Oomaloo Falls are very high and not submerged, even at full flood (Figure 2). The Salmond River has numerous rapids and tiered cascades, the largest of which are probably in Salmond Gorge (Figure 2), however all are presumably submerged during the wet season. Sampling occurred at the end of a moderate wet season and most stream sites had low to medium flow. Environmental data recorded



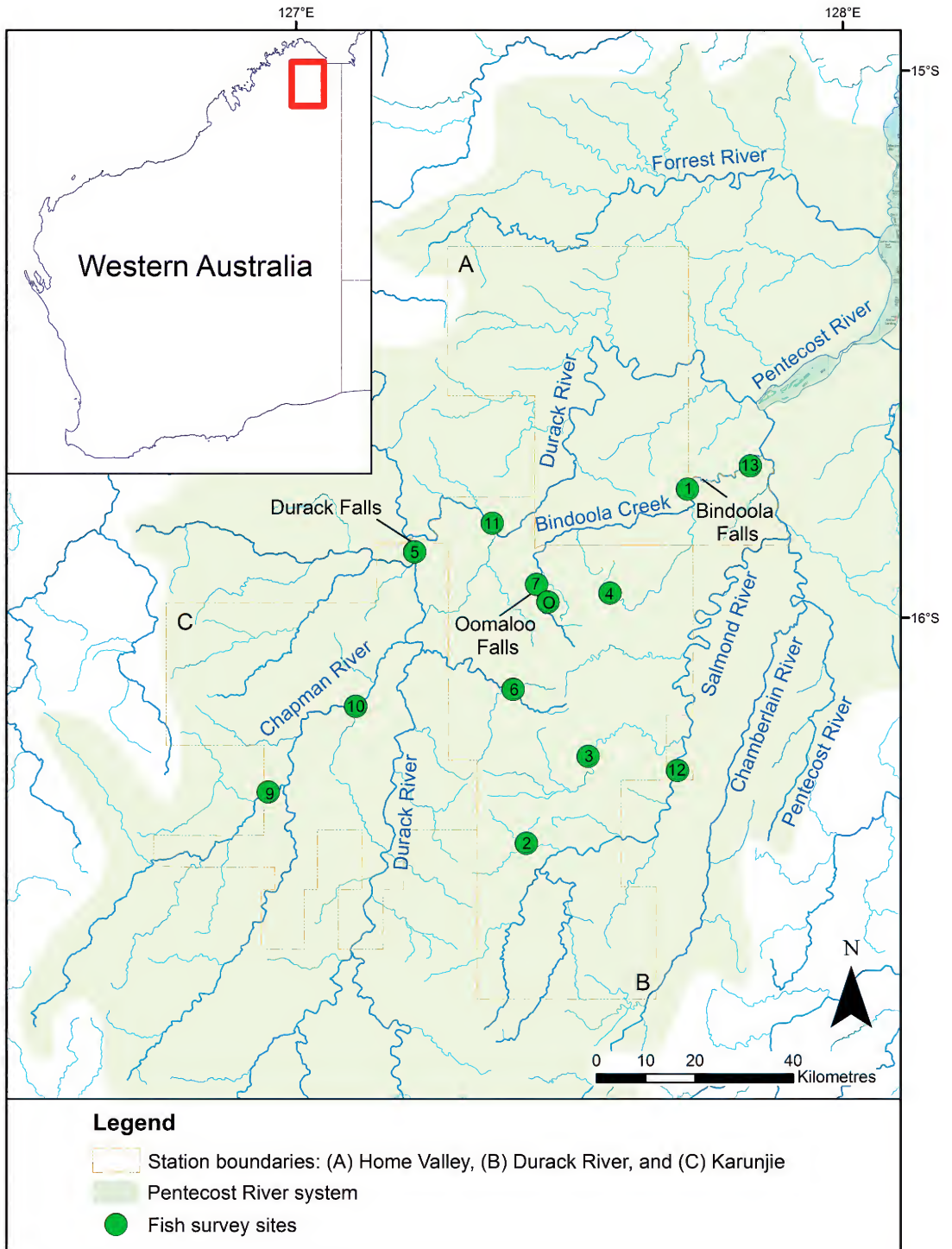


FIGURE 1 Map of study area, showing tributaries, significant geographical features, station boundaries and sampling sites.



FIGURE 2 A. Durack Falls (Station BBK-14-005); B. Bindoola Falls; C. Oomaloo Falls (Station BBK-14-007); D. Cascades in Salmond Gorge (Station BBK-14-012)

for each site included physical characteristics, habitat components and water quality (Table 1).

Sample sites were accessed by helicopter or vehicle between 27 May and 4 June 2014. Freshwater fishes were sampled by a variety of methods, depending on the habitat:

- Backpack electrofishing was undertaken at most sites using a Smith-Root model LR-20B with voltage and frequency adjusted according to water conductivity and fish response;
- Hand netting was used as either a dipnet from the surface or underwater on snorkel;
- Gill netting involved stringing a 4m long net (25–65mm mesh) across a channel or pool, set for approximately one hour with herding often used to assist entrapment;
- Seine netting (7m long, 4mm mesh) was used in conjunction with herding at one site; and,
- Angling was used as a supplemental method at many sites.

Most fishes were identified and released at the point of capture, except those retained as representative

voucher material for taxonomic studies and for identification confirmation (Clemann et al. 2014; Rocha et al. 2014). Fishes were held in a bucket with aeration and transported alive to the laboratory (Home Valley Station) where they were photographed in an aquarium before being euthanased using AQUI-S<sup>®</sup>. Tissue samples were placed into 80% DNA grade ethanol prior to vouchers being preserved in a 10% formalin solution. On return to WAM, all material was sorted and re-examined to confirm identifications and then lodged into the collection (accession numbers provided in Table 1).

## RESULTS

Thirteen sites were sampled for fish, spanning a broad geographic coverage of the Karunjie and Durack River Stations: five in the Durack River, five in Bindoola Creek and three in the Salmond River (Table 1; Figure 1). In Bindoola Creek, four sites were above Bindoola Falls and one was below. Freshwater fishes were recorded from 12 of the 13 sampling sites, with one site isolated upstream of Oomaloo Falls (BBK-14-OOM) yielding no fish (Table 2). Downstream sites in all tributaries supported 12–16 species, while upland sites above Bindoola Falls supported 0–4 species (Table 2).

**TABLE 1** Collection sites on Duraack River, Bindoola Creek and Salmond River, including environmental characteristics and collection methods.  
 AN – Angling; DN – Dipnet; EF – Electrofisher; GN – Gillnet; HN – Handnet (on snorkel); SN – Seine net.

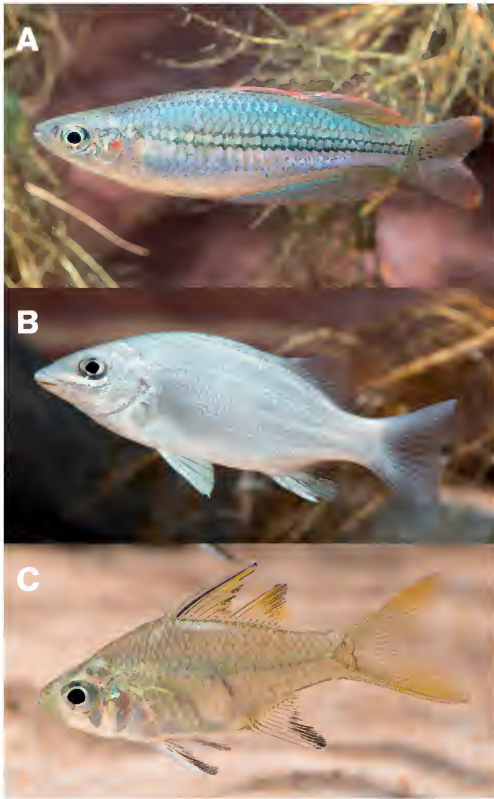
Station	WAM Accession	Tributary	Date	Time	Site	Coordinates	Habitat	Depth (m)	Conductivity (µS/cm)	Temp. (°C)	Methods
BBK-14-001	P.34033	Bindoola Creek	27 May 2014	1330–1500	Crossing on Gibb River Road	-15.764427S 127.716112E	Series of connected rocky pools	0–1	–	–	EF
BBK-14-002	P.34034	Salmond River	28 May 2014	0800–1100	Upper Moonlight Valley	-16.411415S 127.421269E	Alluvial pool with muddy rocky base	0–1	–	–	EF, GN
BBK-14-003	P.34035	Salmond River (Horse Creek)	28 May 2014	1300–1500	Gorge pool	-16.252556S 127.534276E	Riffle zone; large rocky gorge pool	0–1	179	–	EF, AN
BBK-14-004	P.34036	Bindoola Creek (Palmer Creek)	29 May 2014	0900–1200	Plunge pool at base of falls	-15.954562S 127.574138E	Rocky plunge pool with reed bed on downstream bank	0–3	13	24.1	HN, AN
BBK-14-005	P.34037	Duraack River	30 May 2014	0730–1100	Base of Duraack Falls	-15.879353S 127.217103E	Pools with very large sandstone boulders; algae	0–1	68	24.8	EF
BBK-14-006	P.34038	Bindoola Creek	30 May 2014	1300–1330	Above Oomaloo Falls	-15.961594S 127.442542E	Alluvial pool with muddy rocky base	0–1	45	29.1	EF
BBK-14-007	P.34039	Duraack River (Royston Creek)	31 May 2014	0730–1000	Upland pool	-16.130430S 127.397091E	Weedy riffle zone; large rocky gorge pool	0–2	17	23.8	EF, AN
BBK-14-008	P.34040	Bindoola Creek	31 May 2014	1300–1500	Plunge pool at base of Oomaloo Falls	-15.958947S 127.439906E	Large pool with muddy Pandanus-dominated downstream bank	0–1.5	50	26.8	SN, AN
BBK-14-009	P.34041	Duraack River (Chapman River)	2 June 2014	0800–1100	Upstream of Scotty-Salmon Gorge	-16.317933S 126.949113E	Large sandy-edged boulder pool; upstream riffle zone	0–1	128	23.8	EF, AN
BBK-14-010	P.34042	Duraack River (Chapman River)	2 June 2014	1230–1500	Upstream of Centipede Yard	-16.161033S 127.109238E	Series of large connected rocky pools; muddy banks; many snags	0–1.5	160	24.8	EF
BBK-14-011	P.34043	Duraack River	3 June 2014	0730–1000	Upstream of Jack's Waterhole	-15.826972S 127.358783E	Small cascades with series of pools and polished bedrock	0–1	–	–	EF
BBK-14-012	P.34044	Salmond River	4 June 2014	0800–1100	Salmond Gorge	-16.278563S 127.697685E	Large rocky gorge pool; smaller cascade pools above	0–2	48.3	23.8	EF, AN
BBK-14-013	P.34045	Bindoola Creek	4 June 2014	1430–1630	Home Valley Station	-15.721897S 127.831086E	Shallow bouldered pools in paper-bark grove; main creek channel	0–2	62.7	27.1	EF, AN

**TABLE 2** Species recorded at each site on Durack River, Bindoola Creek and Salmond River (see Table 1), including an estimate of the number of individuals observed. New collection records from these tributaries are marked with an asterisk.

Species	001	002	003	004	005	00M	006	007	009	010	011	012	013
<b>Clupeidae</b>													
<i>Nematalosa erebi</i>							10		5	5			5
<b>Ariidae</b>													
<i>Neoarius graeffei</i> *												1	
<i>Neoarius midgleyi</i> *							1		1			5	
<b>Plotosidae</b>													
<i>Neosilurus ater</i> *			5						1		2	1	
<i>Neosilurus hyrtlii</i>	10	10	20				100	10	2			2	5
<i>Neosilurus pseudospinosus</i>		2	7						1	5	15	5	2
<b>Belonidae</b>													
<i>Strongylura krefftii</i> *			1		1							5	
<b>Melanotaeniidae</b>													
<i>Melanotaenia australis</i>		30	50		20		200		100	150	10	20	10
<i>Melanotaenia cf. exquisita</i> *	100			200				200					
<b>Latidae</b>													
<i>Lates calcarifer</i> *					2							1	3
<b>Ambassidae</b>													
<i>Ambassis</i> sp. north-west		30	1		1		2		10	20			
<b>Terapontidae</b>													
<i>Amniataba percoides</i>		20	1		10		10		1	10	5	5	10
<i>Hephaestus jenkinsi</i>		2	20		5		30		20	30	30	20	3
<i>Leiopotherapon unicolor</i>	20	50	50	20	5		50	50	10	50	20	10	20
<i>Syncomistes butleri</i> *					11					5			
<i>Syncomistes kimberleyensis</i>			1		100				50	100	200	50	2
<i>Syncomistes cf. rastellus</i> *			1		25				2	1	10		
<b>Apogonidae</b>													
<i>Glossamia aprion</i>		2								5			1
<b>Toxotidae</b>													
<i>Toxotes chatareus</i>		5	10		10		5		30	3	5	15	1
<b>Eleotridae</b>													
<i>Mogurnda oligolepis</i>	20	1	1	2			10	10					
<i>Oxyeleotris lineolata</i> *			1								10	1	
<i>Oxyeleotris selheimi</i> *		5	5				5		10	5	2	1	
<b>Gobiidae</b>													
<i>Glossogobius giuris</i>		5	10		2		10		20	20	20	20	30
<b>No. Species</b>	4	12	16	3	12	0	12	4	15	14	12	16	12

Twenty three species of freshwater fishes were recorded, representing 12 families (Table 2). The most ubiquitous species was *Leiopotherapon unicolor* (from 12 sites), and five species were each recorded at nine sites (Table 2). One species, *Neoarius graeffei*, was recorded from a single site. Six species of Terapontidae from four genera were collected (Table 2). Ten species were recorded from the surveyed tributaries for the first time (Table 2).

At least three undescribed species were collected (Table 2; Figure 3). The first was a species of slender rainbowfish superficially similar to *Melanotaenia exquisita*, however recent genetic analyses suggested that this population is distinct from other populations known from Kakadu Escarpment country in the Northern Territory. Secondly, north-west glassfish *Ambassis* sp., is a well known species distributed widely across the Kimberley and north-western Australia, but



**FIGURE 3** Undescrbed fishes found during the survey. A. *Melanotaenia* cf. *exquisita*; B. *Syncomistes* cf. *rastellus*; C. *Ambassis* sp. north-west.

currently lacking a formal name due to confusion in nomenclature (i.e. previously known as *A. muelleri* but this name is a junior synonym of the eastern Australian species *A. agassizii*; see Allen et al. (2002)). Finally, a large silver grunter that does not key to any known taxon (Vari 1978; Allen 1989) was recorded. This recently recognised species is superficially similar to *Syncomistes rastellus* and is currently being described (Shelley and Le Feuvre, Melbourne University, personal communication).

## DISCUSSION

The three surveyed tributaries supported a comparatively diverse fauna of freshwater fishes, accounting for nearly half of all species known from the entire Kimberley region (Morgan et al. 2011, 2014b). This result nearly doubles the species previously known from these tributaries (from 13 to 23; see Introduction). The freshwater fishes on Karunjie and Durack River Stations had not been comprehensively reviewed prior to this survey – knowledge was largely limited to a handful

of species sampled at stream crossings on the Gibb River Road. The species list presented here (Table 2) now considers all major habitats of these properties. Further, the study collected important voucher material for broader taxonomic revisions and genetic studies of key species currently under investigation (e.g. rainbowfish, grunters, gudgeons and glassfish) and, as such, the eventual species list is likely to include several more species or names for undescribed forms (e.g. Adams et al. 2013; Morgan et al. 2014b).

Australia's most widespread freshwater fish *Leiopotherapon unicolor*, which occurs as an effectively single genetic population across eastern, central and northern Australia (Allen et al. 2002; Bostock et al. 2006; Morgan et al. 2011), was the most widely recorded species in the present survey. In contrast *Syncomistes kimberleyensis* is a narrow range endemic known only from the Pentecost and Ord river systems and is considered one of the Kimberley's least known freshwater fish species, being previously reported from only a few sites and a handful of individuals (Allen et al. 2002; Morgan et al. 2011). The results of the current study (seven sites, more than 500 individuals) are notable and contribute to broader understanding of conservation requirements in the face of increasing anthropogenic pressures on freshwater ecosystems (e.g. see Morgan et al. 2014b).

Another important finding of the present survey is the effect of the large Bindoola Falls on the migration capacity of the fish communities (Figure 2). These major waterfalls appear to play a role in restricting the upstream movement of fishes, and therefore limiting species diversity (to four species) in the headwaters of the Bindoola Creek sub-catchment (i.e. sites 1, 4, 7). Natural isolation appears to provide a refuge from more mobile and competitive species, providing a stronghold for the Kimberley endemic *Mogurnda oligolepis* and also supporting the only known populations of a likely new species of *Melanotaenia* (see Results). This rainbowfish was the most common fish above Bindoola Falls. Its presence in the area was first noted in 1997 (Tappin 2011) and recent genetic analyses suggested it is a distinct taxon (Unmack et al. 2013), but no voucher material was available until now. This putative new species appears to reside in streams and plunge pools isolated in allopatry above Bindoola Falls from the more widespread *M. australis*. Despite sampling similar habitats outside of the Bindoola Creek sub-catchment (and below the falls), the rainbowfish was not recorded from any other sites, suggesting a highly restricted range and even smaller area of occupancy based on linear aquatic stream habitat. A second population with affinity to *M. exquisita* was reported from the King George River in the Kimberley in the mid-1980s (Allen et al. 2002) and another is known from the Victoria River, Northern Territory (Burrows et al. 2008). Further work is underway by the authors to review the *M. exquisita* species complex.

### Concluding Remarks

The Karunjie and Durack River Stations are expansive and unique areas, with a comparatively diverse freshwater fish fauna. The upland streams and rivers support several species with small global distributions. Habitat protection for these short range endemics and vigilance and proactive management to maintain an environment free of introduced fish species is of paramount importance (Morgan et al. 2004b, 2014b, 2014c) especially for Bindoola Creek. The recent arrival of cane toads to the east Kimberley and their potential direct or indirect detrimental effect on the fishes is of concern (Shine 2010). Finally, there is a long history of traditional knowledge of the freshwater fishes of the region, and we encourage efforts to document the Nyaliga language names for *Ji* (fishes), which would complement other work in this regard elsewhere in the Kimberley (Smith 1997; Morgan et al. 2004a).

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# New larval food plant associations for some butterflies and diurnal moths (Lepidoptera) from the Northern Territory and Kimberley, Australia. Part II

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**ABSTRACT** – This paper documents 103 Lepidoptera-plant associations for eight families of butterflies/diurnal moths (Castniidae, Immidae, Hesperidae, Papilionidae, Pieridae, Nymphalidae, Lycaenidae and Noctuidae (Agaristinae)) from the ‘Top End’, central Australia and Kimberley, of which 86 associations are newly recorded for Australia and 17 are newly recorded for the Northern Territory and/or Western Australia. Of particular note are the first recordings of the families Lauraceae for *Graphium eurypylus* (Papilionidae), Phyllanthaceae for *Hypolycaena phorbis* (Lycaenidae), and Anacardiaceae for *Prosotas dubiosa* (Lycaenidae). Sixteen native plant genera are newly recorded for the following genera of Lepidoptera in Australia: *Semecarpus* (Anacardiaceae) for *Prosotas* (Lycaenidae), *Sarcolobus* (Apocynaceae) for *Danaus* (Nymphalidae), *Vitex* (Lamiaceae) for *Charaxes* (Nymphalidae), *Bossiaea* and *Tephrosia* (Fabaceae) for *Jamides* (Lycaenidae), *Amyema* (Loranthaceae) for *Birhana* (Immidae), *Corymbia* (Myrtaceae) for *Anthene* (Lycaenidae), *Aristida* and *Digitaria* (Poaceae) for *Hypocysta* (Nymphalidae), *Chrysopogon* and *Eriachne* (Poaceae) for *Pelopidas* (Hesperidae), *Mnesithea* (Poaceae) for *Pelopidas* and *Telicota* (Hesperidae), *Sacciolepis* (Poaceae) for *Taractrocera* (Hesperidae), *Sorghum* (Poaceae) for *Synemon* (Castniidae) and *Neohesperilla* (Hesperidae), *Whiteochloa* for *Borbo* and *Taractrocera* (Hesperidae), and *Breynia* (Phyllanthaceae) for *Hypolycaena* (Lycaenidae). The significance of the new plant associations is discussed for the following species: *Birhana cleis*, *Graphium eurypylus*, *Danaus affinis*, *Mycalesis sirius*, *Ogyris amaryllis*, *Candalides margarita*, *Famegana alsulus*, *Euchrysops cnejus* and *Freyeria putli*.

**KEYWORDS:** day-flying moth, insect-plant associations, larval host plant, northern Australia, Top End

## INTRODUCTION

The following catalogue of larval food plant associations for butterflies and day-flying moths is based on field observations and rearing of the early stages from the ‘Top End’ of the Northern Territory (NT) and the Kimberley of Western Australia (WA) by the author during the 4.7 year period, January 2011 to September 2015. One observation from the central arid zone of the NT is also included. For three species of diurnal moths, some preliminary observations before this period are also included that were subsequently investigated in more detail during the present study. The Lepidoptera covered here include the Castniidae, Immidae, Hesperidae, Papilionidae, Pieridae, Nymphalidae, Lycaenidae and Noctuidae (Agaristinae). The new records are in addition to those reported in an earlier account (Braby 2011a) for the region, and contribute

to the growing body of knowledge of insect-plant associations for the Australian Lepidoptera as a whole (see Common 1990; Braby 2000 for review).

The catalogue is presented in annotated form for each association: the scientific and common names of the butterfly/moth appear first as a subheading in bold, followed by the larval food plant and voucher number, and then the relevant field observations. The field observations summarise details of locality, date, immature stages and, in some cases, rearing data and other biological notes (e.g. attendant ants for Lycaenidae). The new Lepidoptera-plant associations are arranged into two groups; firstly, those that comprise new records for Australia as a whole, and secondly, those that are new for the NT and/or WA. In many cases, samples of the early stages of Lepidoptera were preserved, photographed and/or reared to adulthood

in captivity to confirm species level identification, and vouchers of these specimens are lodged in the Museum and Art Gallery of the Northern Territory, Darwin (NTM) or the Australian National Insect Collection, Canberra (ANIC). In some cases, however, the early stages were not reared, and identifications of eggs, larvae or pupae were determined on the author's field experience and knowledge of the relevant species.

Nomenclature for butterflies follows Braby (2010, 2011b), while that for moths follows Nielsen et al. (1996). Voucher specimens of the ants have been lodged in the CSIRO Tropical Ecosystem Research Collection, Darwin. Botanical nomenclature follows a recent updated checklist of vascular plants published by the Northern Territory Herbarium (Short et al. 2011). Voucher numbers refer to plant specimens lodged in the Northern Territory Herbarium, Palmerston (DNA). Introduced, naturalised and ornamental plants are designated by an asterisk (\*). For each site, geocoordinates are given in decimal degrees, followed by datum (e.g. AGD66, WGS84 or GDA94) and the level of sampling precision or accuracy (i.e., radius of the spatial area sampled).

## NEW LEPIDOPTERA LARVAL FOOD PLANT ASSOCIATIONS FOR AUSTRALIA

The following catalogue of species comprises plants that, to the author's knowledge, have not previously been documented as larval food plants for Australian Lepidoptera.

### CASTNIIDAE

#### *Synemon wulwulam* Angel, 1951

##### Sun Moth

*Sorghum plumosum* (R.Br.) P.Beauv. (Poaceae).  
(Voucher M.F. Braby 146, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Batten Rd, 16 km N of Borroloola, NT (15.91425°S, 136.33313°E; WGS84, 10 m), 15 May 2013, M.F. Braby. Several females were observed between 1320–1410 h CST ovipositing on the grass *Sorghum plumosum* growing in savannah woodland; when laying, they settled near the ground for about 60 sec and extended their ovipositor into the base of this perennial tussock. A pupal exuvia was also located and collected from within the central base of a large tussock of *S. plumosum*. Females were observed 'inspecting' *Eriachne obtusa* growing amongst *S. plumosum* but it was not certain if eggs were deposited on this grass. Males were common in the area and most active between 1130–1200 h CST.

### IMMIDAE

#### *Birthona cleis* (R. Felder & Rogenhofer, 1875)

##### Orange-banded Velvet Day-moth

*Amyema sanguinea* (F.Muell.) Danser (Loranthaceae).  
(Not vouchered).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Alawa, Darwin, NT (12.381°S, 130.865°E; GDA94, 2500 m), 22 April 2011, M.F. Braby. Cohorts of eggs and larvae were recorded on the mistletoe *Amyema sanguinea* parasitising a eucalypt growing in suburban parkland; a larva was collected and reared to adult in captivity, emerging on 17 May 2011. The site was revisited on 26 April 2011 and a large cohort of eggs and three larvae were recorded on the larval food plant. The immature stages of *Candalides margarita* were also recorded on the same mistletoe clump at this site (see below).

Robin Falls, 12 km SSE of Adelaide River, NT (13.34518°S, 131.12926°E; WGS84, 50 m), 30 April 2011, M.F. Braby and J.J. Armstrong. Two larvae were recorded on *A. sanguinea* parasitising *Eucalyptus tetradonta* growing on a ridge. An empty cocoon and an adult at rest were also observed on the foliage of the food plant.

*Dendrophthoe glabrescens* (Blakely) Barlow  
(Loranthaceae). (Not vouchered).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Fish River Station, 24 km NW of homestead, NT (14.02131°S, 130.73793°E; WGS84, 250 m), 30 April 2012, M.F. Braby. Two cocoons were recorded on the foliage of the mistletoe *Dendrophthoe glabrescens* parasitising *Erythrophleum chlorostachys* growing in riparian open-forest below a sandstone escarpment.

### PAPILIONIDAE

#### *Graphium eurypylus nyctimus* (Waterhouse & Lyell, 1914)

##### Pale Triangle

*Cryptocarya cunninghamii* Meisn. (Lauraceae).  
(Voucher M.F. Braby 153, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Namarada Dve, Dundee Beach, NT (12.74953°S, 130.37549°E; WGS84, 250 m), 23 February 2014, M.F. Braby. Two eggs

were recorded on the new leaf growth of the laurel *Cryptocarya cunninghamii*, which grew as a tree in long unburnt eucalypt woodland with rainforest elements in the understorey. A pupal exuvia was also recorded on the underside of a leaf of the larval food plant.

***Papilio fuscus canopus* Westwood, 1842**

**Fuscous Swallowtail**

*Zanthoxylum parviflorum* Benth. (Rutaceae). (Voucher M.F. Braby 126, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Marege Dve, Dundee Beach, NT (12.72776°S, 130.35643°E; WGS84, 100 m), 19 May 2012, M.F. Braby and J. Westaway. A mid instar larva was recorded feeding openly on the foliage of a small shrub (<0.5 m high) of *Zanthoxylum parviflorum* growing along the edge of coastal monsoon vine thicket.

**HESPERIIDAE**

***Neohesperilla xiphiphora* (Lower, 1911)**

**Sword-brand Grass-skipper**

*Sorghum intrans* F.Muell. ex Benth. (Poaceae). (Vouchers M.F. Braby 167, 168, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Location 6 km NW of Robin Falls, NT (13.34119°S, 131.11801°E; WGS84, 50 m), 7 February 2015, M.F. Braby. Several females were observed between 1315–1430 h ovipositing on the annual grass *Sorghum intrans*, which grew as a soft grass (i.e. before the inflorescence had bolted) on sandy loam in eucalypt woodland along the edge of a rocky outcrop. The females had a preference for small clumps that were growing in shade in open areas beneath the canopy of *Eucalyptus miniata* trees. Numerous eggs and first instar larvae were also located singly on the grass blades, and a late instar larva was collected from its shelter on the food plant. The site was revisited on 19 March 2015, by which time most plants were substantially taller and flowering, and three larvae (2 first instar, 1 mid instar) were collected from within their shelters on the larval food plant. The site was visited again on 12 April 2015 but neither eggs nor larvae were detected and most of the plants were seeding and the soft basal leaves had died off. First instar larval shelters were noted to comprise blades that were folded near their apex and joined by

silk, whereas later instar shelters comprised several basal stems joined together with silk.

***Proeidosia polysema* (Lower, 1908)**

**Spinifex Sand-skipper**

*Triodia bitextura* Lazarides (Poaceae). (Vouchers M.F. Braby 104, 132, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Saddleback Ridge, El Questro Wilderness Park, WA (15.99434°S, 127.97997°E; WGS84, 250 m), 16 May 2011, M.F. Braby. Three late instar larvae were recorded inside their tubular shelters, each on separate tussocks of the spinifex *Triodia bitextura* growing on the lower slopes of a hill supporting savannah woodland.

Location 1 km N of Zebedee Creek crossing, El Questro Wilderness Park, WA (16.01353°S, 128.01898°E; WGS84, 400 m), 23 May 2011, M.F. Braby. A larva was recorded inside its shelter on *T. bitextura* growing along a dry rocky seasonal gully in savannah open-woodland.

**Australia: Northern Territory:** Wongalara Wildlife Sanctuary, 11 km NE of homestead, NT (14.05720°S, 134.52600°E; WGS84, 500 m), 4 June 2012, M.F. Braby. Four final instar larvae were collected from inside their shelters on tussocks of *T. bitextura* growing in low open woodland on sandstone pavement above a steep cliff/waterfall. The larvae were transported to Darwin and kept inside their shelters in captivity for eight months during which time they did not feed until they were transferred to a potted tussock of the larval food plant.

***Borbo impar lavinia* (Waterhouse, 1932)**

**Yellow Swift**

*Whiteochloa airoides* (R.Br.) Lazarides (Poaceae). (Voucher M.F. Braby 169, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Buffalo Creek, Lee Point, NT (12.33930°S, 130.90683°E; WGS84, 250 m), 13 April 2015, M.F. Braby. Five final instar larvae were recorded in loose shelters on blades of *Whiteochloa airoides*, which grew as a soft grass with broad leaves in beach sand along the edge of coastal monsoon vine thicket. Two larvae were collected and reared in captivity; they pupated and emerged as adult males on 10 May and 2 June 2015. The immature stages of *Taractrocera* sp. were also found on the same grass species at this site (see below).

***Pelopidas lyelli lyelli* (Rothschild, 1915)****Lyell's Swift**

*Chrysopogon elongatus* (R.Br.) Benth. (Poaceae).  
(Voucher M.F. Braby 130, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Wilton River, Wongalara homestead, Wongalara Wildlife Sanctuary, NT (14.14035°S, 134.47461°E; WGS84, 250 m), 2 June 2012, M.F. Braby and S. Hirst. An early instar larva was collected from the grass *Chrysopogon elongatus* growing along a riverbank supporting mixed riparian woodland-evergreen monsoon vine forest.

*Eriachne triodioides* Domin (Poaceae). (Voucher M.F. Braby 176, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Carson River crossing, Kalumburu Rd, c. 18 km SSE of Kalumburu, WA (14.45277°S, 126.66373°E; WGS84, 50 m), 19 May 2015, M.F. Braby and G.J. Paras. A final instar larva was collected from a tussock of *Eriachne triodioides* growing as the dominant grass in an open rocky area along bank of stream in riparian monsoon vine forest. The larva pupated several days later on 23 May and emerged as a female on 2 June 2015.

*Mnesithea rottboellioides* (R.Br.) de Koning and Sosef (Poaceae). (Voucher M.F. Braby 97, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Zebedee Springs, El Questro Wilderness Park, WA (16.01379°S, 128.02489°E; WGS84, 400 m), 19, 29 May 2011, M.F. Braby and B. Hanekom. Larvae were recorded feeding on *Mnesithea rottboellioides*, which grew as a tall grass along the edge of riparian monsoon forest dominated by *Livistona*. The immature stages of *Telicota colon* were also found on the same grass species at this site (see below).

Pentacost River crossing, near El Questro Station, El Questro Wilderness Park, WA (16.01212°S, 127.97939°E; WGS84, 400 m), 21, 31 May 2011, M.F. Braby. Larvae were recorded in rolled leaf shelters of *M. rottboellioides* growing along the edge of riparian paperbark open-forest with monsoon forest elements in the understorey. The immature stages of *Telicota colon* were also found on the same grass species at this site (see below).

Emma Gorge Resort, El Questro Wilderness Park, WA (15.90753°S, 128.12909°E; WGS84, 100 m),

26 May 2011, M.F. Braby. Larvae were recorded in shelters on *M. rottboellioides* growing along Emma Creek woodland.

***Taractrocera ina* Waterhouse, 1932****No-brand Grass-dart**

\**Cenchrus pedicellatus* (Trin.) Morrone (Poaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Alawa, Darwin, NT (12.381°S, 130.865°E; GDA94, 2500 m), 13 April 2012, M.F. Braby. Two final instar larvae inside their leaf shelters were collected from introduced Mission Grass *Cenchrus pedicellatus* growing in suburban parkland. The larvae entered diapause in captivity and did not feed for many months during the dry season.

***Taractrocera* sp.****Grass-dart**

*Sacciolepis indica* (L.) Chase (Poaceae). (Voucher M.F. Braby 163, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Edith Falls, upper plunge pool, Nitmiluk National Park, NT (14.18095°S, 132.19424°E; WGS84, 250 m), 17 April 2014, M.F. Braby and L.J. Aitchison. One final instar larva was collected inside its leaf shelter on the grass *Sacciolepis indica* growing along the edge of a sandstone rock pool. In captivity, the larva remained in diapause during the dry season but eventually died.

*Whiteochloa airoides* (R.Br.) Lazarides (Poaceae). (Voucher M.F. Braby 169, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Buffalo Creek, Lee Point, NT (12.33930°S, 130.90683°E; WGS84, 250 m), 8 November 2014, M.F. Braby. A final instar larva (most likely *T. ina*) was recorded in a rolled cylindrical shelter of *Whiteochloa airoides*, which grew as a soft grass with broad leaves in beach sand along the edge of coastal monsoon vine thicket. The site was revisited on 13 April 2015 and numerous larvae were recorded on the larval food plant. Several larvae were collected and reared to pupation but they subsequently died from viral disease.

***Ocybadistes walkeri olivia* Waterhouse, 1933****Green Grass-dart**

\**Axonopus compressus* (Sw.) P.Beauv. (Poaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Berrimah, Darwin (CSIRO complex), NT (12.41333°S, 130.92194°E; WGS84, 500 m), 18 March 2014, M.F. Braby. A female was observed at 1205 h CST to deposit two eggs on the upperside of separate blades of introduced Broad-leaved Carpet Grass *Axonopus compressus* growing in a disturbed suburban area. The immature stages of *Hypocysta adiante* and *Ypthima arctous* were also recorded on this grass species at this site (see below).

\**Melinis repens* (Willd.) Zizka (Poaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Berrimah, Darwin (CSIRO complex), NT (12.41333°S, 130.92194°E; WGS84, 500 m), 27 August 2013, M.F. Braby. A female was observed at midday to deposit several eggs on the blades of the introduced grass *Melinis repens* growing in open disturbed suburban area.

***Suniana lascivia larrakia* L.E. Couchman, 1951****Dark Grass-dart**

*Ischaemum australe* R.Br. (Poaceae). (Voucher M.F. Braby 120, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Hidden Valley, Kununurra, WA (15.76672°S, 128.75642°E; WGS84, 50 m), 10 February 2012, M.F. Braby and B. Hanekom. A localised breeding colony was located on the grass *Ischaemum australe*, which grew in abundance in riparian woodland with some rainforest elements along a sandstone gully with flowing water. Two final instar larvae were collected from inside their shelters on blades of the grass and reared in captivity, with adults emerging 1–2 weeks later on 20 and 26 February 2012. Numerous other larvae and parasitised pupae were noted at the site.

***Telicota colon argea* (Fabricius, 1775)****Pale-orange Darter**

*Imperata cylindrica* (L.) Reusch. (Poaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Bamboo Creek, Marrakai Rd, 2.5 km E of Stuart Hwy, NT (12.90468°S, 131.16080°E; WGS84, 250 m), 6 April 2013, M.F. Braby. A late instar larva was collected from within its shelter on the grass *Imperata cylindrica* growing in the ecotone of riparian monsoon forest; the larva subsequently proved to be parasitised.

*Mnesithea rottboellioides* (R.Br.) de Koning and Sosef (Poaceae). (Voucher M.F. Braby 97, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Zebedee Springs, El Questro Wilderness Park, WA (16.01379°S, 128.02489°E; WGS84, 400 m), 19, 29 May 2011, M.F. Braby and B. Hanekom. Two larvae were recorded on *Mnesithea rottboellioides*, which grew as a tall grass along the edge of riparian monsoon forest dominated by *Livistona*; one late instar larva was collected and reared to adult in captivity, emerging on 27 June 2011. The immature stages of *Pelopidas lyelli* were also found on the same grass species at this site (see above).

Pentacost River crossing, near El Questro Station, El Questro Wilderness Park, WA (16.01212°S, 127.97939°E; WGS84, 400 m), 21, 31 May 2011, M.F. Braby. Four larvae were recorded on *M. rottboellioides* growing along the edge of riparian paperbark open-forest with monsoon forest elements in the understorey; two larvae were collected and reared in captivity, with adults emerging on 8 and 19 July 2011. The immature stages of *Pelopidas lyelli* were also found on the same grass species at this site (see above).

Emma Gorge plunge pool, El Questro Wilderness Park, WA (15.89524°S, 128.13351°E; WGS84, 400 m), 2 June 2011, M.F. Braby and T. Schwinghammer. Three larvae were recorded in their shelters on *M. rottboellioides* growing in riparian woodland with patches of monsoon forest.

\**Andropogon gayanus* Kunth (Poaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Mt Burrell, Tipperary Station, NT (13.49623°S, 131.03572°E; WGS84, 100 m), 22 March 2014, M.F. Braby. A final instar larva

was collected from its shelter on new regenerating leaf growth of introduced Gamba Grass *Andropogon gayanus* growing at the base of a hill; the larva was reared to adult in captivity, emerging on 12 April 2014.

***Cephenes trichopepla* (Lower, 1908)**

**Yellow Palm-dart**

*Livistona lorophylla* Becc. (Arecaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Pentacost River crossing, near station, El Questro Wilderness Park, WA (16.01212°S, 127.97939°E; WGS84, 400 m), 21, 31 May 2011, M.F. Braby. Three larvae were recorded inside their shelters on the fronds of the palm *Livistona lorophylla* growing in the ecotone of riparian paperbark open-forest with monsoon forest elements in the understorey.

Annie Creek campground, Mornington Wildlife Sanctuary, WA (17.50735°S, 126.11252°E; WGS84, 500 m), 8 August 2011, M.F. Braby and L.J. Aitchison. An early instar larva and numerous unoccupied shelters were recorded on *L. lorophylla* growing in riparian woodland.

Livistona Gully, 13 km SSW of campground, Mornington Wildlife Sanctuary, WA (17.60608°S, 126.04013°E; WGS84, 50 m), 9 August 2011, M.F. Braby and L.J. Aitchison. An egg and three larvae were recorded on *L. lorophylla* growing in a gully with monsoon forest.

**PIERIDAE**

***Eurema herla* (W.S. Macleay, 1826)**

**Macleay's Grass-yellow**

*Chamaecrista nigricans* (Vahl) Greene (Fabaceae). (Voucher M.F. Braby 170, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Location 6 km NW of Robin Falls, NT (13.34119°S, 131.11801°E; WGS84, 50 m), 19 March 2015, M.F. Braby. A female was observed between 1620–1630 h to deposit two eggs on separate plants of the annual legume *Chamaecrista nigricans* growing in eucalypt woodland on sandy loam at the base of a rocky escarpment. Other eggs were also present on the new foliage of the larval food plant.

***Cepora perimale* (Donovan, 1805)**

**Caper Gull**

*Capparis jacobsii* Hewson (Capparaceae). (Voucher M.F. Braby 100, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Location 1.2 km NW of Amalia Creek crossing, El Questro Wilderness Park, WA (15.97100°S, 128.01828°E; WGS84, 400 m), 20 May 2011, M.F. Braby and B. Hanekom. A female was observed ovipositing on shrubs of *Capparis jacobsii* and *C. umbonata* growing along a dry rocky sandstone gully with some monsoon forest elements. The immature stages of *Belenois java* were also found on the same plant at this site (see below).

***Belenois java teutonia* (Fabricius, 1775)**

**Caper White**

*Capparis jacobsii* (Capparaceae). (Voucher M.F. Braby 100, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Location 1.2 km NW of Amalia Creek crossing, El Questro Wilderness Park, WA (15.97100°S, 128.01828°E; WGS84, 400 m), 20 May 2011, M.F. Braby and B. Hanekom. A single pupal exuvia was found on a shrub of *Capparis jacobsii* growing along a dry rocky sandstone gully with some monsoon forest elements. The immature stages of *Cepora perimale* were also found on the same plant at this site (see above).

**NYMPHALIDAE**

***Tirumala hamata* (W.S. Macleay, 1826)**

**Blue Tiger**

*Marsdenia glandulifera* C.T.White (Apocynaceae). (Voucher M.F. Braby 134, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Fogg Dam Conservation Reserve, NT (12.56730°S, 131.30809°E; WGS84, 500 m), 20, 27 October 2012, M.F. Braby. A female was observed at 1632 h and again at 1710 h CST ovipositing on *Marsdenia glandulifera*, which grew as a vine in evergreen monsoon vine forest. An additional four eggs and 10 early instar larvae were recorded on

large new soft leaves of the food plant; all larvae were solitary and were located on the leaf underside. Several larvae were collected and reared to adult in captivity; the larvae were noted to inflict a characteristic feeding pattern by first chewing the perimeter of a circle and then eating the interior to create a hole in the leaf about 10 mm in diameter. The adults emerged on 2 and 9 November 2012, with a pupal duration of 7–8 days.

***Danaus affinis affinis* (Fabricius, 1775)**

**Swamp Tiger**

*Marsdenia viridiflora* R.Br. (Apocynaceae). (Voucher M.F. Braby 143, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Nanguluwur Art site, Nourlangie Rock, Kakadu National Park, NT (12.84262°S, 132.81895°E; WGS84, 250 m), 15 February 2013, M.F. Braby. A female was observed at 1530 h CST ovipositing on the underside of a leaf of the vine *Marsdenia viridiflora* growing in eucalypt open-forest near the base of a sandstone wall.

*Sarcobolus hullsii* (F.Muell. ex Benth.) P.I.Forst. (Apocynaceae). (Voucher M.F. Braby 152, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Nanguluwur Art site, Nourlangie Rock, Kakadu National Park, NT (12.84262°S, 132.81895°E; WGS84, 250 m), 5 February 2011, M.F. Braby. A female was observed at 1106–1109 h CST ovipositing on seedlings of the vine *Sarcobolus hullsii* growing in eucalypt open-forest at the base of a sandstone escarpment; three eggs were laid singly on the underside of separate leaves. The site was revisited on 7 December 2013 and two final instar larvae were recorded on *S. hullsii*.

***Danaus petilia* (Stoll, 1790)**

**Lesser Wanderer**

*Cynanchum liebianum* (F.Muell.) P.I.Forst. (Apocynaceae). (Voucher B. Stuckey 891, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Howard River sandsheet, N of Girraween Road, NT (12.51903°S, 131.11686°E; GDA94, 50 m), 11 December 2011, B. Stuckey. A single larva was photographed eating the

flowers of *Cynanchum liebianum*, which grew as a perennial herb about 1 m high in deep sand dominated by the grass *Eriachne burkittii* with scattered *Pandanus spiralis*.

***Euploea corinna* (W.S. Macleay, 1826)**

**Common Crow**

*Sarcostemma viminale* (L.) R.Br. (Apocynaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Spirit Hills, 42 km NE of Keep River National Park ranger station, NT (15.70199°S, 129.31718°E; WGS84, 50 m), 7 February 2012, M.F. Braby and P. Runyu. A mid instar larva was recorded feeding on *Sarcostemma viminale* growing on open sandstone pavement, and a pupa was recorded nearby suspended from a dead branch.

**Australia: Western Australia:** Champaign Springs, El Questro Wilderness Park, WA (16.03052°S, 127.96643°E; WGS84, 50 m), 8 April 2012, M.F. Braby and L.J. Aitchison. A mid instar larva was recorded on *S. viminale* growing on open sandstone pavement.

***Junonia orithya albicincta* Butler, 1875**

**Blue Argus**

*Buchnera asperata* R.Br. (Orobanchaceae). (Voucher M.F. Braby 99, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Saddleback Ridge, El Questro Wilderness Park, WA (15.99668°S, 127.98529°E; WGS84, 200 m), 18 May 2011, M.F. Braby. A late instar larva and a pupa were recorded on the herb *Buchnera asperata* growing in savannah open-woodland along a dry seasonal gully at the base of a hill.

*Thunbergia arnhemica* F.Muell. (Acanthaceae). (Voucher M.F. Braby 119, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Dundee Beach, Fog Bay, NT (12.77415°S, 130.35603°E; WGS84, 500 m), 6 November 2011, M.F. Braby. A final instar larva was recorded feeding on the underside of a leaf of *Thunbergia arnhemica*, which grew as a vine along the edge of coastal monsoon vine thicket.

***Charaxes sempronius sempronius*  
(Fabricius, 1793)**

**Tailed Emperor**

*Celtis australiensis* Sattarian (Cannabaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Charles Darwin University, Katherine campus, NT (14.39513°S, 132.14429°E; WGS84, 50 m), 16 April 2014, M.F. Braby and L.J. Aitchison. A pupa was collected suspended beneath a leaf of a large tree of *Celtis australiensis* growing in monsoon vine thicket on limestone karst; the pupa was subsequently found to be parasitised and several wasps emerged the next day.

*Vitex acuminata* R.Br. (Lamiaceae). (Voucher M.F. Braby 112, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Windjana Gorge National Park, WA (17.40754°S, 124.94625°E; WGS84, 250 m), 16 August 2011, M.F. Braby and L.J. Aitchison. A female was observed at 1215 h WST ovipositing on a sapling of *Vitex acuminata* growing on river sand in monsoon forest at the base of a limestone cliff; five eggs were laid singly on the leaves over a three-minute period.

***Mycalesis sirius sirius* (Fabricius, 1775)**

**Cedar Bush-brown**

*Imperata cylindrica* (L.) Reusch. (Poaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Robin Falls, creek upstream of falls, NT (13.34877°S, 131.12622°E; WGS84, 250 m), 30 April 2011, M.F. Braby and J.J. Armstrong. Three early instar larvae were collected (and reared to adult in captivity) from the grass *Imperata cylindrica* growing along the edge of riparian evergreen monsoon forest.

***Hypocysta adiante antirius* Butler, 1868**

**Orange Ringlet**

*Aristida macroclada* Henrard (Poaceae). (Voucher M.F. Braby 151, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Marege Dve, Dundee Beach, NT (12.72776°S, 130.35643°E; WGS84, 100 m), 31 March 2012, M.F. Braby and G. Brown. A female was observed at 1445–1450 h CST ovipositing on the grass *Aristida macroclada* growing in an open shaded area along the edge of coastal monsoon vine thicket; three eggs were laid singly on the underside of the blades.

*Digitaria gibbosa* (R.Br.) P.Beauv. (Poaceae). (Voucher M.F. Braby 91, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Nanguluwur Art site, Nourlangie Rock, Kakadu National Park, NT (12.84262°S, 132.81895°E; WGS84, 250 m), 5 February 2011, M.F. Braby. A female was observed at 1130 h CST to deposit a single egg on the underside of a blade of the grass *Digitaria gibbosa* growing in eucalypt open-forest.

*Ischaemum tropicum* B.K.Simon (Poaceae). (Voucher M.F. Braby 123, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Fish River Station, waterfall 24 km NW of homestead, NT (14.00750°S, 130.75212°E; WGS84, 250 m), 24 April 2012, M.F. Braby. A female was observed at 1310 h CST depositing several eggs on the grass *Ischaemum tropicum* growing at the edge of a creek in riparian woodland along a sandstone gorge; an early instar larva was also recorded on a blade of the larval food plant.

\**Axonopus compressus* (Sw.) P.Beauv. (Poaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Berrimah, Darwin (CSIRO complex), NT (12.41333°S, 130.92194°E; WGS84, 500 m), 25 June 2012, M.F. Braby. A female was observed at 1255 h CST to deposit a single egg on the underside of a blade of introduced Broad-leaved Carpet Grass *Axonopus compressus* growing in a disturbed suburban area. The immature stages of *Ocybadistes walkeri* (see above) and *Ypthima arcuous* (see below) were also recorded on this grass species at this site.

\**Cynodon dactylon* (L.) Pers. (Poaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Annie Creek campground, Mornington Wildlife Sanctuary, WA



(17.50735°S, 126.11252°E; WGS84, 500 m), 10 August 2011, M.F. Braby and L.J. Aitchison. A late instar larva was recorded on a blade of non-indigenous Green Couch Grass *Cynodon dactylon* growing in riparian woodland; the larva was in the process of moulting and was located approximately within the centre of a large patch of the larval food plant. The immature stages of *Ocybadistes flavovittatus* were also found on the same grass at this site (see below)

***Ypthima arctous* (Fabricius, 1775)**

**Dusky Knight**

\**Axonopus compressus* (Sw.) P.Beauv. (Poaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Berrimah, Darwin (CSIRO complex), NT (12.41333°S, 130.92194°E; WGS84, 500 m), 3 February 2014, M.F. Braby. A female was observed at 1250 h CST to deposit a single egg on a blade of introduced Broad-leaved Carpet Grass *Axonopus compressus* growing in an open disturbed suburban area. The egg was collected and the resulting larva was reared in captivity, emerging as an adult approximately six weeks later on 20 March 2014. The immature stages of *Ocybadistes walkeri* and *Hypocysta adiante* were also recorded on this grass species at this site (see above).

**LYCAENIDAE**

***Hypochrysops ignitus erythrina*  
(Waterhouse & Lyell, 1909)**

**Fiery Jewel**

*Acacia leptocarpa* A.Cunn. ex Benth (Fabaceae). (Voucher M.F. Braby 164, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Bathurst Island, NT (11.48889°S, 130.33287°E; WGS84, 500 m), 27 May 2014, M.F. Braby. A female was observed at 1250 h CST to deposit two eggs at the base of a stem of a sapling of *Acacia leptocarpa* growing in tall woodland. Numerous *Papyrius* ants were present on the plant and in the general vicinity.

***Arhopala eupolis asopus*  
Waterhouse & Lyell, 1914**

**Purple Oak-blue**

*Terminalia carpentariae* C.T.White (Combretaceae). (Voucher M.F. Braby 156, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Jim Jim Ranger Station, Kakadu National Park, NT (12.93061°S, 132.57068°E; WGS84, 100 m), 10 November 2013, M.F. Braby and C. Webb. Numerous eggs and four early instar larvae were recorded on *Terminalia carpentariae*, which comprised a sapling regenerating after fire in savannah woodland. A final instar larva and a pupa were also collected inside the curled margin of a new leaf of a small tree of the food plant that was regenerating its foliage (*T. carpentariae* is seasonally deciduous during the dry season); an adult emerged from the pupa 10 days later on 20 November 2013. In both cases, *Oecophylla smaragdina* ants attended the immature stages.

*Corymbia disjuncta* K.D.Hill and L.A.S.Johnson (Myrtaceae). (Voucher M.F. Braby 148, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** South Alligator Ranger Station, Kakadu National Park, NT (12.68306°S, 132.47223°E; WGS84, 100 m), 24 April 2013, M.F. Braby. Eggs and two mid instar larvae were recorded feeding on new foliage of a sapling of *Corymbia disjuncta* growing in long unburnt eucalypt woodland with a monsoon vine thicket understorey. The site was revisited on 13 November 2013 and a final instar larva was recorded on the food plant. In each case, numerous *Oecophylla smaragdina* ants attended the larvae. The immature stages of *Anthene seltuttus* were also found on the same sapling at this site (see below)

Popham Bay, Cobourg Peninsula, NT (11.27261°S, 131.85768°E; WGS84, 100 m), 12 August 2014, M.F. Braby. Six final instar larvae were recorded feeding on new foliage of saplings of *C. disjuncta* that were regenerating in response to a recent dry season fire in eucalypt woodland adjacent to monsoon forest. Numerous *Oecophylla smaragdina* ants attended the larvae. The immature stages of *Anthene seltuttus* and *Theclimethes miskini* were also found on the same plant species at this site (see below).

*Eucalyptus miniata* A.Cunn. ex Schauer (Myrtaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Jim Jim Ranger Station, Kakadu National Park, NT (12.93061°S, 132.57068°E; WGS84, 100 m), 21 April 2013, M.F. Braby. A female was observed at 1510 h CST to deposit an egg low down on the main stem of a sapling of *Eucalyptus miniata* growing in savannah woodland; the sampling supported a nest of *Oecophylla smaragdina* ants.

***Ogyris amaryllis meridionalis*  
(Bethune-Baker, 1905)**

**Satin Azure**

*Amyema benthamii* (Blakely) Danser (Loranthaceae).  
(Voucher M.F. Braby 111, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Bluebush, Mornington Wildlife Sanctuary, WA (17.55675°S, 126.17020°E; WGS84, 50 m), 8 August 2011, M.F. Braby and L.J. Aitchison. Numerous eggs were observed on the leaves and stem junctions of the mistletoe *Amyema benthamii* parasitising *Bauhinia cunninghamii* growing in savannah open-woodland. Numerous larval feeding scars were also evident on the leaves, and a female was noted settled on a mistletoe clump. A number of males were observed flying around and settling on the host tree during the morning, indicating the presence of a localised breeding colony. No other mistletoe species grew in the immediate area.

***Ogyris iphis doddi* (Waterhouse & Lyell, 1914)**

**Dodd's Azure**

*Amyema sanguinea* (F.Muell.) Danser (Loranthaceae).  
(Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Danger Pt Rd, Garig Gunak Barlu National Park, NT (11.25417°S, 132.31907°E; WGS84, 50 m), 8 August 2014, M.F. Braby. A pupa and two mid instar larvae were collected from a clump of the mistletoe *Amyema sanguinea* parasitising *Eucalyptus tetradonta* growing in savannah woodland on a laterite outcrop/breakaway with a gentle west-facing slope. The pupa, which was attached to an outer branch of the mistletoe, was partially concealed by foliage and dead flowers that were joined together with silk. The larvae were hiding in hollows constructed by wood boring insects inside branches of the haustorium/basal branches of the mistletoe clump. Numerous *Froggattella kirbii* ants attended all immature stages. The immature stages were reared in captivity, with adults emerging after a pupal duration of 12 days on 22 August 2014 and 15 and 23 September 2014.

***Ogyris zosine zosine* (Hewitson, [1853])**

**Northern Purple Azure**

*Amyema villiflora* ssp. *villiflora* (Domin) Barlow (Loranthaceae). (Voucher M.F. Braby 109, 114, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Location 0.6 km W of Gubara Track, Nourlangie Rock, Kakadu National Park, NT (12.83721°S, 132.84970°E; WGS84, 250 m), 23 April 2011, M.F. Braby and J.J. Armstrong. A colony of 10 larvae and four pupae were collected from the base of several host trees of *Acacia multistipulosa* supporting clumps of the mistletoe *Amyema villiflora* growing in open-woodland on rocky sandstone breakaway. The immature stages were attended by a pale species of sugar ant *Camponotus* sp. (*novaeollandiae* species group). The site was revisited on 29 July 2012 and all but one clump of *Amyema villiflora* had been burnt and killed by fire (dry season control burn in May 2011); a cohort of 14 pupae and several late instar larvae were located in the ground at the base of *Acacia multistipulosa* supporting this single clump of mistletoe, indicating that the colony had survived the fire. However, this tree (and mistletoe) was subsequently destroyed by another fire in November 2012, and the neither the butterfly nor attendant ants could be found. The immature stages of *Candalides margarita* and *Comocrus behri* were also found on the same mistletoe species at this site (see below).

*Diplatia grandibractea* (F.Muell. and Tate) Tiegh.  
(Loranthaceae) (Voucher M.F. Braby 177, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Favenc Range, Carpentaria Hwy, NT (16.70357°S, 135.36717°E; WGS84, 50 m), 17 May 2013, M.F. Braby. Several eggs, mostly hatched, were collected from under loose bark or on epicortical runners of the mistletoe *Diplatia grandibractea* parasitising *Eucalyptus leucophloia* growing in low open woodland on rocky hill slope/breakaway; one fresh egg subsequently proved to be parasitised by small parasitic wasps. The site was revisited on 24 August 2015 and a female was observed at 1405 h perched on the larval food plant; she was possibly about to lay eggs but was disturbed and flew off. The immature stages of *Comocrus behri* were also found on the same mistletoe species at this site (see below).

***Hypolycaena phorbis phorbis* (Fabricius, 1793)**

**Black-spotted Flash**

*Breyinia cernua* (Poir.) Muell.Arg (Phyllanthaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Bowali Information Centre, Kakadu National Park, NT (12.67377°S,

132.81757°E; WGS84, 50 m), 4 February 2011, M.F. Braby. Two larvae comprising one early instar and one final instar were recorded feeding on new leaves of a small shrub of *Breynia cernua* that was growing in close proximity to several taller shrubs of *Clerodendrum floribundum* on which a large colony of the butterfly was established. *Oecophylla smaragdina* ants were attending the larvae.

***Anthene seltuttus affinis*  
(Waterhouse & R.E. Turner, 1905)**

**Dark Ciliate-blue**

*Corymbia disjuncta* K.D.Hill and L.A.S.Johnson (Myrtaceae). (Voucher M.F. Braby 148, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** South Alligator Ranger Station, Kakadu National Park, NT (12.68306°S, 132.47223°E; WGS84, 100 m), 24 April 2013, M.F. Braby. A female was observed at 1500 h CST ovipositing on a sapling of *Corymbia disjuncta* growing in long unburnt eucalypt woodland with a monsoon vine thicket understorey; cohorts of eggs and larvae were also recorded on the new soft leaves. Numerous *Oecophylla smaragdina* ants were attending the larvae. The immature stages of *Arhopala eupolis* were also found on the same sapling at this site (see above).

Popham Bay, Cobourg Peninsula, NT (11.27261°S, 131.85768°E; WGS84, 100 m), 12 August 2014, M.F. Braby. Thirty pupae were recorded clustered in two groups on the stem of a sapling of *Corymbia disjuncta* growing in woodland adjacent to monsoon forest. The pupae were green or brown in colour and oriented head downwards, and attended by numerous *Oecophylla smaragdina* ants. The immature stages of *Arhopala eupolis* (see above) and *Theclinesthes miskini* (see below) were also found on the same plant species at this site.

***Candalides margarita gilberti* Waterhouse, 1903**

**Northern Pencil-blue**

*Amyema sanguinea* (F.Muell.) Danser (Loranthaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Rapid Creek, Rapid Creek, Darwin, NT (12.38083°S, 130.86462°E; WGS84, 50 m), 26 April 2011, M.F. Braby and J.J. Armstrong. Two eggs were recorded on the mistletoe

*Amyema sanguinea* parasitising a eucalypt in a suburban parkland. The immature stages of *Birithana cleis* were also found on the same mistletoe clump at this site (see above).

**Australia: Western Australia:** King River crossing, Gibb River Road, El Questro Wilderness Park, WA (15.91133°S, 128.18486°E; WGS84, 10 m), 3 August 2011, M.F. Braby and L.J. Aitchison. Two eggs were recorded on new leaf shoots of a clump of *A. sanguinea* in the canopy parasitising *Eucalyptus camaldulensis* growing in riparian woodland along the bank of a river. The immature stages of *Delias argenthona* and *Ogyris amaryllis* were also found on the same mistletoe clump at this site (see below).

**Australia: Northern Territory:** Danger Pt Rd, Garig Gunak Barlu National Park, NT (11.25417°S, 132.31907°E; WGS84, 50 m), 8 August 2014, M.F. Braby. Two females were observed at 1200–1215 h CST settled on or flying around the foliage of a clump of *A. sanguinea* parasitising *Eucalyptus tetradonta* growing in savannah woodland; one female eventually deposited an egg on a new soft leaf. Closer inspection of the mistletoe clump revealed a hatched egg and a second instar larva on the foliage.

*Amyema villiflora* ssp. *villiflora* (Domin) Barlow (Loranthaceae). (Voucher M.F. Braby 114, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Location 0.6 km W of Gubara Track, Nourlangie Rock, Kakadu National Park, NT (12.83721°S, 132.84970°E; WGS84, 250 m), 18 December 2011, M.F. Braby. An egg and a first instar larva were collected from the flowers of the mistletoe *Amyema villiflora* parasitising *Acacia multistipulosa* growing in open-woodland on rocky sandstone breakaway. The larva was reared in captivity and an adult emerged a month later on 18 January 2012, with a pupal duration of 10 days. The immature stages of *Ogyris zosine* (see above) and *Comocrus behri* (see below) were also found on the same mistletoe species at this site.

*Dendrophthoe glabrescens* (Blakely) Barlow (Loranthaceae). (Voucher M.F. Braby 108, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Emma Gorge Resort, El Questro Wilderness Park, WA (15.90753°S, 128.12909°E; WGS84, 100 m), 2 June 2011, M.F. Braby and T. Schwinghammer. Two empty egg-shells were collected from the leaf petiole of the mistletoe *Dendrophthoe glabrescens* parasitising *Erythrophleum chlorostachys* growing in riparian woodland. The immature stages of *Delias argenthona* were also found on the same mistletoe clump at this site (see below).

*Dendrophthoe odontocalyx* (F.Muell. ex Benth.) Tiegh.  
(Loranthaceae). (Voucher M.F. Braby 154, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Barrk Track, 0.6 km E of Nanguluwur Art Site, Kakadu National Park, NT (12.84650°S, 132.82295°E; WGS84, 200 m), 15 February 2014, M.F. Braby and J. Westaway. A female was observed at 1410 h CST ovipositing on a leaf bud of the mistletoe *Dendrophthoe odontocalyx* parasitising *Xanthostemon paradoxus* growing in riparian woodland along a seasonal sandstone gully.

### ***Nesolycaena urumelia* (Tindale, 1922)**

#### **Spotted Opal**

*Boronia wilsonii* (F.Muell. ex Benth.) Duretto  
(Rutaceae). (Voucher D. Lewis 1713, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Spirit Hills, 105 km NE of Keep River National Park ranger station, NT (15.22063°S, 129.64844°E; GDA94, 50 m), 13 May 2011, D. Lewis. Two adults were observed flying in close proximity of a large patch of *Boronia wilsonii* growing in open woodland on a steep sandstone rocky slope just below an escarpment in the East Kimberley. Subsequent microscopic examination of herbarium voucher material revealed two hatched eggs on the underside of the leaves. The author visited the site on 8 February 2012 and collected two male butterflies: subsequent morphological examination of this material and dissection of the genitalia confirmed the species level identity as *Nesolycaena urumelia* and not the closely related *N. caesia*, which is known to feed on *B. wilsonii* and which is endemic to the Kimberley and allopatric with *N. urumelia*.

### ***Nacaduba biocellata biocellata* (C. & R. Felder, 1865)**

#### **Two-spotted Line-blue**

*Acacia plectocarpa* ssp. *plectocarpa* A.Cunn. ex Benth.  
(Fabaceae). (Voucher M.F. Braby 98, DNA).

#### MATERIAL EXAMINED

**Australia: Western Australia:** Saddleback Ridge, El Questro Wilderness Park, WA (15.99668°S, 127.98529°E; WGS84, 200 m), 16 May 2011, M.F. Braby. Large numbers of males were noted during the mid morning flying low over the ground in very localised areas around and near the base of the trunk of several trees of *Acacia plectocarpa* growing in savannah woodland

along a dry seasonal gully at the base of a hill, and presumably were searching for freshly emerged females that had, as larvae, descended from the flowers of the food plant to pupate amongst the leaf litter; by early afternoon the behaviour had ceased. A search of the flowers of *A. plectocarpa* confirmed that this species was indeed the larval food plant: two larvae were collected by beating the flowering branches; the larvae were subsequently reared in captivity, with adults emerging 1–2 weeks later on 25 and 29 May 2011.

*Acacia torulosa* Benth. (Fabaceae). (Voucher M.F. Braby 107, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Gubara Track, Kakadu National Park, NT (12.83696°S, 132.85626°E; WGS84, 250 m), 25, 26 June 2011, M.F. Braby. Males were observed to exhibit the same mate-location behaviour observed a month earlier at El Questro Wilderness Park noted above. Large numbers of males were observed at 0930 h CST flying in a very localised area, patrolling close to the ground over leaf litter around the base of a tall tree of *Acacia torulosa* growing in sandy soil adjacent to creek, and no doubt was the larval food plant. The site was burnt out and the tree killed by fire (in November 2012) preventing follow up of this observation to confirm that *A. torulosa* was indeed the larval food plant of *N. biocellata*.

*Acacia tumida* var. *tumida* F.Muell. ex Benth.  
(Fabaceae). (Voucher M.F. Braby 110, DNA).

#### MATERIAL EXAMINED

**Australia: Western Australia:** Hidden Valley, Kununurra, WA (15.76449°S, 128.74844°E; WGS84, 100 m), 1 August 2011, M.F. Braby and L.J. Aitchison. Similar to the observations made earlier at El Questro Wilderness Park and Kakadu National Park noted above, large numbers of males were observed at 0830 h WST, again flying very locally over the ground beneath the canopy of several trees of *Acacia tumida* growing between the camp ground and nature park.

### ***Prosotas dubiosa dubiosa* (Semper, [1879])**

#### **Purple Line-blue**

*Acacia scopulorum* Pedley (Fabaceae). (Voucher M.F. Braby 155, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Nourlangie Rock, 300 m S of Nanguluwur Art Site, Kakadu National Park, NT

(12.84591°S, 132.81886°E; WGS84, 50 m), 7 December 2013, M.F. Braby. A female was observed at 1010 h CST ovipositing on flower buds of *Acacia scopulorum* growing on sandstone.

*Cupaniopsis anacardioides* (A.Rich.) Radlk.  
(Sapindaceae). (Voucher M.F. Braby 150, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Mary River crossing, Arnhem Hwy, Mary River Park, NT (12.90784°S, 131.65155°E; WGS84, 250 m), 20 July 2013, M.F. Braby and J. Westaway. Numerous females were observed during the afternoon ovipositing on flower buds of the tree *Cupaniopsis anacardioides* growing in riparian wet monsoon forest (evergreen vine forest).

*Semecarpus australiensis* Engl. (Anacardiaceae).  
(Voucher K. Brennan 10323, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Popham Bay, Cobourg Peninsula, NT (11.27261°S, 131.85768°E; WGS84, 100 m), 12 August 2014, M.F. Braby. A female was observed at 1125 h CST ovipositing on flower buds of the tree *Semecarpus australiensis* growing along the edge of coastal monsoon forest.

***Theclinesstes miskini miskini* (T.P. Lucas, 1889)**

#### Wattle Blue

*Corymbia disjuncta* K.D.Hill and L.A.S.Johnson  
(Myrtaceae). (Not vouchered).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Popham Bay, Cobourg Peninsula, NT (11.27261°S, 131.85768°E; WGS84, 100 m), 12 August 2014, M.F. Braby. Three larvae were recorded feeding on new soft foliage of saplings of *Corymbia disjuncta* growing in eucalypt woodland adjacent to monsoon forest. All larvae were solitary and not attended by ants; one larva was collected and reared to adult, emerging on 24 August 2014. The immature stages of *Arhopala eupolis* and *Anthene seltuttus* were also found on the same plant species at this site (see above).

*Corymbia* sp. (Myrtaceae). (Not vouchered).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Mt Burrell, Tipperary Station, NT (13.49623°S, 131.03572°E; WGS84, 100 m), 8 December 2012, M.F. Braby. About 20 larvae were

recorded feeding on young soft regenerating foliage of a sapling (<300 mm high) of *Corymbia* sp. (*C. disjuncta* or *C. confertiflora*) growing in savannah woodland near the base of a hill. Numerous small black ants attended the larvae.

Dundee Beach, Fog Bay, NT (12.76420°S, 130.35324°E; WGS84, 50 m), 15 December 2012, M.F. Braby and A. Lilleyman. About 50 larvae were recorded feeding on the new soft regrowth of a plant (<300 mm high) of *Corymbia* sp. (*C. disjuncta* or *C. confertiflora*) growing in an open slashed area on a laterite cliff. The larvae were attended by meat ants *Iridomyrmex sanguineus*.

***Jamides phaseli* (Mathew, 1889)**

#### Purple Cerulean

*Bossiaea bossiaeoidea* (A.Cunn. ex Benth.) Court  
(Fabaceae). (Voucher M.F. Braby 102, DNA).

#### MATERIAL EXAMINED

**Australia: Western Australia:** Emma Creek, Cockburn Ranges, El Questro Wilderness Park, WA (15.89300°S, 128.13385°E; WGS84, 500 m), 24 May 2011, M.F. Braby. A female was observed at 1400 h WST ovipositing on new leaves of the shrub *Bossiaea bossiaeoidea* growing in woodland along a sandstone gully with a spinifex understorey; several other eggs were located on dried leaf tissue. Adults were extremely abundant in the area and, although the food plant was in flower with numerous flower buds present, females did not oviposit on the flowers buds.

*Cajanus aromaticus* Maesen (Fabaceae). (Voucher M.F. Braby 159, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Koongarra Saddle, Kakadu National Park, NT (12.848°S, 132.860°E; WGS84, 200 m), 16 February 2014, M.F. Braby and J. Westaway. A female was observed at 1325 h CST ovipositing on flower buds of the shrub *Cajanus aromaticus* growing in an open area at the edge of monsoon forest on sandstone breakaway. The butterfly was very abundant in the area, flying rapidly around the food plant. The immature stages of *Catochrysops panormus* were also found on the same plant species at this site (see below).

*Tephrosia spechtii* Pedley (Fabaceae). (Voucher M.F. Braby 092, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Location 0.6 km W of Gubara Track, Nourlangie Rock, Kakadu National

Park, NT (12.83721°S, 132.84970°E; WGS84, 250 m), 6 February 2011, M.F. Braby. A final instar larva was collected from the flowers of the shrub *Tephrosia spechtii* growing in open-woodland on sandstone breakaway; two hatched eggs were also noted on the stems of the larval food plant. Adults were extremely abundant in the area and were flying around the food plant. The larva was reared in captivity and an adult emerged on 14 February 2011.

***Catochryops panormus platissa*  
(Herrich-Schäffer, 1869)**

**Pale Pea-blue**

*Cajanus aromaticus* Maesen (Fabaceae). (Voucher M.F. Braby 159, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Koongarra Saddle, Kakadu National Park, NT (12.848°S, 132.860°E; WGS84, 200 m), 16 February 2014, M.F. Braby and J. Westaway. Several females were observed at 1210–1215 h CST ovipositing on flower buds of the shrub *Cajanus aromaticus* growing in an open area at the edge of monsoon forest on sandstone breakaway. The immature stages of *Jamides phaseli* were also found on the same plant species at this site (see above).

*Cajanus pubescens* (Ewart and Morrison) Maesen (Fabaceae). (Voucher M.F. Braby 106, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Livistona Gully, 13 km SSW of campground, Mornington Wildlife Sanctuary, WA (17.60608°S, 126.04013°E; WGS84, 50 m), 9 August 2011, M.F. Braby and L.J. Aitchison. A female was observed at 1515 h WST attempting to oviposit on new leaves of the shrub *Cajanus pubescens*, which grew abundantly as small shrubs in an open rocky gully adjacent to riparian monsoon forest; eggs were subsequently located on flower buds and new leaves of the larval food plant.

***Lampides boeticus* (Linnaeus, 1767)**

**Long-tailed Pea-blue**

*Swainsona canescens* (Benth.) F.Muell. (Fabaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Mulga Park Rd, 12.5 km SE of Curtin Springs, NT (25.39962°S, 131.83987°E;

WGS84, 250 m), 26 September 2013, M.F. Braby. A female was observed ovipositing on the legume *Swainsona canescens* growing in shrubland dominated by spinifex on the ridge of a sand dune; numerous eggs were also located on the bracts of the buds. Several males were hilltopping at the site.

***Zizina otis labradus* (Godart, [1824])**

**Common Grass-blue**

\**Desmodium triflorum* (L.) DC. (Fabaceae). (Voucher M.F. Braby 137, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Wanguri, Darwin, NT (12.37308°S, 130.88657°E; WGS84, 500 m), 12 January 2013, M.F. Braby. A female was observed at 1230 h CST ovipositing on the prostrate scrambler *Desmodium triflorum* growing in a residential garden; the eggs were laid singly on the underside of the leaflets. Further searches revealed additional eggs on the larval food plant.

***Famegana alsulus alsulus*  
(Herrich-Schäffer, 1869)**

**Black-spotted Grass-blue**

*Vigna lanceolata* var. *filiformis* Benth. (Fabaceae). (Voucher M.F. Braby 101, DNA).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Saddleback Ridge, El Questro Wilderness Park, WA (15.99668°S, 127.98529°E; WGS84, 200 m), 18 May 2011, M.F. Braby. A female was observed at 1000 h CST to deposit several eggs on the trailing legume *Vigna lanceolata* growing in savannah woodland along a dry seasonal gully at the base of a hill.

*Vigna radiata* (L.) R.Wilczek (Fabaceae). (Voucher M.F. Braby 161, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Charles Darwin University, Katherine campus, NT (14.39513°S, 132.14429°E; WGS84, 50 m), 16 April 2014, M.F. Braby and L.J. Aitchison. A female was observed at 1310 h CST ovipositing on *Vigna radiata*, which grew as a trailing vine in woodland adjacent to vine thicket on limestone karst.

***Euchrysops cnejus cnidus***  
**Waterhouse & Lyell, 1914**

**Spotted Pea-blue**

*Vigna lanceolata* var. *filiiformis* Benth. (Fabaceae).  
 (Voucher M.F. Braby 117, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Finn Rd, ca. 3 km N of Berry Springs, NT (12.67554°S, 131.00994°E; WGS84, 100 m), 21 January 2012, M.F. Braby. A female was observed at 1220 h CST fluttering slowly around and alighting on *Vigna lanceolata*, which grew as a trailing legume in the grassy understorey of savannah woodland; closer inspection of the larval food plant revealed two freshly laid green eggs on the sepals of a flower bud.

*Vigna radiata* (L.) R.Wilczek (Fabaceae). (Voucher M.F. Braby 122, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Mt Muriel, 7 km SSW of Douglas Daly Research Farm, Fish River Station, NT (13.89433°S, 131.15822°E; WGS84, 500 m), 23 April 2012, M.F. Braby. A female was observed during the early afternoon ovipositing on a vine of *Vigna radiata* growing in savannah woodland on a laterite plateau; several eggs were laid on the stems of the larval food plant, as well as on those of adjacent plants over which the vine grew.

***Freyeria putli putli* (Kollar, [1844])**

**Jewelled Grass-blue**

*Indigofera linifolia* (L.f.) Retz. (Fabaceae). (Voucher M.F. Braby 144, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Timber Creek, NT (15.65278°S, 130.47972°E; WGS84, 50 m), 30 March 2013, M.F. Braby and L.J. Aitchison. A final instar larva was collected from the leaves of the annual herb *Indigofera linifolia* growing in an open disturbed area. The larva, which was attended by two small black ants *Iridomyrmex* sp. (1 *anceps* group), was reared in captivity and an adult emerged on 6 April 2013. Adults were common at the site and were closely associated with the food plant, on which they also observed to feed from the small red flowers.

**NOCTUIDAE: AGARISTINAE**

***Comocrus behri* (Angas, 1847)**

**Mistletoe Day-moth**

Figure 1

*Amyema bifurcata* (Benth.) Tiegh. (Loranthaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Borroloola, NT (16.05725°S, 136.30681°E; WGS84, 500 m), 15 May 2013, M.F. Braby. Two pupae were collected from within their cocoons at the base of a eucalypt festooned with numerous clumps of the mistletoe *Amyema bifurcata* growing near suburban parkland. The adults emerged a week later on 23 May 2013.

*Amyema villiflora* ssp. *villiflora* (Domin) Barlow (Loranthaceae). (Voucher M.F. Braby 109, 114, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Location 0.6 km W of Gubara Track, Nourlangie Rock, Kakadu National Park, NT (12.83721°S, 132.84970°E; WGS84, 250 m), 19 November 2011, M.F. Braby. Four final instar larvae were collected from two clumps of the mistletoe *Amyema villiflora* parasitising *Acacia multistipulosa* growing in open-woodland on rocky sandstone breakaway; a dead parasitised larva also present on the larval food plant. All larvae died in captivity from viral disease. The immature stages of *Ogyris zosine* and *Candalides margarita* were also found on the same mistletoe species at this site (see above).

*Diplatia grandibractea* (Loranthaceae) (Voucher M.F. Braby 177, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Favenc Range, Carpentaria Hwy, NT (16.70357°S, 135.36717°E; WGS84, 50 m), 24 August 2015, M.F. Braby. A final instar larva was collected feeding on the foliage of the mistletoe *Diplatia grandibractea* which grew abundantly in the area parasitising *Eucalyptus leucophloia* in low open woodland on a rocky hill slope/breakaway. The larva pupated the following day and a female emerged on 22 September 2015. The immature stages of *Ogyris zosine* were also found on the same mistletoe species at this site (see above).

***Cruria donowani* (Boisduval, 1832)****No common name**

Figure 2

*Cayratia trifolia* (L.) Domin (Vitaceae). (Voucher M.F. Braby 138, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Mt Burrell, Tipperary Station, NT (13.49623°S, 131.03572°E; WGS84, 100 m), 8 December 2012, M.F. Braby. A female was observed for 10 mins at 1315–1325 h CST ovipositing on small regenerating vines of *Cayratia trifolia* growing in open grassy areas or near the base of tree trunks in savannah woodland at the base of a hill; about five bright yellow-green eggs were laid singly on upperside of the leaves and stems. The female was captured and found to have deposited many eggs on the food plant when held inside a plastic container in captivity. The resulting larvae were reared in captivity and they pupated a few weeks later in late December 2012, with adults emerging in January or October 2013. Previous observations at this site indicated that adults were common seasonally, especially around large trees of Ironwood *Erythrophleum chlorostachys* that were in flower during the pre-monsoon storm period.

***Idalima metasticta* Hampson, 1910****No common name**

Figure 3

*Hibbertia dilatata* (Benth.) J.W.Horn (Dilleniaceae). (Voucher M.F. Braby 118, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Intersection of Finn Rd and Middle Arm Rd, ca. 6.5 km N of Berry Springs, NT (12.64514°S, 131.00986°E; WGS84, 10 m), 21 January 2012, M.F. Braby. A female was observed at 1400 h CST exhibiting pre-oviposition flight behaviour (slow flutter close to the ground) around *Hibbertia dilatata* growing as a low shrub in an open disturbed area comprising remnant woodland that had been graded and slashed; she appeared to be depositing eggs on the leaf litter under grass stems around base of the larval food plant. The female was collected and held in a glass jar with fresh cuttings of the *H. dilatata* in captivity for 48 h, during which time she laid approximately 20 bright yellow eggs on the walls of the jar. The eggs hatched four days later and the larvae were noted to feed on the soft new cladodes (as well as the flowers), eating along

the margin of the flattened stem; at rest they often raised the anterior end into the air resembling a piece of dried leaf material. An adult emerged on 26 February 2012. The site was revisited on 28 January 2012 and a second instar larva was collected from *H. dilatata*.

Finn Rd, ca. 3 km N of Berry Springs, NT (12.67554°S, 131.00994°E; WGS84, 100 m), 2 November 2012, M.F. Braby. A single final instar larva was collected from *H. dilatata* growing in savannah woodland and reared to adult in captivity, emerging on 20 December 2012.

*Hibbertia juncea* (Benth.) J.W.Horn (Dilleniaceae). (Voucher M.F. Braby 133, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Wongalara Wildlife Sanctuary, 17 km WSW of homestead, NT (14.18256°S, 134.32269°E; WGS84, 10 m), 1 June 2012, M.F. Braby and T. Bauer. Two final instar larvae were collected from *Hibbertia juncea* growing as a low shrub in heath-woodland on sand; the larvae were reared in captivity, but died during pupation.

Nitmiluk National Park (Katherine Gorge), walking trail, NT (14.32541°S, 132.44066°E; WGS84, 5 m), 15 April 2014, M.F. Braby and L.J. Aitchison. Four larvae comprising various instars were recorded on *H. juncea* growing in woodland on flat sandy terrain between rocky sandstone outcrops.

***Idalima* sp. 'Arnhem Land'****Rock-art Day-moth**

Figure 4

*Hibbertia candicans* Benth. (Dilleniaceae). (Voucher M.F. Braby 67, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Location 0.6 km W of Gubara Track, Nourlangie Rock, Kakadu National Park, NT (12.83721°S, 132.84970°E; WGS84, 250 m). A series of observations were made at this site by the author on 25 January 2010, 19–20 February 2010, 27 March 2010 and 17 December 2011. Females were observed between 1625–1730 h CST on the three separate occasions depositing eggs on the rock face of boulders close to or directly beneath shrubs of *Hibbertia candicans* growing in eucalypt woodland with a shrubby heath understorey on broken sandstone hill-slope. The eggs were collected and they hatched five days later. A number of larvae comprising various instars ( $n = 15$ ) were also recorded on the larval food plant; the larvae were solitary and were usually found on the underside



of leaves; sometimes more than one larva was present on a particular plant. Several larvae were collected (between December 2009–March 2010), of which two were reared to adult: the larvae pupated a few weeks later and emerged as adults on 10 February and 24 April 2010, respectively, with the pupal duration varying from 18–20 days.

***Periopta diversa* (Walker, [1865])**

**No common name**

\**Oldenlandia corymbosa* L. (Rubiaceae). (Voucher M.F. Braby 140, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Vanderlin Dve, Berrimah, Darwin (CSIRO complex), NT (12.41333°S, 130.92194°E; WGS84, 500 m), 31 January 2013, M.F. Braby. Three mid to late instar larvae were recorded feeding on the introduced annual herb *Oldenlandia corymbosa* growing in a highly disturbed open area along a roadside verge.

\**Spermacoce articularis* L.f. (Rubiaceae). (Voucher M.F. Braby 139, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Vanderlin Dve, Berrimah, Darwin (CSIRO complex), NT (12.41333°S, 130.92194°E; WGS84, 500 m), 8, 14, 31 January 2013, M.F. Braby. Four larvae comprising various instars were recorded feeding on the introduced annual herb *Spermacoce articularis* growing in a highly disturbed open area along a roadside verge. One larva was collected and reared in captivity; an adult emerged on 30 January 2013.

***Radnocera vagata* (Walker, 1865)**

**No common name**

Figure 5

*Cayratia trifolia* (L.) Domin (Vitaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Daly Waters Hotel, NT (16.25331°S, 133.36894°E; WGS84, 100 m), 28 January 2013, M.F. Braby and L.J. Aitchison. Two larvae were recorded on *Cayratia trifolia* growing as a vine on the trunk of a eucalypt in woodland that had

recently been burnt by an extensive dry season fire. One larva was collected and reared in captivity, emerging as an adult on 3 March 2013. This larval food plant for *R. vagata* was previously documented (Braby 2011a) based on the collection and rearing of larvae from Mt Bunday, NT; however, the larvae at Daly Waters comprised an unusual 'pale white' colour morph that has not previously been recorded; usually the larvae (at least in the higher rainfall areas of the Top End) comprise a 'dark' colour morph in which the transverse stripes are brown, grey and white.

***Radnocera* sp. 'Arnhem Land'**

**Boulder Day-moth**

Figure 6

*Ampelocissus acetosa* (F.Muell.) Planch. (Vitaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Nanguluwur Art site, Nourlangie Rock, Kakadu National Park, NT (12.84262°S, 132.81895°E; WGS84, 250 m). A series of observations were made at this site by the author on 7, 19, 20 December 2009, 27 November 2010, 11 December 2010 and 18 November 2011. Females were observed at 1800–1840 h flying close to the ground around or ovipositing on the vine *Ampelocissus acetosa* growing amongst foot-slope boulders at the base of a sandstone escarpment. A number of larvae (n = 19) comprising various instars were collected and reared to adult in captivity.

***Hecatesia* sp. 'Arnhem Land'**

**Kakadu Whistling Moth**

Figure 7

*Cassytha filiformis* L. (Lauraceae). (Voucher M.F. Braby 113, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Location 0.6 km W of Gubara Track, Nourlangie Rock, Kakadu National Park, NT (12.83721°S, 132.84970°E; WGS84, 250 m), 16, 17 December 2011, M.F. Braby. Three late instar larvae (instars IV, V) were collected from separate vines of *Cassytha filiformis* growing over understorey shrubs in eucalypt woodland on broken sandstone hill-slope. The larvae were reared in captivity, with two adults emerging on 2 and 3 January 2012 after a pupal duration of approximately 15 days. A catastrophic



FIGURES 1–8 Larvae of Agaristinae (Noctuidae) from the Northern Territory discussed in this paper: 1, *Comocrus behri* on *Amyema villiflora*, Nourlangie Rock, Kakadu National Park; 2, *Cruria donowani* on *Cayratia trifolia*, Mt Burrell, Tipperary Station; 3, *Idalima metasticta* on *Hibbertia dilatata*, Berry Springs; 4, *Idalima* sp. 'Arnhem Land' on *Hibbertia candicans*, Nourlangie Rock, Kakadu National Park; 5, *Radinocera vagata* on *Cayratia trifolia*, Daly Waters; 6, *Radinocera* sp. 'Arnhem Land' on *Ampelocissus acetosa*, Nourlangie Rock, Kakadu National Park; 7, *Hecatesia* sp. 'Arnhem Land' on *Cassytha filiformis*, Nourlangie Rock, Kakadu National Park; 8, *Hecatesia* sp. 'Kimberley' on *Cassytha capillaris*, Keep River National Park. (Photos by M.F. Braby.)

fire temporarily eliminated the breeding colony in November 2012: subsequent searches in 2013 and 2014 failed to detect the moth, and the larval food plant had not recovered to its former density.

Barrk Track, 0.6 km E of Nanguluwur Art Site, Kakadu National Park, NT (12.84650°S, 132.82295°E; WGS84, 200 m), 7 December 2013, M.F. Braby. A fourth instar larva was collected from *C. filiformis* growing over shrubs in eucalypt woodland on steep broken sandstone hill-slope below the Nourlangie Rock plateau. The larva pupated five days later on 12 December 2013 and emerged as an adult on 26 December 2013. The site was revisited on 26 January 2014 and four larvae (2 instar III, 2 instar V) were collected from *C. filiformis*; all larvae were on separate vines. The site was revisited again on 15 February 2014 and two more larvae (instars III, V) were collected from the larval food plant; a gravid female was also captured and transferred to a glass jar supplied with fresh cuttings of the food plant and held in captivity for 36 h during which time she laid about 100 eggs. The eggs hatched four days later and the resulting larvae were reared in captivity, emerging as adults during March and April 2014, with no evidence of pupal diapause.

***Hecatesia* sp. 'Kimberley'**

**Kimberley Whistling Moth**

Figure 8

*Cassytha capillaris* Meisn. (Lauraceae). (Voucher M.F. Braby 34, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Jininum Gorge, Keep River National Park, NT (15.83376°S, 129.11018°E; WGS84, 50 m), 1–2, 4 February 2008, M.F. Braby. A number of mid to late instar larvae (n = 24) were collected from vines of *Cassytha capillaris* parasitising various grasses, including *Triodia*, growing in savannah open-woodland on flat sandy loam that was long unburnt. All larvae were feeding solitarily and, during the heat of the day (typically 42°C during mid afternoon), they were noted to rest vertically head downwards, fully stretched on the more shaded side of stems of flower spikes or blades of the host grass just above the food plant; often the head and thorax was raised in the air. The site was revisited on 20 March 2008 and three larvae were collected from *C. capillaris*. The site was revisited again on 9 February 2012 and five mid instar larvae were collected from the larval food plant. All larvae reared in captivity during the wet season developed directly, with no evidence of pupal diapause.

Nganalam Art Site, Keep River National Park, NT (15.80501°S, 129.10548°E; WGS84, 10 m), 3 February 2008, M.F. Braby. Eleven larvae were recorded on *C.*

*capillaris* growing in similar habitat to the Jininum Gorge site noted above.

**NEW LEPIDOPTERA LARVAL FOOD PLANT ASSOCIATIONS FOR THE NORTHERN TERRITORY AND/OR NORTHERN WESTERN AUSTRALIA**

The following catalogue of species comprises plants that have previously been recorded as larval food plants from eastern Australia (e.g. Common 1990; Braby 2000) but, to the author's knowledge, have not been previously documented for the NT and/or the Kimberley region of western Northern Territory and north-western Western Australia.

**HESPERIIDAE**

***Ocybadistes flavovittatus vesta*  
(Waterhouse, 1932)**

**Narrow-brand Grass-dart**

\**Cynodon dactylon* (L.) Pers. (Poaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Western Australia:** Annie Creek campground, Mornington Wildlife Sanctuary, WA (17.50735°S, 126.11252°E; WGS84, 500 m), 10 August 2011, M.F. Braby and L.J. Aitchison. A localised breeding colony was located on non-indigenous Green Couch Grass *Cynodon dactylon*, which grew as an extensive hummock in an open damp area with some shade afforded by overstorey trees in riparian woodland. A female was observed at 1040 h WST to oviposit on the larval food plant, and two late instar larvae were collected from their shelters, which were constructed amongst the basal stems and blades of the food plant; both larvae subsequently proved to be parasitised. Males were noted to repeatedly perch on blades of the food plant and other objects close to ground to bask or establish territories for mate location during late morning; conspecific rival males were not tolerated and chased away if they entered the territory of a resident male. The immature stages of *Hypocysta adiantae* were also found on the same grass at this site (see above).

***Suniana lascivia larrakia* L.E. Couchman, 1951**

**Dark Grass-dart**

*Imperata cylindrica* (L.) Reusch. (Poaceae). (Not vouchered).

## MATERIAL EXAMINED

**Australia: Northern Territory:** Wanguri, Darwin, NT (12.37308°S, 130.88657°E; WGS84, 500 m), 1 September 2013, M.F. Braby. Two larvae were collected from the grass *Imperata cylindrica* and reared in captivity, with adults emerging on 7 and 15 October 2013.

## PIERIDAE

***Eurema hecabe* (Linnaeus, 1758)****Large Grass-yellow**

*Phyllanthus* sp. (Phyllanthaceae). (Voucher M.F. Braby 103, DNA).

## MATERIAL EXAMINED

**Australia: Western Australia:** El Questro Gorge, El Questro Wilderness Park, WA (16.02005°S, 128.02899°E; WGS84, 400 m), 17 May 2011, M.F. Braby. A female was observed during the late morning ovipositing on *Phyllanthus* sp., possibly *P. maderaspatensis*, which grew as a herb in an open rocky area along a narrow gully adjacent to monsoon forest.

***Belenois java teutonia* (Fabricius, 1775)****Caper White**

*Capparis lasiantha* R.Br. ex DC. (Capparaceae). (Not vouchered).

## MATERIAL EXAMINED

**Australia: Western Australia:** Location 9 km S of campground, Mornington Wildlife Sanctuary, WA (17.58320°S, 126.08272°E; WGS84, 10 m), 9 August 2011, M.F. Braby and L.J. Aitchison. Numerous pupae, pupal exuviae and adults were recorded on *Capparis lasiantha*, which grew as a large vine around *Bauhinia cunninghamii* in savannah woodland.

***Delias argenthona fragalactea* (Butler, 1869)****Scarlet Jezebel**

*Amyema miquelii* (Lam. ex Miq.) Tiegh. (Loranthaceae). (Not vouchered).

## MATERIAL EXAMINED

**Australia: Northern Territory:** Location 0.6 km W of Gubara Track, Nourlangie Rock, Kakadu

National Park, NT (12.83721°S, 132.84970°E; WGS84, 250 m), 6 February 2011, M.F. Braby. A cohort of five final instar larvae were recorded on a clump of the mistletoe *Amyema miquelii* in the canopy parasitising *Eucalyptus miniata* growing in eucalypt woodland with a heath understorey on broken sandstone hill-slope. The immature stages of *Candalides margarita* were also found on the same mistletoe species at this site (see below).

*Amyema sanguinea* (F.Muell.) Danser (Loranthaceae). (Not vouchered).

## MATERIAL EXAMINED

**Australia: Western Australia:** King River crossing, Gibb River Road, El Questro Wilderness Park, WA (15.91133°S, 128.18486°E; WGS84, 10 m), 3 August 2011, M.F. Braby and L.J. Aitchison. A cohort of five late instar larvae was recorded on a clump of the mistletoe *Amyema sanguinea* in the canopy parasitising *Eucalyptus camaldulensis* growing in riparian woodland along the bank of a river. The immature stages of *Ogyris amaryllis* (see below) and *Candalides margarita* (see above) were also recorded on the same mistletoe clump.

*Dendrophthoe glabrescens* (Blakely) Barlow (Loranthaceae). (Voucher M.F. Braby 108, DNA).

## MATERIAL EXAMINED

**Australia: Western Australia:** Emma Gorge Resort, El Questro Wilderness Park, WA (15.90753°S, 128.12909°E; WGS84, 100 m), 2 June 2011, M.F. Braby and T. Schwinghammer. A cohort of 10 first instar larvae were collected and three prepupae were recorded on a large clump of the mistletoe *Dendrophthoe glabrescens* in the canopy parasitising *Erythrophleum chlorostachys* growing in woodland along the gorge; a live pupa and a dead pupa were also found on a grass blade about 1 m above the ground beneath the mistletoe food plant. The larvae were reared in captivity and pupated on 2 July 2011, emerging as adults 10 days later on 12 July 2011. The site was revisited on 4 August 2011 and a cohort of 14 final instar larvae was recorded on the same larval food plant. The immature stages of *Candalides margarita* were also found on the same mistletoe clump (see above).

Intersection of Lake Argyle Rd and Victoria Hwy, ca. 35 km E of Kununurra, WA (15.96229°S, 128.96069°E; WGS84, 100 m), 1 August 2011, M.F. Braby and L.J. Aitchison. A cohort of 14 final instar larvae was recorded feeding on *D. glabrescens* parasitising *Erythrophleum chlorostachys* growing in savannah open-woodland on sandplain.

**Australia: Northern Territory:** Wilton River, Wongalara homestead, Wongalara Wildlife Sanctuary, NT (14.14035°S, 134.47461°E; WGS84, 250 m), 29 May

2012, M.F. Braby. A female was observed at 1400 h CST ovipositing on *D. glabrescens* in the canopy (approx. 7–8 m above the ground) parasitising *Erythrophleum chlorostachys* growing in riparian woodland; a small cohort of eggs was laid on a new leaf.

## NYMPHALIDAE

### *Euploea corinna* (W.S. Macleay, 1826)

#### Common Crow

*Ichnocarpus frutescens* R.Br. (Apocynaceae). (Voucher M.F. Braby 121, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Bamboo Creek, Marrakai Rd, 2.5 km E of Stuart Hwy, NT (12.90468°S, 131.16080°E; WGS84, 250 m), 15 October 2011, M.F. Braby. Two females were observed at 1055 h and 1104 h CST ovipositing on a vine of *Ichnocarpus frutescens* growing along the edge of wet riparian monsoon forest; each female laid a single egg on the underside or edge of a leaf. A first instar larva was also recorded on the new leaf growth.

\**Adenium obesum* (Forrsk.) Roem. and Schult. (Apocynaceae). (Not vouchered).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Adelaide River, 5.5 km NE of Adelaide River, NT (13.21222°S, 131.1475°E; AGD66 100 m), 26 August 2013, V. Kessner. Numerous larvae and pupae were recorded on several ornamental *Adenium obesum* plants growing in pot-plants in a rural garden.

### *Melanitis leda bankia* (Fabricius, 1775)

#### Evening Brown

*Imperata cylindrica* (L.) Reusch. (Poaceae). (Not vouchered).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Bamboo Creek, Marrakai Rd, 2.5 km E of Stuart Hwy, NT (12.90468°S, 131.16080°E; WGS84, 250 m), 16 March 2013, M.F. Braby. A final instar larva was recorded feeding on the grass *Imperata cylindrica* growing in the ecotone of riparian monsoon forest. The site was revisited on 6 April 2013 and another larva was recorded feeding on the blade of the larval food plant.

## LYCAENIDAE

### *Arhopala eupolis asopus* Waterhouse & Lyell, 1914

#### Purple Oak-blue

*Cupaniopsis anacardioides* (A.Rich.) Radlk. (Sapindaceae). (Not vouchered).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Bullocky Point, Darwin, NT (12.43777°S, 130.83377°E; WGS84, 500 m), 28 February 2011, M.F. Braby. Ten larvae comprising various instars were collected from new soft leaves of the tree *Cupaniopsis anacardioides* growing in suburban parkland. The larvae were attended by *Oecophylla smaragdina* ants and reared in captivity, with adults emerging between 17–20 March 2011.

### *Ogyris amaryllis meridionalis* (Bethune-Baker, 1905)

#### Satin Azure

*Amyema sanguinea* (F.Muell.) Danser (Loranthaceae). (Not vouchered).

#### MATERIAL EXAMINED

**Australia: Western Australia:** King River crossing, Gibb River Road, El Questro Wilderness Park, WA (15.91133°S, 128.18486°E; WGS84, 10 m), 3 August 2011, M.F. Braby and L.J. Aitchison. Numerous eggs were recorded on the stems of a clump of the mistletoe *Amyema sanguinea* in the canopy parasitising *Eucalyptus camaldulensis* growing in riparian woodland along the bank of a river; an early instar larva and a pupa were also collected from under loose bark of the larval food plant. The larva and pupa were reared in captivity to adult; the pupa emerged on 10 August 2011, and the larva on 1 September after a pupal duration of 10 days. Several males were observed at the site and were noted to fly high in the canopy of the host tree, frequently settling on dead branches. The immature stages of *Delias argenthona* and *Candalides margarita* were also recorded on the same mistletoe clump (see above).

*Diplatia grandibractea* (Loranthaceae) (Voucher M.F. Braby 78, DNA).

#### MATERIAL EXAMINED

**Australia: Northern Territory:** Near Lake Mary Ann, 5 km NNW of Tennent Creek, NT (19.60678°S, 134.20479°E; WGS84), 12 September 2015, M.F. Braby. A female was observed at 1310 h to deposit a single egg on a branch of the mistletoe *Diplatia grandibractea*

parasitising *Eucalyptus leucophloia* growing in low open woodland with a ground layer of *Triodia* sp.; three final instar larvae were also collected from the haustoria of another clump, the larvae were sheltering either in borer holes or amongst the basal branches beneath debris of an abandoned birds nest. The larvae were reared in captivity to pupation, with the adults emerging on 10, 15 October 2015. The record confirms this mistletoe as a larval food plant of *O. amaryllis* that was previously based only on the presence of eggs and larval feeding scars (Braby 2011a).

***Hypolycaena phorbas phorbas* (Fabricius, 1793)**

**Black-spotted Flash**

*Planchonia careya* Blume (Lecythidaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Manton River crossing, Stuart Hwy, NT (12.83833°S, 131.13361°E; GDA94, DMS, 250 m), 10 January 2015, M.F. Braby. Two larvae were collected from a large shrub of *Planchonia careya* growing in savannah woodland and reared to adult, with a pair emerging on 22–23 January 2015. The larvae were feeding on the new soft foliage and were attended by numerous *Oecophylla smaragdina* ants.

***Anthene seltuttus affinis*  
(Waterhouse & R.E. Turner, 1905)**

**Dark Ciliate-blue**

*Cupaniopsis anacardioides* (A. Rich.) Radlk. (Sapindaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Fish River, 6 km SE of homestead, Fish River Station, NT (14.23081°S, 130.91939°E; WGS84, 500 m), 29 April 2012, M.F. Braby. Three pupae were recorded on the tree *Cupaniopsis anacardioides* growing in riparian paperbark woodland with monsoon elements in the understorey.

South Alligator Ranger Station, Kakadu National Park, NT (12.68306°S, 132.47223°E; WGS84, 100 m), 25 April 2013, M.F. Braby and C. Webb. A female was observed at 1140 h CST ovipositing on *C. anacardioides* growing in long unburnt eucalypt woodland with monsoon vine thicket in the understorey.

Gunn Point, 1.5 km N of car park, NT (12.22762°S, 131.03122°E; WGS84, 250 m), 30 November 2013, M.F. Braby and D. Bisa. A large cohort of eggs and several early instar larvae were recorded on *C. anacardioides*

growing in coastal monsoon vine thicket. The eggs had been deposited on a stem, and numerous *Oecophylla smaragdina* ants were present.

***Candalides margarita gilberti*  
Waterhouse, 1903**

**Northern Pencil-blue**

*Amyema miquelii* (Lam. ex Miq.) Tiegh. (Loranthaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Location 0.6 km W of Gubara Track, Nourlangie Rock, Kakadu National Park, NT (12.83721°S, 132.84970°E; WGS84, 250 m), 19 November 2011, M.F. Braby. A female was observed for 7 mins between 1555–1602 h CST ovipositing on the flower buds on clumps of the mistletoe *Amyema miquelii* in the canopy parasitising *Eucalyptus miniata* growing in eucalypt woodland with a heath understorey on broken sandstone hill-slope. The immature stages of *Delias argenthona* were also recorded on the same mistletoe species at this site (see above).

***Theclinesthes miskini miskini*  
(T.P. Lucas, 1889)**

**Wattle Blue**

*Atalaya hemiglauca* (F. Muell.) F. Muell. ex Benth. (Sapindaceae). (Not vouchered).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Mataranka Homestead, Thermal Pool campground, NT (14.92277°S, 133.13400°E; WGS84, 10 m), 4 April 2015, M.F. Braby. A female was observed during mid afternoon ovipositing on the new soft foliage of a sapling of *Atalaya hemiglauca* growing in the campground.

***Euchrysops cnejus cnidus*  
Waterhouse & Lyell, 1914**

**Spotted Pea-blue**

\**Macroptilium lathyroides* (L.) Urb. (Fabaceae). (Voucher M.F. Braby 147, DNA).

**MATERIAL EXAMINED**

**Australia: Northern Territory:** Location 48 km N of Borroloola, NT (15.63012°S, 136.38232°E; WGS84, 500 m), 16 May 2013, M.F. Braby. A female observed was ovipositing on the introduced vine *Macroptilium lathyroides* growing in abundance in a paperbark swamp; numerous other eggs were also present.

## DISCUSSION

In total, 103 Lepidoptera-plant associations are documented, of which 86 are new for Australia and 17 are new for the NT and/or WA. Of particular note are the first recordings of the following three plant families for three butterfly species: the Lauraceae for *Graphium eurypylus*, the Phyllanthaceae for *Hypolycaena phorbis*, and the Anacardiaceae for *Prosotas dubiosa*. Moreover, 16 native plant genera are newly recorded for the following genera of Lepidoptera in Australia: *Semecarpus* (Anacardiaceae) for *Prosotas* (Lycaenidae), *Sarcolobus* (Apocynaceae) for *Danaus* (Nymphalidae), *Vitex* (Lamiaceae) for *Charaxes* (Nymphalidae), *Bossiaea* and *Tephrosia* (Fabaceae) for *Jamides* (Lycaenidae), *Amyema* (Loranthaceae) for *Birhana* (Immidae), *Corymbia* (Myrtaceae) for *Anthene* (Lycaenidae), *Aristida* and *Digitaria* (Poaceae) for *Hypocysta* (Nymphalidae), *Chrysopogon* and *Eriachne* (Poaceae) for *Pelopidas* (Hesperiidae), *Mnesithea* (Poaceae) for *Pelopidas* and *Telicota* (Hesperiidae), *Sacciolepis* (Poaceae) for *Taractrocer*a (Hesperiidae), *Sorghum* (Poaceae) for *Synemon* (Castniidae) and *Neohesperilla* (Hesperiidae), *Whiteochloa* for *Borbo* and *Taractrocer*a (Hesperiidae), and *Breynia* (Phyllanthaceae) for *Hypolycaena* (Lycaenidae). In addition, new larval food plant associations are reported for five day-flying moths in the subfamily Agaristinae (*Idalima metasticta*, *Idalima* sp. 'Arnhem Land', *Radnocera* sp. 'Arnhem Land', *Hecatesia* sp. 'Arnhem Land', *Hecatesia* sp. 'Kimberley') for which the life histories have not previously been documented. The final instar larvae of these five species are illustrated for the first time in figures 3, 4, 6–8.

Of the new food plant records, 34 are based on oviposition behaviour of females and/or presence of eggs only, and further observations may be required to determine their suitability. In my experience, however, females rarely make mistakes when ovipositing, and subsequent rearing of the larvae from eggs laid on their respective food plants has demonstrated that in most cases the larvae are indeed able to feed and develop to adulthood on these plants in captivity. In the present work, this assumption of host suitability, based on oviposition records only, was confirmed in at least three cases: *Axonopus compressus* for *Ypthima arctous*, *Amyema villiflora* for *Candalides margarita*, and *Cayratia trifolia* for *Cruria donowani*. In other cases, females were initially observed ovipositing on a plant and then subsequent searching revealed larvae, some of which were reared. For example, in a previous report I observed a female of the hesperiid *Suniana lascivia* deposit a single egg on the grass *Ischaemum australe* in the eastern Kimberley at El Questro Wilderness Park, WA, in July 2009 (Braby 2011a), but did not rear the egg nor search for additional immature stages on the plant. However, subsequent observations

made during this study confirmed that butterfly does exploit *I. australe* – numerous larvae, pupae and shelters were detected on this grass species, and two larvae were collected and reared in captivity to adult, from a localised breeding colony at Kununurra, WA, in February 2012.

Another, but slightly different, example concerns the mate-location behaviour exhibited by the lycaenid *Nacaduba biocellata*. During mate-location, large numbers of males of this species patrol a relatively small area beneath the canopy of the larval food plant, which consists of trees of *Acacia* that have just finished or almost finished flowering, during the mid morning. The males fly very close to the ground near the trunk of the tree in search for freshly emerged females, which pupate amongst the leaf litter, under stones, pieces of bark or in holes in the ground at or near the base of the trunk (Braby 2000). The presence of such male behaviour can thus be used as a clue as to the likely food plant. This assumption was tested and confirmed in the present study at El Questro Wilderness Park in May 2011 by the detection of larvae on the flowers of a tree of the putative larval food plant (in this case *A. plectocarpa*).

It can therefore be assumed that the majority, if not all, of the plants listed are exploited and comprise an important ecological resource for these insects. The suitability of these plants in terms of offspring fitness components (e.g. survival rate, larval growth rate, adult body size attained, and reproductive output of adult females), however, was beyond the scope of this study and was not investigated. It is well known that not all plants are equal in terms of offspring fitness for butterfly species that have broad larval diets (i.e. oligophagous or polyphagous) (e.g. Singer 1984), and further experimentation is required to determine patterns of host preference and/or host suitability in relation to diet breadth for those species which feed on more than one particular plant species.

Comments are provided for several species in terms of the new plant associations reported herein.

Larvae of the aposematic diurnal moth *Birhana cleis* specialise on the mistletoe family Loranthaceae, and previously they have been reported from the genera *Decaisnina* and *Dendrophthoe* (Braby 2011a). In that publication I predicted that the host range of this immid within the Loranthaceae may be considerably wider than available data indicates. The new association with *Amyema* in part confirms this prediction, and is therefore not entirely unexpected.

Larvae of the swallowtail butterfly *Graphium eurypylus* in Australia feed predominantly on Annonaceae and very occasionally Magnoliaceae (Larsen et al. 2008). It is therefore of considerable interest that the species is now known to also exploit Lauraceae, which have not previously been reported for

this species in Australia. This family has been recorded for two other species of *Graphium* in Australia (*G. macleayanum*, *G. sarpedon*) (Braby 2000), but not for *G. eurypylus*.

Larvae of the danaine butterfly *Danaus affinis* in Australia were previously known to feed only on *Cynanchum carnosum* (Apocynaceae), particularly growing at the edge of swamplands in coastal areas (Braby 2000), although recently Moss (2010) added *C. ovalifolium* as a food plant from south-east Queensland. The utilisation of *Marsdenia* and *Sarcolobus* in a different habitat (eucalypt open-forest at the base of sandstone escarpments in inland areas) is somewhat surprising, although both genera belong in the Apocynaceae. These two new plant records indicate a broader host range for *D. affinis*, and it may explain the occurrence of this butterfly in non-coastal areas of the Top End where it is widely distributed. *Sarcolobus* has not previously been recorded for the genus *Danaus* in Australia.

Larvae of the satyrine butterfly *Mycalesis sirius* are known to feed on a limited set of grasses (Poaceae), mainly growing in paperbark swampland or eucalypt woodland adjacent to paperbark swampland (Braby 1995a, b). Manski (1960) listed *Imperata* sp. as a larval food plant for *M. sirius* in northern Queensland; however, Valentine (1988) cast considerable doubt over the reliability of this association and, on the basis of this evidence, the record was not formally included in the review by Braby (2000). Thus, the discovery of larvae feeding on *I. cylindrica* along the edge of riparian evergreen monsoon forest at Robin Falls, NT, confirms the earlier observation by Manski (1960).

Larvae of the lycaenid butterfly *Ogyris amaryllis* specialise on the genus *Amyema* and the closely related genus *Diplatia* within the Loranthaceae (Braby 2000, 2011a). The recording of *A. benthamii* in the Kimberley in 2011 brings the total number of *Amyema* food plant species to about 17. This mistletoe species was subsequently confirmed by Paton (2013), who documented *A. benthamii* as a larval food plant for *O. amaryllis*, based also in the Kimberley, on collections and rearing of pupae at Broome, WA, in July 2013.

Larvae of the lycaenid *Candalides margarita gilberti* were previously known to associate only with the mistletoe genus *Decaisnina* in the Loranthaceae (Samson and Wilson 1995; Braby 2008). Braby (2011a) predicted that the host range of this subspecies was likely to be wider given its broad geographical distribution in the Kimberley, Top End and western Gulf Country. Hence, the five new plant records from the genera *Amyema* (3 species) and *Dendrophthoe* (2 species) confirm this prediction and are not entirely unexpected.

Larvae of the lycaenid *Famegana alsulus* have been previously recorded associated with shrubby legumes

in northern Australia (Braby 2000). However, in a recent report I recorded an association with the twining creeper *Vigna vexillata* in the Top End (Braby 2011a), and in this study females were observed ovipositing on two further species of *Vigna*. The record of *V. lanceolata* from the eastern Kimberley, in particular, supports an earlier observation (Braby 1997) in which I reported a female of *F. alsulus* ovipositing on this species at Townsville, Qld – the association, however, was not formally included in the review by Braby (2000).

Larvae of the lycaenid *Euchrypsops cnejus* feed on various legumes, including at least three species of *Vigna* (Braby 2000). The two additional species of *Vigna* reported here bring the tally for this plant genus to five species. The record of *V. radiata* from Fish River Station in the Top End, in particular, supports the earlier observation of Meyer (1996), who reported a female of *E. cnejus* ovipositing on this species in the Northern Territory [precise details of location and date not provided] – the association, however, was not formally included in the review by Braby (2000).

The usual larval food plants of *Freyeria putli* in Queensland are species of *Indigofera* (Braby 2000), but Meyer (1996) listed *Flemingia lineata* as the only food plant in the Northern Territory. However, at Timber Creek, NT, adults (and larvae) were associated with *Indigofera linifolia*. Subsequent observations made at widely dispersed locations in the Top End, including Gregory National Park (Limestone Gorge), near Borroloola (Bing Bong) and near Katherine (Katherine Gorge), indicated that adults were very numerous around, and frequently settled upon, localised patches of this plant, suggesting that *I. linifolia* may be the preferred or most frequently used food plant. This plant, like the two species of *Indigofera* used in Queensland, is a seasonal annual and highly ephemeral, being only available to larvae during and shortly after the wet season.

## ACKNOWLEDGEMENTS

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# New silverfish species (*Zygentoma*: *Lepismatidae*) from Barrow Island

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**ABSTRACT** – Three new species of the subfamily Ctenolepismatinae (*Qantelsella maculosa* sp. nov., *Q. aurantia* sp. nov. and *Acrotelsella transpectinata* sp. nov.) and one of the subfamily Lepismatinae (*Xenolepisma perexiguum* sp. nov.) are described from Barrow Island. Keys are provided for the described species of *Qantelsella* Smith and *Xenolepisma* Mendes.

**KEYWORDS:** Thysanura, taxonomy, new species

## INTRODUCTION

Smith (2013) reported on the diverse silverfish fauna of Barrow Island, collected by a team from Curtin University (Callan et al. 2011), in which he described just one of the species recorded (*Heterolepisma parva*). This paper describes a further four species, leaving most of the remaining Barrow Island *Acrotelsella* Silvestri, 1935 species undescribed until a wider revision of this large genus is possible.

## SPECIMEN SELECTION AND PREPARATION

Silverfish were collected by Callan et al. 2011, from various locations on Barrow Island, mostly using pitfall traps, Winkler sack sampling of litter, suction sampling of low vegetation and some limited hand-sampling. For details of collection sites and collection methods see Callan et al. (2011). Where many examples of a morphospecies were available, a type series was selected from a few tubes containing mostly larger individuals. All specimens were initially stored in 100% ethanol and later transferred to 75–80% ethanol. All locality grid coordinates are quoted using the datum WGS84 (50).

Measurement data of whole specimens in alcohol and their dissection used the methods described in Smith (2013). The numbers of specimens measured varied with species ranging from just one to 25 depending on availability. Where available, at least one male and one female specimen of the selected type series (always including the holotype) were dissected and each mounted onto two microscope slides (one slide with head and thorax, the other with the abdomen). Types are deposited with the Western Australian Museum, 49 Kew Street, Welshpool, Western Australia 6106. Where sufficient material is available, representative specimens

are also deposited with the Australian Museum, 6 College Street, Sydney, New South Wales 2010 (indicated under material examined for each species) while the remainder of the material will be sent to the Entomology Branch of the Department of Agriculture and Food, Western Australia, 3 Baron-Hay Court, South Perth 6151, Western Australia.

Specimens used for scanning electron microscopy were put through an ethanol dehydration series then critical point dried using a Leica EMCPD300. They were mounted on a pin or on a double-sided carbon tab stub and gold sputter-coated using an Emitech K550 Gold Sputter-coater. Specimens were imaged using the Zeiss EVO LS15 SEM with a Robinson backscatter detector.

Roman numerals are used to indicate abdominal segment number. In addition the following abbreviations are used: AMS: Australian Museum, Sydney; HW: head width (in millimetres); H+B: head and body length (in millimetres); L/W: length to width (ratio); PI, PII, PIII: legs of prothorax, mesothorax and metathorax respectively; PIT: pitfall trap; SEM: scanning electron microscope; SUC: suction sample; WAM: Western Australian Museum; WSC: Winkler sack sample. The term macrochaetae refers to the larger stronger bristles (mostly pectinate in the Ctenolepismatinae and smooth but apically bifurcate in the Lepismatinae), setae refers to smaller thinner bristles (mostly simple), setulae to the very small, usually straight, setae associated with the combs and cilia to the curly thin hairs, often associated with the combs, setal collar or notal margins. Prosternum, mesosternum and metasternum are used for the sterna of the pro-, meso- and metathoracic segments.

In previous publications this author has used the term ‘articles’ for the ‘segments’ of the antennae, terminal filaments and ovipositor. There seems,

however, to be a general consensus among Zygentoma workers that the term article should only be used for articulated non-metameric ‘segments’ which have their own intrinsic musculature (e.g. legs, pedicel, scape, palps) and therefore not appropriate for the flagellum, cerci and ovipositor. The flagellum of the Zygentoma demonstrates both proximal and intercalary growth (Larink, 1986), resulting in a complex arrangement of divisions and annuli each with its own setae and sensillae. In this paper, the term *annulus* will be used for each single unit, usually a widened region carrying a single rosette of setae (but occasionally with a smaller secondary rosette). An annulus may or may not be separated from the adjacent annuli by distinct sutures. Basal annuli are usually simple with a single rosette of setae and distinct trichobothria. More distally these annuli become longer and soon divide into two annuli, each with its own rosette of setae but the trichobothria are only found in the distal annulus. Adel (1984) referred to an annulus with trichobothria as a ‘T-Glied’ and Molero-Baltanás et al. (2000) as a ‘T-joint’. Further divisions usually appear more distally, with three, four or more annuli, again with the trichobothria (-um) only in the most distal annulus. The group of annuli between the T-Glieder (including the distal T-Glied) has been referred to as an ‘Intervall’ (Adel, 1984), ‘periodic unit’ (Molero-Baltanás et al. 2000) or simply ‘division’ (e.g. Mendes 2012) although the term T-interval has also been used in correspondence. The terms *interval* and *T-annulus* will be used in this paper to indicate these periodic units and their distal annulus, recognising that in species of *Qantelsella* Smith, 2015 the trichobothria seem to have been replaced by alternate sensillae on the ultimate annulus in the more distal parts of the antennae. An interval may consist of just a single annulus in the basal part of the antennae or of several annuli in the distal regions. The first subdivision of the basal annuli or intervals generally show a much more distinct suture than seen with subsequent subdivisions, resulting in the interval consisting of two parts, each with one to several annuli. Molero-Baltanás et al. (2000) called each of the resulting two sections of annuli ‘chains’ and this has been followed by Mendes (2012). For the terminal filaments and ovipositor, the term *division* will be used for each ‘segment’ defined by a visible suture, albeit often faint.

## SYSTEMATICS

### Family Lepismatidae Latreille 1802

Lepismenae Latreille, 1802: 70 pro parte.

Lepismatidae Burmeister, 1838: 452 pro parte.

### Subfamily Ctenolepismatinae Mendes 1991

Ctenolepismatinae Mendes, 1991: 11.

### *Qantelsella* Smith, 2015

*Qantelsella* Smith, 2015: 68.

#### TYPE SPECIES

*Qantelsella louisae* Smith, 2015: 68, by original designation.

#### *Qantelsella maculosa* sp. nov.

urn:lsid:zoobank.org:act:4AACB02A-ECC5-4755-B9EC-B2AAF5D93989

Figures 1–55

#### MATERIAL EXAMINED

##### *Holotype*

**Australia: Western Australia:** ♀ (HW 1.00), Barrow Island, site GP2 (339462, 7699669), 15 March 2006, S. Callan, R. Graham, PIT (WAM E88546) on two slides.

##### *Paratypes*

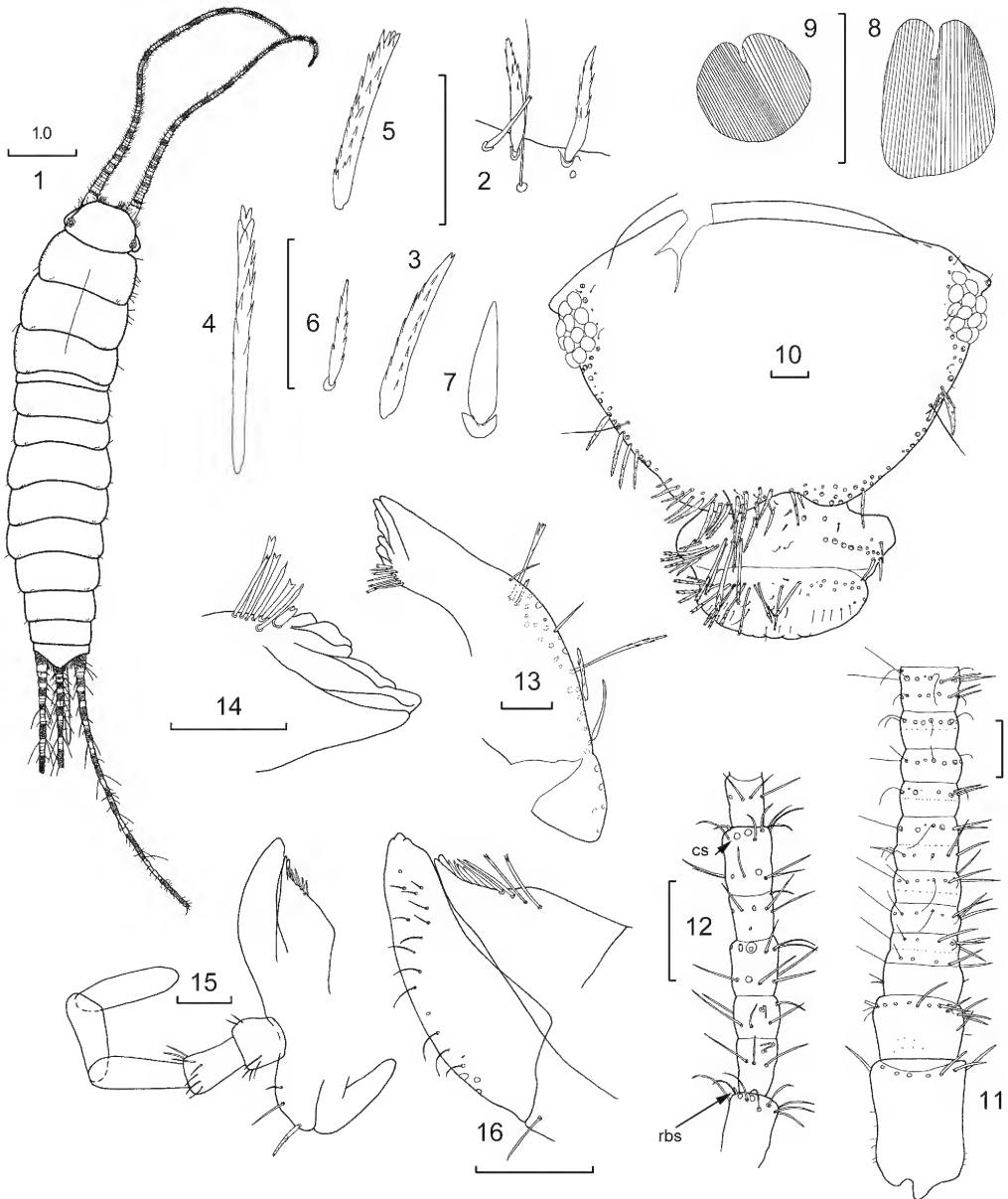
**Australia: Western Australia:** juvenile ♀ (HW 0.78), Barrow Island, site CC2 (337659, 7697280), 15 March 2006, S. Callan, R. Graham, PIT (WAM E88547) in ethanol; juvenile ♀ (HW 0.78), same data as previous (WAM E88548) in ethanol; ♂ (HW 0.93), Barrow Island, site GPX (338920, 7699669), 25 September 2006, S. Callan, R. Graham, PIT (WAM E88549) on two slides; ♂ (HW 0.70), Barrow Island, site N27 (326266, 7691041), 6 May 2006, S. Callan, R. Graham, SUC (WAM E88550) in alcohol.

##### *Other material examined in detail but not included in types series:*

**Australia: Western Australia:** juvenile ♀ (HW 0.78), Barrow Island, site N10 (330643, 7696589), 1 May 2007, S. Callan, K. Edwards, SUC (AMS K261101, K261102) on two slides; juvenile (HW 0.44), same data as previous (WAM E89197); juvenile (HW 0.63) Barrow Island, site N10 (337659, 7697280), 1 May 2007, S. Callan, K. Edwards, WSC (AMS) used for scanning electron microscopy.

#### DIAGNOSIS

This species can easily be distinguished from the other known species of *Qantelsella* by the distinct projections of the frons over the base of the antennae, by presence of combs rather than groups of macrochaetae on the clypeus, by the very short trichobothria located very close to the margins of the nota and not associated with combs of macrochaetae, by the round and glabrous metasternum, by the lateral combs of the urotergites having only a single macrochaeta and by the absence of scales on the terminal filaments (see discussion on generic placement of this and the following species after the description of the next species).



FIGURES 1–16 *Qantelsella maculosa* sp. nov., holotype female (WAM E88546) unless otherwise noted by specimen number: 1, habitus; 2, lateral macrochaetae and thin seta of head (K261101); 3, macrochaeta from anterior margin of head; 4, macrochaeta from clypeus; 5, macrochaeta from anterior corner of prothorax (K261101); 6, macrochaeta from notal collar of prothorax; 7, smooth macrochaeta from apex of tibia; 8, scale from pronotum; 9, scale from metanotum (K261101); 10, head; 11, antenna, scape, pedicel and basal intervals/annuli of flagellum; 12, idem, most distal surviving interval showing rod-like basiconic sensilla (rbs) and circular sensilla (cs); 13, mandible; 14, idem, enlargement of distal end; 15, maxilla; 16, idem, enlargement of distal end of lacinia and galea. Scale bars = 0.1 mm unless otherwise indicated.

## DESCRIPTION

*Appearance:* Body fairly elongate with the thorax only slightly wider than abdominal segment 1, the following abdominal segments about the same width until the sixth and only narrowing slightly towards the posterior end (Figure 1). Appearance when live unknown; in alcohol mottled brown with very distinct, darkly pigmented banding on the terminal filaments and antennae and dark patches on the legs. Dorsally covered with brown scales.

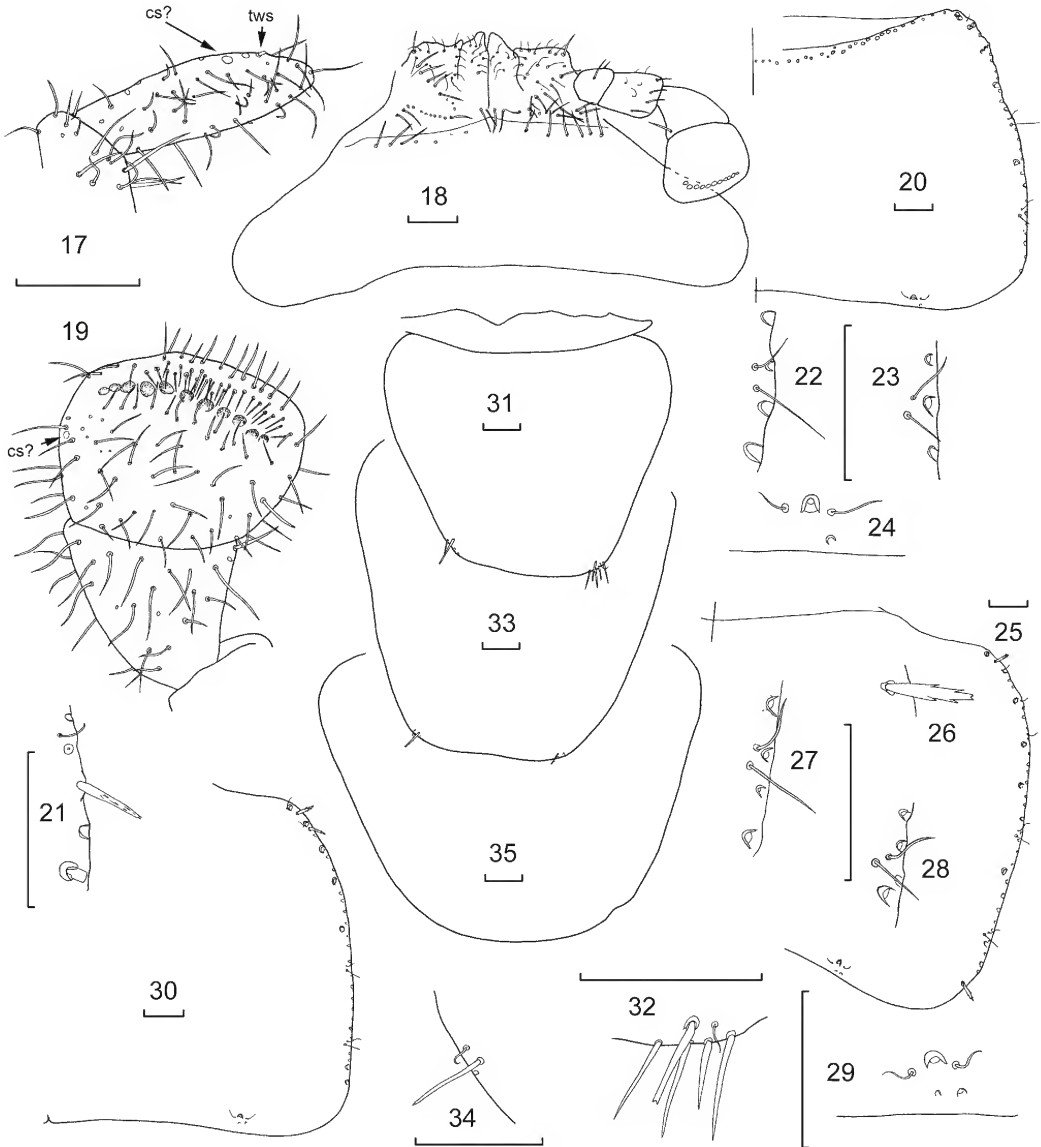
*Body size:* H+B up to about 6.5 mm (♀) (an estimation as abdomen somewhat distended in largest specimen and measured at 7.13 mm), 4.6 mm (♂); maximum head width 1.00 mm; thorax: length up to 1.68 mm or 0.31 times H+B (range 0.24–0.38); width up to 1.43 mm being widest at the meso or metathorax, all nota about the same length; antennae probably incomplete in all specimens, maximum surviving length of antenna 4.75 mm or 0.73 times estimated H+B; terminal filaments quite long although broken in most specimens, maximum surviving length of cercus 5.2 mm or when complete 0.80–0.98 H+B; maximum length of intact median appendage 4.38 mm (1–1.2 H+B).

*Pigmentation:* Often quite dark, especially on older larger specimens. Head without strong pigmentation dorsally but clypeus and labrum distinctly pigmented in larger specimens. Pedicel and scape with pigment; flagellum with bands of dark pigment from about the seventh interval with light and dark bands of approximately equal length, both becoming progressively longer distally. Mandibles with light pigment on outer face. Maxillae with pigment on outer face of stipes, basal article of maxillary palp fairly dark; second, third and penultimate articles with dark patches at each end but little in their midsections; ultimate article with very light pigmentation. Labium with well pigmented glossae; ultimate article of labial palp pigmented along outer margin as well as on the most mediad margin. Legs with very strong pigmentation in some areas, notably along the outer margin of the coxae diminishing in intensity across the ventral face to about the middle, on the outer margin of the trochanter especially basally, on the femur along the posterior margin and adjacent to the tibia, on both ends of the tibia, apically on the basal article of the tarsus and somewhat lighter on the last tarsal article. Coxite VIII lightly pigmented around the stylet insertion, coxite IX also pigmented around the insertion but also over the face of the inner process. Stylets with strong pigmentation at each end but very little in the middle. Ovipositor showing slight pigmentation at the distal end of each division making it comparatively easy to discern the pseudosegmentation. Terminal filaments strongly banded, basally the dark and light bands are short and similar in length but both become progressively longer, however by the distal end the dark sections are much longer than the light sections.

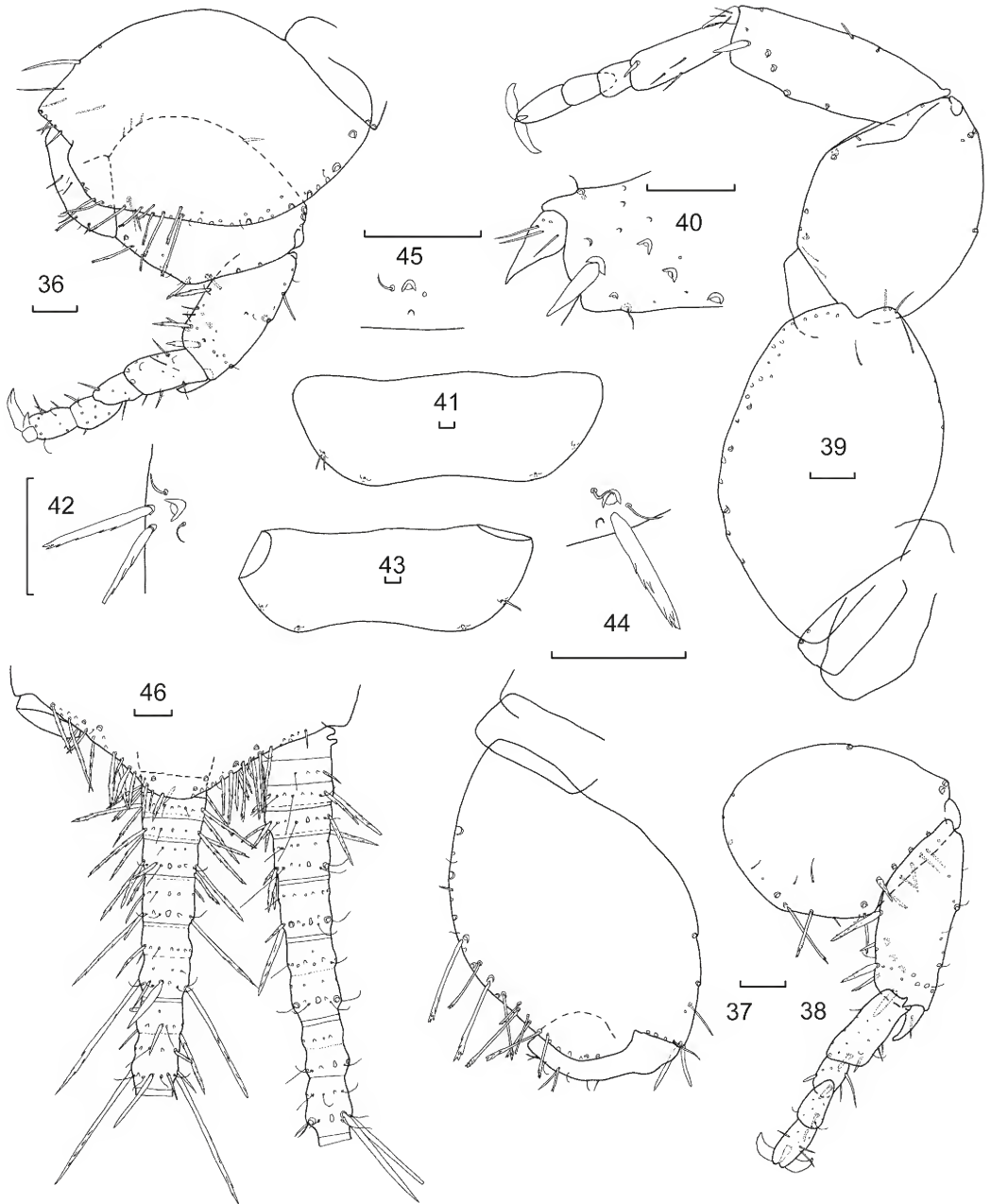
*Macrochaetae:* Very light brown to hyaline and of variable form (Figures 2–7).

*Scales:* With sub-parallel ribs not very close together (Figures 8, 9); darker dorsal scales with brown ribs that do not surpass the edge of the scales, ventral scales similar but hyaline, shape of scales generally round. Scales found on top of head, on scape, all nota, all thoracic sterna, legs except for tarsi, all urotergites and urosternites and stylets IX; absent from stylet VIII (?) and from the terminal filaments.

*Head:* Wider than long (Figure 10). Anterior margin of frons projected forward into distinct ridges over clypeus and bases of antennae. Margins of head laterally and anteriorly with stout setae not forming dense bushes, setae behind antennae accompanied by a long thin submarginal seta (Figure 2), a few stout setae before and one or two at the back of the eye. Clypeus with 1+1 combs of long, pectinate macrochaetae as well as 3+3 stout macrochaetae proximal and medial to these, as well as 2+2 stout macrochaetae on the margins lateral and distal to the combs. Labrum with 1+1 elongate groups of widely spaced, longer, pectinate macrochaetae as well as some simple setulae and cilia. Eyes dark brown of 12 ommatidia. Antennae incomplete in all specimens but fairly long, reaching about three quarters H+B. Scape (Figure 11) with scales over surface and short robust simple setae apically, pedicel with scales, some small setulae basally and a subapical rosette of simple setae, first interval or annulus of the flagellum with a few setulae and a tiny apical trichobothrium, second interval with two rosettes of setae and trichobothria and the first indication of subdivision, subsequent intervals subdivided into two annuli or chains with a hint of further subdivision, each annulus with one or two rosettes of setae and trichobothria in the T-annulus, tiny circular sensillae visible from the eighth interval. Most apical surviving intervals (Figure 12) without obvious trichobothria, forming intervals of five annuli, with pigment in the distal four annuli of every alternate interval. Basal and second annuli of each interval with a rosette of setae and sometimes a cilium, third annulus with basal rosette of setae and a more distal rosette with setae, cilia and some circular sensillae, fourth annulus with rosette of setae, fifth and ultimate annulus with two rosettes, the more basal of setae only, the more distal with at least two circular sensillae, at least one rod-like basiconic sensillae and several cilia. This patterns need to be confirmed with more specimens and preferably using SEM Mandibles (Figures 13, 14) with molar and large incisor areas; a group of about eight apically bifurcated but simple setae distally adjacent to the molar area, the most distal being very short and stout, and a bush of about 30 macrochaetae externally. Maxilla (Figures 15–17) with one stout pectinate macrochaeta, one smooth macrochaeta and a small seta externally proximal to the palp, the lacinia with two teeth, followed by about four lamellate processes and a row of four, apically bifurcate setae, galea surpassing the apex of the lacinia; palp without strong setae although a rosette of slightly



FIGURES 17–35 *Qantelsella maculosa* sp. nov., holotype female (WAM E88546) unless otherwise noted by specimen number: 17, maxilla, ultimate article of palp showing possible circular sensilla (cs?) and thin-walled basiconic sensilla (tws); 18, labium, one palp missing; 19, idem, ultimate article of palp, showing possible circular sensilla (cs?); 20, pronotum, right half; 21, idem, macrochaeta on lateral margin (K261101); 22, idem, anterior trichobothrial area; 23, idem, posterior trichobothrial area; 24, idem, posterior comb; 25, mesonotum, right side; 26, idem, macrochaeta from posterolateral corner; 27, idem, anterior trichobothrial area; 28, idem, posterior trichobothrial area; 29, idem, right posterior comb; 30, metanotum; 31, prosternum; 32, idem, posterolateral chaetotaxy; 33, mesosternum; 34, idem, posterolateral chaetotaxy; 35, metasternum. All scale bars = 0.1 mm.



FIGURES 36–46 *Qantelsella maculosa* sp. nov., holotype female (WAM E88546) unless otherwise noted by specimen number: 36, PI; 37, PII, coxa and trochanter; 38, PII, femur, tibia and tarsi; 39, PIII (WAM E88549); 40, idem, end of tibia; 41, urotergite V; 42, idem, marginal setae of left lateral comb; 43, urotergite VI; 44, idem, macrochaeta of right lateral comb; 45, submedial comb of urotergite IV; 46, urotergite X and base of terminal filaments. All scale bars = 0.1 mm.

stronger setae near the apex of the second article, apical article of maxillary palp (Figure 17) 2.2 times longer than wide (range 1.6–3.0) and 1.3 times longer than penultimate article (range 1.2–1.4), the sensillae of the ultimate article ambiguous, possibly one thin-walled basiconic sensilla (type C of Adel, 1984) subapically and some small rod-like basiconic sensillae (type B of Adel, 1984) near it and possibly a small circular sensilla. Labium (Figure 18) short and broad with rows of short strong setae on the prementum, glossae and paraglossae broad with transverse and oblique rows of setae, apically with short curved setulae; labial palp short, apical article expanded medially (Figure 19), 0.85 times longer than wide (range 0.77–0.96) with row of 11 or 12 papillae of compact type arranged in a single row, possibly with small circular sensilla on the outer margin, covered with numerous fine short setae as well as longer fine setae on along the distal end.

*Thorax:* Pronotum (Figure 20) with single row of macrochaetae forming notal collar (all macrochaetae lost except for the most lateral on both the dissected holotype and paratype, where it is short and pectinate (Figure 6); lateral margins with a few small stout pectinate setae, three combs of two (sometimes only one) macrochaetae (most lost except most anterior one on paratype which is long and quite pectinate similar to that illustrated in figure 3 from anterior margin of frons) and one macrochaeta on margin of paratype in the anterior quarter with another two single submarginal macrochaetae in the next half of the margin but otherwise only marginal setae (Figure 21). Two very small open trichobothrial areas; the anterior area (Figure 22) is about almost half the way along the margin with the trichobothrium almost on the margin and only associated with a cilium (no macrochaeta). Posterior trichobothrial area (Figure 23) located about three quarters the distance along the margin and similarly inconspicuous, almost on the margin and not associated with a macrochaeta; the hairs of both trichobothria are very short (not more than twice the length of the adjacent cilia). Posterior margin with 1+1 single macrochaetae each associated with one or two submarginal setulae and a cilium on each side (Figure 24). Mesonotum (Figure 25) with lateral and posterior chaetotaxy similar to pronotum with five or six single submarginal macrochaetae (but not forming combs of two) along the anterior two thirds of the margins; marginal setae mostly lost except most posterior (Figure 26). Both trichobothrial areas similar to those on the pronotum i.e. very tiny trichobothria, close to the margin and associated with a similar sized cilium; the anterior trichobothrial area (Figure 27) located about halfway along the lateral margin and the posterior trichobothrial area (Figure 28) about three quarters the distance along the margin. Posterior margin with 1+1 combs (Figure 29) each consisting of a single macrochaeta with a cilium on each side and one to three setulae between

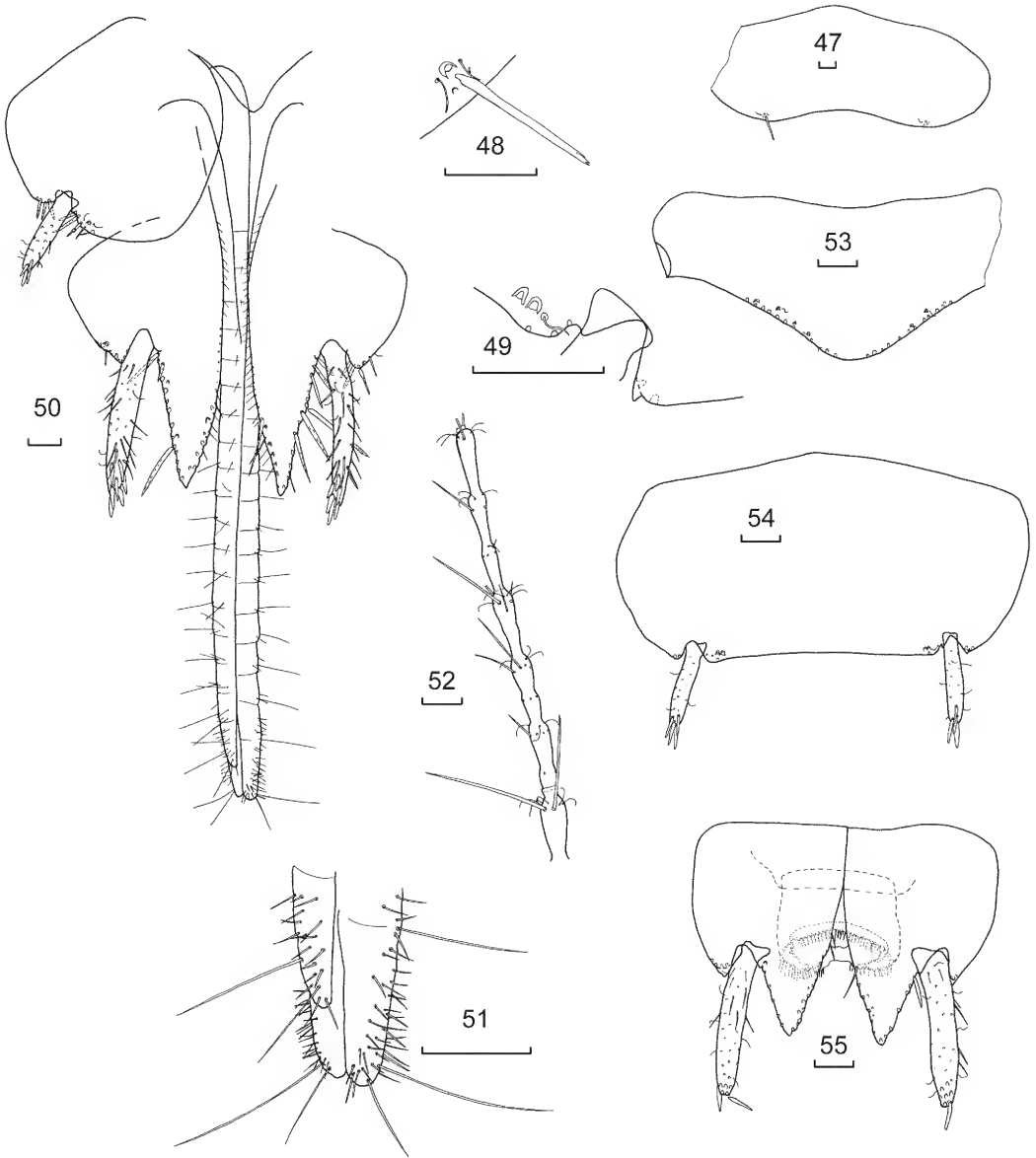
the macrochaeta and the margin. Metanotum (Figs 30) similar to mesonotum.

Presternum narrow and glabrous (Figure 31). All thoracic sterna with hyaline scales. Prosternum (Figure 31) large rounded trapezoidal, almost as long as the corresponding coxa, slightly wider at its base than long, anterolateral corners glabrous, posterior-lateral corners with 1+1 single submarginal pectinate macrochaetae, three or four fine simple marginal setae and a cilium (Figure 32). Mesosternum (Figure 33) also rounded trapezoidal, as long as the corresponding coxa, as long as wide at its base, each posterior corner with a small submarginal pectinate seta and perhaps a cilium and a couple of marginal setulae (Figure 34). Metasternum (Figure 35) with round posterior margin, not strongly trapezoidal, about 1.2 times wider than long, glabrous.

Legs quite widely spaced and quite stout, tibia L/W ratio of legs PI 2.0 (range 1.91–2.08), PII 2.2 (2.0–2.33), PIII 2.7 (2.25–3.17); tarsi L/W ratio PI 4.3 (range 3.69–5.43), PII 4.4 (3.29–5.56), PIII 5.2 (4.0–6.0). PI (Figure 36) with lateral comb of two macrochaetae on precoxa. Coxa with scales, external margin with longer and shorter pectinate macrochaetae and some cilia, some simple stout setae in the more distal part, internal margin with some simple setae distally and over the articulation with the trochanter, a few fine setae on ventral face. Trochanter with one short thin pectinate macrochaeta and some fine setulae. Femur with scales both ventrally and dorsally, posterior margin with several pectinate macrochaetae, anterior margin with one seta medially and two stronger macrochaetae distally (only insertion sockets remaining). Tibia of PI with some stout pectinate macrochaetae on the ventral margin, especially distally and also midway along the dorsal margin as illustrated; apex of tibia with a stout pectinate macrochaeta which is shorter than the glabrous apical spur. Tarsi with four articles, the basal article of PI about 40% of the total length of the tarsus, its joint with the next article not as oblique as that between the second and third articles, all tarsal articles with some short setae, of which some ventrally are more robust with slightly rounded tips, as well as some cilia. Pretarsus with two long curved lateral claws and a much shorter curved medial claw. PII (Figures 37, 38) and PIII (Figures 39) similar to PI; with PII only slightly longer than PI, but PIII noticeably longer. Apical spur of tibia with one or two setae on PII and about four or five on PIII (Figure 40).

*Abdomen:* Urotergite I with 1+1 lateral combs of a single macrochaeta with a cilium on each side and two setulae on or near the margin. The macrochaetae have been lost from all segments, however one short, fairly robust pectinate macrochaeta from the right lateral comb on urotergite VI of the holotype is aligned in a way that suggests it came from the macrochaeta socket. Urotergites II–VIII (Figures 41–45) with 2+2 combs each of a single macrochaeta (mostly lost but those on V are fairly robust and pectinate); all combs also





FIGURES 47–48, 51–52 *Qantelsella maculosa* sp. nov., holotype female (WAM E88546).

FIGURES 49–50, 53–55 *Qantelsella maculosa* sp. nov., paratype male (WAM E88549): 47, urosternite V(?); 48, idem, right comb; 49, urosternite VIII, left stylet insertion; 50, urosternites VIII, IX, stylets and ovipositor; 51, ovipositor, detail of apical divisions; 52, cerci, most distal surviving divisions; 53, urotergite X of male; 54, urosternite VIII of male and stylets; 55, coxites IX of male, penis and stylets. All scale bars = 0.1 mm.

TABLE 1 Number of macrochaetae per bristlecomb — *Qantelsella maculosa* sp. nov.

Segment	Urotergite		Urosternite
	Lateral	Submedial	
I	1	0	0
II	1	1	0
III	0-1	1	1
IV	1	1	1
V	1	1	1
VI	1	1	1
VII	1	1	1-2
VIII	1	1	2
IX	0	0	0

associated with 0-3 marginal setae and a cilium on one or either side of the macrochaeta (Figures 42, 44, 45). The macrochaeta insertion is missing from the lateral comb of urotergite III of the holotype but the cilia and setae insertions are present. Urotergite IX glabrous. Urotergite X (Figure 46) short rounded subtriangular, much wider than long (L/W at base about 0.30) with many strongly pectinate setae along entire margin, both above and below, with 3+3 submarginal macrochaetae (all lost and only visible from insertion sockets).

Urosternites I and II glabrous, urosternites III-VIII with 1+1 lateral combs each of just a single macrochaeta with a cilium on each side and one or two submarginal setae (all lost), most macrochaetae lost except one on urosternite V(?) and one on VII(?) both of which are apically pectinate and about one quarter as long as the respective urosternites (Figures 47, 48). On the male paratype, one of the combs on urosternite VII(?) and both combs on urosternite VIII are composed of two macrochaetae, two cilia and one or two submarginal setae. The combs on urosternite VIII are mediad to the stylet insertion (Figure 49); urosternite VIII with four or five pectinate setae on the margins on both sides adjacent to the stylets.

Two pair of stylets present in both sexes (Figures 50, 54, 55); those on VIII about half as long as those on IX, with four (?) stout, darker, rounded macrochaetae apically. Stylets IX with six or seven, similar macrochaetae; these stylets are only slightly longer than the internal processes.

Genital region of ♀ as in figure 50, the internal process of coxite IX fairly long, twice as long as wide at its base and about four times longer than the short external process. Apex of internal process acute with slightly pectinate macrochaetae along much of the margins. Ovipositor of medium length (up to 2.0 times HW), in holotype surpassing the apex of the inner

processes by about twice the length of these processes, consisting of about 20 divisions; of primary type with numerous short and two very long, thin setae on the last division of the gonapophyses (Figure 51).

Cerci (Figs 46, 52) with four basal divisions shorter than wide then progressively longer with setae, pectinate macrochaetae and trichobothria becoming increasingly stronger and longer distally, fifth division showing first signs of subdivision with two rosettes, distinctly subdivided by seventh division which also shows signs of further subdivision with a nascent second rosette present in each annulus; macrochaetae progressively becoming less pectinate distally; most distal surviving division (14<sup>th</sup>) divided into eight annuli (Figure 52). Median dorsal appendage (Figure 46), first division glabrous, next division with pectinate setae, following divisions also short with pectinate setae and trichobothria in increasing numbers as well as long pectinate macrochaetae laterally and below, fifth division longer with second rosette of very small setae and trichobothria, sixth division as long as wide, seventh division indistinctly divided into two annuli, the distal dorsal macrochaeta being noticeably darker, broader and smoother than the others, further divisions becoming increasingly longer and the macrochaetae becoming much less pectinate. Divisions beyond the tenth lost in holotype.

*Male:* Similar to female except urotergite X (Figure 53) slightly shorter (L/W 0.25) and only 1+1 macrochaetae obvious (possibly due to smaller size of specimen), coxites VIII not divided (Figure 54), internal process of coxites IX not as elongated, about 2.6 times longer than the external process but slightly longer than broad at its base, only a little longer than half the length of the stylets; external and internal margins of internal process with macrochaetae (presumably all stout and not pectinate based on the small number of surviving setae). Outer process small, triangular with a few setae on the hidden upper side of its apex. Penis typical with numerous glandular setae apically (Figure 55). Parameres absent.

#### ETYMOLOGY

The species is named from the Latin word *maculosus* meaning mottled or stained, referring to the appearance of the scales in alcohol as well as the very dark pigment patches on the legs.

#### HABITAT

Only nine specimens of this species from six different sites were found among the extensive Barrow Island material. These were collected in both natural and disturbed habitats, including limestone flats and low ridges and coastal dunes. They were taken in pitfall traps, in Winkler sack litter samples and one by suction sampling of vegetation, giving little indication of the preferred habitat of the species. The curved tarsi may suggest climbing on thin objects but this is purely conjecture.

***Qantelsella aurantia* sp. nov.**

<http://zoobank.org/NomenclaturalActs/F9E9E067-C24B-4179-89D9-B45CBB7206B2>

Figures 56–106

**MATERIAL EXAMINED*****Holotype***

**Australia: Western Australia:** ♂ (HW 0.71), Barrow Island, site GP7 (337722, 7699467), 15 March 2006, S. Callan, R. Graham, PIT (WAM E89198) on two slides.

***Paratypes***

**Australia: Western Australia:** ♀ (HW 0.75), same data as holotype (WAM E89199) on two slides; ♀ (HW0.70), same data as holotype (WAM E89200) in alcohol; ♀ (HW 0.70), Barrow Island, site CC1 (337391, 7697313), 25 September 2006, S. Callan, R. Graham, PIT (WAM E89201) on two slides; ♂ (HW 0.70), same data as previous (WAM E89202) in alcohol; ♂ (HW 0.68), same data as previous, 25 September 2006 (WAM E89203) in alcohol; ♂ (HW 0.73), same data as previous (WAM E89204) in alcohol; ♀ (HW 0.68), same data as previous (WAM E89205) in alcohol; ♀ (HW 0.70), same data as previous (WAM E89206) in alcohol; ♂ (HW 0.70), Barrow Island, site GP5 (338740, 7701088), 15 March 2006, S. Callan, R. Graham, PIT (WAM E89207) in ethanol; ♀ (HW 0.75), Barrow Island, site GP8 (337670, 7699230), 15 March 2006, S. Callan, R. Graham, PIT (WAM E89208) in alcohol; ♀ (HW 0.78), same data as previous (WAM E89209) in alcohol; juvenile ♂ (HW 0.58), same data as previous (WAM E89210) in alcohol.

***Other material examined in detail but not included in types series:***

**Australia: Western Australia:** juvenile ♂ (HW 0.58), Barrow Island, site N13 (332808, 7694467), 6 May 2006, S. Callan, R. Graham, PIT D (AMS K261096, K261097) on two slides; juvenile ♂ (HW 0.63), same data as previous (AMS K377615) in alcohol; subadult ♀ (HW 0.63), Barrow Island, site N15 (336732, 7698579), 1 May 2007, S. Callan, K. Edwards, PIT (AMS K377616) in alcohol; ♂ (HW 0.65), Barrow Island, site CC1 (337391, 7697313), 25 September 2006, S. Callan, R. Graham, PIT (AMS K377617) in alcohol; ♀ (HW 0.68), Barrow Island, site GTPZ1SUC5 (338419, 7699767), 19–30 March 2012, N. Gunawardene, C. Taylor (AMS K377618) in alcohol; ♂ (HW 0.60), Barrow Island, site N05b (334218, 7692088), 1 May 2007, S. Callan, K. Edwards, PIT (AMS) used for scanning electron microscopy.

**DIAGNOSIS**

This species can easily be distinguished from other species of *Qantelsella* by the presence of combs rather than groups of macrochaetae on the labrum, by its

reddish eyes (in alcohol), by the distinct tawny orange colouring of the macrochaetae and the more posterior abdominal segments, by the cordiform and rounded thoracic sterna and by the presence of only a single pair of stylets (see discussion on generic placement).

**DESCRIPTION**

**Appearance:** Body not elongate with thorax only slightly wider than abdominal segment I, the following abdominal segments about the same width until the sixth and only narrowing slightly towards the posterior end (Figure 56). Appearance when live unknown; in alcohol mottled brown or somewhat orange without distinct pigment markings; eyes reddish. Dorsally covered with brown scales.

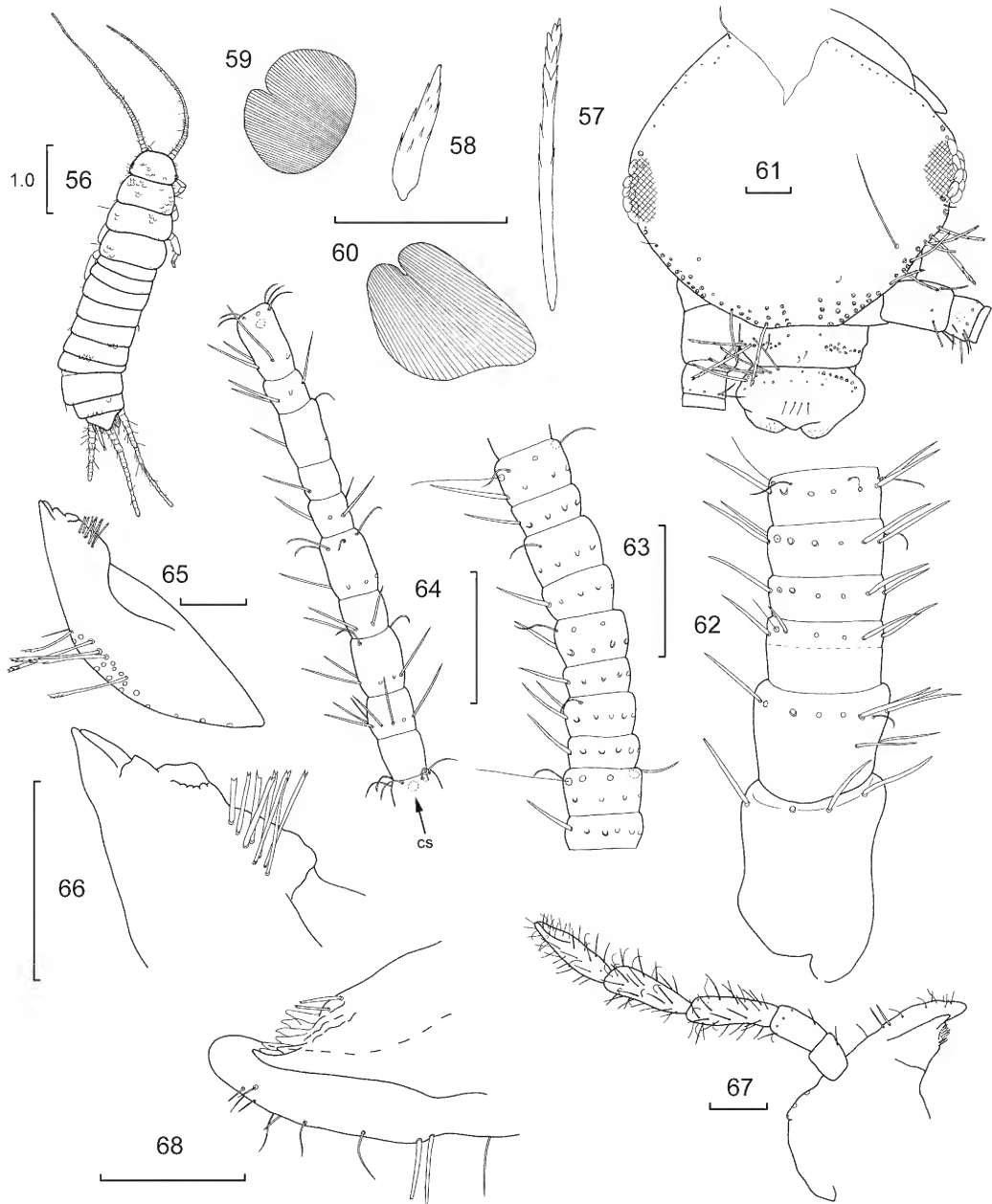
**Body size:** H+B length up to about 5.4 mm (♀), 4.0 mm (♂); maximum head width 0.78 mm; thorax: length up to 1.5 mm or 0.29 times H+B (range 0.24–0.33); width up to 1.05 mm with no great difference in the relative width of the nota, meso and metanota only slightly shorter than the pronotum; antennae probably incomplete in all specimens, maximum surviving length of antenna 3.5 mm or 0.65 times estimated H+B; terminal filaments quite long, maximum surviving length of cercus 2.25 mm or 0.70 H+B; maximum length of intact median appendage 2.30 mm (up to 0.72 H+B).

**Pigmentation:** Orange-brown. Head without distinct pigmentation. Pedicel and scape with pigment; flagellum evenly brown. Mandibles with light pigment on outer face. Maxillary palp overall, slightly orange, with more pigment in the penultimate and ultimate articles. Labium with weak bands of pigment at sides of prementum; ultimate article of labial palp slightly pigmented. Legs with pigmentation, notably distally on the outer margin of the femur and most strongly on the tibia and on the basal article of the tarsus. Coxite IX pigmented or sclerotised, somewhat orange in colour, with its stylet distinctly lighter in colour. Ovipositor slightly orange overall. Terminal filaments evenly brown.

**Macrochaetae:** Very orange-brown to hyaline, of variable form (Figures 57, 58).

**Scales:** (Figures 59, 60) of variable shape with sub-parallel brown ribs that do not surpass the edge of the scales, ventral scales similar. Scales found on top of head, on scape, mandibles, all nota, all thoracic sterna, legs except for tarsi, all urotergites and urosternites and stylets IX and a few appear to be present basally on the terminal filaments (?).

**Head:** Wider than long (Figure 61). Anterior margin of frons not projected forward into distinct ridge over clypeus and bases of antennae. Lateral margins of head behind antennae with rows of stout pectinate macrochaetae and a long thin seta (trichobothria?) a little remote from the margin; two macrochaetae posterior to the eyes, anterior margin of head with 1+1 weak bushes with some setae aligned in rows two to



FIGURES 56–68 *Cantelsella aurantia* sp. nov., holotype male (WAM E89198) unless otherwise noted by specimen number: 56, habitus composite drawing, head and body of WAM E89206, antennae of WAM E89201; 57, macrochaeta from clypeus; 58, macrochaeta from tibia of PI; 59, scale from middle of pronotum; 60, scale from posterior margin of urosternite VIII; 61, head (cross-hatched areas obscured by eye pigment); 62, antenna, scape, pedicel and basal intervals of flagellum (WAM E89201); 63, idem, section of antenna at about one third the length of the antenna (WAM E89201); 64, idem, most distal surviving interval showing possible circular sensilla (cs) on opposite side of antenna (WAM E89201); 65, mandible; 66, idem, distal end; 67, maxilla; 68, idem, distal end of lacinia and galea. Scale bars = 0.1 mm unless otherwise indicated.

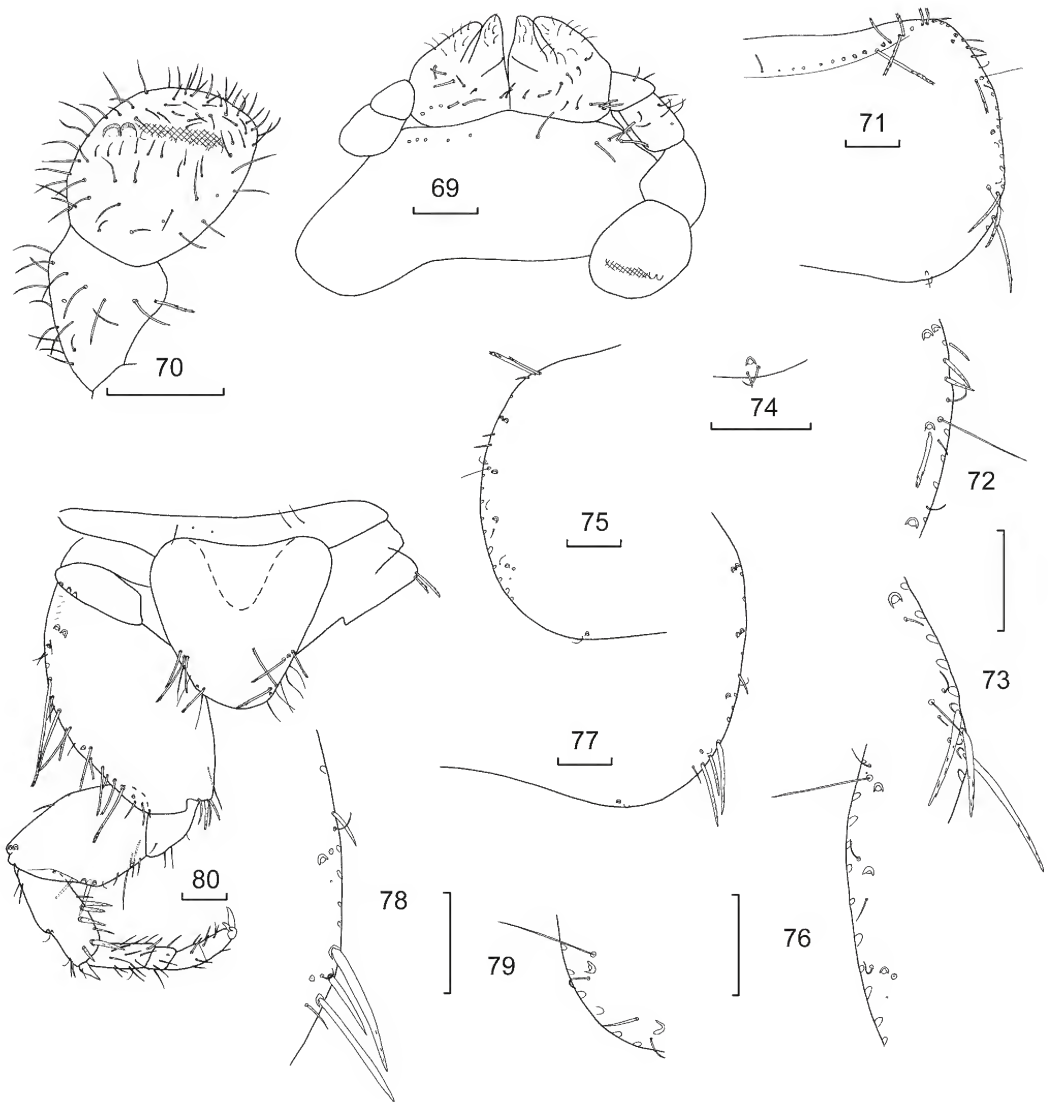
four macrochaetae long. Clypeus with 1+1 irregular bushes of long pectinate macrochaetae. Labrum with 1+1 combs of long pectinate macrochaetae as well as some simple setulae anteriorly. Eyes reddish in alcohol, of about 12 ommatidia. Antennae incomplete in all specimens but fairly long, reaching about two thirds H+B. Scape (Figure 62) with scales over surface and short robust simple setae apically, pedicel without scales, with a subapical rosette of simple setae and cilia as well as some thinner setae proximally, first interval of flagellum indistinctly subdivided with a rosette of setae and a trichobothrium subapically, following intervals similar but becoming gradually longer, and with more cilia; intervals divide into two annuli by presumed fifth interval and five annuli by the presumed seventh interval, then six and finally eight annuli (Figure 63). The trichobothria are no longer visible beyond the basal third of the flagellum. Specialised sensillae could not be observed under the light microscope but both circular (poculiform?) and rod-like basiconic sensillae were present (Figures 64, 105 and 106); the specimen needs to be correctly aligned if they are to be seen. Mandibles (Figures 65, 66) with molar and large incisor areas; a group of four to eight apically bifurcated but smooth setae distally adjacent to the molar area and a bush of about 30 pectinate macrochaetae externally. Maxilla (Figures 67, 68) with three long pectinate macrochaetae on stipes posterior to the scape, the lacinia with two teeth, followed by about six lamellate processes and two simple or apically bifurcate setae, galea surpassing the apex of the lacinia; palp without strong setae, apical article of maxillary palp 3.6 times longer than wide (range 2.8–4.75) and 1.3 times longer than penultimate article (range 1.11–1.46), the sensillae of the ultimate article ambiguous, possibly one circular sensilla and one or more small rod-like basiconic sensillae near the apex (?). Labium (Figure 69) with row of short strong setae on the prementum largely interrupted in the medial region, glossae and paraglossae with transverse and oblique rows of setae, apically with short curved setulae; apical article of labial palp not expanded medially (Figure 70), about as long as wide (range 0.84–1.25) covered with fine short setae as well as longer fine setae on along the distal end and with row of six to ten papillae (not clearly seen in most specimens) of compact type arranged in a single row; other sensillae not identified.

*Thorax:* Pronotum (Figure 71) with single row of macrochaetae forming notal collar, the macrochaetae in the medial region much shorter than those laterally; lateral margins with a few small stout weakly pectinate setae in the anterior two thirds, becoming longer and stronger towards the posterior corner, each margin with two anterior combs each of two pectinate macrochaetae followed by two single submarginal macrochaetae, the first associated with the anterior trichobothrium. Two open trichobothrial areas; the anterior area (Figure 72)

is about one quarter the way along the margin with the trichobothrium located between a macrochaeta and the margin. Posterior trichobothrial area (Figure 73) located about two thirds the distance along the margin with a macrochaeta located between the trichobothrium and the margin (absent on the right side in the holotype); the hairs of both trichobothria are not long, being much shorter than the longest marginal macrochaeta. Posterior margin with 1+1 single macrochaetae each associated with a cilium and sometimes a marginal setula (Figure 74), the macrochaeta insertion is missing on the left side in the holotype. Mesonotum (Figure 75) slightly longer than pronotum with lateral and posterior chaetotaxy similar to pronotum, each side with two anterior combs each of two pectinate macrochaetae and three submarginal single macrochaetae; marginal setae mostly lost but those remaining are short tapering and with almost indistinct pectinations. Anterior trichobothrial areas (Figure 76) about one third the way along the margin, with a short trichobothrium almost on the margin, laterad to a single macrochaeta. The posterior trichobothrial area located about three quarters the distance along the margin (Figure 76) with a macrochaeta and a cilium between the trichobothrium and the margin. Posterior margin with 1+1 combs similar to pronotum. Metanotum (Figure 77) slightly longer than mesonotum, with two combs each of two macrochaetae in the anterior half and only one submarginal macrochaeta in the posterior half, which is associated with the anterior trichobothrium (Figure 78). The posterior trichobothrial areas without a submarginal macrochaeta in holotype but one is present in paratype (WAM E89199) (compare Figures 78 and 79). Posterior margin as for pro- and mesonota.

Presternum narrow and with a few small setae (Figure 80). All thoracic sterna with hyaline scales. Prosternum (Figure 80) not large, parabolic, only a little more than half the length of the corresponding coxa, slightly wider at its base than long, anterolateral corners glabrous, posterior third with long thin marginal setae, 1+1 stronger setae near the apex and one to three short combs of one to three pectinate macrochaetae on each side (compare figures 81 and 82 of holotype and paratype). Mesosternum (Figure 83) slightly larger than prosternum but also parabolic and about as long as wide at its base, a little more than three quarters as long as the corresponding coxae, posterior apex with 1+1 subapical combs each of two or three pectinate macrochaetae and sometimes a longer smooth seta further apically (only present on right side in holotype and paratype WAM E89199) and one or two fine setae on the margin of each side (Figure 84). Metasternum (Figure 85) also wider than long and parabolic with 1+1 subapical combs each of two or three pectinate macrochaetae and two marginal setae near each comb (Figure 86).

Legs (Figures 80, 87, 88) quite stout, tibia L/W ratio of legs PI 2.4 (range 1.55–2.94), PII 2.6 (2.22–3.50),



FIGURES 69–80 *Qantelsella aurantia* sp. nov., holotype male (WAM E89198) unless otherwise noted by specimen number: 69, labium; 70, idem, ultimate article of palp; 71, pronotum, right half; 72, idem, anterior trichobothrial area; 73, idem, posterior trichobothrial area; 74, idem, posterior comb; 75, mesonotum, left half; 76, idem, part of left margin with both anterior and posterior trichobothrial areas; 77, metanotum, right half; 78, idem, posterior part of right margin with both anterior and posterior trichobothrial areas; 79, left posterior trichobothrial area of metanotum (WAM E89199); 80, presternum, prosternum and Pl. All scale bars = 0.1 mm.

PIII 2.9 (2.15–3.33); tarsi L/W ratio PI 4.6 (range 3.17–5.33), PII 5.0 (4.50–5.38), PIII 6.6 (5.14–8.0). PI (Figure 80) with lateral comb of two to three short macrochaetae on precoxa. Coxa with anterolateral comb of two macrochaetae and a row of long pectinate macrochaetae and some small setae along the outer margin, internal margin with some short stout pectinate macrochaetae distally over the articulation with the trochanter. Trochanter with a few simple setae. Femur with about six stout pectinate macrochaetae on posterior margin, anterior margin with one seta medially and two stronger macrochaetae distally (only insertion sockets remaining). Tibia of PI with some stout pectinate macrochaetae on the ventral margin and also midway along the dorsal margin as illustrated; apex of tibia with a stout pectinate macrochaeta which is longer than the apical spur. Tarsi with four articles, the basal article of PI about 40% of the total length of the tarsus, its joint with the next article about as oblique as that between the second and third articles, all tarsal articles with some short setae, some of which ventrally are more robust, as well as some cilia. Pretarsus (Figure 89) with two long curved lateral claws and a much shorter curved medial claw. PIII noticeably longer with stout pectinate macrochaeta at the end of the tibia about twice the length of the apical spur, first article of tarsus equal in length to the remaining three articles together. Apical spurs of tibiae of all legs usually with one seta (Figure 90).

*Abdomen:* Urotergite I with 1+1 lateral combs each of a single pectinate macrochaeta with one or two marginal setulae. The macrochaetae have been lost from all segments of the holotype except for one submedial on urotergite IV and a lateral on urotergite VI. Urotergites II–VIII (Figure 91) with 2+2 combs, the lateral combs consisting of only one macrochaeta in the anterior segments and two in the posterior segments (Figure 92), each lateral comb associated with one or two cilia and one or two marginal setulae; the submedial combs (Figure 93) with just a single macrochaeta associated with a laterad cilium and in one case a marginal setula. Urotergite IX glabrous. Urotergite X (Figure 94) short rounded subtriangular, about three times wider than long at base with many strongly pectinate setae along entire margin, both above and below, except for the apex, with 3+3 submarginal pectinate macrochaetae. In some specimens, especially smaller ones, urotergite X can be quite round, rather than rounded subtriangular, and sometimes even slightly truncated.

Urosternite I and II glabrous, urosternites III–VIII (Figure 95) each with 1+1 lateral combs of one to four macrochaetae with a cilium on the laterad end of each comb and one marginal seta. Most macrochaetae lost in holotype except for one macrochaeta of each comb of urosternite VII(?), where one is quite long (about one third the length of the respective urosternite) and distinctly pectinate and the other appears short and constricted apically (Figures 96, 97).

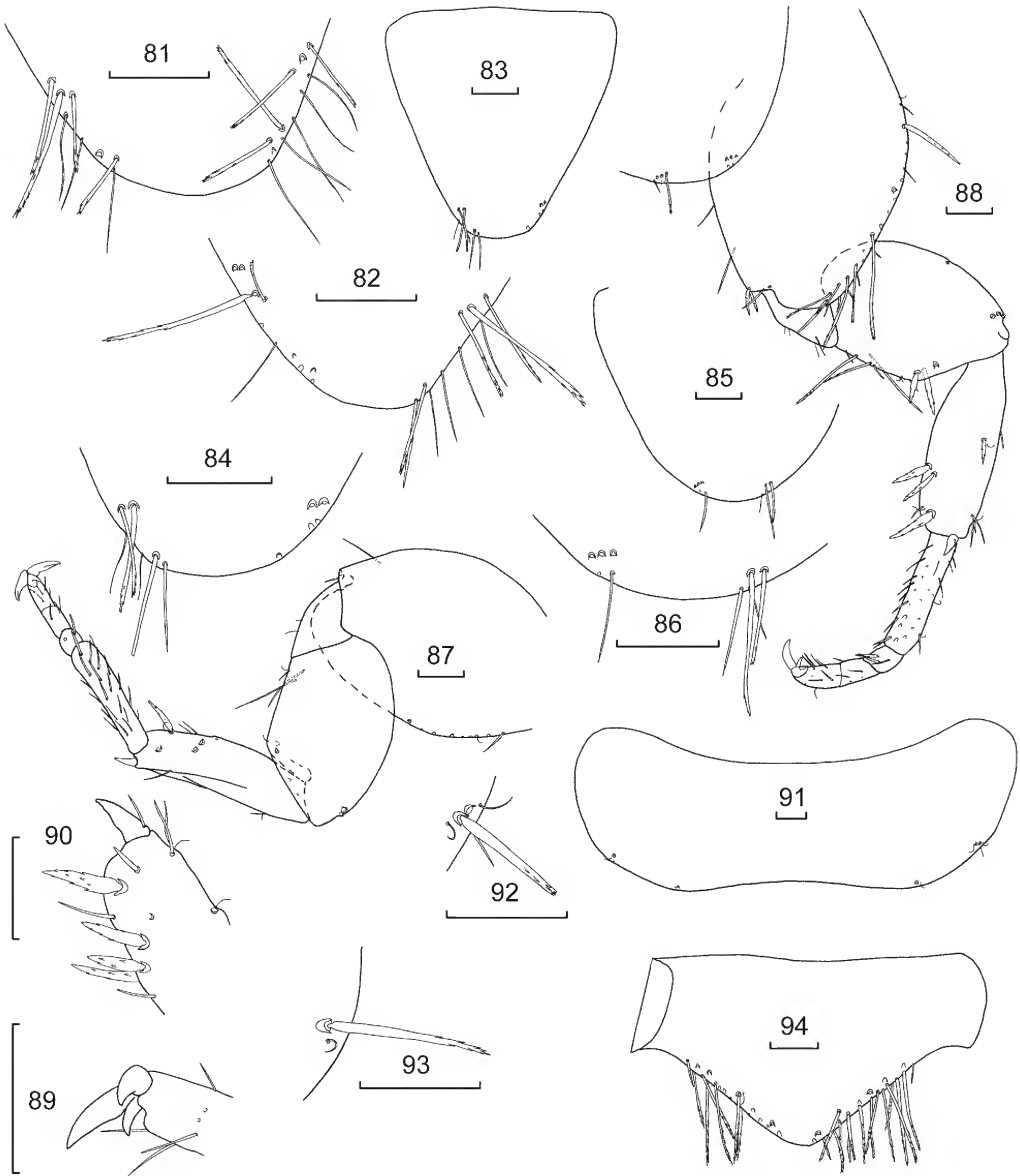
TABLE 2 Number of macrochaetae per bristlecomb — *Qantelsella aurantia* sp. nov.

Segment	Urotergite		Urosternite
	Lateral	Submedial	
I	1	0	0
II	1	1	0
III	1–2	1	3
IV	1	1	3–4
V	2	1	3–4
VI	2	1	1–4
VII	2	1	3–4
VIII	2	1	3–4
IX	0	0	0

Only one pair of stylets present in both sexes (Figure 98), being about twice the length of the inner process of coxite IX in the male. Stylets with about four smooth macrochaetae apically and more in along the ventral face.

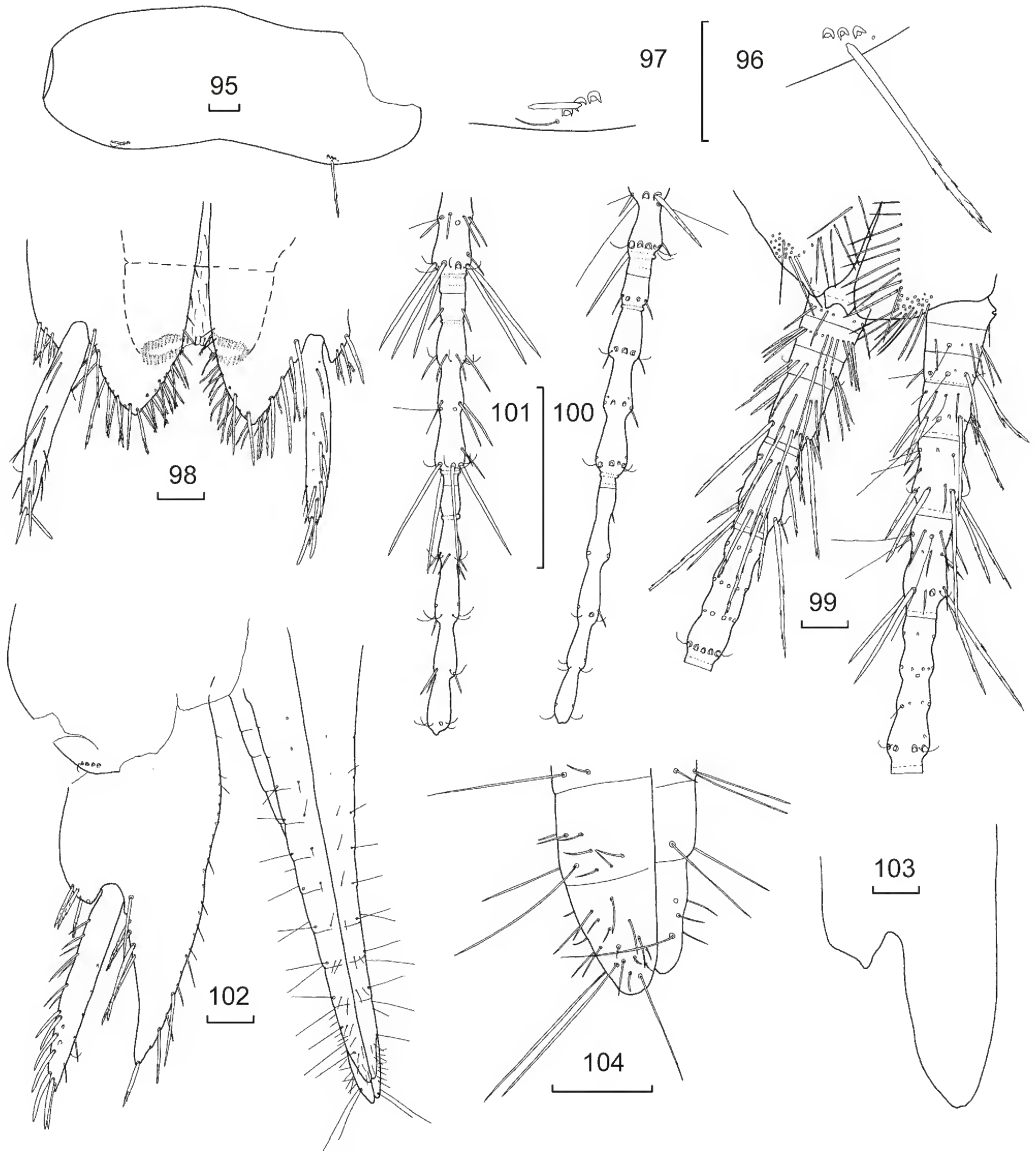
Male genital region (Figure 98), coxites VIII not divided, internal process of coxites IX about three times longer than the small external process but slightly shorter than broad at its base, about half the length of the stylets; external and internal margins of internal process with numerous macrochaetae with a submarginal row extending to the base of the stylet, the macrochaetae inserted on the dorsal side of the margin more pectinate than those inserted on the ventral face. Outer process small, triangular with a few short, stout pectinate macrochaetae above and below the outer margin. Penis typical for family with numerous glandular setae apically (Figure 98). Parameres absent.

Cerci (Figures 99, 100) with three basal divisions shorter than wide, basal division glabrous, second and third with single rosette of setae, pectinate macrochaetae, cilia and trichobothria, divisions then progressively longer. Division four with two rosettes, the proximal rosette with setae and trichobothria, the distal with setae, pectinate macrochaetae, cilia and trichobothria, fifth division similar but longer and lacking trichobothria in distal rosette, sixth division with two annuli and three rosettes, the proximal two with setae and trichobothria, the distal with macrochaetae cilia and setae. Division seven with four annuli. A few scales visible on basal four or five divisions. The macrochaetae become less pectinate distally. Most distal surviving division (ninth) (Figure 100) divided into five annuli without clear divisions between them. Median filament (Figures 99, 101) with first division short, glabrous, next three divisions also short but with single rosette of pectinate setae, fifth division longer than wide with two rosettes of pectinate macrochaetae, those distally much longer and also stronger with some



FIGURES 81–94 *Qantelsella aurantia* sp. nov., holotype male (WAM E89198) unless otherwise noted by specimen number: 81, prosternum, detail of chaetotaxy; 82, idem (WAM E89199); 83, mesosternum; 84, idem, detail of chaetotaxy; 85, metasternum; 86, idem, detail of chaetotaxy; 87, PII (WAM E89199); 88, PIII (WAM E89201); 89, pretarsus of PI; 90, apex of tibia of PI; 91, urotergite III; 92, lateral comb of urotergite VI; 93, submedial comb of urotergite IV; 94, urotergite X. All scale bars = 0.1 mm.





FIGURES 95–104 *Qantelsella aurantia* sp. nov., holotype male (WAM E89198) unless otherwise noted by specimen number: 95, urosternite VII; 96, idem, left lateral comb; 97, idem, right lateral comb; 98, coxites IX, stylets and penis; 99, base of terminal filaments; 100, cerci, most distal surviving divisions; 101, median filament, most distal surviving divisions; 102, coxites VIII and IX of ♀, stylet and ovipositor (WAM E89201); 103, right coxite IX of another paratype (WAM E89199); 104, apex of ovipositor (WAM E89199). All scale bars = 0.1 mm.

cilia, sixth division similar but longer, seventh division with four rosettes. Most distal surviving division (tenth) (Figure 101) subdivided into five indistinctly defined annuli. A raised ridge is present around the constriction above the macrochaetae in the most distal annulus and at the join between the basal and following annulus of the most distal divisions of both the cerci and median filament.

*Female*: Similar to male except genital region as in figure 102, the internal process of coxite IX fairly long, about twice as long as wide at its base and about six or seven times longer than the short external process, reaching to about three quarters of the stylet length. Apex of internal process acute on one paratype (WAM E89201) but more rounded in another (WAM E89199) (compare figures 102 and 103) with slightly pectinate macrochaetae along much of the margins, those on the dorsal side of the margin more pectinate than those inserted ventrally. Ovipositor not long (up to 1.6 times HW), only just surpassing the apex of the inner processes of coxites IX, consisting of about 11 divisions; of primary type with numerous short and two very long, thin setae on the last division of the gonapophyses (Figures 102, 104).

#### ETYMOLOGY

The species is named from the new Latin adjective *aurantius*, meaning orange coloured or tawny, referring to the orange-brown of the macrochaetae and especially the posterior segments of the abdomen in alcohol preserved specimens.

#### HABITAT

Almost 150 specimens of this species were collected, almost always in pitfall traps, with only one being collected using Winkler sack litter sampling and four individuals collected by suction sampling at a

single site. They were collected from a wide variety of habitats on the island from ridge tops to the edge of beaches including also disturbed habitats such as around the current airport. The largest numbers appear to be found habitats such as coastal dunes, floodplains and valley flats.

#### DISCUSSION

These two species are placed within the recently described genus *Qantelsella* Smith, with some hesitation. In comparison to the Australian species of *Acrotelsella*, they all share a reduction in cephalic chaetotaxy with fewer macrochaetae on the anterior of the frons. However, the Somalian and Arabian species of *Acrotelsella* also show a divergence from this pattern. The disappearance of the submarginal group of macrochaetae behind the antennae in Australian *Acrotelsella* species is also notable (compare with Figure 107). The long thin seta associated with this group is found on its own, much closer to the margin in species of *Qantelsella*. There is only a single row of macrochaetae in the pronotal collar, combs of more than one macrochaeta are restricted to the anterior half of the nota. The posterior 1+1 combs consist of only a single macrochaeta. The dorsal abdominal chaetotaxy is reduced to 2+2 combs on urotergites II–VII. On the more distal antennal intervals all have circular sensillae, presumably poculiform (but this has not been confirmed in *Q. maculosa* and *Q. louisae* due to insufficient material being available for electron microscopy). These are generally considered absent in *Acrotelsella*, but this may reflect the inadequate knowledge of the genus. Circular sensillae could not be found in electron micrographs of one undescribed *Acrotelsella* species from north-western Victoria but are reported in the following species which is tentatively placed within *Acrotelsella*. All three *Qantelsella* species



FIGURE 105 *Qantelsella aurantia* sp. nov.: distal intervals of antennae. Scale bar = 0.01mm.

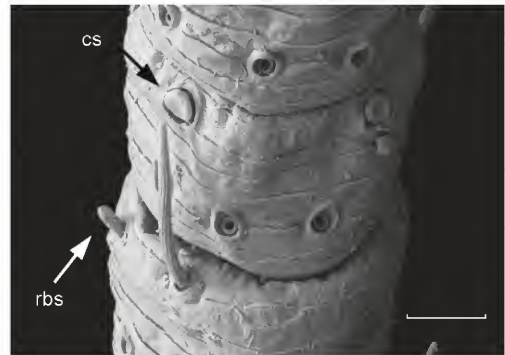


FIGURE 106 *Qantelsella aurantia* sp. nov.: idem, rod-shaped basiconic sensilla (rbs) and circular sensilla (cs). Scale bar = 0.01mm.

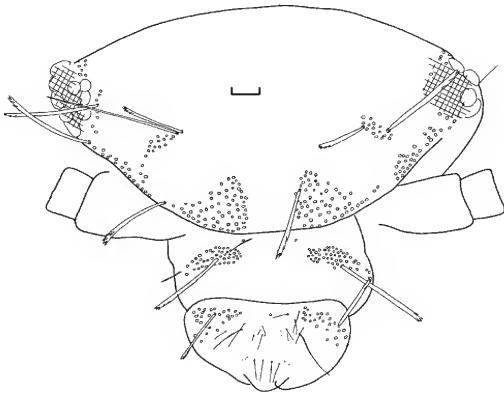
**Acrotelsella Silvestri, 1935**

FIGURE 107 *Acrotelsella* sp. Barrow Island: head.  
Scale bar = 0.1 mm.

share a markedly rounded, subtriangular urotergite X which lacks combs but has very dense marginal setae, with those protruding from the lower face of the margin being very pectinate, almost plumose.

However, there are some quite significant differences between the three species of *Qantelsella*. The chaetotaxy of the clypeus and labrum can consist of either weak bushes or distinct combs (always bushes and often very dense in Australian *Acrotelsella*), the papillae on the labial palps appear to be either of the compact or aufgelöst type. The shape and chaetotaxy of the thoracic sterna can be quite variable, from trapezoidal to cordiform, with multiple lateral combs to glabrous. Stylets can be present in one or two pairs and scales may be present or absent on the terminal filaments.

A key to the described species of the genus *Qantelsella* is given below.

- Stylets present only on segment IX; thoracic sterna all rounded; distinct orange tawny colour to macrochaetae and posterior abdominal segments ..... *Q. aurantia* sp. nov.  
Stylets present in two pairs; some or all thoracic sterna trapezoidal ..... 2
- All thoracic sterna trapezoidal with 1+1 posterior combs; terminal filaments not distinctly banded; scales present on basal divisions of terminal filaments ..... *Q. louisae* Smith, 2015  
Metasternum glabrous with round posterior margin; terminal filaments distinctly banded; scales absent from terminal filaments .....  
..... *Q. maculosa* sp. nov.

*Stylifera* Stach, 1932: 333, 345 pro parte.

*Acrotelsella* Silvestri, 1935: 307.

## TYPE SPECIES

*Acrotelsa producta* Escherich, 1905 by original designation.

***Acrotelsella transpectinata* sp. nov.**

<http://zoobank.org/NomenclaturalActs/B01B03C2-6355-4E6C-9275-92DBD8846143>

Figures 108–160

## MATERIAL EXAMINED

*Holotype*

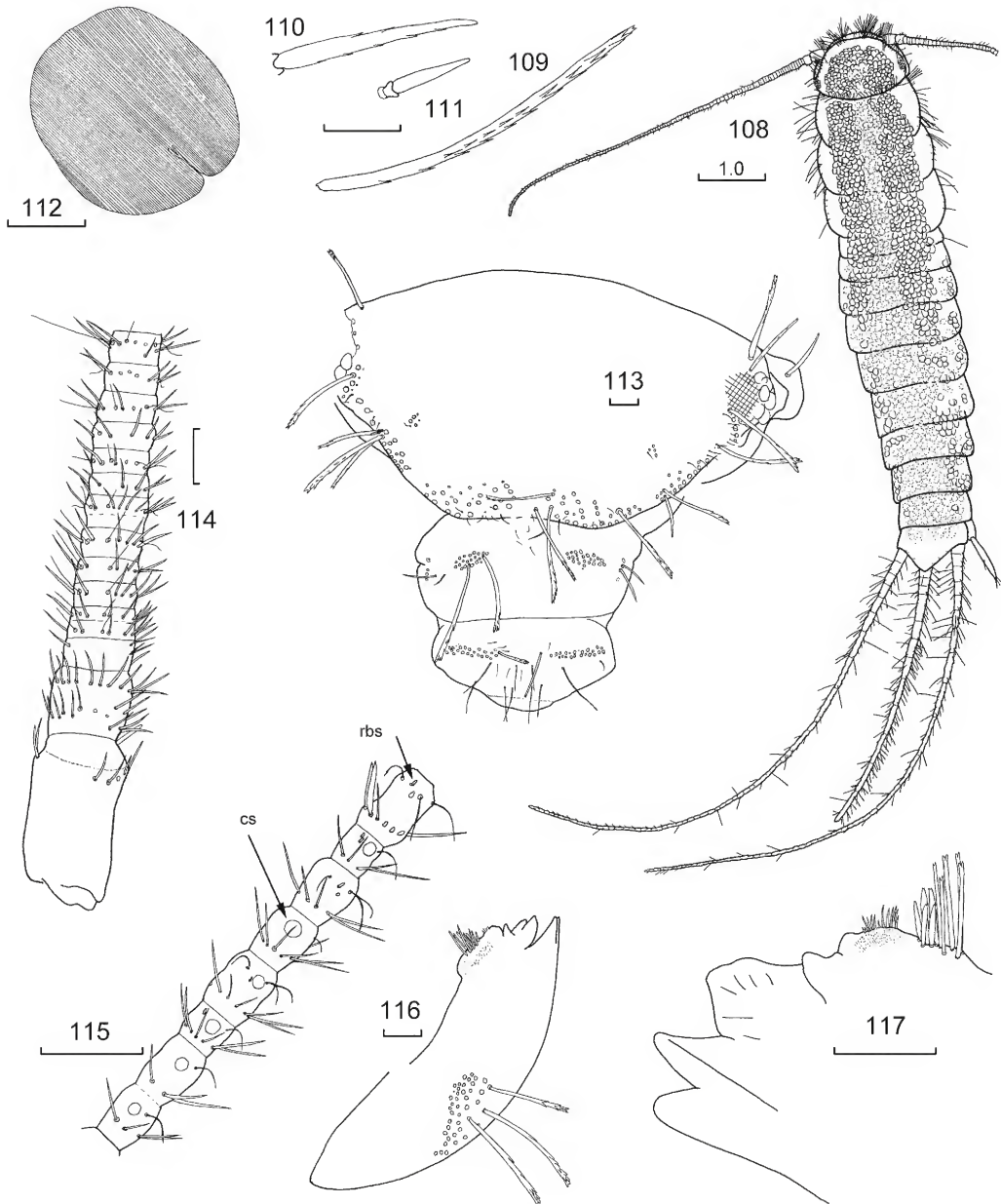
**Australia: Western Australia:** ♂ (HW 1.39), Barrow Island, site GP6 (337733, 7700903), 15 March 2006, S. Callan, R. Graham, PIT (WAM E89211) on two slides.

*Paratypes*

**Australia: Western Australia:** ♂ (HW 1.29), same data as holotype (WAM E89212) in ethanol; ♂ (HW 1.35), same data as holotype (WAM E89213) in ethanol; ♂ (HW 1.33), same data as holotype (WAM E89214) in alcohol; ♂ (HW 1.28), Barrow Island, site CC2 (337659, 7697280), 15 March 2006, S. Callan, R. Graham, PIT (WAM E89215) in alcohol; ♂ (HW 1.18), Barrow Island, site GP7 (337722, 7699467), 15 March 2006, S. Callan, R. Graham, PIT (WAM E89216) in alcohol; ♀ (HW 1.14), Barrow Island, site GP5 (338740, 7701088), 15 March 2006, S. Callan, R. Graham, PIT (WAM E89217) in alcohol; ♀ (HW 1.18), same data as previous, PIT (WAM E89218) in alcohol; ♂ (HW 1.18), same data as previous (WAM E89219) on two slides; ♂ (HW 1.13), same data as previous (WAM E89220) in alcohol (in two pieces); ♂ (HW 1.05), Barrow Island, site GP9 (338695, 7699237), 15 March 2006, S. Callan, R. Graham, PIT (WAM E89221) in alcohol; ♀ (HW 1.15), same data as previous (WAM E89222) on two slides; ♂ (HW 1.31), Barrow Island, N13 (332808, 7694467), 15 March 2006, S. Callan, R. Graham, PIT (WAM E89223) in alcohol.

*Other material examined in detail but not included in types series:*

**Australia: Western Australia:** ♂ (HW 1.31), Barrow Island, site GP4 (339635, 7700983), 15 March 2006, S. Callan, R. Graham, PIT (AMS) used for electron microscopy; sex unknown (HW 1.03), Barrow Island, site CC2 (337659, 7697280), 15 March 2006, S. Callan, R. Graham, PIT (AMS K261098) on one slide (incomplete specimen, lacking abdominal segments VIII–X); ♂ (HW unknown), same data as previous, (AMS K261099) on one slide (abdominal segments



FIGURES 108–117 *Acrotelsella transpectinata* sp. nov., holotype male (WAM E89211): 108, habitus; 109, lateral macrochaeta of mesonotum; 110, macrochaeta from tibia; 111, smooth macrochaeta from basal tarsal article; 112, darker scale from nota; 113, head (cross-hatched area obscured by eye pigment); 114, antenna, scape, pedicel and basal intervals of flagellum; 115, idem, most distal surviving interval showing rod-like basiconic sensilla (rbs) and circular sensilla (cs); 116, mandible; 117, idem, distal end. Scale bars = 0.1 mm unless otherwise indicated.

VIII–X); sex unknown (HW 1.28), same data as previous, (AMS K261100) on one slide (incomplete specimen, lacking abdominal segments VIII–X); ♀ (HW 0.98), Barrow Island, site N06b (336837, 7699444), 1 May 2007, S. Callan, K. Edwards, PIT (AMS K377611) in alcohol; juvenile (HW 0.73), Barrow Island, N14 (336303, 7698063), 1 May 2007, S. Callan, K. Edwards, PIT (K377612) in alcohol; ♂ (HW 0.99), Barrow Island, site GP6 (337733, 7700903), 15 March 2006, S. Callan, R. Graham, PIT (AMS K377613) in alcohol; ♂ (HW 1.15), Barrow Island, site GP4 (339635, 7700983), 25 September 2006, S. Callan, R. Graham, PIT (AMS K377614) in alcohol (in two pieces).

## DIAGNOSIS

This species can easily be distinguished from other described *Acrotelsella* by the presence of transverse combs on coxites IX, the single pair of stylets and the circular (poculiform?) sensillae on the antennae.

## DESCRIPTION

*Appearance:* Scale pattern when live unknown; in alcohol brown. Middle of the head covered with brown scales, with wide areas of hyaline scales along the sides and front of the head; body with two longitudinal darker stripes along most of the length, more obvious anteriorly, with hyaline scales between the darker stripes and along the sides of the body (Figure 108).

*Body size:* Medium-sized silverfish with fairly elongate body, medium length antennae and long terminal filaments; thorax only slightly wider than abdominal segment I, the following abdominal segments about the same width until the fifth and only narrowing moderately towards the posterior end. H+B up to 9.2 mm (♀), 9.0 (♂); maximum head width 1.46 mm; thorax: length up to 2.28 mm or 0.25 times H+B (range 0.22–0.32); width up to 2.0 mm with no great difference between the pro, meso and metanota although the mesonotum is the widest and the pronotum the narrowest, all nota about the same length; antennae incomplete in most specimens, maximum length of antenna 5.7 mm or 0.7 times H+B (range 0.71–0.78); maximum length of intact cercus 8.15 mm or 0.86 H+B (range 0.71–1.02); median dorsal appendage broken in all specimens measured although in some other specimens the median dorsal appendage was almost 1½ times H+B.

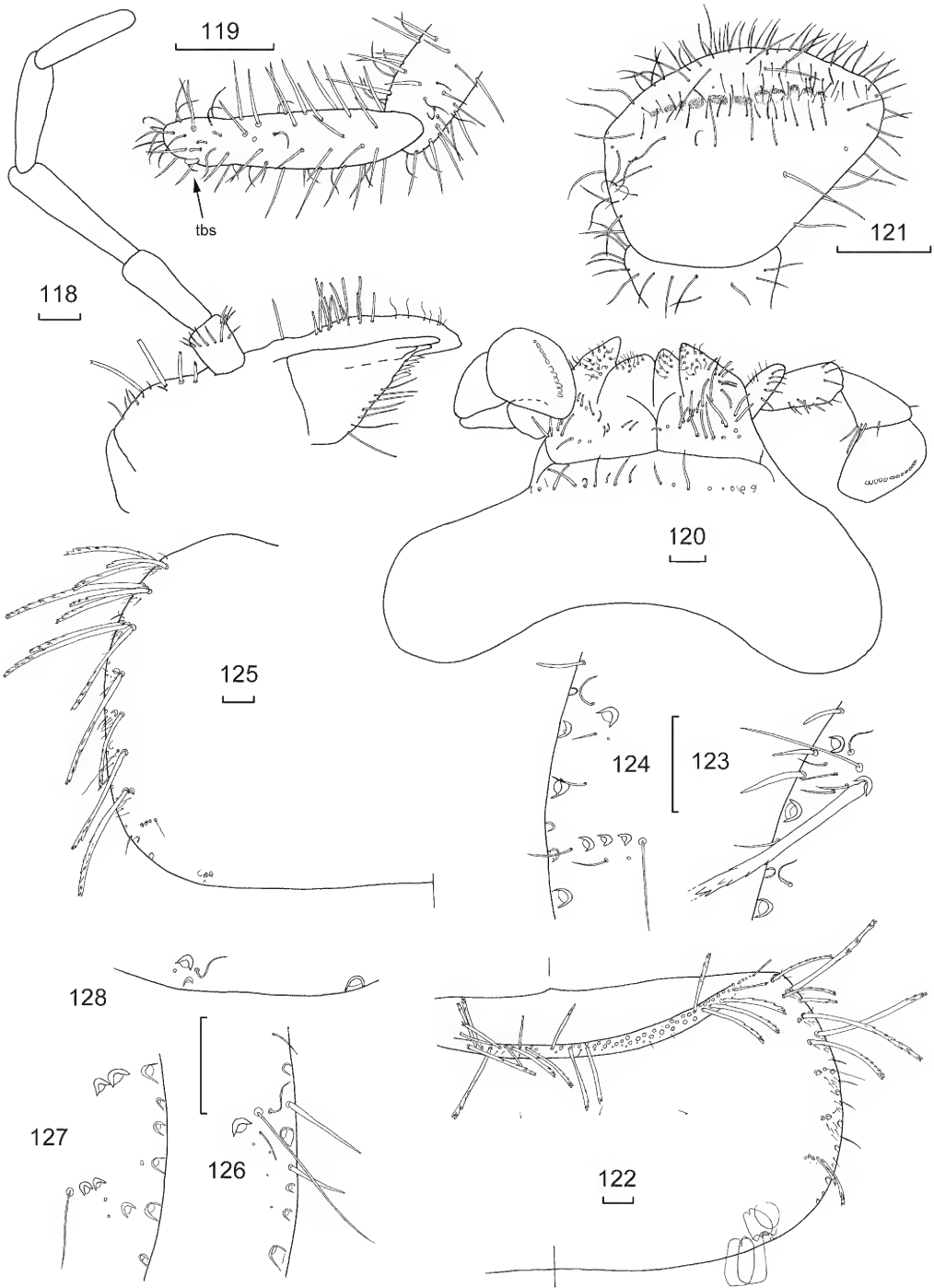
*Pigmentation:* Pedicel and scape with faint light brown or slightly orange pigment, denser distally on the pedicel and laterally on the scape; flagellum without pigment. Head and mouthparts largely without pigmentation except for light brown-orange pigment on the last two articles of the maxillary palp, being slightly more intense on the penultimate article. Legs mostly without pigment; some light pigment distally on the outer side of the tibia, more intense dorsally and a little on the tarsi. PII and PIII with some pigment laterally on the distal end of the femur but the last two tarsal articles

are without pigment. Stylets without pigment. Terminal filaments not banded, fairly even brown in colour although the colour on the medial filament decreases along its length to be almost absent distally.

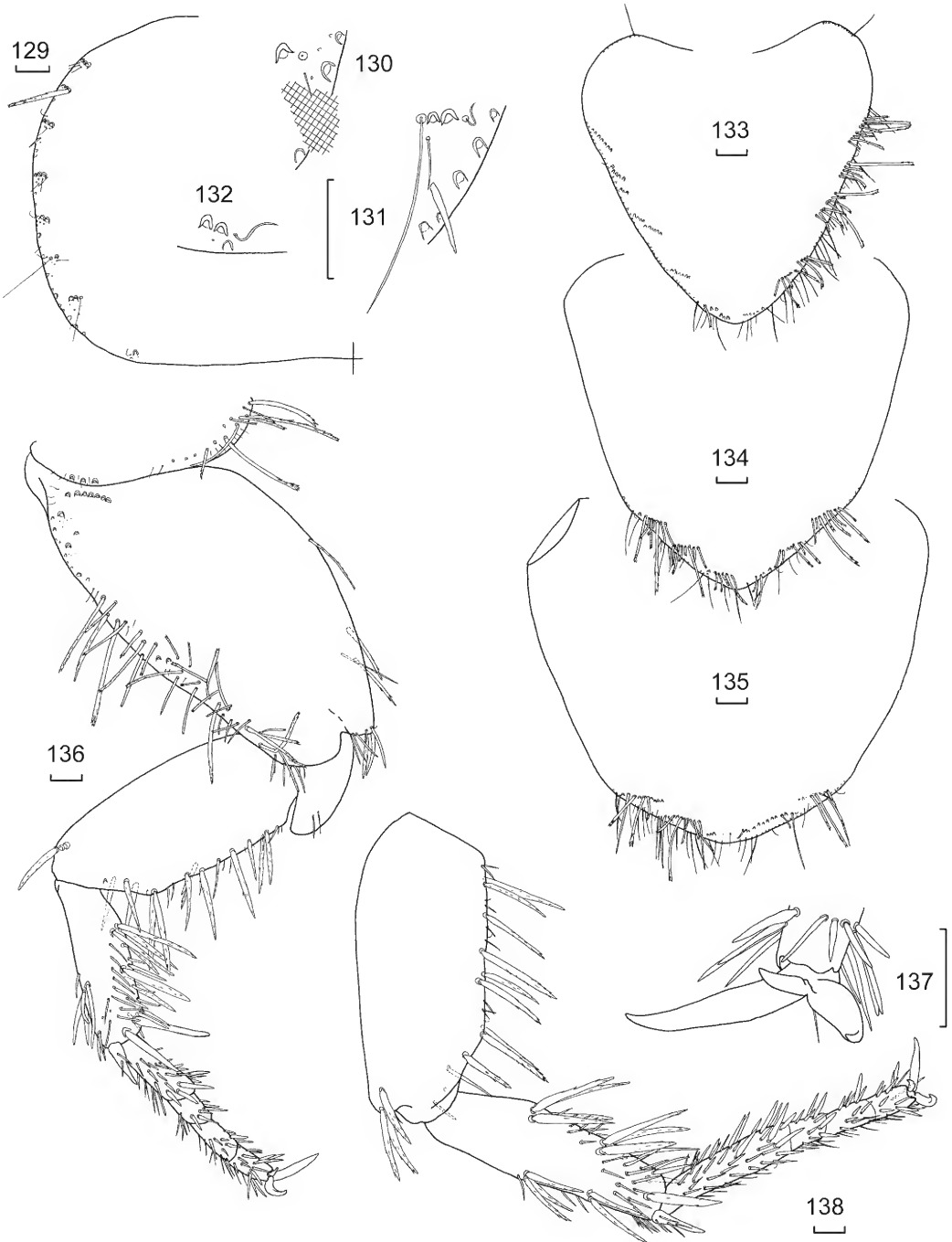
*Macrochaetae:* Pectinate, of variable form (Figures 109–111), mostly hyaline but those of the pronotal collar and some on the tibia are slightly brown.

*Scales:* With numerous sub-parallel ribs (Figure 112), which can be quite different in their spacing (Figure 156); darker dorsal scales with brown ribs that do not surpass the edge of the scales, hyaline scales with rays further apart; shape of scales generally round, although the ends of the scales can be very straight for those scales on the posterior margins of the tergites and others shaped to fit around setae or combs. Scales found on top of head, on pedicel, all nota, all thoracic sterna, legs except for distal three articles of tarsi, all urotergites and urosternites, stylets IX and on parts of the terminal filaments. The scales of the terminal filaments very diverse in shape including some broader, very irregularly shaped scales as well as some lanceolate scales (Figure 157).

*Head:* Wider than long (Figure 113, 158), with 1+1 bushes of pectinate macrochaetae on the anterolateral corners not very dense and not aligned in distinct rows. There is a small gap along the margin the above the antennal bases after which there are marginal rows about two to three macrochaetae wide running along the sides of the head to the level of the eyes and then running above the eyes. On each side of the head there is also a small isolated group of macrochaetae posterior to the antennal bases. Clypeus with 1+1 bushes of about 20–25 macrochaetae as well as some curved setae laterally. Labrum also with 1+1 bushes of pectinate macrochaetae as well as many simple setae and two longer thin setae. Eyes dark brown with 12 ommatidia (Figure 158). Antennae incomplete in all specimens but fairly long, reaching about three quarters H+B. Scape (Figure 114) quite long with scales over surface and short robust simple setae pre-apically, pedicel with scattered setae over face and a pre-apical rosette of simple setae, first interval/annulus of flagellum with a few simple setae, subsequent intervals with single rosette of setae transversely across the middle of the interval and two short trichobothria per interval, and, from about the fifth interval, some long curled cilia. Intervals further divide from the sixth with the trichobothria only in the most distal annulus; the trichobothria becoming longer from about the ninth interval, after which the intervals further divide to give four annuli per interval. Circular (poculiform?) sensillae appearing on some annuli from the 12th interval (Figures 159, 160). Intervals fully subdivided into eight annuli by the seventeenth interval. More apical intervals (Figure 115) with eight annuli, the T-annulus with wider setae than other annuli as well as some rod-like basiconic sensillae and some fine pre-apical cilia; the



FIGURES 118–128 *Acrotelsella transpectinata* sp. nov., holotype male (WAM E89211): 118, maxilla; 119, idem, ultimate article of palp showing thin-walled basiconic sensilla (tbs); 120, labium; 121, idem, ultimate article of palp; 122, pronotum, right half; 123, idem, left anterior trichobothrial area; 124, idem, left posterior trichobothrial area; 125, mesonotum, left side; 126, idem, right anterior trichobothrial area; 127, idem, right posterior trichobothrial area; 128, idem, right posterior comb. All scale bars = 0.1 mm.



FIGURES 129–138 *Acrotelsella transpectinata* sp. nov., holotype male (WAM E89211): 129, metanotum, left half; 130, idem, right anterior trichobothrial area (cross-hatched area obscured by dirt); 131, idem, right posterior trichobothrial area; 132, idem, right posterior comb; 133, prosternum; 134, mesosternum; 135, metasternum; 136, Pl, smaller setae omitted; 137, pretarsus; 138, PII (smaller setae omitted). All scale bars = 0.1 mm.

distribution of the sensillae needs to be confirmed but in the holotype the basal five and penultimate annuli of an interval with circular (poculiform?) sensillae. Mandibles (Figures 116, 117) typical for *Acrotelsella* with well-developed molar and incisor areas; a group of about nine to ten strong apically bifurcated but simple setae distally adjacent to the pectinate molar area and a bush of about 40 pectinate macrochaetae externally. Maxilla (Figure 118) with some thick apically bifurcate but otherwise smooth macrochaetae externally proximal to the palp, the lacinia with three strong teeth, one set further back than the other two, followed by about five lamellate processes and a row of seven thin simple setae, galea with about 13 strong, smooth, apically bifurcate setae externally in its basal half and a few cilia distally; apical article of maxillary palp (Figure 119) 4.1 times longer than wide (range 3.4–5.2) and 1.1 times longer than penultimate article (range 0.92–1.31), the ultimate article in both sexes with a thin-walled basiconic sensilla subapically (type C of Adel, 1984) and some small rod-like basiconic sensillae near it (type B of Adel, 1984), last four articles of palp with fine setae only, basal article with oblique rosette of slightly thicker setae and a few similar setae on one side subapically. Labium (Figure 120) short and broad, prementum with transverse row of apically bifurcate setae, glossae and paraglossae with transverse and oblique rows of short strong apically bifurcated setae, apically with short curved setulae; labial palp short, apical article expanded medially (Figure 121), 1.1 times wider long (range 0.80–1.43) with row of 11–12 (?) papillae of compact type arranged in a single row, apparently without sensillae on the outer margin, covered with numerous fine short setae as well as longer fine setae on along the distal end.

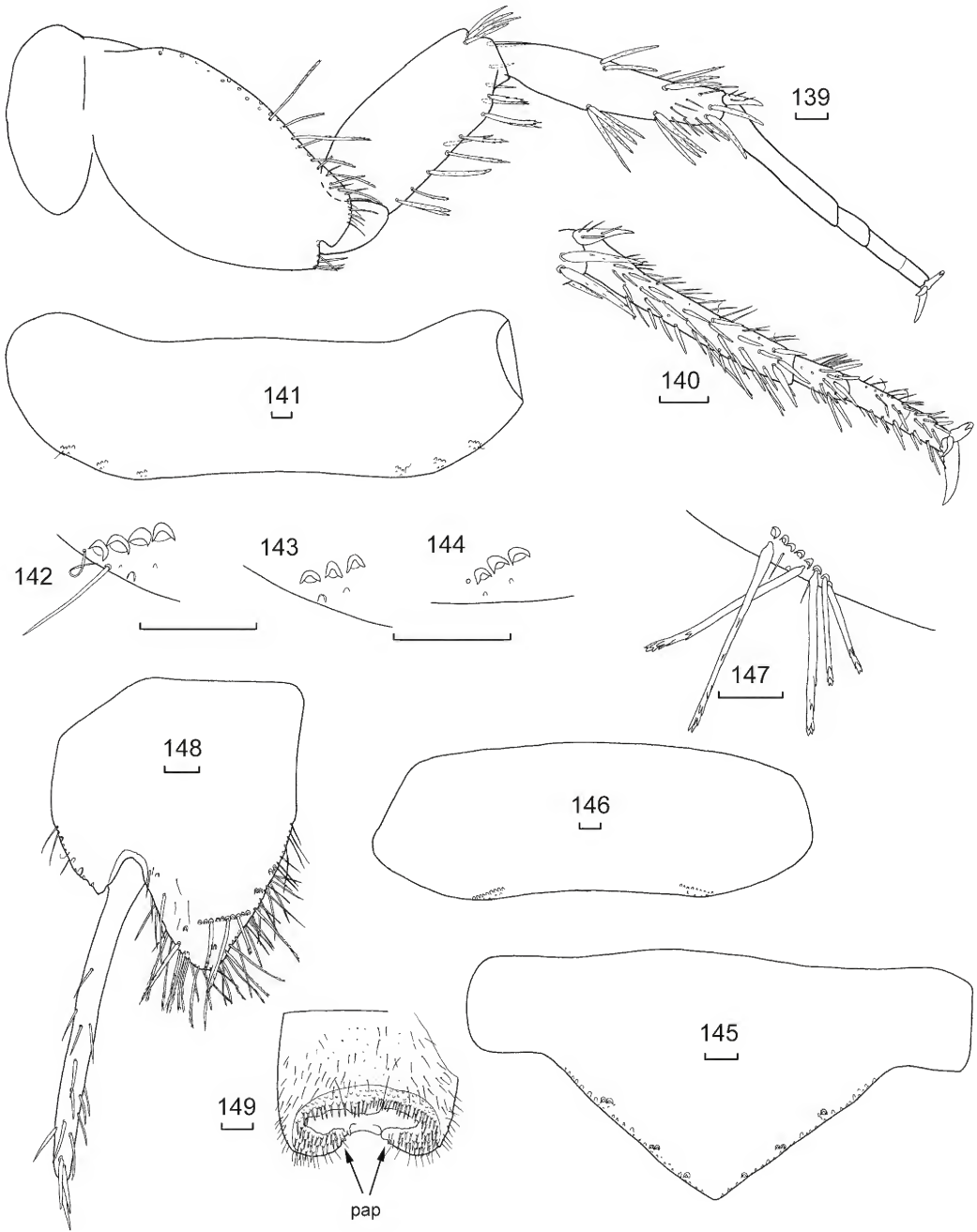
*Thorax:* Pronotum (Figure 122) with narrow setal collar about two macrochaetae wide composed of similar length macrochaetae as well as some small cilia; lateral margins with a few setae along the margin, with a comb of two pectinate macrochaetae at the anterior corner followed by seven combs of one to four pectinate macrochaetae evenly spaced along the anterior three quarters of the notum, the combs associated with one to six setulae posterior to the comb. Two open trichobothrial areas; the anterior area (Figure 123) is slightly forward of the midpoint and associated with the fifth comb with its trichobothrium located between the comb of a single macrochaeta and the macrochaeta on the margin. Posterior trichobothrial area (Figure 124) around three quarters of the distance along the margin and associated with the last comb of three to four, somewhat smaller, pectinate macrochaetae, its trichobothrium located at the mediad end of the comb. Both areas have a few setulae posterior to the comb. Posterior margin with 1+1 single macrochaetae each associated with a marginal seta and a cilium, the posterior combs being positioned quite laterally.

Mesonotum (Figure 125) with lateral chaetotaxy similar to pronotum with eight combs of one to three pectinate macrochaetae, the anterior trichobothrial area (Figure 126) located about two thirds the way along the lateral margin associated with the sixth comb of just one macrochaeta with the trichobothria located between the macrochaeta and the margin, with a few setulae posterior to the comb and a cilium between the trichobothrium and the margin. Posterior trichobothrial area (Figure 127) slightly more posterior than that on the pronotum, the trichobothria located mediad to eighth comb of two to three weaker pectinate macrochaetae and a couple of setulae posterior to the comb. Posterior margin with quite laterad 1+1 combs (Figure 128) of one or two macrochaetae with a cilium at the outer end, a marginal seta and perhaps a setula between the comb and the margin similar to that of pronotum. — Metanotum (Figures 129–132) similar to mesonotum but with only seven combs of one to three macrochaetae, the anterior trichobothrial area associated with the sixth comb of just one macrochaeta about two thirds the distance along the margin, the posterior trichobothrial area associated with the following comb and the posterior 1+1 combs again quite laterad with one or two macrochaetae, a laterad cilium, a marginal seta and a setula.

Presternum narrow, with transverse row of long macrochaetae. All thoracic sterna with hyaline scales. Prosternum (Figure 133) large, about as long as wide at its base, rounded apically, anterolateral corners with fringe of fine simple setae, posterior three quarters of lateral margins with long fine simple setae and some cilia as well as six to eight short combs of three to eight pectinate macrochaetae on each side as illustrated. Mesosternum (Figure 134) a little larger than prosternum and slightly more acute apically, but also about as long as wide at its base, with long, thin simple marginal setae and 3+3 combs in its distal third, composed of three to eight shorter and longer pectinate macrochaetae. Metasternum (Figure 135) apically rounded, about 1.25 times wider than long with marginal setae and cilia along distal quarter of lateral margins and 3+3 combs of longer and shorter pectinate macrochaetae but the macrochaeta at one or both ends of the combs are simple not pectinate; the most distal comb may almost merge with the adjacent comb.

Legs quite long and slender, tibia L/W ratio of legs PI 2.9 (range 1.66–5.71), PII 3.6 (2.88–4.87), PIII 4.4 (3.71–5.33); tarsi L/W ratio PI 5.6 (range 5.07–6.80), PII 7.3 (5.44–8.50), PIII 11.0 (8.29–12.67). PI (Figure 136) with transverse comb of three macrochaetae laterally on precoxa. Coxa with scales and a comb of about seven macrochaetae on the anterolateral corners followed by many strong pectinate macrochaetae along the external margin; inner margin with a few finer macrochaetae and about seven setae of varying thickness distally





FIGURES 139–149 *Acrotelsella transpectinata* sp. nov., holotype male (WAM E89211): 139, PIII, smaller setae omitted and all setae from tarsus also omitted; 140, idem, tarsus; 141, urotergite II; 142, idem, left lateral comb; 143, idem, left sublateral comb; 144, idem, left submedial comb; 145, urotergite X; 146, urosternite VI; 147, left lateral comb of urosternite IV; 148, right coxite IX and stylet, with smaller setae of stylet omitted; 149, penis, showing papillae (pap). All scale bars = 0.1 mm.

over the articulation. Trochanter with a few scales. Femur ventrally with several strong, thick pectinate macrochaetae and dorsally with three pectinate macrochaetae in addition to fine setae scattered over the mediad one third of the dorsal surface. Tibia of PI with numerous stout, carrot-shaped, slightly pectinate macrochaetae along most of the ventral margin and a submarginal row of shorter stout, rounded setae parallel to the margin; dorsal surface with group of stout setae about two thirds of the distance along the margin; apex of tibia with two stout pectinate macrochaetae and the usual apical spur which has some stout, rounded setae. Tarsi with four articles, the basal article of PI about 40% of the total length of the tarsus, its join with the next article not particularly oblique, the ventral face of all tarsal articles with rounded, stout setae which are longer near the apex of each article, dorsally with some simple setae. Pretarsus with two very long curved lateral claws and a much shorter curved medial claw (Figure 137). PII (Figure 138) and PIII (Figure 139) similar to PI except lacking the anterolateral comb on the coxa; legs progressively longer from anterior to posterior and the relative length of the basal tarsal article is progressively longer, being about 60% of the total length on PIII (Figure 140).

*Abdomen:* Urotergite I with 1+1 lateral combs of three to four macrochaetae each associated with one marginal seta, two to three setulae and a cilium at the laterad end of the comb, urotergites II–VII (Figure 141) with 3+3 combs of macrochaetae as in table 3, the lateral combs (Figure 142) also associated with 0–2 marginal setae, 1–7 setulae and one or two cilia, almost always at the laterad end of the comb but occasionally at both ends, the sublateral combs (Figure 143) usually associated with one to four setulae, occasionally a marginal seta but lacking cilia, the submedial combs (Figure 144) associated with none or one marginal seta, up to four

setulae and with a cilium at the laterad end of the comb.

Urotergite VIII with 2+2 combs, lacking the sublateral comb; urotergite IX glabrous. Urotergite X (Figure 145) obtusely triangular, in ♂ holotype, wider than long (L/W at base about 0.35) with many setae along entire margin, and 3+3 combs with one or two macrochaetae per comb as well as a few setulae posterior to the combs.

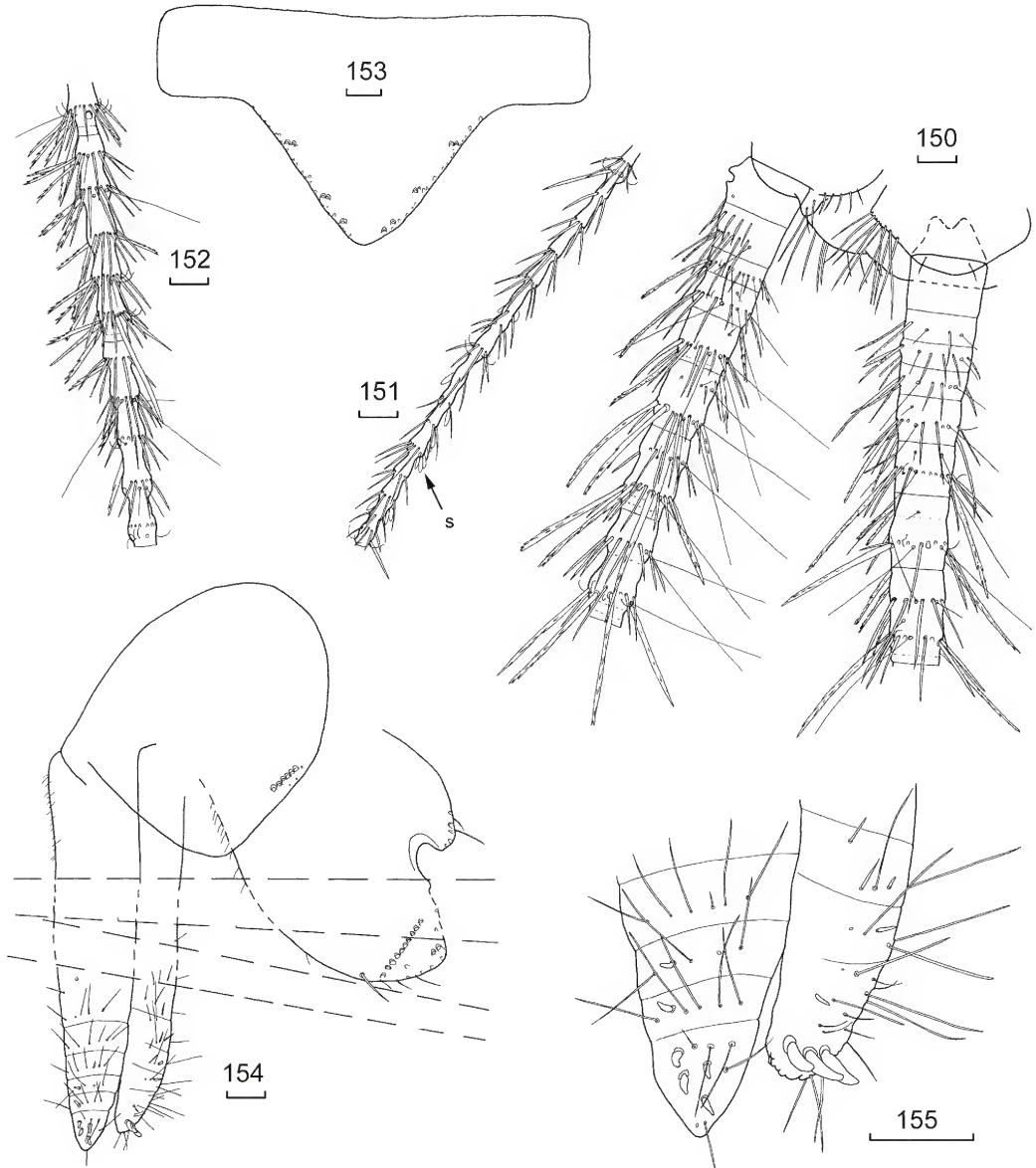
Urosternite I and II glabrous, urosternites III–VII with 1+1 lateral combs of six to eleven pectinate macrochaetae (Figures 146, 147) each usually associated with a small marginal seta and two to six setulae and rarely a cilium at the laterad end of a comb. The distance between the lateral combs 3.0–8.7 times the average width of these combs, the ratio being largest on urosternite III and decreasing posteriorly.

Each coxite IX (Figure 148) in male with obvious transverse comb of nine to ten macrochaetae across the inner process as well as a smaller comb of two to three macrochaetae on the inner margin and two more macrochaetae further anterior along the medial margin; the internal process in the male neither acute nor elongated, about three times longer than the external process but only 0.8 times as long as broad at its base; external and internal margins of internal process and external margin of outer process with many long, thin, often pectinate setae. Outer process small, triangular with a few setae along the outer margin. Only one pair of long slender stylets (Figure 148) present (on IX) in both sexes; each stylet with three short robust macrochaetae apically. Stylets IX in male holotype (excluding the apical macrochaetae) about three times the length of the internal process. Penis typical with numerous glandular setae apically, each set on a protuberance; with a small three- or four-armed papilla located on either side of opening (Figure 149). Parameres absent.

Cerci (Figures 150, 151) with four basal divisions shorter than wide, then progressively longer, with setae, macrochaetae and trichobothria becoming increasingly stronger and longer distally, divisions from about the seventh subdivided into two annuli and again into four annuli by the ninth and into five by the tenth eventually to eight annuli; scales present in places along entire length of cerci; most distal surviving divisions very long and thin as in figure 151, with setae and cilia but apparently without trichobothria (although these are present along most of the length of the cerci). Median dorsal appendage (Figures 150, 152), first division glabrous, next division with small setae and trichobothria, the setae above simple while those below are pectinate, following division also short with setae and trichobothria in increasing numbers, scales visible at sides on the surfaces proximad to each rosette of chaetotaxy from the fifth division to about the twelfth division after which they are rare but still occasionally found along the length of the remaining appendage (Figure 157), divisions begin to subdivide into two

TABLE 3 Number of macrochaetae per bristlecomb — *Acrotelsella transpectinata* sp. nov.

Segment	Urotergite			Urosternite
	Lateral	Sublateral	Submedial	
I	3–4	-	-	-
II	3–4	3	2–3	-
III	3–4	3	2–3	3–7
IV	3–5	3–4	2–3	3–8
V	5–6	2–4	1–3	4–8
VI	5–6	4	2–3	4–9
VII	5–7	4	2–3	5–8
VIII	5–9	-	2–3	9–11
IX	-	-	-	9–10



FIGURES 150–152

*Acrotelsella transpectinata* sp. nov., holotype male (WAM E89211): 150, base of cerci and median dorsal appendage; 151, most distal surviving divisions of cercus, showing some scales (s); 152, most distal surviving divisions of median dorsal appendage.

FIGURES 153–155

*Acrotelsella transpectinata* sp. nov. paratype female (WAM E89222): 153, urotergite X; 154, left coxites VIII and IX and anterior and posterior valves of ovipositor; 155, idem, detail of apices of gonapophyses. All scale bars = 0.1 mm.

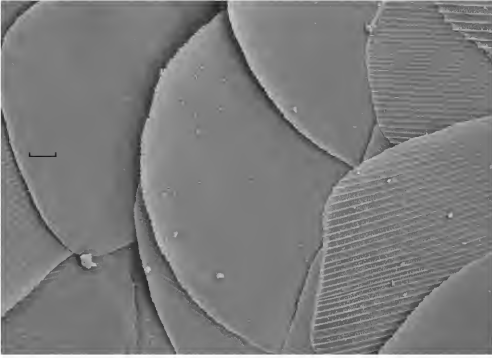


FIGURE 156 *Acrotelsella transpectinata* sp. nov.: scales of urotergites, showing large differences in spacing of ribs. Scale bar 0.01mm.

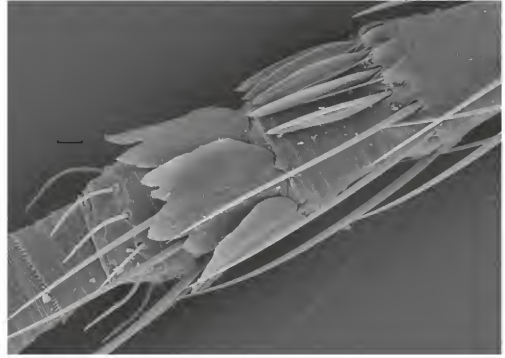


FIGURE 157 *Acrotelsella transpectinata* sp. nov.: scales on cerci. Scale bar 0.01mm.

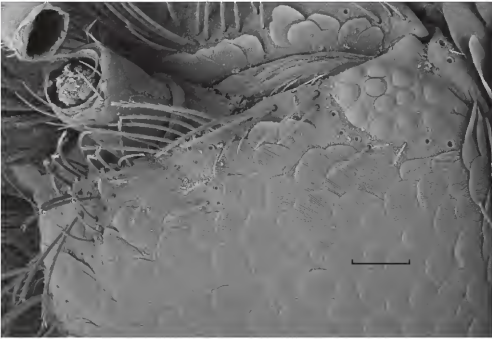


FIGURE 158 *Acrotelsella transpectinata* sp. nov.: top of head. Scale bar 0.1 mm.

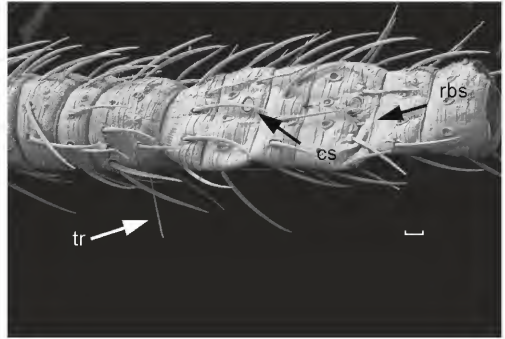


FIGURE 159 *Acrotelsella transpectinata* sp. nov.: most apical surviving intervals of antenna showing the trichobothrium (tr) on Tannulus, a circular sensilla (cs) and a rod-like basiconic sensillae (rbs). Scale bar = 0.01 mm.

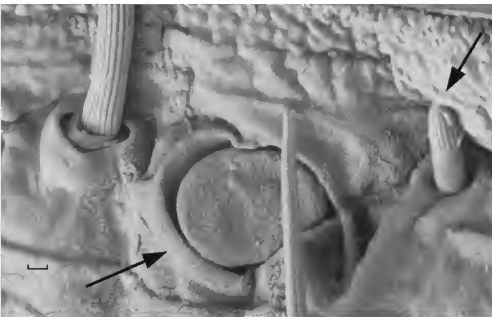


FIGURE 160 *Acrotelsella transpectinata* sp. nov.: circular (poculiform?) sensilla (left arrow) and rod-like basiconic sensilla (right arrow). Scale bar = 0.001 mm.

annuli by about the seventh division, and further into four divisions at about the ninth and into five annuli by the eleventh division (Figure 152).

*Female*: Similar to male except urotergite X more equilaterally triangular (L/W 0.56) also with 3+3 combs of 1–2 macrochaetae (Figure 153). Genital region of female as in figure 154, the internal process of coxite IX short, about two thirds as long as wide at its base and only four times longer than the rounded external process, almost as long as the ovipositor. Apex of internal process rounded with macrochaetae along much of the margins, a distinct transverse comb present as in the male. Ovipositor short (up to 0.9 HW), only just reaching the apex of the short internal processes of coxites IX, both pairs of gonapophyses consisting of a long basal divisions (about half the length of the ovipositor), and seven or eight smaller divisions (Figure 154); of secondary type with three modified spines on the last division of the posterior gonapophyses and four on the last division of the anterior gonapophyses (Figure 155), also with long fine setae.

#### ETYMOLOGY

The species is named for the transverse comb on coxites IX, a character not previously recorded for species of *Acrotelsella*.

#### HABITAT

More than 170 specimens were collected and all were taken in pitfall traps and were absent from leaf litter. This suggests that they are a quite mobile species as further indicated by its long legs. They therefore probably hide under rocks, or in other cracks in the soil. They were collected in a range of habitats including both valley flats and on limestone ridges and from both natural habitats and those with a history of human disturbance.

#### DISCUSSION

The species is placed within the genus *Acrotelsella* with some hesitation. While it has notal and abdominal chaetotaxy typical of *Acrotelsella* (apart from the transverse combs on coxites IX), it only carries a single pair of stylets in both sexes. Perhaps more critically, it has a reduced anterior chaetotaxy on the frons and the distal intervals of the antennae have circular (poculiform?) sensillae, characters seen in *Qantelsella*. Species of *Acrotelsella* are very common in Australia and quite diverse, with many specimens of undescribed species collected by the author, as well others in various Australian museum collections. It is quite widespread with species being described from the Afrotropical, Australian, Neotropical and Oriental Regions and also found on several oceanic islands (e.g. Hawaii, Seychelles). Our understanding of it, especially with regards to the details of antennal sensillae etc is incomplete and a detailed examination of the morphology of this quite large genus is required.

### Subfamily Lepismatinae Latreille, 1802

Lepismenae Latreille, 1802: 70 pro parte.

#### *Xenolepisma* Mendes, 1981

*Asterolepisma* (*Xenolepisma*) Mendes, 1981: 200.

*Xenolepisma* Mendes, 1988: 12.

#### TYPE SPECIES

*Lepisma globosa* Escherich, 1905, by original designation.

#### *Xenolepisma perexiguum* sp. nov.

<http://zoobank.org/NomenclaturalActs/801DCA7B-E983-4766-8BA7-6E95381D9EE5>

Figures 161–191

#### MATERIAL EXAMINED

##### *Holotype*

**Australia: Western Australia:** ♀ (HW 0.48), Barrow Island, site N22 (335631, 7695646), 1 May 2007, S. Callan, K. Edwards, PIT (WAM E89224) on two slides.

N.B. due to the small size of the specimen, attempts to dissect the head were abandoned and the head was mounted more or less entire on the slide. Interpretation of the mouthparts was quite difficult and the head appears somewhat distorted in the illustrations. Furthermore there was some damage to the posterior end of the specimen prior to receiving the specimen, where the tip of stylets IX, part of urotergite X, the terminal appendages and the ovipositor had all been broken or chewed off.

#### DIAGNOSIS

This species can easily be distinguished from other described *Xenolepisma* by its very small size and the complete absence of dorsal chaetotaxy on the nota and urotergites, apart from the 1+1 infralateral seta on each segment.

#### DESCRIPTION

*Appearance*: Very small silverfish with abdomen tapering strongly posteriorly (Figure 161). Scale pattern when live unknown; in alcohol mottled brown with the dorsal scales darker on the posterior end of each tergite.

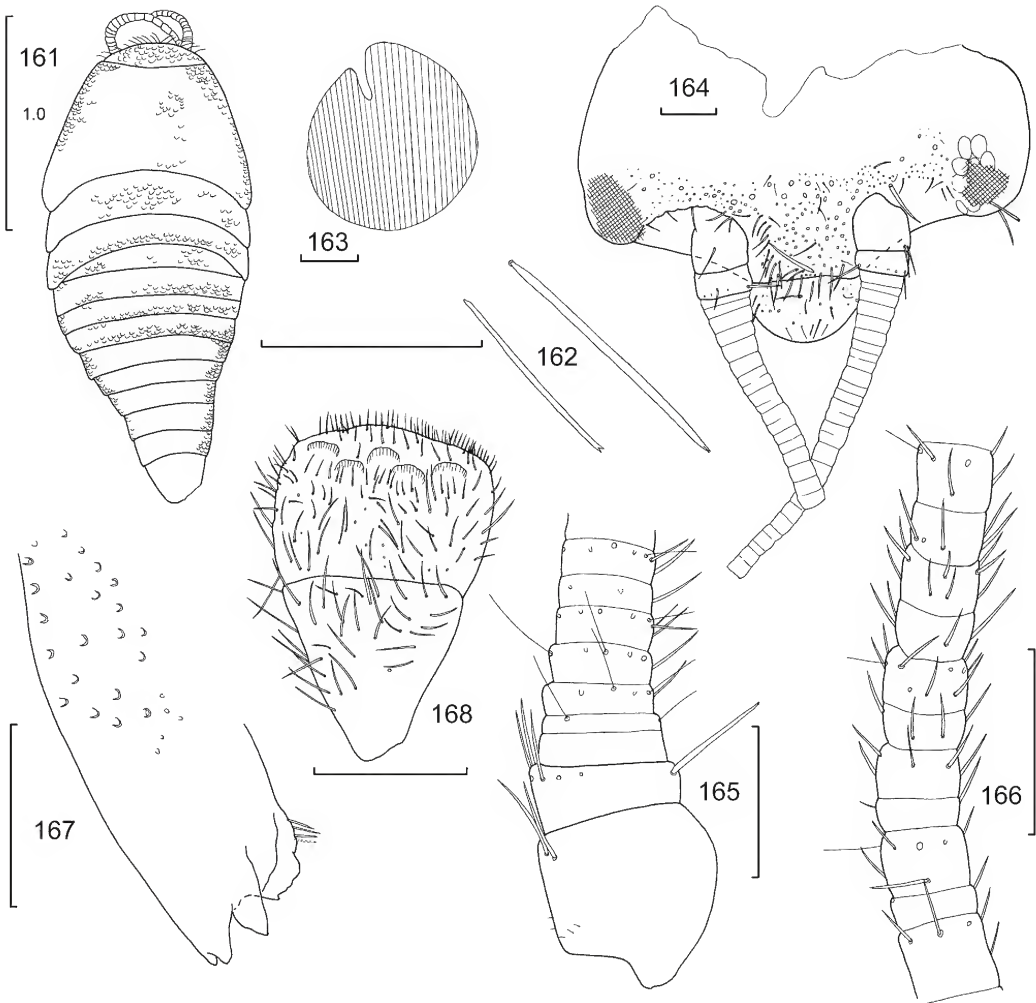
*Body size*: Body length about 2 mm, although it is suspected that the specimen is somewhat contracted; maximum head width difficult to measure as withdrawn under pronotum, about 0.48 mm; thorax: length up to 0.80 mm or 0.39 times H+B; width up to 0.93 mm being widest at the metathorax, the pronotum slightly longer than the meso and metanota combined. Antennae incomplete, maximum surviving length of antenna

0.8 mm (>0.4 times H+B); terminal filaments broken, probably not protruding much beyond the posterior end of the short urotergite X.

*Pigmentation:* Where present mottled brown. Head with pigment around eyes and anteriorly, clypeus and labrum not very pigmented. Antennae without banding; pedicel and scape without pigment; flagellum without pigment. Mandibles with pigment on outer

face. Maxillae with pigment on outer face of stipes, palps missing. Labium with well pigmented glossae; ultimate article of labial palp pigmented over proximal half. PII without obvious markings, other legs missing. Ovipositor and stylets without pigment.

*Macrochaetae:* Smooth, hyaline, some more robust and apically bifurcate (Figure 162) but all macrochaetae of the dorsal and ventral combs have been lost.



FIGURES 161–168 *Xenolepisma perexiguum* sp. nov., holotype female (WAM E89224): 161, habitus (N.B. enlarged three times more than habitus drawings of three species described above); 162, macrochaetae of mandible; 163, scale from urotergite; 164, head (cross-hatched area not clear due to eye pigment); 165, antenna, scape, pedicel and basal intervals of flagellum; 166, idem, most distal surviving intervals; 167, mandible; 168, ultimate article of labial palp. Scale bars = 0.1 mm unless otherwise indicated.

*Scales:* With sub-parallel rays which do not surpass the posterior margin of the scale (Figure 163), in alcohol mostly dark to lighter brown in colour or hyaline. Scales on top of head but lacking elsewhere on head and absent from mouthparts and antennae, thoracic sterna and coxae scaled, but scales absent from remaining leg articles. Ovipositor and terminal filaments without scales.

*Head:* Wider than long (Figure 164); eyes very dark, placed well forward; anterior half of frons merges with clypeus without obvious suture; this area (from the level of the eyes forward) is covered with numerous setae, setulae and cilia. Labrum with a few setae in across the mid-line. Antennae (Figures 164–166) incomplete (only thirteen intervals remaining), scape and pedicel (Figure 165) quite short, first interval of flagellum with some setae on one side, intervals two to five with setae and two or three trichobothria, intervals six to eight divided into two annuli and intervals nine to eleven further subdivided with the trichobothrium only in the distal annuli. Annuli of most distal surviving intervals as in Figure 166, composed of four annuli with setae and a single trichobothrium near the apex of the T-annulus. Specialised sensillae not visible but the antennae are incomplete, very small and the quality and orientation of the preparation is less than ideal. Mandibles (Figure 167) difficult to observe, with three or four incisor teeth, and a distinct molar region adjacent to a group of four(?) setae, externally with a field of about 40 strong, simple or apically bifurcate macrochaetae. Maxillae very difficult to observe, apparently with three small teeth, one shorter than the others, but the remaining details are not visible; maxillary palps lost. Labium largely obscured in preparation, apical article of palp (Figure 168) 1.4 times wider than longer, with 3+2 large compact sensory papillae apically; other specialised sensillae not observed.

*Thorax:* Pronotum (Figure 169) about 1.2 times longer than mesonotum and 1.3 times longer than the metanotum respectively, although in the whole specimen the prothorax appears much longer than the other two due to them been partially covered anteriorly by the posterior margin of the preceding notum but also probably due to uneven contraction; lacking collar of setae along anterior margin. All nota with setae and some setulae along the lateral margins with the most posterior insertion point looking somewhat larger than the others and with one to three short macrochaetae directed laterally in the anterior corners, posterior margin glabrous. All nota with two closed trichobothrial areas (isolated from margins by scales), those of the prothorax located anteriorly and subposteriorly, while those of the meso- (Figure 170) and metanota (Figure 171) are both subposterior. Each trichobothrial area provided with a short trichobothrium and all appear to lack setulae (Figure

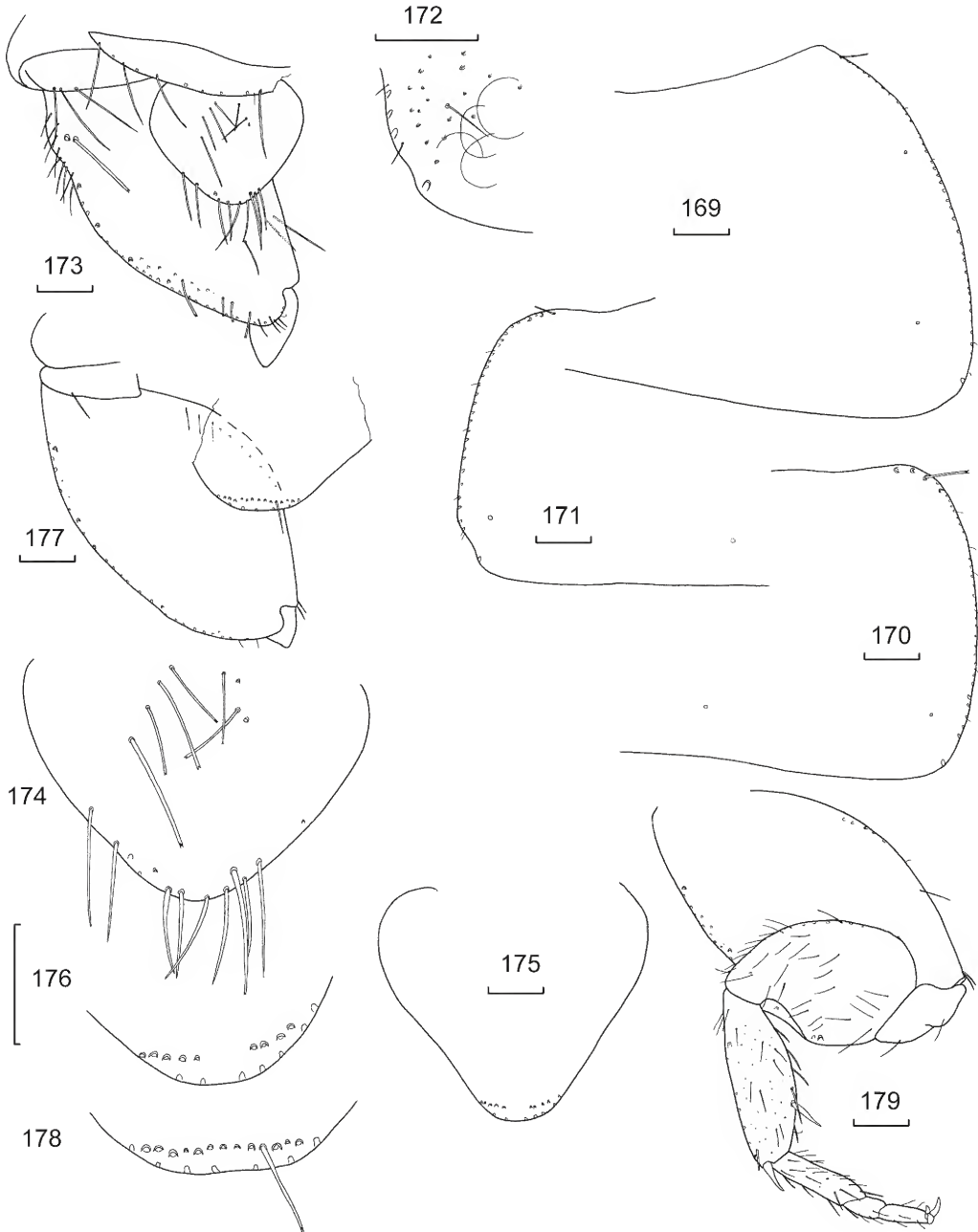
172) although in one case there appears that there could be two setula insertions.

Presternum (Figure 173) with posterior marginal row of fine delicate simple setae. All thoracic sterna with hyaline scales. Prosternum (Figures 173, 174) small, subcordiform, slightly wider at its base than long, with several fine marginal setae distally and 1+1 simple submarginal setae, as well as 4+3 setae submedially. Mesosternum (Figures 175, 176) only slightly wider than long and about twice the size of the prosternum, with several small marginal setae distally and 1+1 subapical combs of five setae; the distance between the combs being less than the length of each comb. Metasternum (Figures 177, 178) not intact, with only the apical part discernible, with a few marginal setae apically and a single comb of 15 setae extending across the entire width of the apex of the sternum.

Legs all lost except for a single PII (Figure 179) whose tibia L/W is 3.4 and tarsi L/W 4.8; subcoxa of PI with three long thin simple setae. Coxae of all legs scaled with setae and short apically bifurcate macrochaetae along the external margin. Coxa of PI (Figure 173) with comb of two long, strong apically bifurcate macrochaetae near the anterior lateral margin, coxae of PII and PIII with only single macrochaeta in this position (Figures 179, 177 respectively). Trochanter fairly large with a few fine setae only. Femur with one longer stout and one smaller macrochaeta at medial posterior angle and a row of fine setae along the anterior margin, the ventral face covered with fine setae. Tibia with two(?) short macrochaetae distally on the external margin and another in the anterior quarter of this margin, posterior margin with one stout macrochaeta about two thirds the distance along the margin and the face covered with fine setae. Tarsi consisting of three articles covered with setae, some of the setae near the distal end of the basal article a bit stronger than the others. Pretarsus with two lateral claws and a medial slightly shorter epodial claw.

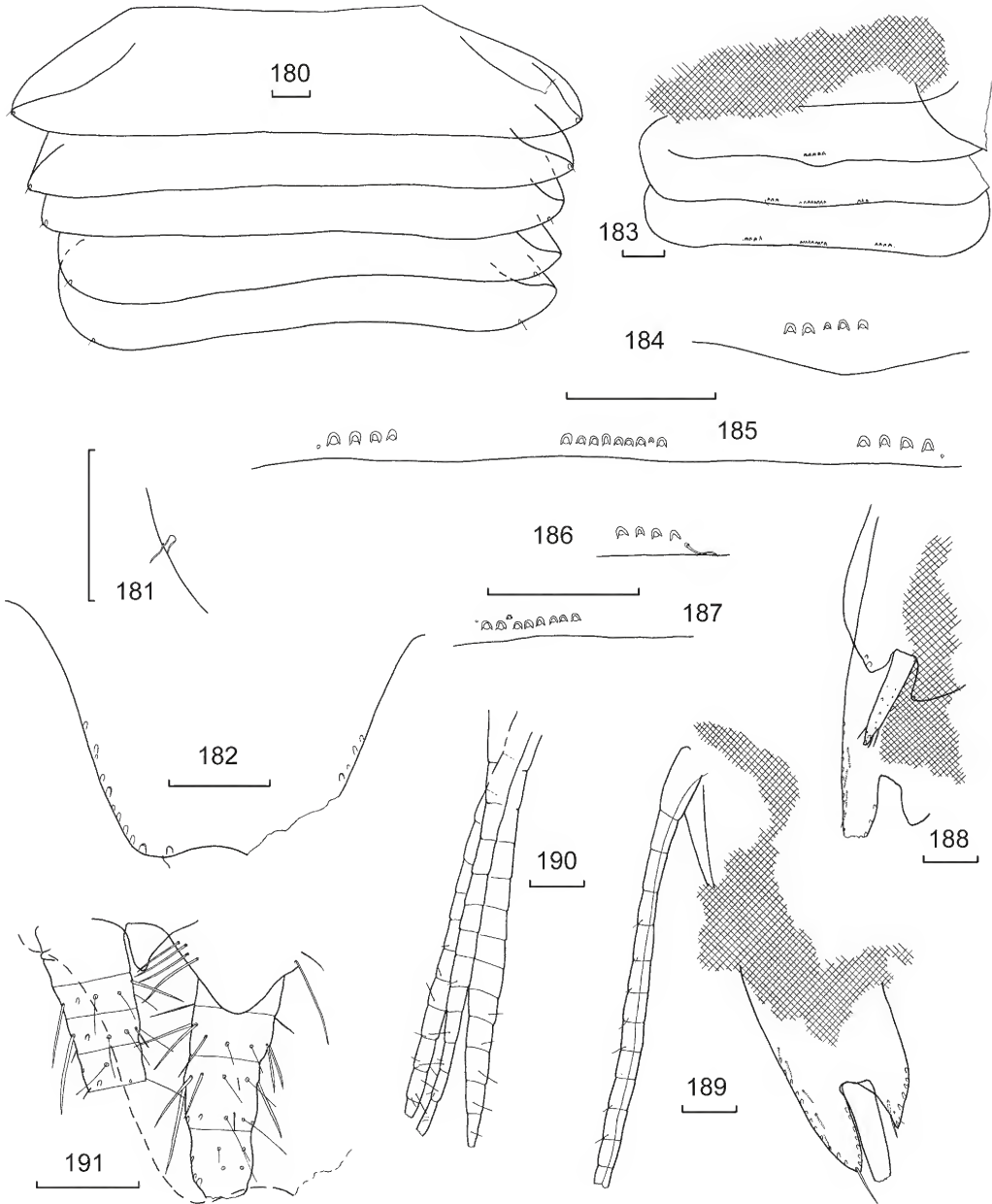
*Abdomen:* Urotergites I–IX (Figure 180) with 1+1 infralateral macrochaetae only (all lost but probably small judging from size of insertions) each insertion point associated with a marginal cilium on the outer edge of the insertion point (Figure 181). Urotergite X (Figure 182) trapezoidal, partially damaged, about 0.6 times as long as wide at its base, with several marginal setae and 2+2 (?) macrochaetae at the rounded corners of the concave posterior margin.

Urosternite I appears to be without combs (partially obscured by tissue) (Figure 183). Urosternite II with a narrow medial comb of five macrochaetae on a small protuberance of the margin (Figures 183, 184). Urosternites III–VII (Figure 183) with 1+1 sublateral combs (Figures 185, 186) each of 3–5 setae sometimes associated with a small cilium at the laterad end and one medial comb (Figures 185, 187) of 5–9 setae, often



FIGURES 169–179 *Xenolepisma perexiguum* sp. nov., holotype female (WAM E89224): 169, pronotum, right half; 170, mesonotum, right half; 171, metanotum, left half; 172, idem, lateral trichobothrial area, also showing scale insertions and the outline of some scales; 173, presternum, prosternum, coxa and trochanter of P1; 174, prosternum; 175, mesosternum; 176, idem, enlargement of apex; 177, metasternum and coxa of PIII; 178, detail of apex of metasternum; 179, PII. All scale bars = 0.1 mm.





FIGURES 180–191 *Xenolepisma perexiguum* sp. nov., holotype female (WAM E89224): 180, urotergites I–V; 181, insertion point left lateral macrochaeta of urotergite V; 182, urotergite X, damaged in right posterior corner; 183, urosternites I–IV, cross hatched area obscured by tissue; 184, posterior margin of urosternite II; 185, posterior margin of urosternite IV; 186, left lateral comb of urosternite V; 187, medial comb of urosternite V; 188, urosternite VIII, cross-hatched areas obscured by tissue; 189, urosternite IX and valve of ovipositor, apex of stylet and ovipositor damaged; 190, ovipositor, remaining valves; 191, remaining divisions of cerci and median dorsal appendage, with outline of urotergite X. PII. All scale bars = 0.1 mm.

TABLE 4 Number of macrochaetae per bristlecomb — *Xenolepisma perexiguum* sp. nov.

Segment	Urotergites Isolated macrochaetae per side (including infralaterals)	Urosternites	
		Macrochaetae per comb	
		Sublateral	Medial
I	1+1	-	-
II	1+1	-	5
III	1+1	3	8
IV	1+1	4	9
V	1+1	4–5	9
VI	1+1	4–5	9
VII	1+1	4	6
VIII	1+1	2	-
IX	1+1	-	-

with one or two of the setae much smaller (judging by the size of the insertions) and offset from the line of the comb anteriorly, rarely associated with a cilium (only seen once on VII). The sublateral combs on III more mediad than those of the more posterior segments and the posterior margin of VII somewhat more concave than the rest.

Coxites VIII of female with not well preserved, appear to be without combs but with two setae on one of the processes (internal?) (Figure 188). Internal process of coxite IX of female (Figure 189) about twice as long as broad at the base and 1.4 times as long as the external process. Stylets on urosternites VIII and IX in female holotype, although damaged on coxite IX (Figures 188, 189). Ovipositor (Figures 189, 190) with apex missing, surviving portion just reaching to end of apex of coxites IX, with 13 divisions remaining and only one to three short, fine setae per division in the more distal divisions.

Terminal filaments damaged but probably not extending much beyond the end of urotergite X, only four divisions of both cerci and median filament preserved; both appendages with setae and trichobothria as in figure 191.

*Male*: Unknown.

ETYMOLOGY

The species is named from the Latin adjective *perexiguus* meaning very small or very short, referring to its minute size.

HABITAT

Only a single female specimen was found among the extensive Barrow Island material. It was taken in a

pitfall trap near the old drill workshops, along with 23 other silverfish of the genus *Acrotelsella*. Ants of several species were also found in this pitfall trap and, given the strongly ateluriform shape of this species and the associations known for other species of *Xenolepisma*, it is probably associated with one of the smaller ant species.

DISCUSSION

This is fifth species to be described from the genus and the second to be described from Australia. A key to the described species of the genus *Xenolepisma* is given below.

1. Posterior margins of nota with submarginal row of isolated macrochaetae .... *X. monteithi* Smith, 2015  
  
Posterior margins of nota glabrous (except for a single lateral macrochaeta in each posterolateral corner) ..... 2
2. Posterior margins of urotergites I–VIII glabrous (except for 1+1 single infralateral macrochaetae) ..... *X. perexiguum* sp. nov.  
  
Posterior margins of urotergites with 3+3 or 5+5 isolated submarginal dorsal macrochaetae ..... 3
3. Posterior margins of urotergites I–VIII provided with 5+5 macrochaetae. Median comb of urosternites with 4–5 and the laterals with 2–4 setae, the distance separating them 3–4 times greater than the width of the latter. Parameres very small, provided with about six thin setae. Internal process of coxite IX of the male a bit longer than wide at its base .....  
..... *X. subnigrina* (Silvestri, 1938)  
  
Posterior margins of urotergites II–VIII with 3+3 macrochaetae. Internal process of coxites IX of male more than 1.5 times longer than wide at base ..... 4
4. Medial comb of urosternites with 6–10 macrochaetae, the sublateral combs with four setae, the distance that separates them 2–2.5 times the width of the former. Pigment intense on the vertex of head, appendages and part of body. Parameres reduced, devoid of chaetotaxy ..... *X. globosa* (Escherich, 1905)  
  
Median comb of urosternites with 3–5 long, thin macrochaetae, the sublateral combs with 2–4 macrochaetae, the distance separating them more than four times the width of the former. Pigment on head only intense on lateral and anterior margins. Parameres small with a few thin setae ..... *X. penangi* Smith and Kuah, 2011

### ACKNOWLEDGEMENTS

I would like to thank Ms Sue Lindsay (Microscopy and Microanalysis Unit, Australian Museum, Sydney) for the electron micrographs, Dr Luis Mendes (Instituto de Investigação Científica Tropical (IICT), Lisbon, Portugal) for advice on the generic placement of the species, Dr Rafael Molero-Baltanás (University of Cordoba) for discussions on the nomenclature of antennal components and Professor Jonathon Majer, Dr Nihara Gunawardene, Dr Shae Callan and the Curtin University team for the supply of the material.

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# A new troglobitic schizomid (Hubbardiidae: Paradraculoides) from the Pilbara region, Western Australia

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**ABSTRACT** – A new species of Hubbardiidae, *Paradraculoides eremius* sp. nov., is described from Bungaroo, Pilbara, Western Australia based on male and female specimens collected from troglofauna traps. Although similar in form to other *Paradraculoides* known from the Pilbara bioregion, it has a distinctive male flagellum which is distally rounded rather than tapering to a point as in other species. It is known from only a small area of less than 10 km<sup>2</sup> in the Hamersley Range.

**KEYWORDS:** taxonomy, morphology, subterranean, short-range endemic

## INTRODUCTION

The Pilbara bioregion is well-known for its distinctive and diverse subterranean fauna. Previous studies have documented a great diversity of invertebrates including insects, crustaceans, worms and arachnids (see Guzik et al. 2011; Humphreys 2006, 2008 and references therein). This fauna is of particular interest due to the large number of species with restricted distributions in habitats that are currently undergoing intensive mineral extraction processes. Due to the abundance of goethite-hematite channel iron deposits or CIDs (formerly known as the Robe pisolite), Bungaroo is one of the sites of interest for resource development and may be mined in future (Ramanaidou et al. 2003) yet very little has been published about the fauna in this area. However, one particularly noteworthy denizen of Bungaroo Creek is the blind cave eel *Ophisternon candidum* Mees, 1962 (Humphreys et al. 2013) which was originally collected from Cape Range and has ‘vulnerable’ status under federal (*Environment Protection and Biodiversity Conservation Act 1999*) and state (*Wildlife Conservation Act 1950*) threatened species legislation.

One of the best studied components of the Pilbara troglofauna is the arachnid order Schizomida (Harvey 1988, 1992; Harvey and Humphreys 1995; Humphreys 1989). Schizomids are small arachnids that are largely confined to the tropical and subtropical regions of the world and usually inhabit leaf litter or caves. There are 286 species in 53 genera known world-wide (Zawierucha et al. 2013). The Australian fauna comprises 53 species in nine genera, distributed in Western Australia, Northern Territory and Queensland (Harvey 2013). Although many new species have been discovered in the Pilbara bioregion and are awaiting formal description, six species of *Draculoides* Harvey, 1992 and four species of *Paradraculoides* Harvey, Berry, Edward and Humphreys, 2008, have been described (Harvey et al. 2008). Eight of these species are currently listed as Schedule 1 Specially Protected Fauna in Western Australia under the Wildlife Conservation Act 1950 due to their restricted distributions in areas potentially threatened by mining activities such as iron ore extraction. Here we describe the first schizomid from Bungaroo in the Hamersley Range (Figure 1), which was collected from subterranean habitats.

## MATERIAL AND METHODS

The material utilised in the present study is lodged in the Western Australian Museum, Perth (WAM). Terminology and mensuration largely follow Harvey (1992) and Reddell and Cokendolpher (1995). The following abbreviations were used for the setae of the flagellum: dm1, 4 (dorso-median 1, 4), dl1, 3 (dorso-lateral 1, 3), vm1, 2, 4, 5 (ventro-median 1, 2, 4, 5), vl1, 2 (ventro-lateral 1, 2).

The specimens were initially stored in 100% ethanol. Some structures (e.g. chelicera, female genitalia) were dissected from the specimen and examined by preparing temporary slide mounts by immersing the specimen in 75% lactic acid at room temperature for several days, and mounting them on microscope slides with 10 mm coverslips supported by small sections of 0.25 mm or 0.50 mm diameter nylon fishing line. They were examined with a Leica MZ16 dissecting microscope and a Leica DM2500 compound microscope, and illustrated with a WACOM Intuos Pro digital tablet. Whole body images were taken with a digital camera attached to the MZ16 using Leica Automontage version 3.7.0 software. After study the specimens were returned to 75% ethanol with the dissected portions placed in 12 x 3 mm glass genitalia microvials (BioQuip Products, Inc.).

## SYSTEMATICS

### Family Hubbardiidae Cook, 1899

### Subfamily Hubbardiinae Cook, 1899

### Genus *Paradraculoides*

### Harvey, Berry, Edward and Humphreys, 2008

*Paradraculoides* Harvey, Berry, Edward and Humphreys, 2008: 185.

#### TYPE SPECIES

*Paradraculoides kryptus* Harvey, Berry, Edward and Humphreys, 2008, by original designation.

#### REMARKS

The genus *Paradraculoides* is morphologically very similar to *Draculoides*, which also occurs in the Pilbara region of Western Australian. Species of both genera share the apomorphic character of a lack of a small mesal spur on the pedipalpal trochanter (Harvey 1992; Harvey et al. 2008). This mesal spur is present in all other Australian schizomids and most other hubbardiid genera (see Reddell and Cokendolpher, 1995 and Harvey et al. 2008 and references therein). *Paradraculoides* differs from *Draculoides* and all other hubbardiid genera by the presence of three macrosetae on tergite II.

### *Paradraculoides eremius* sp. nov.

<http://zoobank.org/NomenclaturalActs/262FA90F-8570-45F7-9EF8-9324DEC2E22A>

Figures 2–10

#### MATERIAL EXAMINED

##### *Holotype*

**Australia: Western Australia:** ♂, Bungaroo, 35.4 km SE. of Pannawonica, 21°56'37" S, 116°26'26" E, 15 April 2011, troglofauna trap, J. Alexander, S. Werner (WAM T114968). Genbank accession number for COI: KU291135.

##### *Paratypes*

**Australia: Western Australia:** 1 ♀, Bungaroo, 34.8 km SE. of Pannawonica, 21°56'07" S, 116°26'54" E, 15 April 2011, troglofauna trap, J. Alexander, and S. Werner (WAM T114972); 1 ♂ Bungaroo, 35.3 km SE. of Pannawonica, 21°56'37" S, 116°26'39" E, 15 April 2011, troglofauna trap, J. Alexander, S. Werner (WAM T114969).

##### *Other material examined*

**Australia: Western Australia:** 1 juvenile, same data as paratype ♂ (WAM T114970).

#### DIAGNOSIS

The distal end of the male flagellum is distally rounded instead of tapering to a point as in other described *Paradraculoides* species. Females of this species differ from all other congeneric females by the rectangular-shaped backward folding genital gonopod and the presence of two pairs of sub-terminal microsetae near dl3 and vl2 on the third segment of the flagellum; other described *Paradraculoides* species have either one (*P. anachoretus*, *P. gnophicola* and *P. kryptus*) or three pairs of sub-terminal microsetae (*P. bythius*).

#### DESCRIPTION

##### *Adults*

**Colour:** ranging from yellow-brown to dark orange-brown.

**Cephalothorax:** propeltidium with 9 setae, arranged 2 (in row): 2: 1: 2: 2: 2 anterior margin drawn to a point between chelicerae; eye spots absent. Mesopeltidia widely separated. Metapeltidium divided. Anterior sternum with 14 setae, including two sternapophysial setae; posterior sternum triangular, with 6–7 (♂), 7 (♀) setae.

**Chelicera:** fixed finger with two large teeth plus five smaller teeth between these, basal and distal teeth each with one small, blunt, lateral tooth; brush at base of fixed finger composed of eight (♂), 7 (♀) setae, each densely pilose in distal half; lateral surface with three large, lanceolate, terminally pilose setae; internal face of chelicera with 4 short whip-like setae, no serrations visible; movable finger file composed of 20 (♂), 18 (♀) long lamellae, blunt guard tooth present subdistally, one

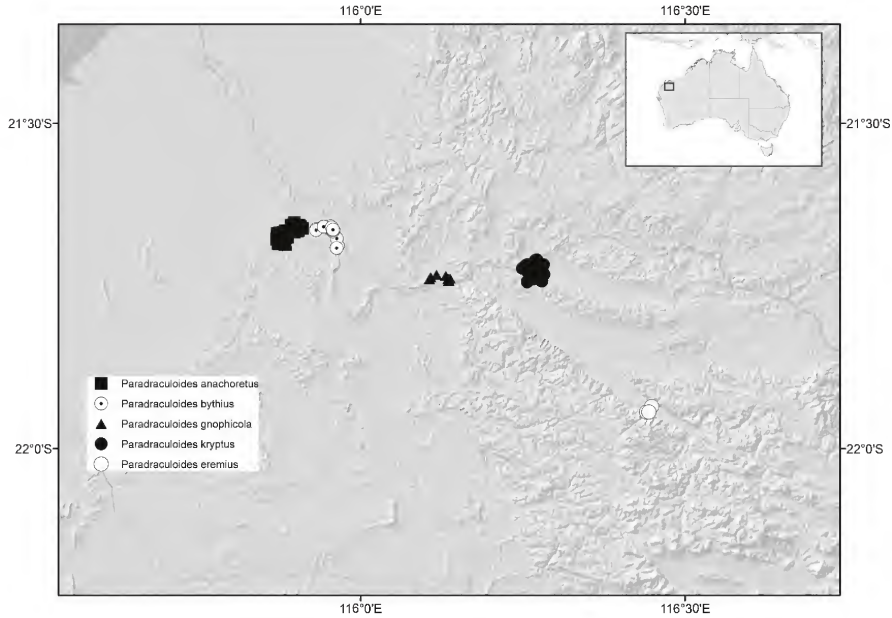


FIGURE 1 Known distribution of *Paradraculoides eremius* sp. nov., with the four other named species of the genus.

large and one small accessory teeth present near middle of file.

**Pedipalp:** without apophyses; trochanter with sharply produced distal extension, ventral margin with stout setae, without mesal spur; tibia and tarsus lacking spines; tarsus with spurs; claw 0.47 (♂), 0.42 (♀) length of tarsus.

**Legs:** tarsus I with six segments; femur IV 2.81 (♂), 2.82 (♀) × longer than wide; anterodorsal margin of femur IV produced at about a 90° angle.

**Abdomen:** chaetotaxy of tergites I–IX: ♂, two macrosetae + four microsetae (microsetae diagonal): three macrosetae + six microsetae (microsetae in column): 2: 2: 2: 2: 2: 2: 2; ♀, two macrosetae + four microsetae (microsetae diagonal): three macrosetae + six microsetae (microsetae in column): 3: 2: 2: 2: 2: 2; segment XII of male and female with small dorsal process.

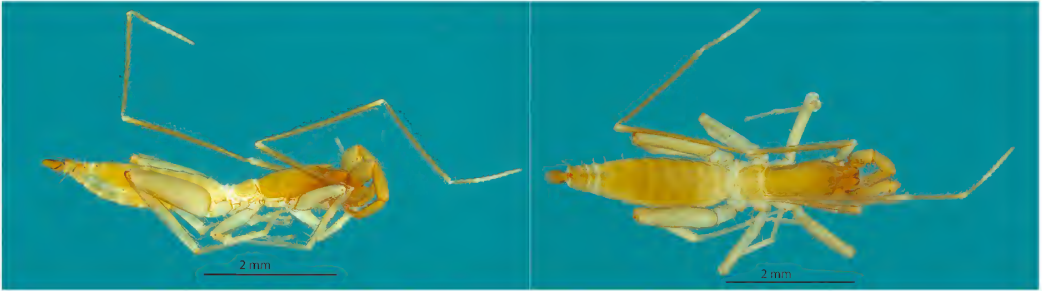
**Flagellum:** male: broad, distally rounded posteriorly, 1.8 × longer than broad (Figures 4–6); seta dm1 situated dorso-medially, seta dl1 small, situated posterior to vl1, dm4 small, situated distally between dl3, dl3 situated at posterior margin, vm1 situated slightly posterior to vm2, vm4 situated between vm1 and vm5, vm5 slightly posterior to vl1, vl2 situated distally, additional microsetae present near dl1, dl3 and vl2. Female: three segmented (Figures 7–9), first segment slightly longer than second, third longest, slightly curving upwards

posteriorly, 4.88 × longer than broad, one pair of microsetae positioned laterally on anterior end of second segment, two pairs additional microsetae present near vl2 and dl3, seta dm1 situated dorso-medially, seta dl1 situated dorsolaterally between dm1 and dm4, dm4 situated subdistally, closer to dl3 than to dl1, dl3 situated at posterior margin slightly posterior to vl2, vm1 large, situated slightly anterior to vm2, vm4 situated midway between vm1 and vm5, vm5 situated slightly closer to vm4 than to vl2, vl1 posterior to vm4 and anterior to dl1.

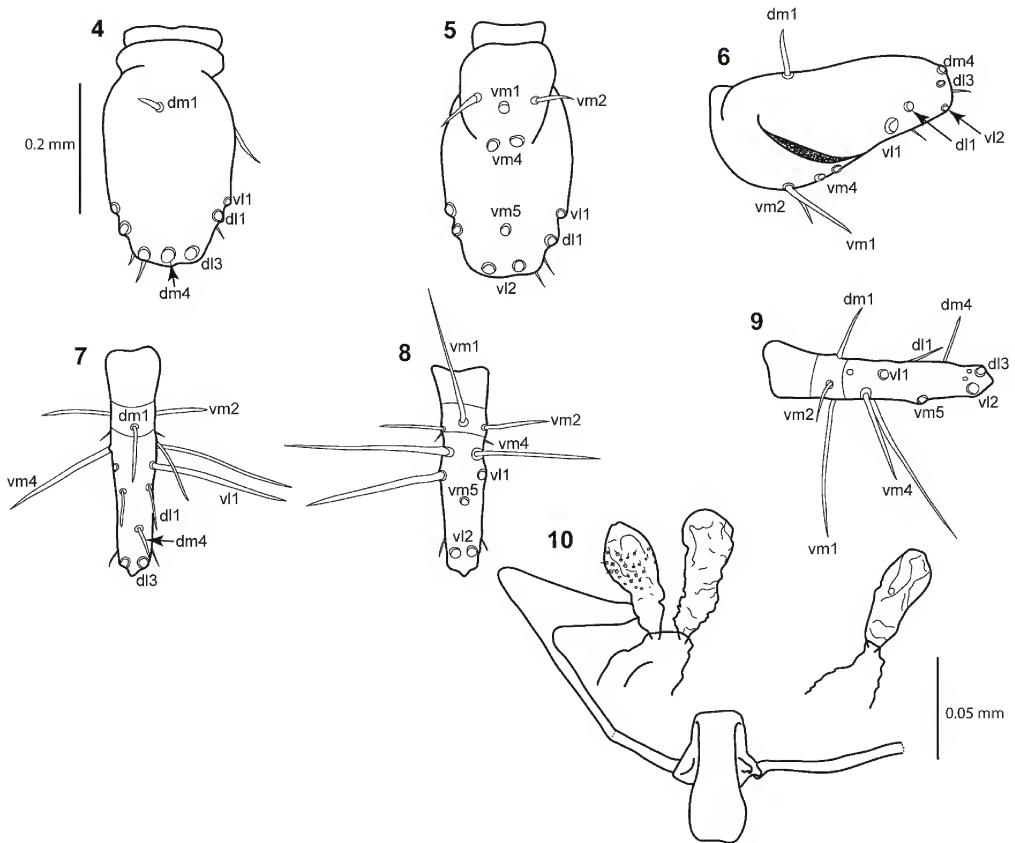
**Female genitalia:** Two pairs of spermathecae, each pair connected basally before connection with bursa, distally round and smooth (Figure 10); evenly covered with small pores; gonopod rectangular and folded back like a tongue.

**Dimensions (mm):** Holotype ♂ (paratype ♀, WAM T114972): Body length 4.30 (3.29). Propeltidium 1.15/0.64 (0.95/0.65). Chelicera 0.43 (0.28). Flagellum 0.35/0.19 (0.39/0.08). Pedipalp: trochanter 0.51 (0.46), femur 0.52 (0.55), patella 0.54 (0.57), tibia 0.51 (0.53), tarsus 0.28 (0.25), claw 0.06 (0.06), total excluding claw 2.36 (2.42). Leg I: trochanter 0.60 (0.53), femur 0.43 (0.37), patella 1.57 (1.16), tibia 2.02 (1.37), metatarsus 1.43 (1.11), tarsus 1.23 (0.92), total 7.28 (6.89). Leg IV: trochanter 0.40 (0.32), femur 1.32/0.47 (1.07/0.38), patella 0.53 (0.42), tibia 1.02 (0.78), metatarsus 0.89 (0.74), tarsus 0.60 (0.55), total 4.76 (3.88).

**Variation:** propeltidium length 0.95–1.15 mm (n = 3).



FIGURES 2–3 *Paradraculoides eremius* sp. nov., male holotype (WAM T114968), lateral and dorsal views, respectively. Scale bar = 2 mm.



FIGURES 4–10 *Paradraculoides eremius* sp. nov.: 4-6, male holotype (WAM T114968): 4, flagellum, dorsal; 5, flagellum, ventral; 6, flagellum, lateral; 7-10, female paratype (WAM T114972): 7, flagellum, dorsal; 8, flagellum, ventral; 9, flagellum, lateral; 10, genitalia, dorsal, damaged during collection. The scale bar beside figure 4 also applies to figures 5-9. See Materials and Methods for setal abbreviations.

## REMARKS

*Paradraculoides eremius* sp. nov. has only been found in channel iron deposits in the Bungaroo valley, situated south-east of Pannawonica in the Pilbara region of Western Australia.

## ETYMOLOGY

The specific epithet refers to the solitary existence of this species within the subterranean environment in Bungaroo (*eremius*, Greek, solitude, desert, wilderness).

## ACKNOWLEDGEMENTS

We are grateful to staff of Biota Environmental Sciences (Jason Alexander and Scott Werner) for collecting these specimens. Funds to support KMA were supplied by RioTinto and facilitated by Caitlin O'Neill and Sam Luccitti. We also thank Joel Huey and Mia Hillyer (Western Australian Museum, Perth) for supplying the CO1 sequence data. Sequencing was supported by a Gorgon Barrow Island Net Conservation Benefits grant administered by the Western Australian Department of Parks and Wildlife.

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# A new species of the pseudoscorpion genus *Synsphyronus* (Pseudoscorpiones: Garypidae) from Barrow Island, Western Australia

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**ABSTRACT** – A new species of *Synsphyronus*, *S. gurdoni*, is described from Barrow Island, Western Australia. The species occurs extensively across the eastern region of the island where it inhabits soil and litter habitats. Molecular data derived from four specimens found divergence levels of up to 0.46% in Cytochrome Oxidase 1.

**KEYWORDS:** taxonomy, morphology, Arachnida, short-range endemics

## INTRODUCTION

Barrow Island is the second largest continental island in Western Australia and lies approximately 56 km from the mainland. The island is characterised by a variety of habitats, ranging from undulating sand dunes to steep valleys, escarpments, claypans and mangroves (Moro and Lagdon 2013). Fluctuating sea levels have played an important role in shaping both the physical aspects and the distinctive biota of Barrow Island. Rising sea levels separated the island from the neighbouring Pilbara and Cape Range bioregions around 8,000 years ago and this isolation is thought to have contributed to the survival of numerous species (particularly mammals), that have reduced mainland populations due to human colonisation (Moro and Lagdon 2013). The island hosts a remarkable 2,800 native species of plants and animals and is noteworthy for harbouring three subterranean vertebrate species, including a fish, an eel and a snake (Moro and Lagdon 2013). While the island is an important refuge for wildlife and has been a Class A nature reserve since 1910, it is not an undisturbed environment as it also supports a longstanding oil industry (since the 1960s) and more recently developed gas industry.

Regular surveys of terrestrial invertebrates on Barrow Island have been conducted since 2005 to provide baseline data prior to the construction of a liquid gas processing plant on the eastern side of the island (Gunawardene et al. 2013). Numerous pseudoscorpions were collected during the surveys including species of the genus *Synsphyronus* Chamberlin, 1930. *Synsphyronus* is endemic to Australasia where there are currently 31 named species (Harvey 1987, 2011, 2012). Most species have been described from Australia, including Tasmania, and two are recorded from New Zealand. Many additional unnamed species are also known from Australia (Harvey, unpublished data), and a new species has been found on the Pacific island of New Caledonia (Harvey 1996). This paper reports the discovery of a previously undescribed species of *Synsphyronus* collected from Barrow Island.

## MATERIAL AND METHODS

The material utilised in the present study is lodged in the Western Australian Museum, Perth (WAM). They were examined by preparing temporary slide mounts by immersing the specimen in 75% lactic acid at room temperature for one to several days, and mounting

them on microscope slides with 10 or 12 mm coverslips supported by small sections of nylon fishing line. Specimens were examined with a Leica MZ16 dissecting microscope, a Leica DM2500 or Olympus BH-2 compound microscopes, and illustrated with the aid of a drawing tube. Measurements (in mm) were taken at the highest possible magnification using an ocular graticule. After study the specimens were rinsed in water and returned to 75% ethanol with the dissected portions placed in 12 x 3 mm glass genitalia microvials (BioQuip Products, Inc.).

Terminology and mensuration largely follow Chamberlin (1931), with the exception of the nomenclature of the pedipalps, legs and with some minor modifications to the terminology of the trichobothria (Harvey 1992), chelicera (Harvey and Edward 2007; Judson 2007) and faces of the appendages (Harvey et al. 2012).

Molecular sequence data were obtained from four specimens of *Synsphyronus* collected on Barrow Island to assess divergence levels for Cytochrome Oxidase 1. The techniques used to obtain the sequence are outlined in Harvey et al. (2015).

### Family Garypidae Simon, 1879

#### Genus *Synsphyronus* Chamberlin, 1930

*Synsphyronus* Chamberlin 1930: 616.

*Maorigarypus* Chamberlin 1930: 617 (synonymised by Chamberlin 1943: 488).

*Idiogarypus* Chamberlin 1943: 499 (synonymised by Morris 1948: 37).

#### TYPE SPECIES

*Synsphyronus*: *Synsphyronus paradoxus* Chamberlin, 1930, by original designation.

*Maorigarypus*: *Maorigarypus melanochelatus* Chamberlin, 1930, by original designation.

*Idiogarypus*: *Garypus hansenii* With, 1908, by original designation.

#### *Synsphyronus gurdoni* sp. nov.

<http://zoobank.org/NomenclaturalActs/BC3E240E-9389-4D1D-AD25-9ECD2DBE4302>

Figures 1–13

#### MATERIAL EXAMINED

##### *Holotype*

**Australia: Western Australia:** ♂, Barrow Island, Gorgon Project footprint plot CC2, 20°49'02"S, 115°26'24"E, 10–15 March 2006, wet pitfall traps, low limestone flats, S. Callan, R. Graham (WAM T123308).

##### *Paratypes*

**Australia: Western Australia:** 1 ♂, Barrow Island, plot N22, old drill workshops, 20°49'55"S, 115°25'13"E, 6 May 2006, S. Callan, R. Graham (WAM T101471); 1 ♀, Barrow Island, trap 1.27, 20°47'21"S, 115°27'18"E, November 2003, sieved from spinifex debris, R. Teale, G. Harold (WAM T60177); 1 ♀, Terminal Tanks, Barrow Island, 20°47'24"S, 115°27'22"E, 23 November 2003, sieved debris, R. Teale, G. Harold (WAM T57749); 3 ♀, Barrow Island, Gorgon Project footprint plot GP5, 20°46'59"S, 115°27'03"E, 15 March 2006, winkler sac, high limestone flats, S. Callan, R. Graham (WAM T123310); 1 ♀, Barrow Island, plot N05b, current airport, 20°51'50"S, 115°24'23"E, 26 April–1 May 2007, wet pitfall traps, S. Callan, K. Edwards (WAM T123321).

##### *Other material examined (not types)*

**Australia: Western Australia:** 1 tritonymph, WSW. of Latitude Point, Barrow Island, 20°46'51"S, 115°26'28"E, 11 August 2002, S. Slack-Smith (WAM T59964); 1 ♀, 1 deutonymph, 1 protonymph, Barrow Island, Gorgon Project footprint plot GP7, 20°47'51"S, 115°26'27"E, 15 March 2006, limestone ridge to drainage line, S. Callan, R. Graham (WAM T123309); 1 ♂, 1 tritonymph, Barrow Island, Gorgon Project footprint plot GPX, 20°47'45"S, 115°27'08"E, 15 March 2006, winkler sac, low limestone ridge, S. Callan, R. Graham (WAM T123311, T135256); 1 deutonymph, Barrow Island, Gorgon Project footprint plot GP8, 20°47'59"S, 115°26'25"E, 25 September 2006, winkler sac, valley flats, S. Callan, R. Graham (WAM T123312); 1 protonymph, Barrow Island, Gorgon Project footprint plot CC2, 20°49'02"S, 115°26'24"E, 25 September 2006, winkler sac, low limestone flats, S. Callan, R. Graham (WAM T123313); 1 deutonymph, 2 protonymphs, Barrow Island, Gorgon Project footprint plot CC2, 20°49'02"S, 115°26'24"E, 15 March 2006, winkler sac, low limestone flats, S. Callan, R. Graham (WAM T123314); 1 protonymph, Barrow Island, Gorgon Project footprint plot GP4, 20°47'03"S, 115°27'33"E, 15 March 2006, winkler sac, low limestone flats, S. Callan, R. Graham (WAM T123315); 1 ♂, 1 ♀, 1 tritonymph, Barrow Island, Gorgon Project footprint plot GP9, 20°47'59"S, 115°27'00"E, 15 March 2006, winkler sac, low limestone ridge, S. Callan, R. Graham (WAM T123316, T135257, T135258); 1 tritonymph, Barrow Island, Gorgon Project footprint plot GP6, 20°47'05"S, 115°26'28"E, 15 March 2006, winkler sac, high limestone flats, S. Callan, R. Graham (WAM T123317); 1 protonymph (pedipalps missing), Barrow Island, plot N20, old air strip, 20°45'00"S, 115°26'51"E, 6 May 2006, winkler sac, S. Callan, R. Graham (WAM T123318); 1 ♂, 1 tritonymph, Barrow Island, plot N05a, current airport, front office, 20°51'58"S, 115°24'22"E, 1 May 2007, winkler sac, S. Callan, K. Edwards (WAM T123319, T135259); 1 ♂, 1 protonymph, Barrow Island, plot N05b, current airport, helicopter hanger, 20°51'50"S, 115°24'23"E, 1 May 2007, winkler sac, S. Callan, K. Edwards (WAM T123320); 1 deutonymph, Barrow Island, site 45, 20°47'18"S, 115°26'31"E, 24 April 2005,

29 April 2005, winkler sac, K. Edward, S. Callan (WAM T123322); 1 ♀, 1 protonymph, Barrow Island, site 22, 20°47'12"S, 115°27'17"E, 17 May 2005, winkler sac, S. Callan et al. (WAM T126235); 1 deutonymph, Barrow Island, site 105, 20°48'08"S, 115°26'48"E, 17 May 2005, winkler sac, S. Callan et al. (WAM T126236).

## DIAGNOSIS

*Synsphyronus gurdoni* differs from all other members of the genus by the highly reduced basal blades of the cheliceral rallum (Figure 11).

## DESCRIPTION

### Adults

Colour (Figures 1–4) of sclerotised portions generally red-brown; tergites II–X with paired darker patches; anterior and lateral regions of carapace dark, median and posterior areas pale yellow-brown. Waxy epicuticle. Setae generally aligned perpendicularly from body, each seta quadricarinate. Most cuticular surfaces roughened, but not granulate.

*Chelicera*: with 5 setae on hand and 1 subdistal seta on movable finger, all setae acuminate; setae sbs and bs shorter than others; 2 dorsal lyrifissures and 1 ventral lyrifissure; galea of ♂ and ♀ unbranched; rallum of 3 blades, the most distal blade with one spinule on leading edge, other blades much reduced and smooth (Figure 11); serrula exterior with 18 (♂), 16 (♀) blades; lamina exterior present.

*Pedipalp* (Figure 9): trochanter 1.38 (♂), 1.30 (♀), femur 0.61–0.825 (♂), 0.86–1.00 (♀), patella 0.58–0.61 (♂), 0.75–0.845 (♀), chela (with pedicel) 1.11–1.21 (♂), 1.36–1.50 (♀), chela (without pedicel) 1.06–1.13 (♂), 1.27–1.36 (♀), hand 1.90 (♂), 1.61–1.63 (♀) x longer than broad, hand 1.10 (♂), 1.09 (♀) x longer than movable finger. Fixed chelal finger with 8 trichobothria, movable chelal finger with 3, or occasionally 2, trichobothria (Figure 5): eb, esb and isb situated basally in straight row, est submedially, et subdistally, ib and ist basally in diagonal row, and it subdistally, well posterior to et; st situated midway between sb and t; patch of microsetae present on external margin of fixed chelal finger near et. Venom apparatus present in both chelal fingers, venom ducts long, terminating in nodus ramosus midway near et in fixed finger and close to t in movable finger. Chelal teeth retrorse and acute distally, becoming rounded basally; fixed finger with 37 (♂), 34 (♀) teeth; movable finger with 25 (♂), 27 (♀) teeth; accessory teeth absent.

*Carapace* (Figures 1, 3): 0.91 (♂), 0.81 (♀) x longer than broad; anterior margin slightly indented medially; subtriangular; with 2 pairs of rounded corneate eyes (Figure 10) situated ca. one-third carapace length from anterior margin; anterior eye broad, not constricted and not covered partially by cuticle; with 2 setae near anterior margin and 4 near posterior margin; with numerous lyrifissures; without furrows.

*Coxal region* (Figures 2, 4): manducatory process rounded, with 3 apical acuminate setae, plus 4 (♂, ♀)

additional setae; medial maxillary lyrifissure situated submedially; chaetotaxy of coxae I–IV: ♂, 1: 2: 2: 3; ♀, 1: 2: 2: 6.

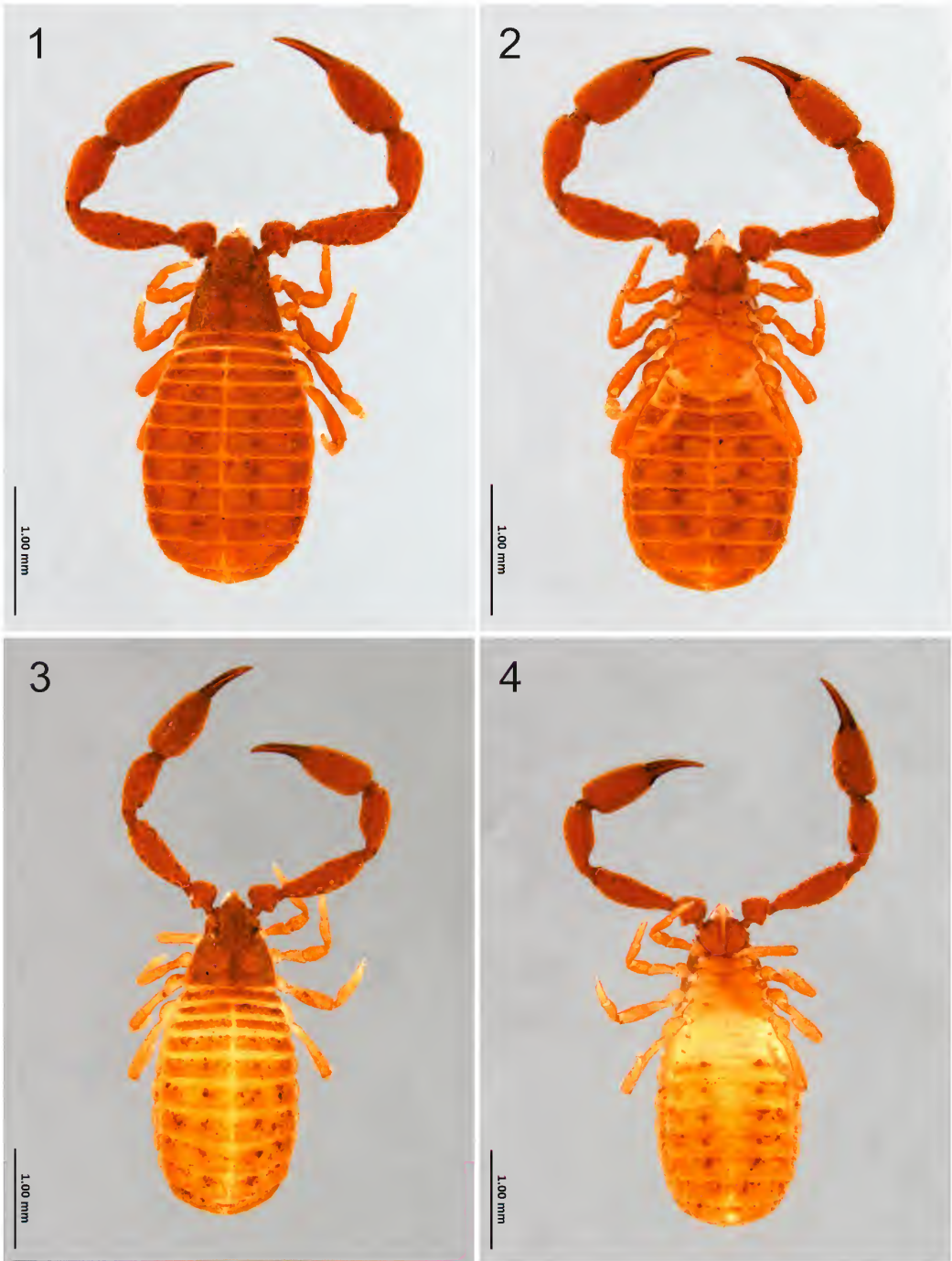
*Legs* (Figures 12, 13): junction between femora and patellae I and II slightly oblique to long axis; junction between femora and patellae III and IV very angulate; femora III and IV much smaller than patellae III and IV; femur + patella of leg IV 3.56 (♂), 4.14 (♀) x longer than broad; metatarsi and tarsi not fused and without tactile seta; subterminal tarsal setae arcuate and acute; arolium much longer than claws, not divided.

*Abdomen*: tergites II–X (♂, ♀) and IV–X (♂), V–X (♀) with median suture line (Figures 1–4). Chaetotaxy of tergites I–XII: ♂, 4: 4: 4: 4: 4: 4: 4: 4: 4: 5: 4: 2; ♀, 4: 4: 4: 4: 4: 4: 4: 4: 4: 4: 2; uniseriate; all setae quadricarinate. Chaetotaxy of sternites II–XII: ♂, 10: (0) 5 [4 + 4] (0): (0) 5 (0): 4: 4: 4: 4: 4: 4: 2; ♀, 5: (0) 6 (0): (0) 7 (0): 7: 6: 6: 6: 6: 6: 4: 2; uniseriate; all setae quadricarinate except for setae on sternites II–IV and medial setae on sternites V–VIII, which are acuminate. Spiracles without helix. Anal plates (tergite XII and sternite XII) situated within sternite XI, surrounded by slightly raised rim. Pleural membrane wrinkled-plicate; without any setae.

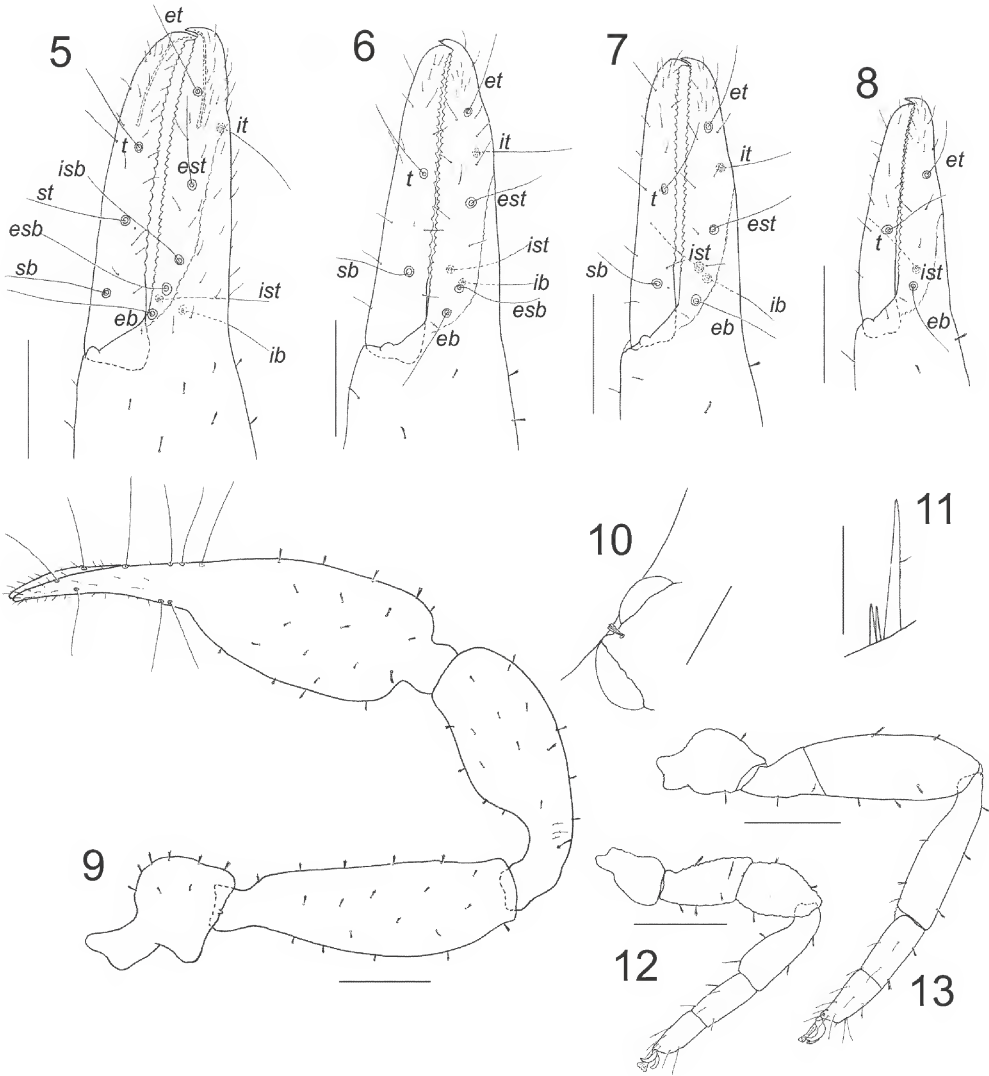
*Genitalia*: male: lateral apodeme laterally extended and distally broadened; anterior apodeme acute; a pair of acute dorsal apodemes; lateral rod very broad ventrally and with a blunt, anterior projection; ejaculatory canal atrium large and cup-shaped. Female: with one pair of lateral cribriform plates and 2 pairs of median cribriform plates.

*Dimensions*: male: holotype (WAM T123308) followed by 5 other males (when measured): Body length 2.65 (2.35–2.64). Pedipalps: trochanter 0.40/0.29, femur 0.855/0.25 (0.61–0.825/0.25–0.27), patella 0.72/0.275 (0.58–0.61/0.25–0.29), chela (with pedicel) 1.26/0.35 (1.11–1.36/0.31–0.36), chela (without pedicel) 1.18 (1.06–1.13), hand length (without pedicel) 0.615 (0.58–0.67), movable finger length 0.58 (0.5–0.58). Chelicera 0.255/0.115, movable finger length 0.16. Carapace 0.74/0.81; eye diameter, anterior 0.07, posterior 0.07. Leg I: femur 0.26/0.165, patella 0.21/0.14, tibia 0.26/0.095, metatarsus 0.16/0.07, tarsus 0.15/0.06. Leg IV: femur + patella 0.64/0.18, tibia 0.43/0.11, metatarsus 0.195/0.08, tarsus 0.18/0.08.

*Female*: paratype (WAM T123321) followed by 7 other females (when measured): Body length 3.34 (3.125–3.27). Pedipalps: trochanter 0.43/0.33, femur 0.99/0.275 (0.86–1.00/0.29–0.35), patella 0.80/0.29 (0.75–0.85/0.31–0.37), chela (with pedicel) 1.37/0.395 (1.36–1.50/0.38–0.46), chela (without pedicel) 1.29 (1.27–1.36), hand length (without pedicel) 0.685 (0.67–0.75), movable finger length 0.61 (0.61–0.69). Chelicera 0.26/0.13, movable finger length 0.16. Carapace 0.815/1.005; eye diameter, anterior 0.09, posterior 0.075. Leg I: femur 0.295/0.125, patella 0.24/0.145, tibia 0.305/0.105, metatarsus 0.175/0.075, tarsus 0.155/0.065. Leg IV: femur + patella 0.765/0.185, tibia 0.505/0.11, metatarsus 0.211/0.095, tarsus 0.195/0.08.



FIGURES 1–4 *Synsphyronus gurdoni* sp. nov.: 1, male holotype (WAM T123308), dorsal; 2, male holotype (WAM T123308), ventral; 3, female paratype (WAM T123321), dorsal; 4, female (WAM T123321), ventral.



FIGURES 5–13 *Synsphyronus gurdoni* sp. nov., male holotype (WAM T123308), unless stated otherwise: 5, left chela, lateral; 6, left chela, lateral, tritonymph (WAM T123317); 7, left chela, lateral, deutonymph (WAM T126326); 8, left chela, lateral, protonymph (WAM T123313); 9, right pedipalp, dorsal; 10, left ocular region, dorsal; 11, left rallum, lateral; 12, left leg I; 13, left leg IV. Scale lines = 0.25 mm (Figures 9, 12, 13), 0.2 mm (Figures 5–8), 0.1 mm (Figure 10), 0.05 mm (Figure 11).

TABLE 1 Specimens used in the molecular analysis of *Synsphyronus gurdoni* sp. nov., and their pairwise divergence levels (p-distance).

Registration number	Gender	GenBank number, CO1	T123316	T135256	T135257
WAM T123311	Male	KT881494	0.0000	0.0046	0.0000
WAM T123316	Male	KT881495		0.0046	0.0000
WAM T135256	Male	KT881497			0.0046
WAM T135257	Male	KT881496			

### *Tritonymph*

Colour mostly as for adults, but generally paler.

*Chelicera*: with 5 setae on hand and 1 on movable finger; galea unbranched.

*Pedipalp*: trochanter 2.73, femur 3.43, patella 2.79, chela (with pedicel) 3.47, chela (without pedicel) 3.24, hand (without pedicel) 1.66 x longer than broad, and movable finger 0.94 x longer than hand (without pedicel). Fixed chelal finger with 7 trichobothria, movable chelal finger with 2 trichobothria (Figure 6): *eb*, *esb*, *ist* and *ib* situated basally; *est* situated medially; *et* distally; *it* subdistally; *b* subbasally; *t* subdistally.

*Carapace*: 0.90 x longer than broad; with 2 setae near anterior margin and 4 near posterior margin.

*Legs*: much as in adults except metatarsi and tarsi fused.

*Abdomen*: tergal chaetotaxy: 4: 4: 4: 4: 4: 4: 4: 4: 4: 2: 2. Sternal chaetotaxy: 0: (0) 2 (0): (0) 2 (0): 4: 4: 4: 6: 6: 4: 4: 2.

*Dimensions (mm)*: WAM T123317: Body length 2.54. Pedipalps: trochanter 0.355/0.285, femur 0.79/0.23, patella 0.67/0.24, chela (with pedicel) 1.18/0.34, chela (without pedicel) 1.10, hand length (without pedicel) 0.565, movable finger length 0.53. Carapace 0.74/0.82.

### *Deutonymph*

Colour mostly as for adults, but generally paler.

*Chelicera*: with 5 setae on hand and 1 on movable finger; galea unbranched.

*Pedipalp*: trochanter 1.44, femur 3.26, patella 2.44, chela (with pedicel) 3.57, chela (without pedicel) 3.35, hand (without pedicel) 1.63 x longer than broad, and movable finger 1.03 x longer than hand (without pedicel). Fixed chelal finger with 6 trichobothria, movable chelal finger with 2 trichobothria (Figure 7): *eb*, *ist* and *ib* situated basally; *est* situated medially; *et* distally; *it* subdistally; *sb* subbasally; *t* subdistally.

*Carapace*: 0.84 x longer than broad; with 2 setae near anterior margin and 4 near posterior margin.

*Legs*: metatarsi and tarsi fused.

*Abdomen*: tergal chaetotaxy: 4: 4: 4: 4: 4: 4: 6: 6: 4: 2: 2. Sternal chaetotaxy: 0: (0) 2 (0): (0) 2 (0): 2: 2: 4: 4: 6: 4: 4: 2.

*Dimensions (mm)*: WAM T126236: Body length 2.05. Pedipalps: trochanter 0.295/0.205, femur 0.62/0.19, patella 0.50/0.205, chela (with pedicel) 0.965/0.27, chela (without pedicel) 0.905, hand length (without pedicel) 0.44, movable finger length 0.455. Carapace 0.595/0.71.

### *Protonymph*

Colour mostly as for adults, but generally paler.

*Chelicera*: with 4 setae on hand and 0 on movable finger; galea unbranched.

*Pedipalp*: trochanter 1.58, femur 3.14, patella 2.19, chela (with pedicel) 3.48, chela (without pedicel) 3.27, hand (without pedicel) 1.57 x longer than broad, and movable finger 1.09 x longer than hand (without pedicel). Fixed chelal finger with 3 trichobothria, movable chelal finger with 1 trichobothria (Figure 8): *eb* and *ist* situated basally; *et* situated distally.

*Carapace*: 0.90 x longer than broad.

*Legs*: metatarsi and tarsi fused.

*Abdomen*: tergal chaetotaxy: 2: 2: 2: 2: 2: 2: 2: 2: 2: 2: 2. Sternal chaetotaxy: 0: (0) 2 (0): (0) 2 (0): 2: 2: 2: 2: 2: 2: 2: 2.

*Dimensions (mm)*: WAM T123313: Body length 1.51. Pedipalps: trochanter 0.245/0.155, femur 0.455/0.145, patella 0.355/0.16, chela (with pedicel) 0.765/0.22, chela (without pedicel) 0.72, hand length (without pedicel) 0.345, movable finger length 0.375. Carapace 0.51/0.565.

### REMARKS

*Synsphyronus gurdoni* is a small species that has been found at many localities on the eastern side of Barrow Island. It has not yet been located on the adjacent Australian mainland, although numerous other new species of the genus are known from the Pilbara region of Western Australia (unpublished data). Also, despite rigorous sampling for terrestrial invertebrates on Barrow Island (Gunawardene et al. 2013), *S. gurdoni* is the only species of the genus to be found on the island thus far. The restricted island distribution of *S. gurdoni* seems to

indicate that this species should be regarded as a short-range endemic species (Harvey 2002; Harvey et al. 2011).

The two basal blades of the rallum are noticeably shorter than the anterior blade (Figure 11), which serves to distinguish this species from all others. In all other species of *Synsphyronus*, the basal blades are about half as long as anterior blade, (With 1908, figure 2; Chamberlin 1943, figure 10; Morris 1948, figure 5a; Harvey 1987, figure 8).

Four male specimens of *S. gurdoni* were sequenced for COI, revealing two haplotypes, with three variable sites. The divergence among specimens was up to 0.46% (Table 1), confirming the existence of only a single species on the island.

#### ETYMOLOGY

This species is named for Nobel Laureate Sir John Gurdon in recognition of his contributions to developmental biology.

#### ACKNOWLEDGEMENTS

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# A new species of peacock spider, *Maratus proszynskii* sp. nov. (Araneae: Salticidae: Euophryini), from Tasmania, with a review of *Maratus* in Tasmania, Australia

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**ABSTRACT** – A new species of the peacock spider genus *Maratus*, *M. proszynskii*, is described from north-eastern Tasmania, Australia. This species appears most similar to *M. velutinus* Otto and Hill, 2012, and brings to four the number of described species of *Maratus* known from Tasmania: *M. pavonis* (Dunn, 1947), *M. harrisi* Otto and Hill 2011, *M. tasmanicus* Otto and Hill 2013, and *M. proszynskii* sp. nov.

**KEYWORDS:** taxonomy, morphology, peacock spiders, Tasmania, Australia

## INTRODUCTION

The genus *Maratus* was first described by Karsch (1878), and after being subsumed into *Saitis* by Bonnet (1958) following Simon (1901), was revalidated by Žabka in 1987. The genus was further expanded when Otto and Hill (2012) synonymised *Lycidas* Karsch, 1878, thus expanding *Maratus* to cover more than 45 species, with another six recently described species (*M. madelineae* Waldock, 2014, *M. hortorum* Waldock, 2014, *M. jactatus* Otto and Hill, 2015a, *M. sceletus* Otto and Hill, 2015a, *M. elephants* Otto and Hill, 2015b and *M. personatus* Otto and Hill, 2015c) bringing the total number to 55 described species at the time of writing (World Spider Catalog, 2015).

Recent work by Maddison (2015) has confirmed the placement of *Maratus* within the Tribe Euophyrini, a monophyletic group (based on molecular data) which has a cosmopolitan distribution and includes many Australasian taxa.

This study documents the description of *Maratus proszynskii* sp. nov. from specimens collected in heathlands of northeastern Tasmania for a spider survey supported by the Plomley Foundation. Additionally, a review of the other three named species of *Maratus* from Tasmania includes *M. tasmanicus* Otto and Hill, *M. pavonis* (Dunn), and *M. harrisi* Otto and Hill.

## MATERIAL AND METHODS

Material examined for this study is lodged in the Queen Victoria Museum and Art Gallery, Launceston,

Tasmania, Australia (QVM), Tasmanian Museum, Hobart, Tasmania, Australia (TM) and Australian Museum, Sydney, New South Wales, Australia (AM).

Specimens were preserved and described in 75% ethanol, illuminated with Halogen lights, and illustrated with the abdomen and cephalothorax in a horizontal position. Female genitalia were examined by dissecting epigynes and clearing them in 10% lactic acid overnight. Epigynes were mounted in glycerol and illustrated with a camera lucida on a Leica DM 2500 compound microscope. Other drawings and measurements were made using a Leica MS5 or Leica MZ16A stereo microscope and Leica Application Suite V3.8.0 from Leica Microsystems Ltd.

## TAXONOMY

**Family Salticidae Blackwall, 1841**

**Subfamily Salticinae Blackwall, 1841**

**Tribe Euophryini Simon, 1901**

**Genus *Maratus* Karsch, 1878**

*Maratus* Karsch, 1878: 27.

## TYPE SPECIES

*Maratus amabilis* Karsch, 1878, by subsequent designation of Bonnet (1957: 2713).



## COMPOSITION

At the time of writing, the World Spider Catalog (2015) listed 55 species under the genus *Maratus*.

## REMARKS

The specific (and often spectacular) colour patterns on male *Maratus* species are the result of specialised short squamous setae which cover the dorsal abdominal scute and parts of the dorsal carapace, however in the two species discussed in this paper, *M. velutinus* Otto and Hill, 2012 and *M. proszynskii* sp. nov., the squamous abdominal setae are lengthened and noticeably extend beyond the posterior edge of the abdomen (Figures 1–2; see also Otto and Hill, 2012, figure 67(2)).

In other species of *Maratus* it has been noted that when preserved in alcohol, the vibrancy of the colours of the squamous setae may be reduced, e.g. setae that appear red in life will show as orangey to light brown and with *M. proszynskii* sp. nov. this is compounded by the fading of the specimens over time so that the once black long squamous setae on the abdomen range from dark brown through to orangey brown.

***Maratus proszynskii* sp. nov.**

Prószynski's peacock spider

<http://zoobank.org/urn:lsid:zoobank.org:act:7696C5CC-2992-47C3-98AE-56E872DA961E>

Figures 1–9

## MATERIAL EXAMINED

*Holotype*

**Australia: Tasmania:** ♂, Eddystone Point, Mt William National Park, site 4, 41°00'02"S 148°19'15"E, October 1987, T. Churchill (QVM 13:1257).

*Paratypes*

**Australia: Tasmania:** 1 ♀, Eddystone Point, Mt William National Park, site 3, 40°59'44"S 148°19'27"E, October 1986, T. Churchill (QVM 13:186); 10 ♂, 1 ♀, same data except site 4, 41°00'02"S 148°19'15"E, October 1986, T. Churchill (QVM 13:175, 13:178-9, 13:180-4, 13:187); 17 ♂, 3 ♀, same data except site 4, 41°00'02"S 148°19'15"E, November 1986, T. Churchill (QVM 13:155, 13:158, 13:164, 13:167-9, 13:297, 13:716, 13:160-1, 13:154, 13:163, 13:157); 3 ♂, 2 ♀, same data except site 4, 41°00'02"S 148°19'15"E, December 1986, T. Churchill (QVM 13:190, 13:193-4, 13:191, 13:197); 1 ♀, same data except site 4, 41°00'02"S 148°19'15"E, May 1987, T. Churchill (QVM 13:1200); 1 ♀, same data except site 3, 40°59'44"S 148°19'27"E, October 1987, T. Churchill (QVM 13:3470); 12 ♂, 1 ♀, same data except site 4, 41°00'02"S 148°19'15"E, October 1987, T. Churchill (QVM 13:1253-4, 13:1258, 13:1259, 13:1260, 13:1262-4, 13:1267, 13:1273, 13:3313,

13:3575); 11 ♂, 6 ♀ same data except site 4, 41°00'02"S 148°19'15"E, November 1987, T. Churchill (QVM 13:1225, 13:1227, 13:1230, 13:1232, 13:1234-5, 13:1236, 13:1238, 13:1239, 13:1241, 13:1242, 13:1244, 13:1245, 13:1246, 13:1274, 13:3915, 13:19531); 7 ♂, 3 ♀, same data except site 4, 41°00'02"S 148°19'15"E, December 1987, T. Churchill (QVM 13:1204, 13:1206, 13:1215, 13:1217, 13:4231, 13:1210-1, 13:1218); 1 ♀, same data except site 3, 40°59'44"S 148°19'27"E, January 1988, T. Churchill (QVM 13:4594); 1 ♀, same data except site 4, 41°00'02"S 148°19'15"E, January 1988, T. Churchill (QVM 13:4595).

*Additional material*

**Australia: Tasmania:** 1 ♂, Waterhouse Point [Waterhouse Conservation area], site 1, 40°50'51"S 147°38'07"E, October 1986, T. Churchill (QVM 13:84); 1 ♂, same data except site 2, 40°50'20"S 147°40'45"E, October 1986, T. Churchill (QVM 13:188); 2 ♂, same data except site 1, 40°50'51"S 147°38'07"E, November 1986, T. Churchill (QVM 13:171, 13:174); 1 ♂, same data except site 2, 40°50'20"S 147°40'45"E, November 1986, T. Churchill (QVM 13:159); 1 ♀, same data except site 1, 40°50'51"S 147°38'07"E, January 1987, T. Churchill (QVM 13:1193); 1 ♂, 1 ♀, same data except site 1, 40°50'51"S 147°38'07"E, November 1987, T. Churchill (QVM 13:1243); 1 ♂, 1 ♀, same data except site 2, 40°50'20"S 147°40'45"E, November 1987, T. Churchill (QVM 13:1240, 13:1237).

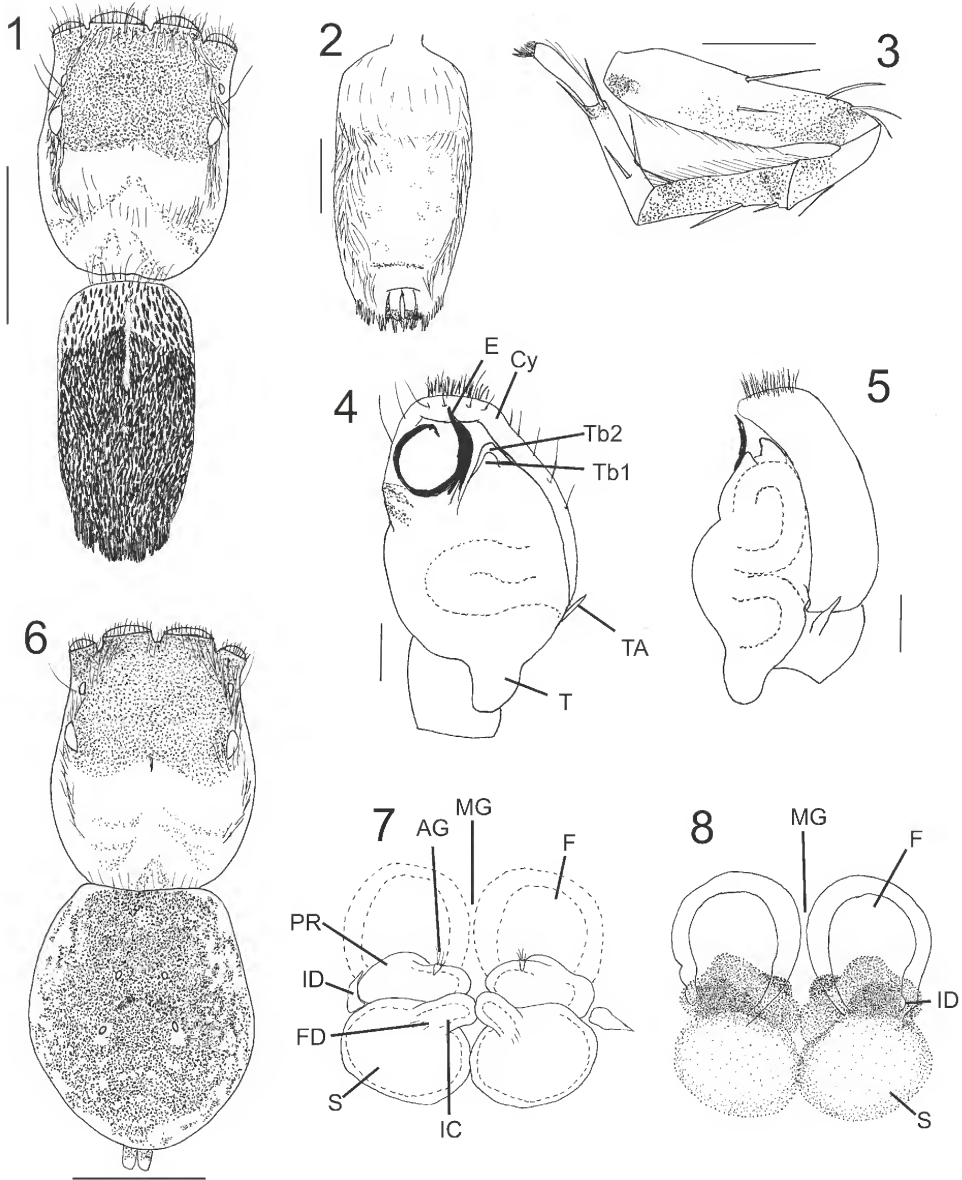
## DIAGNOSIS

Males of *Maratus proszynskii* sp. nov. can be distinguished from all other known species of *Maratus*, other than *M. velutinus*, by the presence of elongate rather than truncate squamous setae on the abdominal scute (which extend noticeably beyond the posterior edge of the scute: see Figure 2), and by the lack of abdominal flaps and lack of thick brushes on leg III (Figure 3). *Maratus proszynskii* sp. nov. differs from *M. velutinus* by the presence of an anterior narrow band of mauve-grey/blue-green squamous setae, by an elongate central stripe anterior to a small mauve-grey/blue-green central spot, and by the presence of short brownish bristles within the ocular quadrangle and white setae around the anterior eyes, and by the absence of a strip of white setae posterior to the fovea (Figure 1). In contrast, *M. velutinus* has reddish bands extending behind the anterior eyes, broad white bands between these eyes, and a broad band of white setae extending from between the AME and beyond the fovea to a point three-quarters down the length of the pars thoracica (see Otto and Hill 2012, figures 68, 69).

## DESCRIPTION

*Male (holotype)*

Cephalothorax black to dark brown with white setae bordering lateral edges and clypeus. No squamous setae. Dense patches of fine white setae extend from behind



FIGURES 1–8 *Maratus prozysniskii* sp. nov., male holotype (QVM 13:1257): 1, cephalothorax and abdomen, dorsal view; 2, abdomen, ventral view; (QVM 13:1257): 3, left leg III, prolateral view; 4, left pedipalp, ventral view (QVM 13: 1243); 5, left pedipalp, retrolateral view (QVM 13:1243). Female paratype (QVM 13:3470): 6, cephalothorax and abdomen, dorsal view; 7, cleared epigyne, dorsal view; 8, epigyne, ventral view. Scale lines = 1 mm (Figures 1, 6), 0.5 mm (Figures 2, 3), 0.1 mm (Figures 4, 5), 0.2 mm (Figs 7, 8). Cy = cymbium; E = embolus; T = tegulum; TA = tibial apophysis; TB1–2 = tegular bulges 1–2; AG = accessory gland; F = fossa; FD = fertilisation duct; IC = intermediate canal; ID = insemination duct; MG = median guide; PR = proximal receiver; S = spermatheca.

anterior lateral eyes, below posterior lateral eyes and along sides of cephalothorax, dissipating before steep drop to posterior margin; no white patch of short setae posterior to fovea. Anterior eyes fringed with creamy setae along dorsal margin; rest of cephalothorax lightly covered with scattered short white setae and brown bristles (Figure 1). Clypeus tan, chelicerae tan, cream distally. Maxillae light brown, labium tan with cream edge. Sternum tan.

Venter of abdomen dark yellow with greyish smudges anteriorly, border above spinnerets dark grey; spinnerets grey. Venter posterior to epigastric furrow covered with pelt of long cream setae, densest along border with dorsal scute. Dorsal abdominal scute not developed as lateral flaps (Figure 2). Entire dorsum densely covered in dark brown elongate squamous setae, except for a very small central spot of mauve-grey/blue-green short squamous setae and a narrow central elongate stripe extending from anterior margin of abdomen to just above the central spot (Figure 1). Posterior border of abdominal scute fringed with elongate brown squamous setae which extend over spinnerets (Figures 1, 2). Anterior third of dorsum lighter brown than rest (Figure 1), edged with thin line of mauve-grey/blue-green short squamous setae, no stiff bristles at anterior corners of abdomen. Stiff long brown bristles projecting from anterior border of abdomen (Figure 1). Abdomen swollen anteriorly raising anterior part of scute, exposed sides of abdomen with greyish patterning, no squamous setae. The long venter setae do not extend onto these lateral regions (Figure 2).

Legs I, II, III and IV: proximal femora pale yellow dorso-anteriorly with dark grey patches ventro-posteriorly; patellae and tibiae tan; metatarsi and tarsi pale yellow with grey bands at joints; covered with dense short white setae interspersed with black bristles. Leg III: patella, tibia, metatarsus and tarsus with brush of fine white setae dorso-ventrally. No long setae covering claws (Figure 3).

Pedipalpal femur grey, distal segments creamy yellow. Tibial apophysis straight, narrowing distally from a broad base (Figure 5). Cymbium, dorsal tibia and dorsal patella densely covered with long white setae, a single very long black seta on dorsal pedipalpal patella; tibia and cymbium with a few long creamy setae on ventral side just under tegulum. Embolus with broad tip and conductor closely aligned with embolus into tight coil, tucked under tip of cymbium; tegulum with two bulges adjacent to embolus (Figure 4).

#### *Female (paratype, QVM 13:3470)*

Ocular region tan, densely covered with short brown setae; areas around eyes black-brown with white setae in patches around all eyes; rest of cephalothorax yellowish-grey with scattered brown setae. With pale grey bands posterior to ocular area (Figure 6). Clypeus

light yellow; chelicerae yellow with light grey patches, maxillae, labium light yellow with white border. Sternum yellow with light grey edging.

Abdomen oval with tan dorsal sigillae and brown bristles scattered amongst brown and creamy setae; most of dorsum covered in diffuse greyish patch on creamy background that narrows to point above spinnerets, three creamy chevrons between posterior sigillae and spinnerets (Figure 6). Venter of abdomen cream, with small grey spots in longitudinal rows. Ventral spinnerets cream, dorsal pair light grey.

Femora and patellae of all legs creamy; dorsal femora of legs III and IV with light grey central stripe, femora I and II with grey stripe only in proximal third; all leg segments except metatarsi I and II and tarsi I to IV with light grey patches at joints; all femora with light grey patches ventro- and posterolaterally.

Proximal receivers of epigyne large, separated from each other at median guide. Intermediate canals abutting each other across median guide, resting on spermathecae, openings directed off-centre of anterior of spermathecae. Insemination duct opening on lower lateral border of fossae (Figures 7–8).

#### *Dimensions (mm)*

Holotype ♂ (paratype ♀, QVM 13:3470): total length (excluding chelicerae) 3.36 (4.03). Carapace length 1.60 (2.08). Abdomen length 1.70 (2.08). Leg I: femur 0.64 (0.84), patella 0.42 (0.62), tibia 0.46 (0.42), metatarsus 0.40 (0.31), tarsus 0.34 (0.27). Leg II: femur 0.59 (0.86), patella 0.46 (0.60), tibia 0.41 (0.42), metatarsus 0.37 (0.37), tarsus 0.33 (0.37). Leg III: femur 1.14 (1.39), patella 0.50 (0.64), tibia 0.70 (0.73), metatarsus 0.54 (0.68), tarsus 0.36 (0.33). Leg IV: femur 0.84 (1.04), patella 0.36 (0.65), tibia 0.59 (0.68), metatarsus 0.48 (0.75), tarsus 0.35 (0.43). Legs, relative lengths: III: IV: I: II/III: IV: II: I.

#### DISTRIBUTION

*Maratus prozysniskii* has been collected from two widely separated locations of heathland (for site descriptions see Churchill, 1996) in northeastern Tasmania, namely Mount William National Park (two sites near Eddystone Point) and Waterhouse Conservation Area (two sites near Waterhouse Point) (see Figure 9). Waterhouse and Eddystone Points are approximately 58 km apart, with the intervening habitat consisting of areas that have been cleared for farmland and other purposes. Mount William National Park (Eddystone Point) is the larger reserve, now consisting of 18,425 hectares, first established in 1973 (MWNP, 2010). Tracey Churchill's (1996) study sites 3 and 4 were located up to 800 m inland from the beach zone on the coast south of Eddystone Point. The Waterhouse Point sites, in Waterhouse Conservation Area (WCA), are less than 600 m from the beaches on the eastern and western sides of the point. The WCA extends in a narrow band

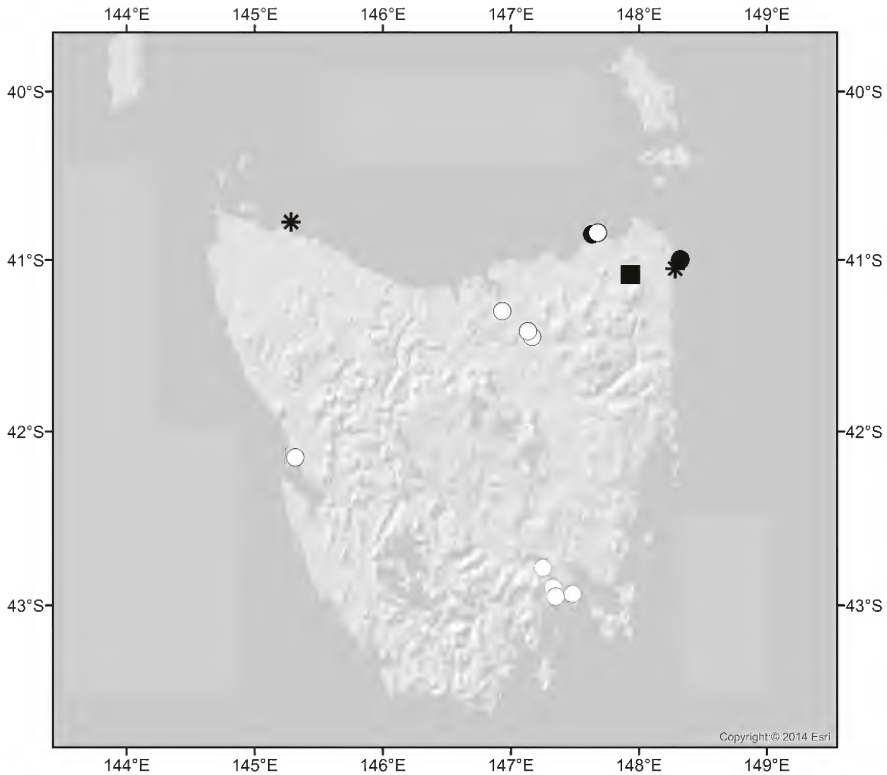


FIGURE 9 Map of Tasmania with the collection sites for *Maratus prozysniskii* sp. nov. (closed circles); *Maratus pavonis* (open circles); *Maratus harrisi* Otto and Hill, 2011 (closed square); *Maratus tasmanicus* Otto and Hill, 2013 (asterisks).

from around the point and south-westerly along the coast, encompassing 6, 953 hectares and one of the largest areas of heathland on the Tasmanian northeast coast (WCAMP 2003).

#### REMARKS

*Maratus prozysniskii* closely resembles *M. velutinus*, with the males of both species possessing dark-brown to black elongate squamous setae, and lacking brushes on leg III and lateral abdominal flaps (see Otto and Hill, 2012). In addition to the differences in colour pattern on the carapace and abdomen (see Diagnosis, above), the males of *M. velutinus* are slightly larger than those of *M. prozysniskii*, with the total length of *M. velutinus* ranging from 3.25 to 4.20 mm averaging 3.76 mm ( $n = 7$ ), whilst *M. prozysniskii* males range from 2.98 to 3.98 mm averaging 3.43 mm ( $n = 10$ ).

Otto and Hill (2012) describe the embolic tip of *M.*

*velutinus* as consisting of the apices of the inner and outer rings of the embolus which present a prominent distal apex (see Otto and Hill 2012, figures 67-5, -6, -7); this statement is interpreted here as referring to the conductor being shorter than the embolus resulting in the embolus tip extending above the tip of the conductor. This arrangement of the embolus and conductor has been noted by Žabka (1987: page 472), “[e]mbolus narrow, forming a single coil, accompanied by a shorter strongly sclerotized conductor”. Upon comparison the embolic tip of *M. velutinus* is broader than that of *M. prozysniskii* but the overall arrangement of the embolus and conductor does not differ significantly (see Figures 4, 5).

The female of *M. velutinus* is unknown so it is not possible to compare them with *M. prozysniskii*.

Both *M. velutinus* and *M. prozysniskii* share characters that separate them from the more spectacular species of

*Maratus*. The lack of brightly coloured squamous setae on the abdomen, lack of squamous setae in the optical quadrangle and most significantly, the lack of brushes on leg III suggest that these two species may be closely related.

#### ETYMOLOGY

The specific epithet is a patronym in honor of Polish Professor Dr Jerzy Prószyński, who, since 1969, has dedicated a lifetime to salticid systematics.

#### *Maratus tasmanicus* Otto and Hill, 2013

*Maratus tasmanicus* Otto and Hill, 2013: 14, figs 15–25.

#### MATERIAL (NOT EXAMINED)

**Australia: Tasmania:** Stanley, 40°46'30.71"S 145°16'58.65"E, J. Otto (TM); Ansons Bay, 41°03'S 148°17'E, 1 January 1929, V. V. Hickman (AM KS30911) as listed in Otto and Hill, 2013.

#### *Maratus pavonis* (Dunn, 1947)

*Saitis pavonis* Dunn, 1947: 83.

*Maratus pavonis* (Dunn): Żabka, 1991: 39; Otto and Hill, 2014: 46, figs 52–55.

#### MATERIAL EXAMINED

**Australia: Tasmania:** 1 ♂, no data, (QVM 13:42186); 1 ♂, Claremont, Hobart, [42°47'S 147°15'E], inside house, 5 December 1982, B. Watson, (TM J2721); 2 ♀, Exeter [41°18'S 146°56'E], 21 November 1970, R. T. G. (QVM 13:42902-3); 2 ♂, Invermay, Launceston, [41°25'S 147°08'E], 19 March 1996, V. Case (QVM "1796"); 1 ♂, Launceston, [41°27'S 147°10'E], 16 November 1970, R. Upsom (QVM 13:42904); 1 ♂, Launceston, [41°27'S 147°10'E], 1 December 1975, H. Dell (QVM 13:42905); 1 ♂ [abdomen missing], Lower Sandy Bay, Hobart, [42°54'S 147°20'E], 2 November 1975, E. L. Martin, (TM J1079); 1 ♂, same locality, E. L. Martin, (TM J1161); 1 ♂, same locality, 13 December 1983, K. Medlock (TM E1907); 1 ♂, Punchbowl, [41°27'S 147°10'E], 26 November 1994, G. Finnigan (QVM 13:16588); 1 ♂, Sandford, [42°56'S 147°29'E], inside of window in house, 30 October 1984, M. Gaffney, (TM J1936); 1 ♂, Strahan, *Melaleuca* swamp, [42°09'S 145°19'E] on ground cover, 15 November 1973, K. C. Collins (AM KS17120); 1 ♂, Tarooma, [42°57'S 147°21'E], 5 January 1977, R. J. Burns, (TM J1171); 1 ♂, 1 ♀ [very faded], Waterhouse Point, site 2, 40°50'20"S 147°40'45"E, Dec. 1987, T. Churchill (QVM 13:1203).

#### Other Tasmanian *Maratus* Species

#### *Maratus harrisi* Otto and Hill, 2011

*Maratus harrisi* Otto and Hill, 2011: 4, figs 4–10.

#### MATERIAL EXAMINED

**Australia: Tasmania:** 1 ♂, Friend Creek, E of Pioneer, in pitfall trap in open bracken, [41°05'S 147°56'E], 27 March 1990, R. Taylor (TM J3113).

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