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TWO FURTHER *NEOCAECULUS* SPECIES (ACARI: PROSTIGMATA: CAECULIDAE) FROM BARROW ISLAND, WESTERN AUSTRALIA

Christopher K. TAYLOR

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Dept of Environment and Agriculture, Curtin University, Perth, WA 6845, Australia. Chris.Taylor@curtin.edu.au

ABSTRACT — Two new species of *Neocaeculus* (Acari: Caeculidae) are described from Barrow Island, Western Australia: *Neocaeculus kinnearae* and *N. nudonates*. *Neocaeculus kinnearae* is a likely epigean species closely related to *N. knoepffleri*; *N. nudonates* is likely to be a sand-burrowing species. *Neocaeculus knoepffleri* and *N. bornemisszai* are also recorded from Barrow Island.

KEYWORDS — Rake-legged mites; Acarina; taxonomy

INTRODUCTION

The Caeculidae are a cosmopolitan family of relatively large, predatory mites (Coineau, 1974a; Otto, 1993), commonly known as 'rake-legged mites' in reference to the rows of enlarged, often spine-like setae present on their forelegs. These are used in the capture of smaller arthropods (Otto, 1993). Caeculids are most diverse in hot, dry environments (Hagan, 1985) and as such may be expected to be widespread in arid Australia. However, Australia's caeculid fauna remains little studied, with only six species described to date (Taylor *et al.*, 2013). The most recent of these was *Neocaeculus imperfectus* Taylor *et al.*, 2013, which was described from Barrow Island in northern Western Australia. The current paper describes two further species of *Neocaeculus* from this location.

Barrow Island is Western Australia's second largest offshore island, and was established as a wildlife reserve in 1908 (Moro and Lagdon, 2013). Its terrestrial invertebrate fauna has been extensively surveyed in recent years as part of the monitoring requirements for the construction of a natural gas refinery (Majer *et al.*, 2013). Due primarily to its arid climate, the northwest sector of Australia is sparsely settled, with few major centres of population. As a result, much of its fauna has been only intermittently studied, and the Barrow Island fauna is one of the region's best known.

In addition to the new species described below, specimens of *Neocaeculus knoepffleri* Coineau and Enns, 1969 (Fig. 1A) and *N. bornemisszai* Coineau and Enns, 1969 (Fig. 1B) have also been collected on Barrow Island. Both these species were originally described from inland in the Kimberley region, and their collection on Barrow Island indicates that they are probably widespread in northern Western Australia. Specimens of *N. knoepffleri* have been observed live at night on coastal limestone rocks, holding their front legs extended in the

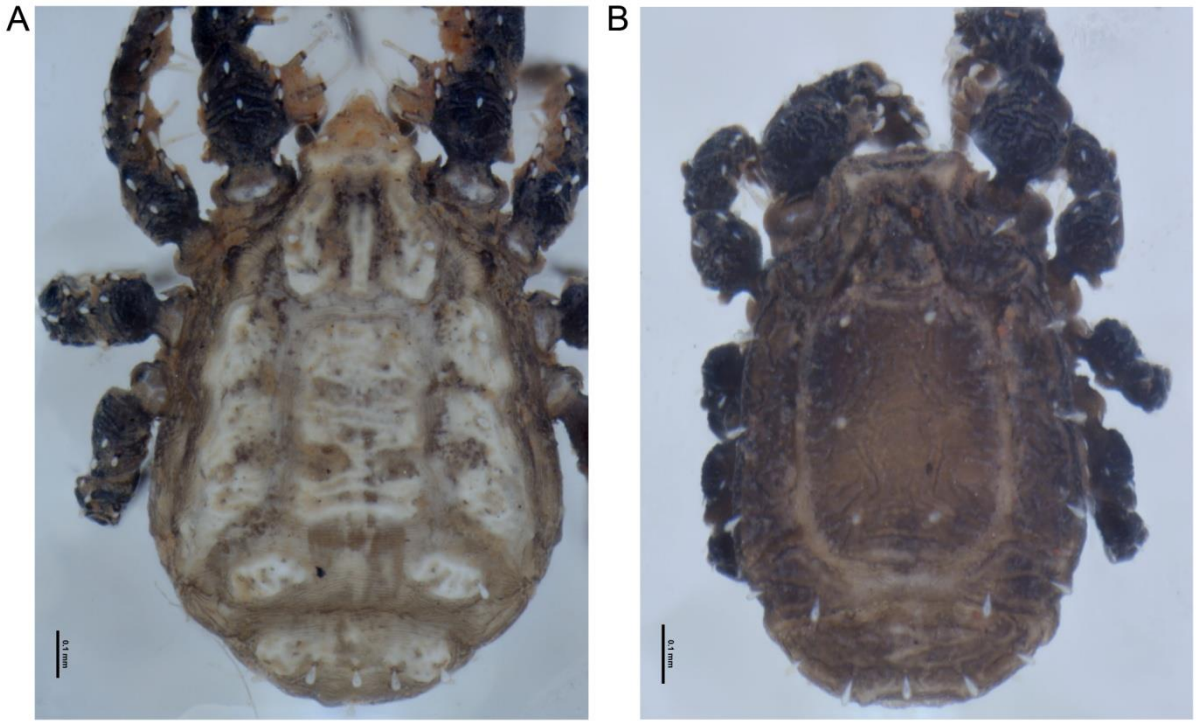

FIGURE 1: *Neocaeculus* species found on Barrow Island: A – *Neocaeculus knoepffleri* (tritonymph, collected September 2012); B – *Neocaeculus bornemisszai* (adult, collected September 2012).

manner described by Otto (1993) for *Microcaeculus pica* Otto, 1993.

With five recorded species, Barrow Island is now home to over half the known diversity of Caeculidae from Australia. This further underscores the likelihood that the true diversity of Australian caeculids is much higher than currently realised.

METHODS

Specimens were collected using pitfall traps, and were observed in 85 % ethanol after partial clearing in 50 % lactic acid using a Nikon SMZ1500 stereo microscope; measurements and photographs were taken using the NIS-Elements D program. The holotypes of the new species and one paratype of *Neocaeculus nudonates* were further cleared in 10 % potassium hydroxide, then relaxed in water and slide-mounted in CMC-10 mounting medium. Measurements are given in micrometres; positions of selected features are described as a proportion of the length of the supporting structure (e.g. eupathidium at 0.3 of a given leg segment indicates that it is about one-third down the segment from the proximal end).

Paratypes of *Microcaeculus pica* were supplied for examination by Bruce Halliday (CSIRO, Canberra).

Neocaeculus kinnearae new species (Figures 2-3)

Holotype — Female, Barrow Island, Western Australia, 20°41’30"S 115°25’09"E, 19-30 March 2012, N. Gunawardene, C. Taylor, pitfall trap (WAM T132729; slide-mounted).

Paratypes — 1 female, Barrow Island, Western Australia, 20°49’37"S 115°26’48"E, 19-30 March 2012, N. Gunawardene, C. Taylor, pitfall trap (WAM T132730; in ethanol); 1 female, Barrow Island, Western Australia, 20°41’26"S 115°25’01"E, 17-29 March 2013, N. Gunawardene, C. Taylor, pitfall trap (WAM T132731; in ethanol).

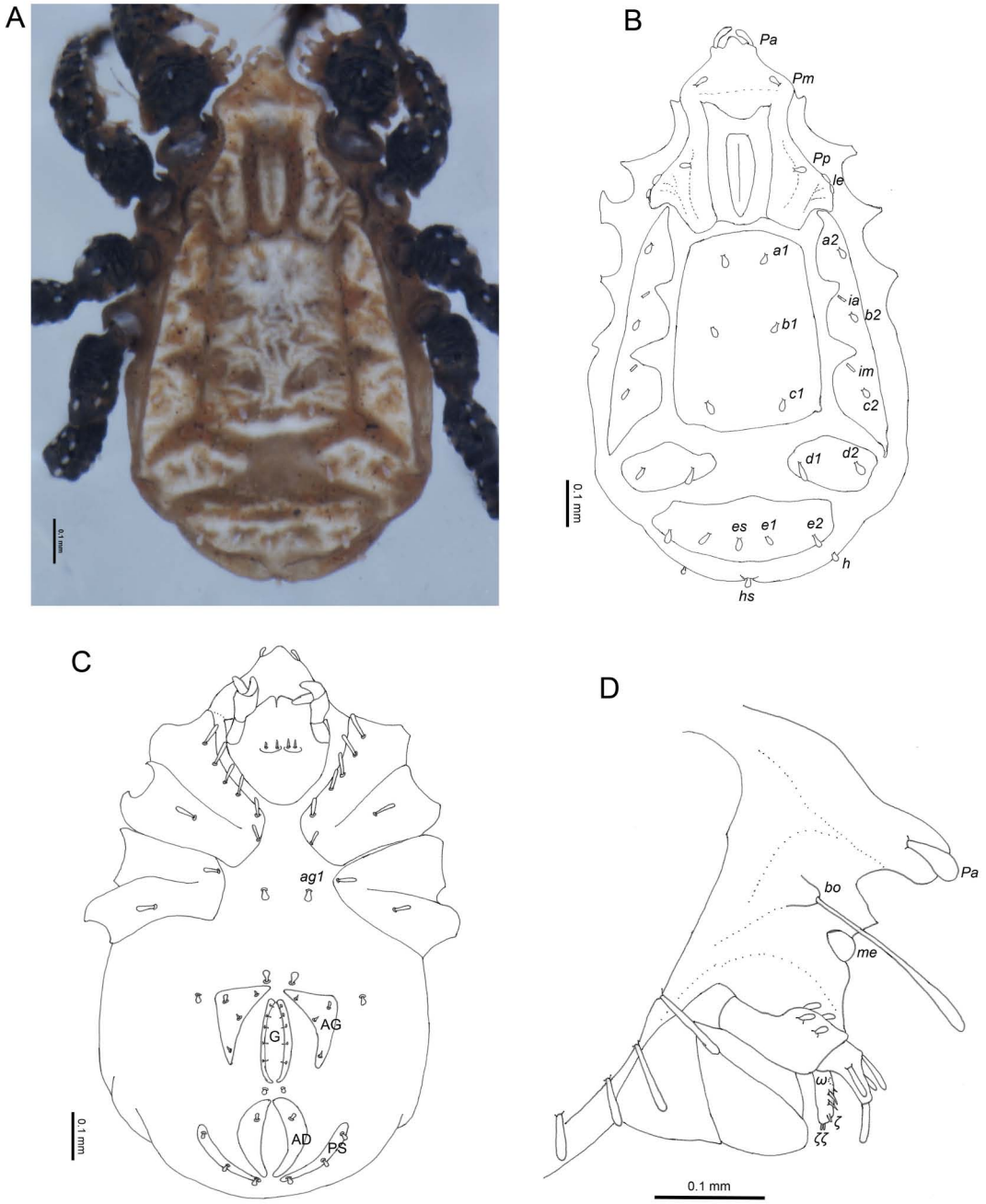

FIGURE 2: *Neocaeculus kinnearae*: A – Dorsal view; B – diagram of dorsum of idiosoma showing positions of setae and lyrifissures; *le* = lateral eyes; C – venter of idiosoma: AD = adanal sclerite, AG = aggenital sclerite, G = genital sclerites, PS = pseudanal sclerite; D – lateral view of anterior of idiosoma, showing palp and anterior bothridial seta *bo*. Solenidion indicated by ω; eupathidia indicated by ζ; *me* = median eye.

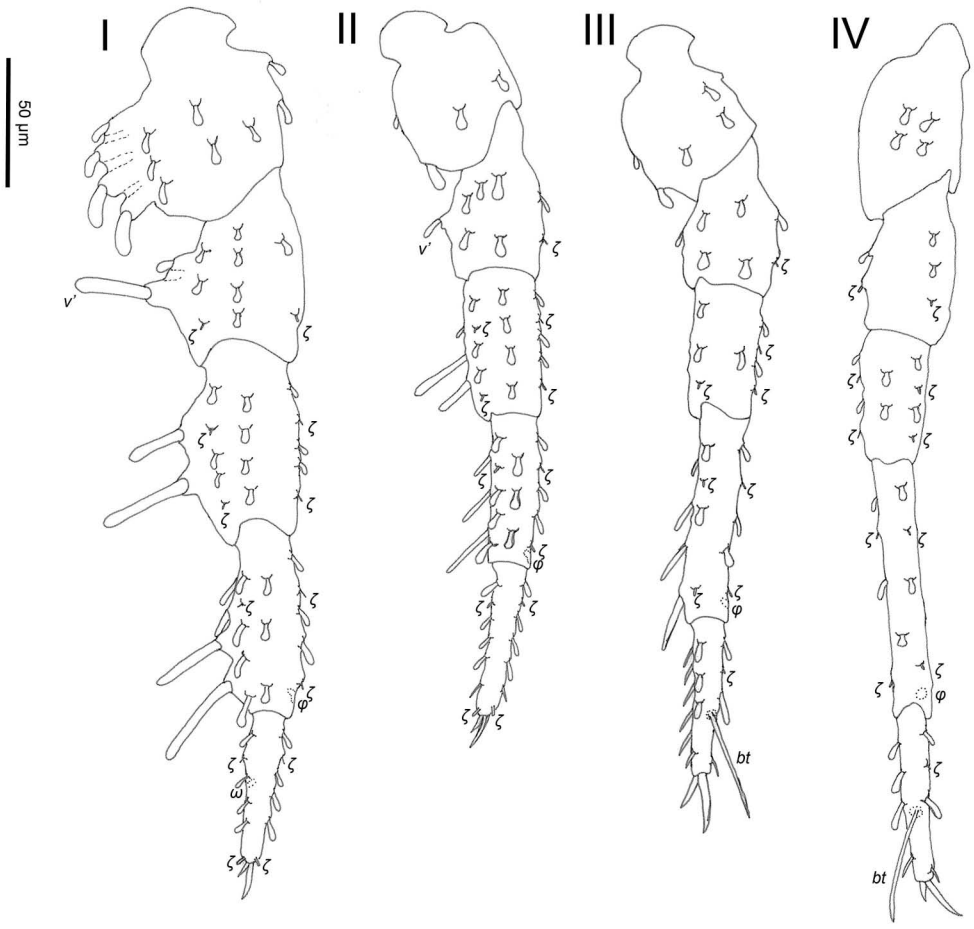

FIGURE 3: Legs of the left side of *Neocaeculus kinnearae* in dorsal view. Selected proventral setae v' marked on legs I and II to facilitate orientation. Eupathidia marked with ζ; tibial solenidia marked with φ; tarsal solenidia marked with ω.

Etymology — Named for Adrianne Kinnear, who identified many of the mites from Barrow Island and incited my own interest in mites.

Diagnosis — In the key to Australasian Caeculidae provided by Taylor *et al.* (2013), *Neocaeculus kinnearae* would key out to *N. knoepffleri*, to which it is very similar. It differs from *N. knoepffleri* in its smaller size (about 1.1-1.2 mm in idiosoma length vs 1.5-1.6 mm in *N. knoepffleri*) and lack of a retroventral spinose seta on femur I. *Neocaeculus kinnearae* also has the major setae less sharply spinose than those of *N. knoepffleri*, with the tips baculate rather than acute. *Neocaeculus bornemisszai* has shorter, more clavate major setae on the legs (Coineau andEnns, 1969). *Neocaeculus kinnearae* differs from *N. luxtoni* Coineau, 1967, *N. imperfectus* and *Microcaeculus pica* in having bothridial seta *bo* elongate and non-capitate. It differs from *N. johnstoni* Coineau, 1974b and *N. womersleyi* Coineau, 1974b in having femur I undivided.

Dorsum — Idiosoma length 1130-1179, width 645-686. Cream-coloured sclerites divided by darker striated integument. Dorsal setae small, can be difficult to distinguish. Aspidosomal sclerite with median rectangular area outlined by dark-pigmented grooves; sclerite length 355-445, width 316-415; setae *Pa* situated at anteriormost end of sclerite; setae *Pm* at 0.2 on anterior lateral corners of sclerite; setae *Pp* at 0.7 towards retrolateral corners of sclerite. Accessory sclerite bearing two pairs of eyes fused to lateral margin of rear of aspidosomal sclerite; anterior margin of anterior eyes roughly level with setae *Pp*. Centrodorsal sclerite with paired setae *a1*, *b1*, *c1* present; centrodorsal sclerite length 413-549, width 315-378. Lateral sclerites each subdivided by two mediolateral indentations; paired setae *a2*, *b2*, *c2* sequentially placed with one seta on each sub-region of sclerite demarcated by indentations; lyrifissure *ia* angled laterally rearwards, placed at about 0.7 between setae *a2* and *b2*; lyrifissure *im* angled laterally rearwards, placed about halfway between setae *b2* and *c2*. Opisthosoma with broadly separated medial sclerites bearing setae pairs *d1*, *d2*; one transverse posterior sclerite bearing setae pairs *e1*, *e2*, and unpaired median seta *es*; and two lateral pluriposterior sclerites bearing seta *h* medially together with single median pluriposterior sclerite bearing seta *hs*. Seta *ds* absent.

Venter — Epimeres dark brown; surrounded by darker cream integument; venter of idiosoma largely darker cream except genital and adanal sclerites dark brown, aggenital and pseudanal sclerites grey-brown. Median eye present below anterior projection of aspidosomal sclerite, seta *Po* reduced to minute spine above median eye; bothridial setae *bo* lateral to median eye elongate, distally fusiform but not distinctly capitate. Infracapitulum with two pairs of setae arranged in a transverse line. Epimeres I and II fused; epimere I with six elongate setae; epimere II with one elongate seta. Epimeres III and IV fused, each with one elongate seta. Genital valves with five to seven pairs of setiform setae; genital opening length 173-193. Eight pairs of aggenital setae present, with four pairs of setiform setae on aggenital sclerites; anteriormost clavate aggenital seta close to level of anterior of epimere IV; one pair each of clavate setae present just anterior to genital opening, exterior to aggenital sclerite and posterior to genital opening. Adanal sclerites with one pair of clavate setae; pseudanal sclerites with three pairs of clavate setae; anal opening length 152-173.

Gnathosoma — Gnathosoma uniformly black. Palp with four segments; fused femur-genu with four dorsal barbed setae; tibia with three dorsal barbed setae and one large barbed seta distally; tarsus with recessed solenidion proximodorsally, four setiform setae around halfway, and four eupathidia with two paired eupathidia terminally and two separated eupathidia close to distal end.

Legs — Legs black with white setae. All legs with femora undivided. All legs with anterior tarsal claw much smaller than posterior claw. Prodorsal, dorsal and retrodorsal rows of clavate setae present on all legs. Elongate bothridial seta *bt* absent on legs I and II, present dorsally at about 0.6 on tarsi III and IV. Trochanter I with four elongate prolateral tubercles each bearing rounded terminal seta; femur I proventrally with one elongate clavate seta at about 0.6, retroventrally with five clavate setae on raised tubercles, paired dorsolat-

eral eupathidia present distally; genu I proventrally with two or three elongate clavate setae, retroventrally with one elongate clavate seta, paired dorsolateral eupathidia present at about 0.3 and distally; tibia I proventrally with three spinose setae, retroventrally with two spinose setae; paired dorsolateral eupathidia present at about 0.3; retrodorsal eupathidium present distally with recessed solenidion and seta *k"* slightly more ventrodistal; tarsus I with proventral and retroventral rows of spinose setae, paired dorsolateral eupathidia at about 0.3 and distally, recessed prolateral solenidion at about halfway, setae *er* claw-like and directed parallel to tarsus. Leg II with elongate spinose setae on genu and tibia, remaining ventral setae not enlarged; arrangement of eupathidia as for leg I; prolateral solenidion also present at about halfway on tarsus.

Comments — The life habits of *Neocaeculus kinnearae* are unknown, but its collection from pitfall traps rather than on vegetation suggests it is probably terrestrial rather than scansorial as has been suggested for *N. imperfectus* (Taylor *et al.*, 2013). Its elongate major leg setae suggest that it is probably an epigean species like *N. knoepffleri* (see above) rather than a burrower in the likely manner of *N. bornemisszai* and *N. nudonates*. The blunter major leg setae of *N. kinnearae* than those of *N. knoepffleri* may indicate that these species differ in microhabitat; *N. kinnearae* may prefer a coarser substrate than the clay or rock from which *N. knoepffleri* has been collected (Coineau and Enns, 1969, and above).

Neocaeculus kinnearae is similar in overall morphology to *Neocaeculus knoepffleri*, and the two species seem likely to be closely related. However, while the anterior section of the aspidosomal sclerite of *N. knoepffleri* is strongly downturned above the gnathosoma (Coineau and Enns, 1969: Fig. 2 therein), that of *N. kinnearae* is less downturned and projects slightly forwards (Fig. 2D). This is problematic, as the anterior projection of the aspidosomal sclerite has previously been used to distinguish *Neocaeculus* from the genus *Microcaeculus* (Taylor *et al.*, 2013).

Further consideration has convinced me that distinguishing these two genera by this character alone is untenable, as it is unclear whether it can be consistently applied. The aspidosomal sclerite of *Microcaeculus sabulicola* Franz, 1952 (Coineau, 1969: Fig. 3 therein) is only a little more produced than that of *Neocaeculus luxtoni* Coineau, 1967 (Fig. 6 therein), and less expansive overall than that of *N. knoepffleri*. The anterior part of the aspidosomal sclerite of the latter species is in fact relatively elongate despite being downturned. This stands in contrast to *N. johnstoni* Coineau, 1974b, whose '*Neocaeculus*' profile is due to direct truncation of the aspidosomal sclerite itself, and not due to a downturn of the anterior portion (indeed, Coineau, 1974b, made no mention of the aspidosomal sclerite in his list of characters associating the latter species with *Neocaeculus*). Nor is any distinct downturn of the aspidosomal sclerite evident in the profiles of *N. imperfectus* (Taylor *et al.*, 2013: Fig. 2 therein) or *N. nudonates* (Fig. 4D), despite the truncate profiles of both.

Nevertheless, it remains premature at this point to synonymise the two genera. Taylor *et al.* (2013) noted characters that may be synapomorphic for *Neocaeculus*, including fusion of the basifemur and telofemur of leg I into a single segment (absent in *N. johnstoni* and *N. womersleyi* Coineau, 1974b) and reduction of the adanal setation to a single seta (lost entirely in *N. nudonates*). Also noteworthy is that the four-segmented palp of *Neocaeculus* species (with femur and genu fused) contrasts with the five-segmented palp of many *Microcaeculus* species (e.g. Coineau, 1968, 1969; Coineau and Haupt, 1977; Piffl, 1965), though the type species of that genus, *M. austriacus* Franz, 1952, was originally illustrated with a four-segmented palp (a detail that requires confirmation).

Unfortunately, many *Microcaeculus* species (in particular *M. austriacus*) have not been described in detail and would benefit from further investigation. For instance, species of *Microcaeculus* described from South America by Franz (1962, 1964) may be better placed in *Andocaeculus* (A. Porta, pers. comm., 2014).

Neocaeculus nudonates new species (Figures 4-5)

Holotype — Female, Barrow Island, Western Australia, 20°47′39"S 115°27′15"E, 19-30 March 2012, N. Gunawardene, C. Taylor, pitfall trap (WAM T132732; slide-mounted).

Paratypes — 4 females, as for holotype (WAM T132733 [1 specimen, slide-mounted]; WAM T132734 [remaining specimens, in ethanol]).

Etymology — Noun in apposition, from the Latin *nudus*, uncovered or exposed, and *nates*, buttocks, in reference to the small posterior sclerites.

Diagnosis — In the key to Australasian Caeculidae provided by Taylor *et al.* (2013), *Neocaeculus nudonates* would key out with *Neocaeculus imperfectus*, *N. luxtoni* and *Microcaeculus pica*. It differs from *N. imperfectus* in having the enlarged setae on femur I clavate rather than spinose, and from *N. luxtoni* and *M. pica* in lacking seta *es*. It also differs from *M. pica* in the lower number of setae on the legs and epimeres, in having the setae *Pa* located on the anterior edge of the aspidosomal sclerite rather than ventral to the anterior edge, and in lacking the strikingly contrasting coloration of *M. pica* (Otto 1993). It differs from *N. knoepffleri*, *N. bornemisszai*, *N. johnstoni* and *N. womersleyi* in having the bothridial setae *bo* globose-capitate.

Dorsum — Idiosoma length 608-667; width 358-400. Dark brown sclerites separated by light brown striated integument. Aspidosomal sclerite with median depression poorly demarcated; setae *Pa* situated at anteriormost corners of sclerite; setae *Pm* at 0.3 on anterior lateral corners of sclerite; setae *Pp* at about 0.7 towards posterior lateral margins of sclerite, which are distinctly rounded rather than angular; aspidosomal sclerite length 192-249, width 166-177. Two pairs of eyes on accessory sclerite lateral to rear of aspidosomal sclerite; anterior margin of anterior eyes roughly level with setae *Pp*. Centrodorsal sclerite with paired setae *a1*, *b1*, *c1* present; posterior margin of centrodorsal sclerite distinctly emarginate; centrodorsal sclerite length 196-276, width 185-223. Lateral sclerites not distinctly subdivided by emarginations; paired setae *a2*, *b2*, *c2* present roughly level with corresponding setae on centrodorsal sclerite; lyrifissure *ia* angled slightly laterally forwards, about one-fifth width of lateral sclerite, placed about midway between setae *a2* and *b2*; lyrifissure *im* angled laterally rearwards, similar in size to *ia*, placed at about 0.6 between setae *b2* and *c2*. Opisthosoma with broadly separated medial sclerites bearing setae pairs *d1*, *d2*, with unpaired seta *ds* present medially on soft integument; broadly separated posterior sclerites bearing setae pairs *e1*, *e2*; and two lateral pluriposterior sclerites bearing seta *h* medially, together with single median pluriposterior sclerite bearing seta *hs*. Seta *es* absent. Lyrifissure *ip* oval in shape, positioned on side of body in line with division of medial and posterior sclerites.

Venter — Epimeres dark brown; surrounded by darker cream integument; venter of idiosoma largely darker cream except sclerites dark brown. Median eye present below anterior projection of aspidosomal sclerite, seta *Po* reduced to minute spine above median eye; bothridial setae *bo* lateral to median eye globose-capitate. Infracapitulum bearing two pairs of setiform setae, median pair slightly anterior to lateral pair. Epimeres I and II fused; epimere I bearing four elongate setae; epimere II bearing one elongate seta. Epimeres III and IV fused, each bearing one elongate seta. Genital valves with six pairs of setiform setae; genital opening length 76-104. Nine pairs of clavate aggenital setae present, four pairs on aggenital sclerites; anteriormost pair level with epimere IV; one pair just anterior, two pairs exterior and one pair just posterior to aggenital sclerites. Adanal setae absent; pseudanal sclerites with three pairs of clavate setae; anal opening length 95-138.

Gnathosoma — Gnathosoma uniformly dark brown. Palp with four segments; fused femur-genu with three dorsal barbed setae; tibia with one prolateral setiform seta, and three dorsal and one terminal barbed setae; tarsus with recessed solenidion proximodorsally, three setiform setae around halfway, and paired eupathidia terminally.

Legs — Legs black bearing white clavate setae. All femora undivided. All legs with anterior tarsal claw much smaller than posterior claw. Elongate bothridial seta *bt* absent on legs I and II, present

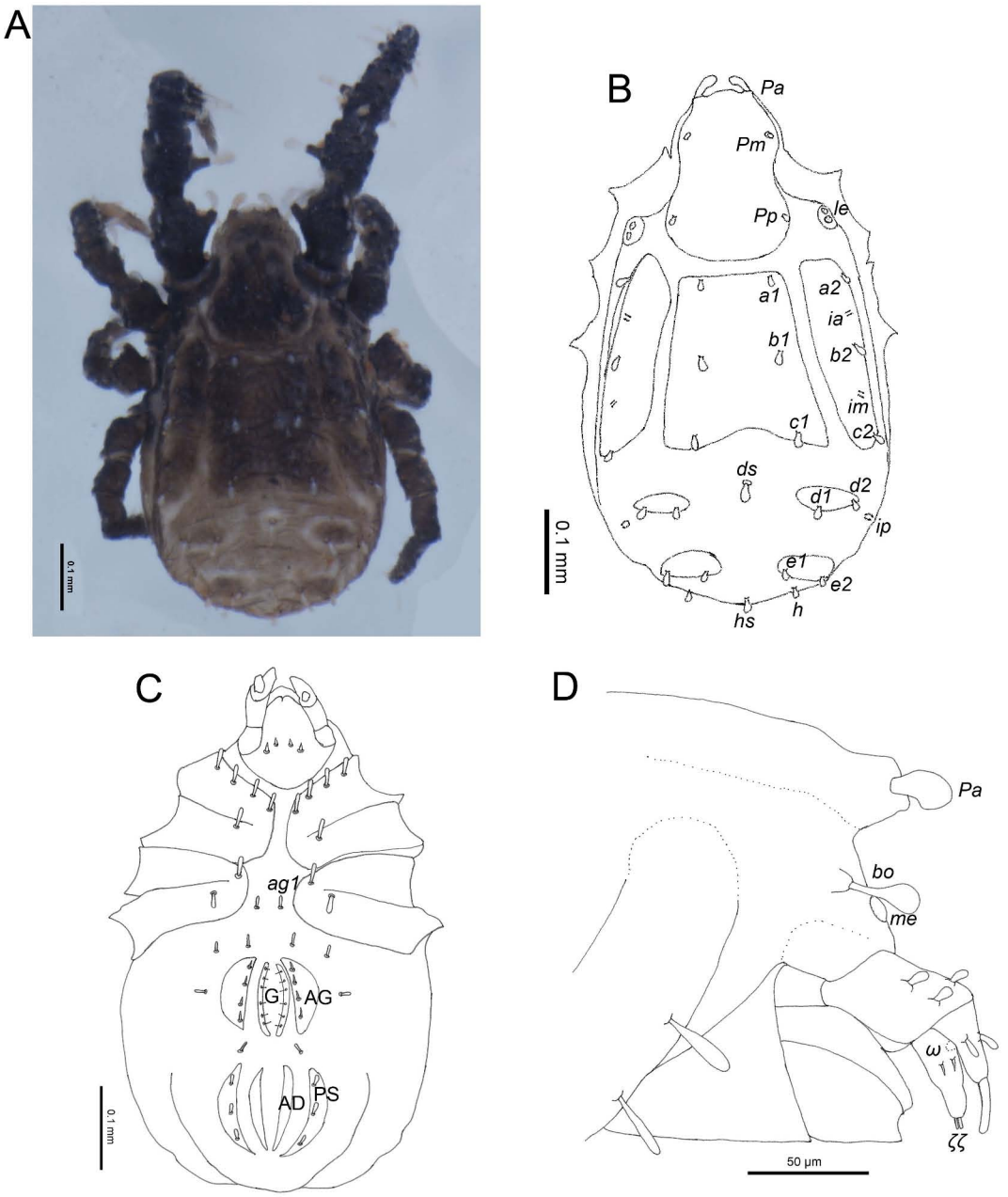

FIGURE 4: *Neocaeculus nudonates*, labels as for figure 2: A – Dorsal view; B – diagram of dorsum of idiosoma; C – venter of idiosoma; D – lateral view of anterior of idiosoma.

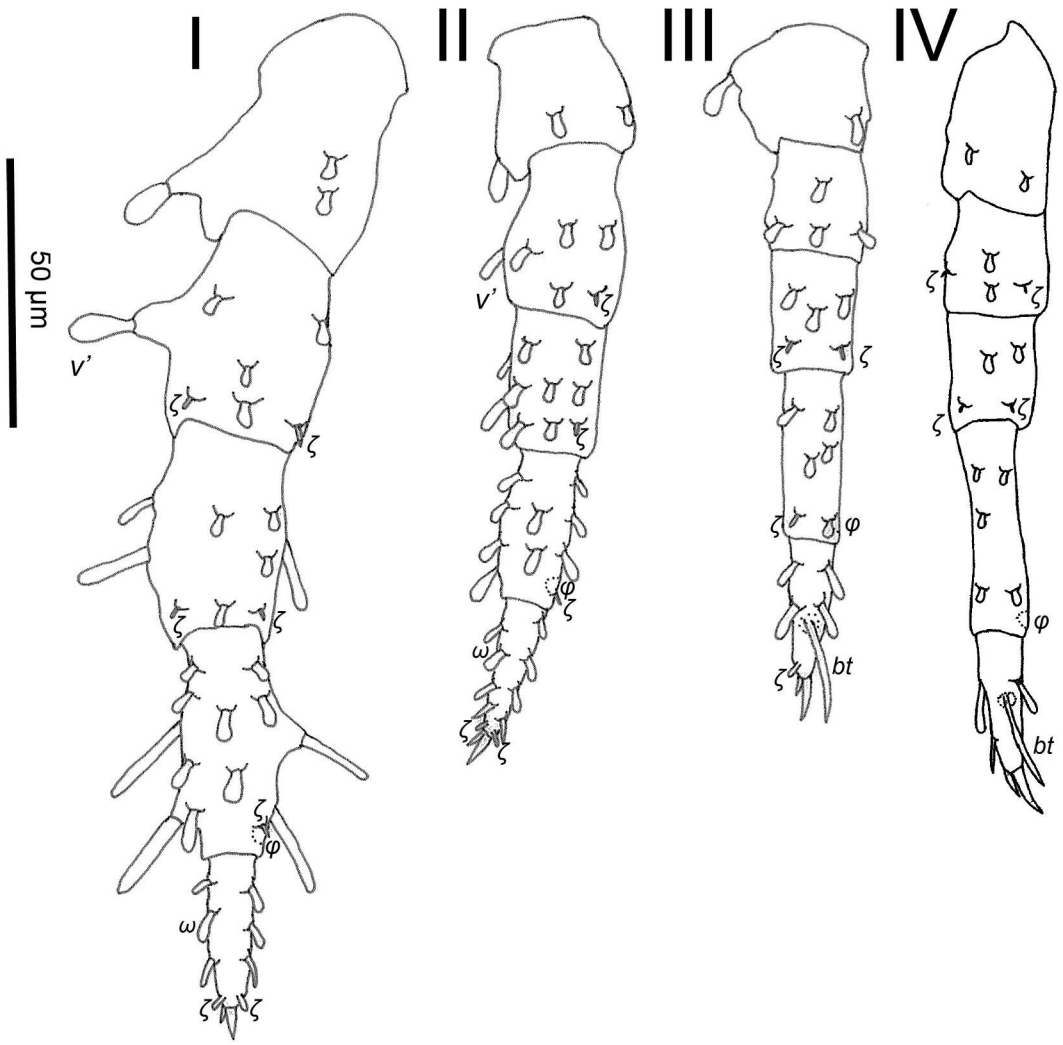

FIGURE 5: Legs of the left side of *Neocaeculus nudonates* in dorsal view; labels as for figure 3.

dorsally at about 0.6 on tarsi III and IV. Clavate setae present dorsally on all legs. Trochanter I with elongate prolateral tubercle bearing clavate seta; femur I with large proventral and retroventral seta, paired dorsolateral eupathidia present distally; genu I with two large proventral and one retroventral spinose setae, paired dorsolateral eupathidia present distally; tibia I with two proventral and two retroventral spinose setae, retrodorsal eupathidium present distally with recessed solenidion and seta *k"* slightly more ventrodistal; tarsus I with recessed prolateral solenidion at about halfway, setae *er* claw-like and directed parallel to tarsus. Leg II with large proventral clavate setae on femur and genu, remaining ventral setae not enlarged; arrangement of eupathidia as for leg I; prolateral solenidion also present at about halfway on tarsus.

Comments — Other species of Caeculidae with clavate rather than spinose enlarged leg setae are known to be diggers in sandy substrates (Coineau and Enns, 1969; Coineau, 1974a; Otto, 1993), and it seems likely that *Neocaeculus nudonates* is similar in habits. Barrow Island is therefore inhabited by two likely fossorial species, *N. nudonates* and *N. bornemisszai*. Data are currently inadequate to determine whether these two species exhibit any differences in habitat preference, though it may be noted that *N. bornemisszai* is more heavily sclerotised than *N. nudonates*.

The reduced opisthosomal sclerotisation of *N. nudonates* immediately distinguishes it from all other Australasian caeculids, most of which have the posterior sclerites in particular tending to become fused into a single transverse sclerite (as in Fig. 2a). The species most similar to *N. nudonates* in this regard is *Microcaeculus pica* which, as noted by Taylor *et al.* (2013), may prove more closely related to *Neocaeculus* once the relationship of this genus with *Microcaeculus* is better established.

Together with *Microcaeculus pica*, *Neocaeculus luxtoni* and *N. imperfectus*, *N. nudonates* is part of a group of species that are distinctive in the possession of a strongly globose-capitate bothridium *bo*. Taylor *et al.* (2013) believed that this bothridial morphology had not been recorded outside Australasian species; however, André (1936) illustrated a similar bothridium for the Italian species *Microcaeculus pisanus* (André, 1936). Unfortunately, *M. pisanus* was described (in the genus *Caeculus*) from the larva only, and Coineau (1974a) listed it as a species of *Microcaeculus* without further comment. Its relationship with other caeculid species therefore remains uncertain.

Discussion

The species recorded herein for Barrow Island have been found in only a small number of samples, with correspondingly low numbers of individuals in each sample. This contrasts with the abundance in samples from Barrow Island of *Neocaeculus imperfectus* (Taylor *et al.*, 2013). However, it should be noted that at least some of this apparent difference in abundance may reflect bias in the collection methods used by the Barrow Island survey (Callan *et al.*, 2011; Majer *et al.*, 2013). The likely scansorial *N. imperfectus* has primarily been collected through suctioning of vegetation, while the other, probably more terrestrial species have only been collected in pitfall traps. Pitfall traps may not be ideal for collecting the fossorial species if they are likely to be just beneath the soil surface rather than walking above it. Conversely, if *N. knoepffleri* is a primarily epilithic species that rarely crosses looser substrates, then it may be unlikely to occur in locations where pitfalls can easily be dug. Though each only rarely collected, neither *N. knoepffleri* nor *N. kinnearae* appears to be markedly localised on Barrow Island, as they have each been found in other, widely separated sites. *Neocaeculus bornemisszai* and *N. nudonates* have each only been collected on Barrow Island on a single occasion, but *N. bornemisszai* is also known from the Kimberley region (Coineau and Enns, 1969) and is similarly unlikely to be restricted in distribution.

Though most Australian caeculid species have not been recorded subsequent to their original descriptions, museum collection records support the assumption that Caeculidae are widespread in Australia (Atlas of Living Australia, www.ala.org.au). It is also notable that the encyrtid wasp *Globulencyrtus dahmsi* Simutnik and Trjapitzin, 2008, described

from Queensland, represents a genus known elsewhere to be parasitic on Caeculidae (Coineau and Davis, 1999). It seems almost certain that we have only begun to appreciate Australia's caeculid diversity.

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