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Discovery of the pill millipede genus *Epicyliosoma* (Diplopoda: Sphaerotheriida: Sphaerotheriidae) in Western Australia, with the description of a new species

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Abstract – This paper describes the second species of sphaerotheriid millipede to be recorded from Western Australia, *Epicyliosoma (Epicyliosoma) sarahae* sp. nov. It is restricted to low rainfall biotopes in the southeast coastal province of Western Australia and may be under threat from climate change and fire. *Epicyliosoma sarahae* is more restricted within its range than the other Western Australian species, the threatened *Cynotelopus notabilis* Jeekel, and both species are short-range endemics.

Keywords: Conservation, *Cynotelopus*, fire, prescribed burning, short-range endemic species

INTRODUCTION

In Australia the Sphaerotheriida, or pill millipedes, are represented by the family Sphaerotheriidae. This family is of Gondwanan origin and is also present in South Africa, Madagascar, India, Sri Lanka, and New Zealand (Jeekel 1974). There are three genera in Australia, with the third further divided into two subgenera: *Cynotelopus* Jeekel, 1986, *Procyliosoma* Silvestri, 1917, *Epicyliosoma (Epicyliosoma)* Silvestri, 1917, and *Epicyliosoma (Paracyliosoma)* Verhoeff, 1928. All are Australian endemic genera, with the exception of *Procyliosoma*, which is also represented in New Zealand by five species (Holloway 1956). Jeekel (1986) provided keys and/or descriptions to distinguish these genera and subgenera.

Only two species of Sphaerotheriidae have been found in Western Australia, and both are restricted to the south coast. The first, *Cynotelopus notabilis* Jeekel, 1986, is in a monotypic genus which is endemic to high rainfall areas of the far southwest (Main *et al.* 2002). A second species has been recently found east of Esperance, in the southeast coastal province, and is described in this paper: *Epicyliosoma (Epicyliosoma) sarahae* sp. nov. This is the first record of the genus *Epicyliosoma* in Western Australia, with other species of the genus known only from Queensland and New South Wales, as far south as Penrith in Sydney (33°44'S, 150°45'E). Thus, *E. sarahae* sp. nov. is the most southern species recorded to date of the genus.

MATERIALS AND METHODS

The specimens examined here were hand collected in the field and preserved in 75% ethanol, with one specimen from each site preserved in 100% ethanol for future DNA analysis. All specimens are lodged in the Western Australian Museum, Perth (WAM). Specimens were examined with a Leica MZ6 stereo microscope, and all images, except those in the field, were produced utilizing a MZ16 stereo microscope and the package Automontage Pro version 5.02(p) (Syncroscopy, Cambridge, UK). A map of species distribution was produced in Arcview GIS Version 3.1 (Environmental Systems Research Inc.). Terminology follows Wesener and Sierwald (2005a), except when discussing male genitalia.

SYSTEMATICS

Family Sphaerotheriidae C.L. Koch, 1847

Genus *Epicyliosoma* Silvestri, 1917

Epicyliosoma Silvestri, 1917: 68. Type species: *Zephronia albertisii* Silvestri, 1895, by subsequent designation.

Remarks

Epicyliosoma is distinguished from *Procyliosoma* and *Cynotelopus*, the other two genera present in Australia, by the structure of the male genitalia, in particular the anterior and posterior telopods.

Jeekel (1986) notes that the anterior telopods of *Epicyliosoma* and *Cynotelopus* feature a large prefemur, with reduced femur and tibiotarsus (e.g., Jeekel 1986, figure 5; Verhoeff 1928, plate VI, figures 4 and 6). In contrast, the femur and tibiotarsus of *Procyliosoma* is more developed, whereas the prefemur is smaller (e.g., Holloway 1956, figures 10 and 20). *Epicyliosoma* differs from *Cynotelopus* in the shape of the posterior telopods. The tibiotarsus of *Cynotelopus* is squat and broad, with a round inflated area in the basal half (Jeekel 1986, figure 6), whereas *Epicyliosoma* has a tibiotarsus which is long and curved (Figure 7, this paper).

There are currently 15 species in the genus *Epicyliosoma*, with five in the subgenus *Epicyliosoma*, seven in the subgenus *Paracyliosoma*, and three with an uncertain subgeneric status (Jeekel 1986; Mesibov 2006). The two subgenera can be distinguished by differences in the male anal shield and the femoral process of the posterior telopods. The anal shield of male *Epicyliosoma* is without sexual modification, but with fine scattered setae, and the femoral process is approximately the size of the tibiotarsus, giving a pincer-like appearance to the posterior telopods (Jeekel 1986). The anal shield of male *Paracyliosoma* has a distinctive line of setae down the middle (e.g., Verhoeff 1928, plate VI, figure 7), and the femoral process is approximately half the length of the tibiotarsus (Jeekel 1986; and see Verhoeff 1928, plate VI, figure 5).

Epicyliosoma (Epicyliosoma) sarahae sp. nov.

Figures 1–8

Material Examined

Holotype

Australia: *Western Australia*: ♂, Cape Le Grand National Park, inland from Thistle Beach, 34°00'20"S, 122°11'39"E, in soil, 17 November 2006, M.L. Moir (WAM T78757).

Paratypes

Australia: *Western Australia*: 5 ♂, 8 ♀, Cape Le Grand National Park, inland from Thistle Beach, 34°00'19"S, 122°11'47"E, in soil, 17 November 2006, M.L. Moir (WAM T78948).

Other material examined

Australia: *Western Australia*: 4 ♂, 3 ♀, 4 juveniles, Cape Arid National Park, Mt Arid, gully, 33°58'15"S, 123°13'22"E, in soil, 16 November 2006, M.L. Moir & O. Massenbaur (WAM T78752, T78753); 4 ♀, 5 juveniles, Cape Le Grand National Park, inland from Thistle Beach, 34°00'19"S, 122°11'47"E, in soil, 17 November 2006, M.L. Moir (WAM T78754, T78755); 3 ♀, 1 juvenile, Cape Le Grand National Park, Mt Le Grand, 33°59'49"S, 122°07'13"E, in soil, 27 November 2006, M.L. Moir & K.E.C. Brennan (WAM T78758, T78759); 3 ♀, 3 juveniles, Cape Arid National Park, Mt Arid, gully, 33°58'09"S, 123°12'52"E, in soil, 16 November 2006, M.L. Moir & O. Massenbaur (WAM T78750, T78751); 2 ♀, Cape Le Grand National Park, inland from Thistle Beach, 34°00'20"S, 122°11'39"E, in soil, 17 November 2006, M.L. Moir (WAM T78947); 1 ♀, Cape Le Grand National Park, Mt Le Grand, 33°59'25"S, 122°07'35"E, under rock, 27 November 2006, M.L. Moir & K.E.C. Brennan (WAM T78791); 1 ♀, Cape Arid National Park, Hill Springs, 33°58'14"S, 123°14'11"E, wet pitfall trap, 15 November 2005, S. Comer (WAM T74781).

Diagnosis

Epicyliosoma sarahae differs from all other previously named species within the genus by the shape of the anterior telopods, the prefemur of which lacks a lobe, or projection of any kind, on the inner posterior-lateral margin.

Description

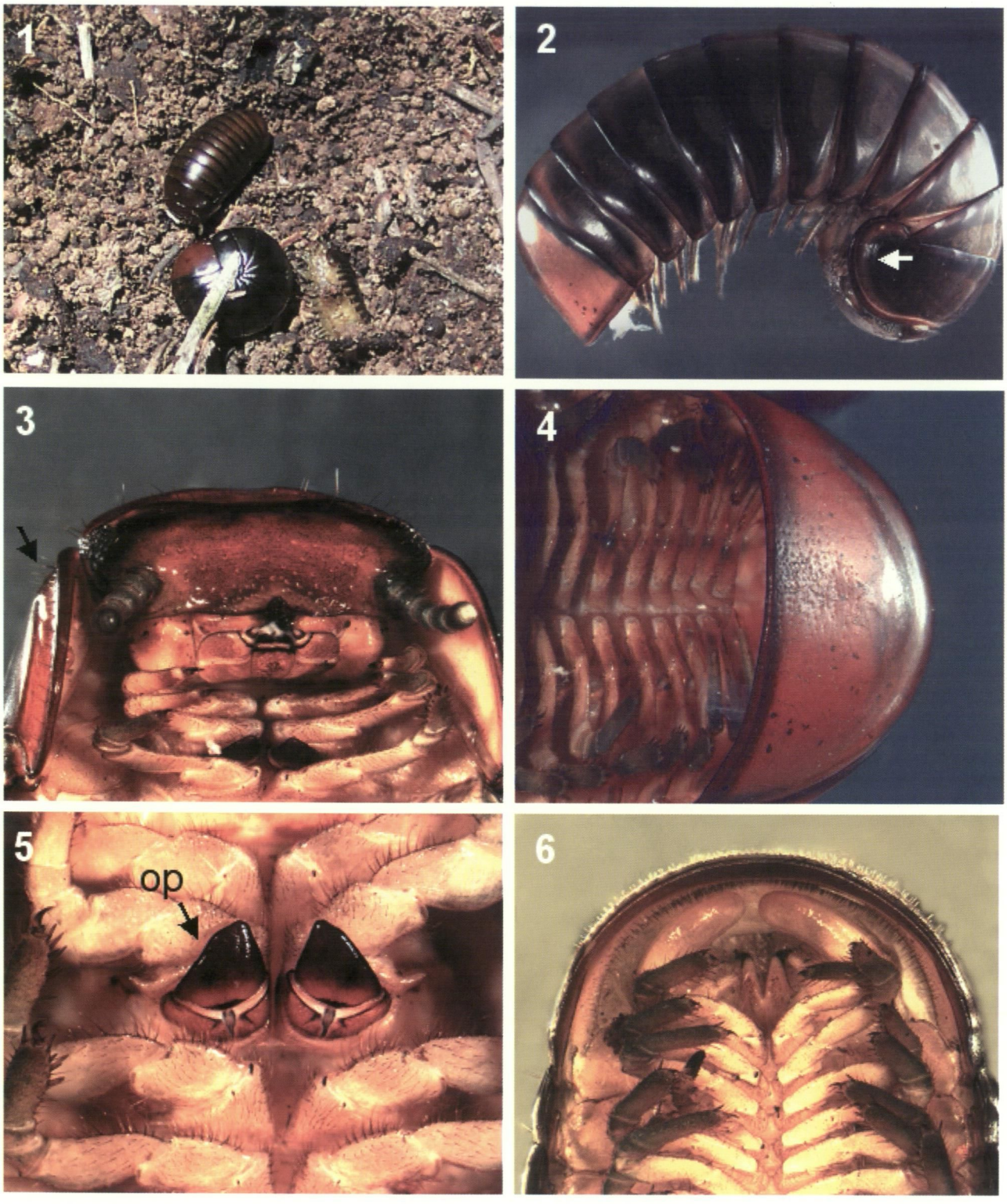
Body measurements. Length ♂ 10.7 ± 1.3 mm, ♀ 14.2 ± 0.8 mm; width ♂ 4.5 ± 0.6 mm, ♀ 6.0 ± 0.5 mm.

Colour. Tergites and collum olive-green, becoming orange towards posterior margins, which are dark brown (Figures 1 and 2). Anal shield orange (Figures 1 and 4). Head orange mottled with olive green, oral margin dark brown to black, antennae olive-grey (Figure 3). Ventral surface and legs cream to light orange. Tarsi and tarsal spines brown. Sclerites of female genitalia, or vulva, dark brown (Figure 5). Immature specimens often olive-grey dorsally.

Head and antennae. Antennae with 4 sensory cones on the terminal segment. Head with scattered setae becoming denser anteriorly, towards labrum (Figure 3). Labrum medially notched with one labral tooth. Eyes with approximately 38 ocelli.

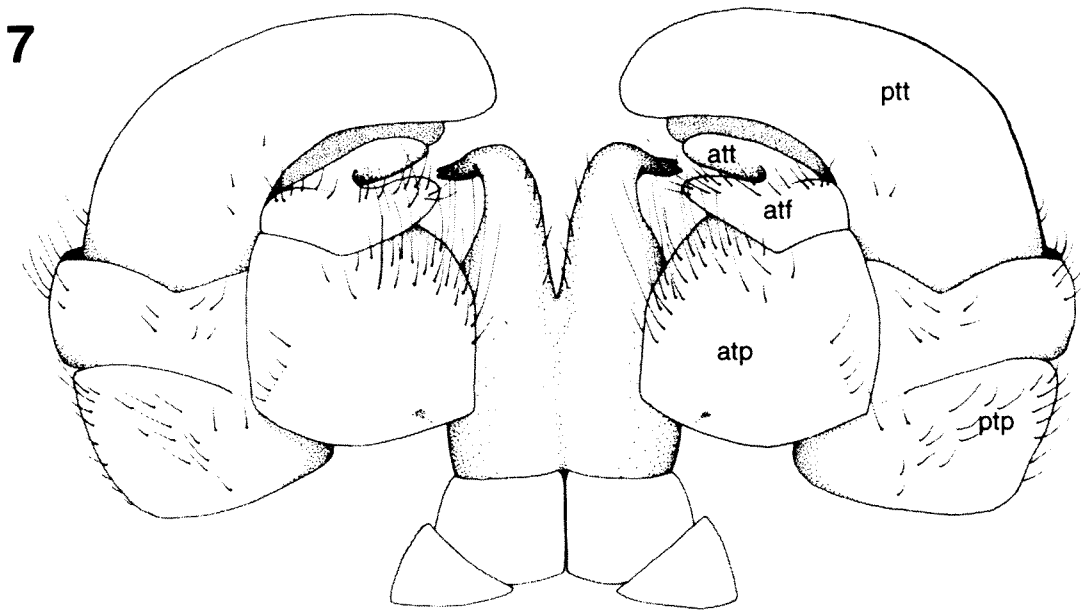
Body. Legs with 6–8 ventral tarsal spines and one supra-apical spine. Anal shield of female smooth, anal shield of male without sexual modification, but with fine scattered setae (Figures 4 and 6). Lateral shields of collum with concave area extending along margin from the eye to the posterior edge (see arrows, Figures 2 and 3). This depressed area contains row of setae extending from the eye to beginning of the posterior margin (Figure 3). Marginal rim well developed.

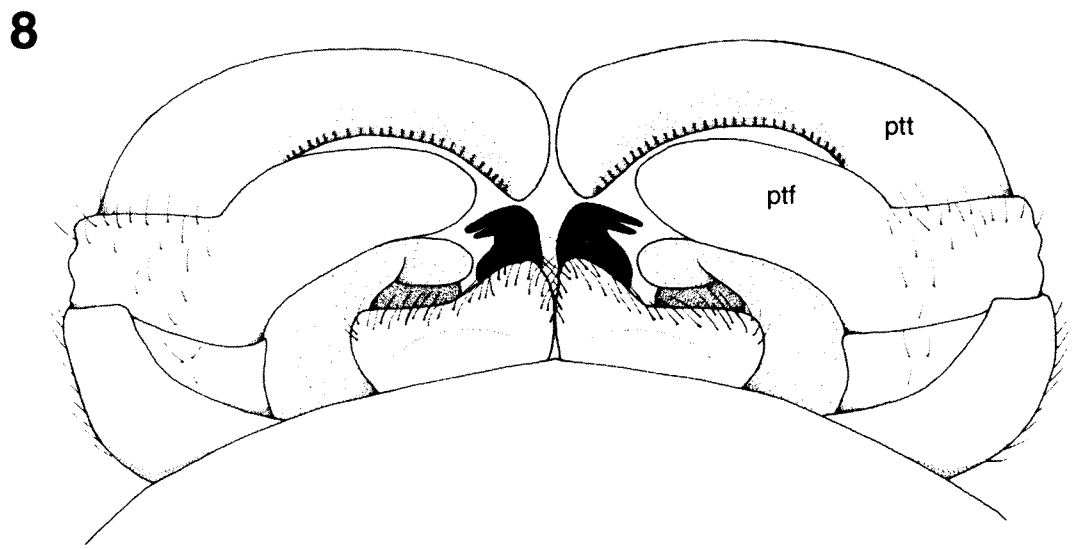
Female genitalia. Distal sclerite of vulva (= operculum) triangular, longer than wide. Basal margin convex. Remaining two sclerites (= bursa) rounded and small. Vulva large, covering coxa of 2nd pair of legs (Figure 5).



Figures 1–6 *Epicyliosoma (Epicyliosoma) sarahae* sp. nov.: 1. habitus in field, 2. habitus, lateral view, ventral views of 3. head, 4. male anal shield, 5. female genitalia, and 6. male genitalia. Key: *op,* operculum of vulva.

Male genitalia. Prefemur of posterior telopods square with setae along outer edge and ventral surface (Figure 7). Femoral process approximately equal in size to tibiotarsus, giving pincer-like appearance to posterior telopods (Figure 8). Anterior margin of tibiotarsus deeply serrated. Base of femoral process with setiferous patch on dorsal surface (Figure 8). Prefemur of anterior telopods comparatively large, without any projection along the inner margin (Figure 7). Femur and tibiotarsus reduced. Prefemur with patch of long setae on inner margins. Tibiotarsus with a densely setiferous lobe (Figure 7).





Figures 7–8 *Epicyliosoma (Epicyliosoma) sarahae* sp. nov. male genitalia: 7. ventral view, and 8. dorsal view. Key: *atp*, anterior telopod prefemur; *atf*, anterior telopod femur; *att*, anterior telopod tibiotarsus; *ptf*, posterior telopod femur; *ptp*, posterior telopod prefemur; *ptt*, posterior telopod tibiotarsus.

Etymology

This species is named in honour of ecologist Sarah Comer (Department of Environment & Conservation, Western Australia), who collected the first specimen, and for her ongoing commitment to invertebrate conservation along the south coast of Western Australia. We suggest "Sarah's pill millipede" as the common name.

Distribution

A community funded survey of short-range endemic invertebrates of the south-west coast (South Coast Regional Initiative Planning Team – http://www.script.asn.au/), found this species in Cape Le Grand National Park (ca. 40 km east of Esperance) and in Cape Arid National Park (Figure 9). The majority of specimens were collected from the soil, and perhaps only emerge at night to feed on rotting vegetation, as noted for other Sphaerotheriidae species by Holloway (1956). Thus *E. sarahae* may have been overlooked by previous collectors and may have a wider distribution. One of us (MLM) unsuccessfully searched likely habitats around Esperance (Duke of Orleans Bay, Mt Ridley,

Mt Heywood, Blue Haven Beach gully, eastern beach gullies of Stokes National Park). Unsearched potential localities for *E. sarahae* include beach gullies at Alexander Bay and Taylor Boat Harbour. These localities lie between Cape Arid and Cape Le Grand National Parks, hence discoveries of *E. sarahae* in these areas would not extend the species range.

Discussion

The described species is placed in *Epicyliosoma* due to its large prefemur and reduced femur plus tibiotarsus of the anterior telopods (Jeekel 1986). The species is assigned to the subgenus *Epicyliosoma* due to the morphology of the male anal shield which is lacking any sexual modification except a band of setae, and the size of the femoral process of the posterior telopods, which is approximately the same size as the tibiotarsus (Jeekel 1986). *Epicyliosoma sarahae* is unlikely to be one of the uncertain species described from more than 2000 km away in eastern Australia (Mesibov 2006), nor is it likely to be *Sphaerotherium convexum* Koch, 1847 (from "Neuholland"), which has a predominately orange anal shield (see Koch 1863, figure 27). Unfortunately, the genitalia of the male were not illustrated by Koch in either of his descriptions of *S. convexum* (Koch 1847, 1863), and location of the type specimens is unknown. When using Jeekel's (1986) keys, *E. sarahae* is most similar to *E. sennae* (Silvestri, 1898) (Northern Queensland) and *E. penrithense* (Brölemann, 1913) (New South Wales). However, *E. sarahae* is clearly distinct. For example, the absence of a projection or lobe along the inner margin of the anterior telopod prefemur of *E. sarahae* contrasts to the strong projection in both *E. penrithense* and *E. sennae* (e.g., Brölemann 1913, figures 6 and 24, respectively).

With a total distribution of less than 10,000 km^2, *E. sarahae* is a short-range endemic (Harvey 2002). *Cynotelopus notabilis*, the only other pill millipede recorded from Western Australia, is also a short-range endemic and is restricted to the high rainfall zone along the south coast (> 1000 mm/y), 400 km to the west of *E. sarahae* (Main *et al.* 2002; Figure 9). Rainfall in the southeast coastal zone where *E. sarahae* occurs is approximately 600 mm/yr (Hopper and Gioia 2004), and although this total is higher than that for the surrounding semi-arid zones (< 400 mm/y), *E. sarahae* survives in an area with a lower rainfall than that experienced by any other Australian sphaerotheriid species. *Epicylio-*

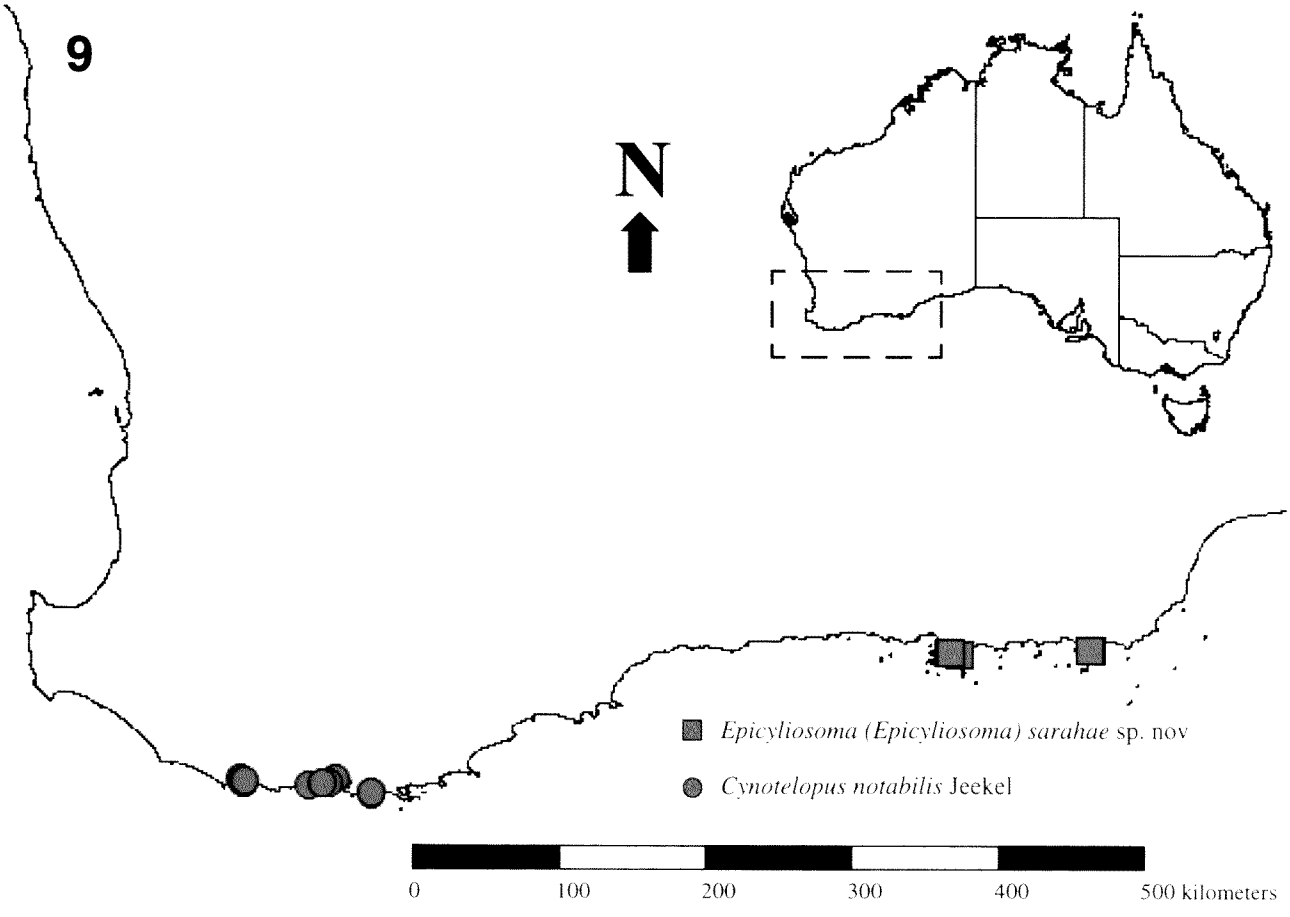


Figure 9 Map of southwestern Western Australia with collection localities of Sphaerotheriida species.

soma sarahae seems to prefer thick leaf litter in damp, well shaded gullies, close to the coast (< 8 km inland). Such coastal gullies are wetter and have a taller and denser canopy than surrounding land, which is dominated by heath and/or mallee. Hamer *et al.* (2006) found two species of *Sphaerotherium* in soil in savanna regions in South Africa, although both species are more abundant in wetter coastal forests. *Epicyliosoma sarahae* similarly extends into surrounding heath on the southern slopes of Mt Arid during the wetter months (M. Moir pers. obs.).

Given its restricted range and its preference for damper coastal areas, *E. sarahae* could be threatened with extinction through climate change, inappropriate fire regimes and land clearing. Land clearing is unlikely to affect known *E. sarahae* populations as all occur in National Parks which are protected. Conversely, climate change is highly likely to impact *E. sarahae* populations as rainfall in the south-west is predicted to decrease by as much as 60% by the year 2070 (Pittock 2003). With respect to fire regime, one of the two localities at which *E. sarahae* occurs, Cape Arid, was burnt extensively by wildfire in 2004–2005. During dry months *E. sarahae* has only been found in the Cape Arid gullies which escaped this fire. These longer unburnt gullies were characteristically overgrown, were shaded by a dense canopy, and had a deep leaf litter layer (M. Moir pers. obs.). Similarly, *C. notabilis* prefers deep leaf litter of karri (*Eucalyptus diversicolor*) forests that have been unburnt for more than 10 years (both authors pers. obs.; Main *et al.* 2002). Sphaerotheriidae species elsewhere also prefer deep leaf litter, perhaps because decaying leaf litter is their main food source (Eastern Australia – Jeekel 1981; New Zealand – Holloway 1956, Meads 1990; Tasmania – Mesibov 2000; Madagascar – Wesener and Sierwald, 2005b). As Main *et al.* (2002) pointed out, this raises the question of whether local extinction is likely to occur under fire regimes featuring short intervals between fires and/or high fire intensities. These will reduce the leaf litter layer, promote open canopies and result in drier micro-climatic conditions. Days after one of us (MLM) collected most specimens examined here, extensive wildfires caused by lightning strikes burned throughout both Cape Arid and Cape Le Grand National Parks. Populations of *E. sarahae* have survived these fires in the wetter regions, such as the southern slopes of Mt Arid (M. Moir pers. obs.). The fires occurred during late spring and summer when *E. sarahae* populations were avoiding desiccation by sheltering in the soil profile. Thus, fires occurring in later autumn, winter or early spring when individuals are more active and above ground could be detrimental to populations. In the southwest of Western Australia most prescribed burns occur in spring or autumn. Although there are no current management plans for Cape Arid and Le Grand National Parks, a proposal suggests implementing a mosaic style fire management plan to reduce the effects of large intense wildfires (Department of Environment and Conservation 2007). If prescribed burns are to be implemented in Cape Arid and Le Grand National Parks, we strongly recommend that further research on the post-burn survival of *E. sarahae* populations be undertaken. Thus of primary importance, and initiated by this project, are the development of distribution maps of *E. sarahae* populations. Until conclusive results on the effect of fire on populations, we suggest that the habitat of *E. sarahae* be actively protected from any fires in late autumn, early spring or winter.

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