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Selachochthonius naledi sp. nov. (Pseudoscorpiones, Pseudotyrannochthoniidae), a new troglobitic species from South Africa

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Abstract

A new pseudoscorpion species, *Selachochthonius naledi* **sp. nov.**, is herein described. It can be distinguished from the other species of the genus mainly by the absence of eyes, number and morphology of chelal teeth and coxae setae and by the appendices proportions. This new species represents the fourth record for the genus in South Africa. We also provide some ecological remarks of the new species and recommendations for future research.

Keywords

Cave-dwelling, pseudoscorpion, taxonomy

Introduction

Pseudoscorpions (Arachnida: Pseudoscorpiones) are small sized predatory arthropods distributed throughout terrestrial habitats commonly found across six continents (except for Antarctica). They occur in a diversity of habitats including leaf litter, beneath

bark or stones, as well as bird nests or animal burrows. Several species are also recorded from caves and may exhibit subterranean-adapted traits (Chamberlin 1931; Harvey 1988; Harms 2018). These arachnids are highly diverse, comprising of 26 families and 465 genera (Benavides et. al. 2019; World Pseudoscorpiones Catalog 2021).

The family Pseudotyrannochthoniidae comprises 69 species distributed in five genera: *Allochthonius* Chamberlin, 1929 with 28 species, *Afrochthonius* Beier, 1930 with seven species, *Centrochthonius* Beier, 1931 with three species, *Pseudotyrannochthonius* Beier, 1930 with 28 species and *Selachochthonius* Chamberlin, 1929 with three species (Harms 2013; Harms and Harvey 2013; Viana and Ferreira 2021; World Pseudoscorpiones Catalog 2021).

This family is diagnosed by the presence of *ib* and *isb* trichobothria located at the base of the fixed finger and coxal spines present only in coxae I (Harms and Harvey 2013). While the Northern Hemisphere members of the family present a more variable carapacal chaetotaxy, the Southern Hemisphere species share the presence of 18 carapace setae (Schwarze et al. 2021). In South Africa, pseudotyrannochthoniid pseudoscorpions are represented by two genera, namely *Afrochthonius* and *Selachochthonius*, from which the latter can be identified mainly by the presence of an intercoxal tubercle (Ellingsen 1912; Beier 1930).

During an expedition to caves in South Africa (carried out 5–17 October 2019), two specimens of Pseudotyrannochthoniidae pseudoscorpions were found, belonging to a new species herein described. We also provide some notes on its habitat and potential threats, conservation issues, a brief discussion on its association with the cave environment and a comparison of morphological features with all *Selachochthonius* species, presenting their distribution in South Africa.

Materials and methods

Study area

The study areas included two cave systems, namely Villa Louisa (26°01'25.5"S, 27°42'43.0"E) and Yom Tov (26°01'14.92"S, 27°42'53.46"E) caves (Fig. 1A–C), located in the Cradle of Humankind UNESCO World Heritage Site (Gauteng Province, South Africa). The landscape is associated with the Rocky Highveld Grassland, which generally supports a high diversity of species. Rain often occurs as thunderstorms during the hot summer months with an average of 700 mm per year. The caves are mainly developed in dolomitic bedrock, which form part of the Monte Christo Formation (Malmani Subgroup, Transvaal Supergroup) (Dirks et al. 2015).

Field sampling

Fieldwork was conducted in October 2019. This trip was part of a worldwide scale project (with samplings in all continents, except Antarctica) aiming to evaluate how habitat traits influences invertebrate communities (manuscript in prep.). In South Africa, seven caves were sampled. Untimed direct intuitive searches (*sensu* Wynne et al.

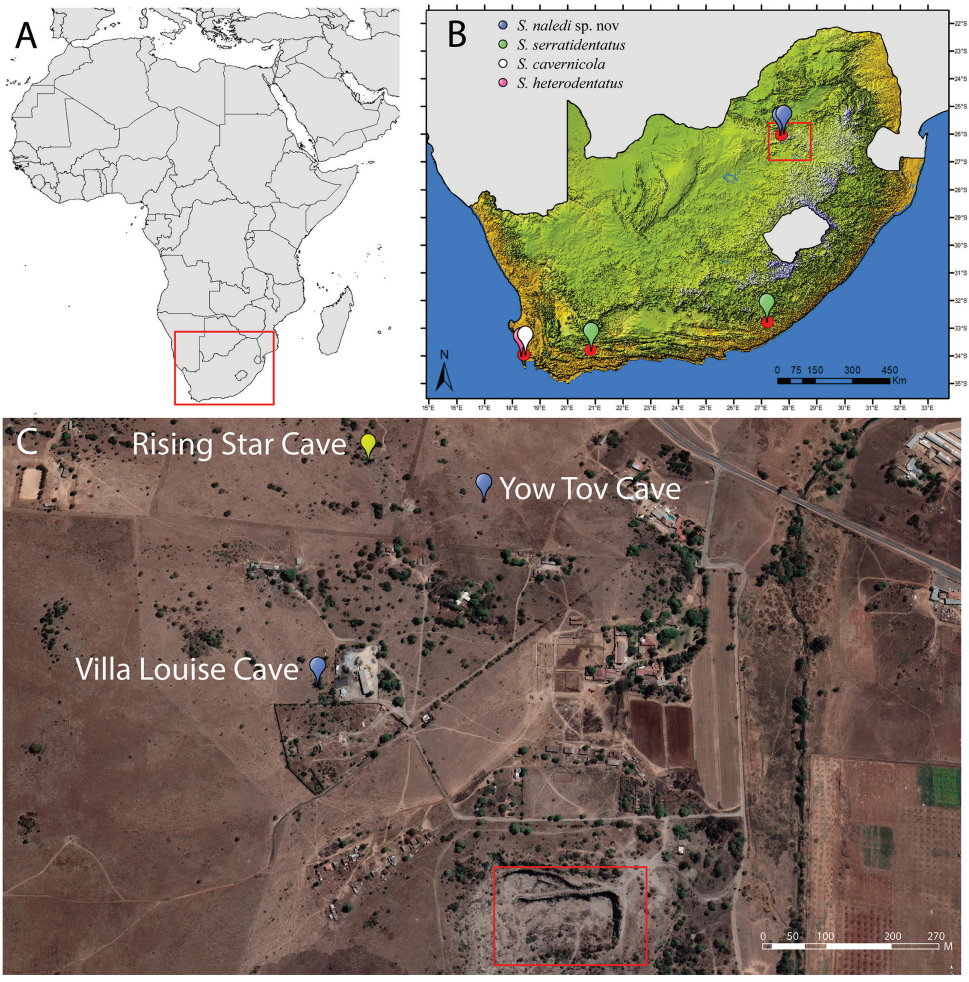

Figure 1. Distribution map of *Selachochthonius* species in South Africa **A** Africa continent, detail on South Africa country **B** South Africa, exhibiting distribution of *Selachochthonius* species with detail on *S. naledi* sp. nov. type localities **C** *Selachochthonius naledi* sp. nov. distribution area, exhibiting Yom Tov, Villa Louise and Rising Star Caves (*Homo naledi* type locality), detail on quarry activity occurring nearby.

2019) were used within multiple 10×3 m transects. The number of sampled transects was proportional to the cave size. Opportunistic sampling was also carried out to collect arthropods prioritizing organic deposits and microhabitats. All invertebrates were collected with a fine brush and stored in 70% ethanol.

Analysis and preparation

To properly examine taxonomic characters, specimens were photographed, dissected and mounted on temporary cavity slides with glycerine. Photographs and measurements were taken using a Zeiss Axio Zoom V16 stereomicroscope and ZEN 2.3

software package. Appendices and structures were mounted on Kaiser's glycerol gelatine for drawings, due to its stabilisation and low temperature solidification. Drawings were prepared with a drawing tube on an Olympus BX40 optical microscope equipped with phase contrast. Following, illustrations were vectorized using Inkscape 1.1 software package (Montesanto 2015; inkscape.org). The holotype and paratype were deposited in the National Collection of Arachnida (NCA), Pretoria, South Africa.

Terminology

Terminology follows Chamberlin (1931), Harvey (1992) and Judson (2007). Abbreviations for the trichobothria: *b* = basal; *sb* = sub-basal; *st* = sub-terminal; *t* = terminal; *ib* = interior basal; *isb* = interior sub-basal; *ist* = interior sub-terminal; *it* = interior terminal; *eb* = exterior basal; *esb* = exterior sub-basal; *est* = exterior sub-terminal; *et* = exterior terminal. Abbreviation for repository: NCA – National Collection of Arachnida.

Results

Family Pseudotyrannochthoniidae Beier, 1932
Genus *Selachochthonius* Chamberlin, 1929

***Selachochthonius naledi* sp. nov.**
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Material examined. ***Holotype*** female (NCA 2021/1351), preserved in ethanol: South Africa, Cradle of Humankind (UNESCO WHS), Maquassi Hills Municipality, Villa Louisa cave (26°01'25.5"S, 27°42'43.0"E), 09 October 2019, leg. R.L Ferreira. ***Paratype*** male (NCA 2021/1352), Cradle of Humankind, Maquassi Hills Municipality, Yom Tov Cave (26°01'14.92"S, 27°42'53.46"E), 17 October 2019, leg. R.L Ferreira.

Etymology. The epithet *naledi* refers to *Homo naledi*, an extinct hominid species discovered within the Dinaledi chamber. This chamber is located in the Rising Star Cave (Fig. 1C), a World Heritage site located approximately 50 km from Johannesburg. The caves where the pseudoscorpions were found are located on the same hill as Rising Star Cave. The distances between the entrance of Rising Star Cave and the entrances of Vila Louise and Yom Tov caves are approximately 425 and 220 meters, respectively. Considering the fissure system associated with the carbonatic rock in the area, it is likely that the pseudoscorpions are able to disperse through small fissures to other macrocaves in the hill, including Rising Star Cave.

Diagnosis. *Selachochthonius naledi* sp. nov. differs from other members of the genus by the following combination of characters: absence of eyes or eyespots (*S. heterodentatus* Beier, 1995 with four well-developed eyes and *S. serratidentatus* Ellingsen, 1912 bearing four small eyes) (Ellingsen 1912; Beier 1955); epistome triangular and strongly dentate (*S. cavernicola* Lawrence, 1935 presents a flattened apex and slightly dentated

epistome) (Lawrence 1935); palpal femur with length of 0.65–0.66 mm or 6.2 times longer than wide (4.0 times in *S. serratidentatus* and *S. heterodentatus* with femur length of 1.0 mm); chela 6.1–6.2 times longer than wide (3.8 times in *S. serratidentatus* and 5.0 times in *S. heterodentatus*) (Ellingsen 1912; Beier 1955); fixed finger with 32–34 simple, sparse, acute and triangular teeth (*S. cavernicola* with 23 sparse, simple and triangular teeth, presented in only 2/3 of the segment; *S. heterodentatus* with 28 acute teeth intercalated by 24 smaller teeth and *S. serratidentatus* with sparse, acute and complex teeth, each one intercalated by one or two smaller teeth) (Ellingsen 1912; Lawrence 1935; Beier 1955); movable finger with 29–31 simple, sparse acute and triangular teeth (*S. cavernicola* with 17 simple, sparse, acute and triangular teeth; *S. heterodentatus* with 16 acute and triangular, intercalated by 12 smaller teeth) (Lawrence 1935; Beier 1955); presence of a small tubercle in both chelae between the 13th and 14th teeth of the female movable finger and between the 10th and 11th teeth of the male movable finger (*S. cavernicola*, *S. heterodentatus* and *S. serratidentatus* lacks tubercle); 7–11 coxal spines tripinnate arranged in a single row on the anterior portion of the coxa I (*S. cavernicola* with 12 bipinnate coxal spines) (Lawrence 1935).

Description. (Fig. 5E–F). Body pale yellowish, mostly translucent; chelicerae slightly reddish orange, abdomen beige. Some parts of the body scaly. Vestitural setae sharp and anteriorly projected.

Carapace. (Fig. 2B–D). Ratio length/width near 1.0, strongly constricted posteriorly showing a difference between ocular width and posterior width of 0.08–0.10 mm; anterior margin smooth; absence of eyes or eyespots; epistome strongly dentate and saw-like; posterior margin of carapace smooth; chaetotaxy 6: 4: 4: 2: 2 (18), lateral pre ocular setae are shorter in female (Fig. 2C).

Chelicera. (Fig. 2A). Hand with 7–8 setae; movable finger with 1 subdistal seta and fixed finger with 1 subdistal setae as well; galea absent; fixed finger with 11–12 acute teeth; movable finger with 8–9 acute teeth including one large distal tooth; rallum with 11 blades, middle blades long; serrula exterior with 22–25 blades, serrula interior with 19–21 blades.

Tergites. Not divided; surface smooth; chaetotaxy uniseriate, I–XI 2: 2: 4: 4: 4–6: 6–8: 6: 4–6: 4: 4: 4. Anal operculum with two dorsal setae. Pleural membrane smooth.

Coxae. (Fig. 3A–C). Manducatory process with two apical setae (the distal one about half of the length of the proximal one); rest of palp coxae with 3 setae arranged in a triangle; delicate lamellae outlined by 15 small spines. Pedal coxae (Fig. 3A–C): coxal spines tripinnate, with smooth tips arranged in a single oblique row in coxae I (7–11), chaetotaxy: I 4, II 4, III 4–5, IV 5 intercoxal tubercle present reduced between coxae III and IV, female bearing two setae and the male one.

Genital operculum of female: setae distributed in three horizontal rows: 2: 2: 3, genital opening not bifurcated (horizontally contiguous).

Genital operculum of male (Fig. 3D): setae distributed in two horizontal rows: 2: 2; Anterior genital operculum with 10 setae; genital opening with 8–9 valvular genital setae.

Sternites. chaetotaxy IV−XI: 10–12: 12–14: 6–12: 6–8: 6: 6: 6: 4. Anal operculum with two ventral setae.

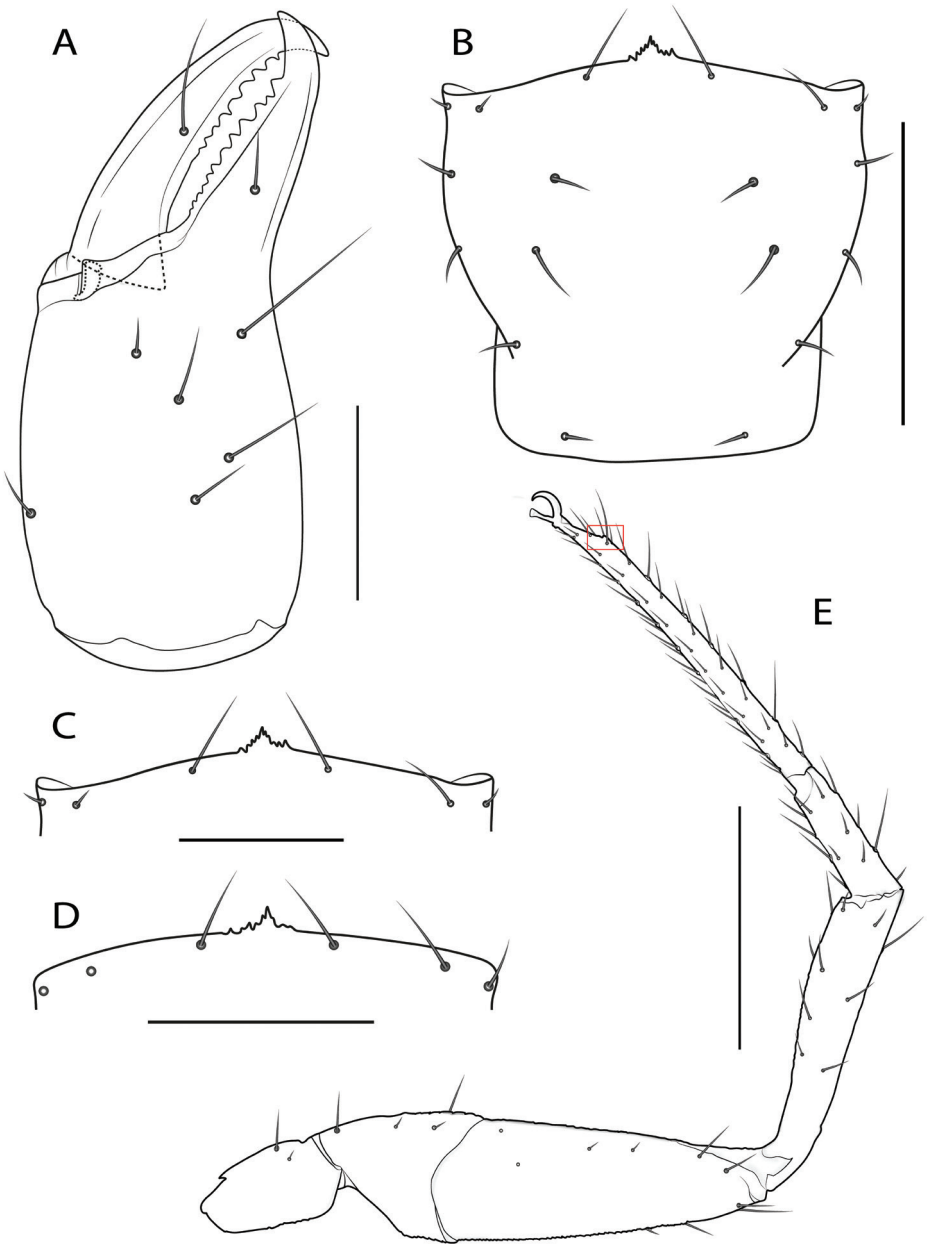

Figure 2. *Selachochthonius naledi* sp. nov. **A** left chelicera of female holotype, antiaxial view **B** female holotype carapace, showing chaetotaxy of carapace **C** detailed anterior margin of female paratype carapace **D** detailed anterior margin of male paratype carapace **E** leg IV of female holotype, showing tubercle location. Scale bars: 0.25 mm (**A, C–D**); 0.5 mm (**B, E**).

Palp (Fig. 4A–D). Trochanter 1.4–1.8 times longer than wide, patella 2.3–2.4 times longer than wide, femur 6.2–6.6 times longer than wide. Femoral chaetotaxy 3: 4: 4–5: 2: 7: 1. Trichobothrial pattern: *ib* and *isb* located at the distal portion of

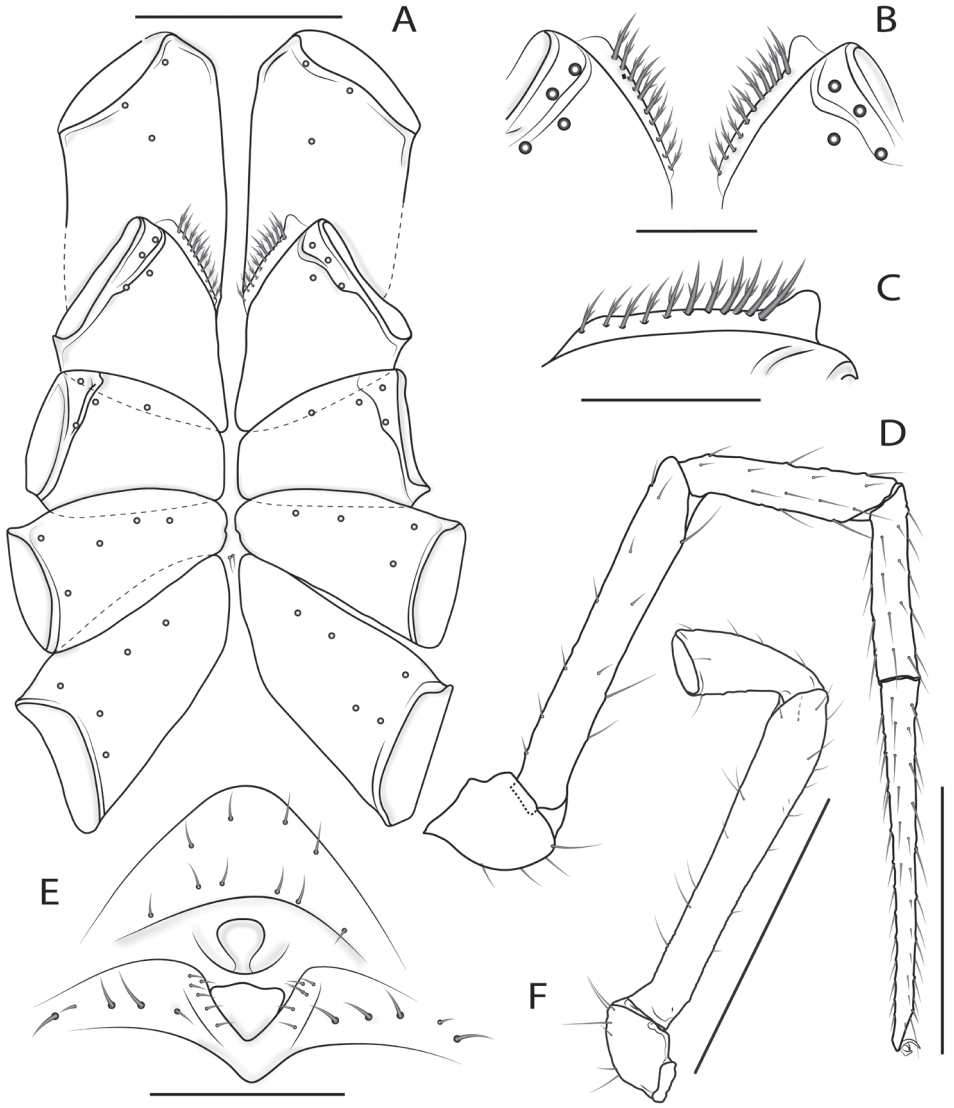

Figure 3. *Selachochthonius naledi* sp. nov. **A** female holotype palp and pedal coxae **B** detail of female holotype coxa I **C** detail of female holotype coxal spines **D** leg I of female holotype **E** male paratype genitalia, showing arrangement of setae **F** right pedipalp of female holotype, dorsal view. Scale bars: 0.3 mm (**A**); 0.1 mm (**B–C**); 0.5 mm (**D**); 0.05 mm (**E**); 1.0 mm (**F**).

the hand on a tiny hump (Fig. 4C–D), adjacent to each other, *eb* proximad to *esb*, *ist* distad to *esb* (about the same distance between both), *eb-esb-ist* located at the base of fixed finger, *it* distad to *est*, *et* distad from *it*. Trichobothrium *st* located at third teeth level, *sb* proximad to *b*, *t* distad to *b*, *b* at the same distance from *t* and *sb* (Fig. 4C–D). Fixed finger almost straight, movable finger slightly bent (Fig. 3A–D). Chelal fixed finger with 32–34 acute, triangular, and widely spaced teeth. Movable finger with

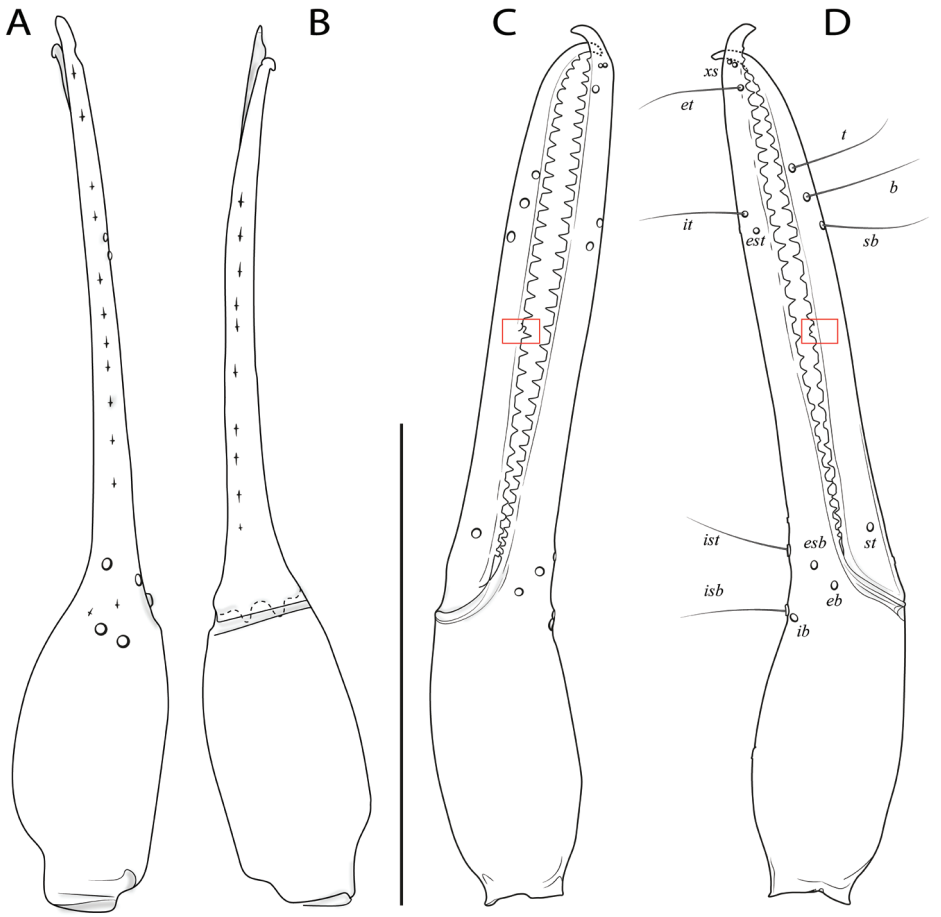

Figure 4. *Selachochthonius naledi* sp. nov., female holotype **A** right pedipalp chela, showing lyrifissures and trichobothrial pattern, dorsal view **B** right pedipalp chela, showing lyrifissures arrangement, ventral view **C** left pedipalp chela, showing teeth morphology, trichobothrial pattern and tubercle location, antiaxial view **D** right pedipalp chela, antiaxial view. See Material and methods for abbreviations. Scale bar: 1.0 mm.

29–31 acute teeth, growing from basal to distal, tubercle present between the 13th and 14th teeth of the female movable finger and between the 10th and 11th teeth of the male movable finger (Fig. 4C–D).

Leg. IV (Fig. 2E). Arolia same length as claws; a tiny protuberance near end of tarsus.

Measurements. (length/width or depth in mm; ratios in parenthesis calculated by using three significant digits): Female holotype and male paratype range. Body length 2.33 [1.86]. Carapace 0.55–0.70/0.52–0.70 (1.0). Palps: trochanter 0.21–0.35/0.15–0.20 (1.4–1.8), femur 0.93–1.22/0.14–0.20 (6.2–6.6), patella 0.38–0.51/0.16–0.21 (2.3–2.4), chela 1.39–1.8/0.30–0.23 (6.1–6.2), movable finger length 0.92–1.14. Leg I: trochanter 0.13–0.23/0.10–0.18 (1.3), femur 0.44–0.67/0.08–0.10 (5.9–6.8), patella 0.29–0.38/0.07–0.09 (4.1–4.4), femur/patella 1.5–1.8, tibia 0.23–0.35/0.05–

Figure 5. Type locality and habitat of *Selachochthonius naledi* sp. nov. **A** Villa Louise cave entrance **B** Villa Louise cave interior general aspect **C** Villa Louise cave interior, showing altered floor **D** Yom Tov cave entrance **E** live female holotype **F** live male paratype.

0.07 (4.3–5.1), tarsus 0.54–0.65/0.05–0.06 (10.7–11.3). Leg IV: Trochanter: 0.24–0.27/0.13–0.17 (1.6–1.8), femur + patella 0.77–1.30/0.19–0.27 (4.1–4.8), tibia 0.50–0.68/0.10–0.12 (5.2–5.4), basitarsus 0.25–0.30/0.07–0.09 (3.4–3.6), telotarsus 0.55–0.73/0.05–0.06 (10.9–12.1).

Habitat and ecological remarks. Despite extensive efforts in search of invertebrates in the caves, only two specimens of *Selachochthonius naledi* sp. nov. were found,

thus indicating their low population density. In both Vila Louise and Yom Tov caves, the specimens were found in the deeper, moist and aphotic areas. The two individuals were collected from under block rocks in the cave floor. Neither specimens exhibited any phototactic behaviour. An interesting behaviour was observed for the individual from Vila Louise cave (female holotype): when gently touched by the brush bristles, the individual responded aggressively, repeatedly grasping the bristles. Even though one of the authors (RLF) has been collecting cave pseudoscorpions for the last 30 years (especially Chthonioidea), this "aggressive" behaviour has never been recorded by him before. Potential prey in both caves include springtails, juvenile crickets and isopods (Styloniscidae).

Discussion

Selachochthonius taxonomy and distribution in South Africa

Species of *Selachochthonius* have been reported from four areas in South Africa (Fig. 1B). *Selachochthonius serratidentatus* was reported from Grootvadersbosch Nature Reserve (Swellendam, Western Cape Province) and Pirie locality (near King Williams Town, Eastern Cape Province). *Selachochthonius heterodentatus* was recorded from the Table Mountain epigean environment, in the vicinity of Wynberg Cave, while *S. cavernicola* was reported only within Wynberg Cave (Table Mountain, Cape Town, Western Cape Province) (Fig. 1A–C). *Selachochthonius naledi* sp. nov. is the first record for the family in Gauteng Province and was found in Yom Tov and Villa Louise caves in the Cradle of Humankind (Chamberlin 1929; Lawrence 1935; Beier 1955, 1964, 1966; Sharratt et al. 2000).

Overall, the taxonomy of *Selachochthonius* has some shortcomings due to lack of detailed morphology on the characters used to differentiate pseudotyrannochthoniid species. The diagnosis of the genus is largely based on the type species *S. serratidentatus*, originally attributed to *Chthonius* by Ellingsen (1912) and subsequently transferred to the new genus *Selachochthonius* by Chamberlin (1929). Beier (1964), provided additional information on various morphological features based on specimens, some of which were from Lesotho. *Selachochthonius cavernicola* presents unique bipinnate coxal spines on coxa I, in fact, the only species within the genus whose description includes drawings of the coxal spines (Lawrence 1935). The new species bears tripinnate spines, which resembles *Pseudotyrannochthonius* and *Centrochthonius*, individually inserted on a single row on the ledge of first pedal coxa (Fig. 3A–C) (Morikawa 1956; Harms and Harvey 2013; Schwarze et al. 2021). The new species herein described is attributed to *Selachochthonius* due to reduced size of the intercoxal tubercle, the smooth aspect of coxal spines and the presence of 18 carapacal setae. As for *S. serratidentatus* and *S. heterodentatus*¸ published descriptions lack detailed information on the morphology of the coxal spines (Ellingsen 1912; Beier 1955, 1964).

The absence of eyes or eyespots — a feature frequently attributed to subterranean-adapted species — is observed in the new species and in *S. cavernicola* (Lawrence

1935). The limited measurements in the original descriptions of *S. cavernicola* and *S. heterodentatus* make comparisons between the length/width ratio of the appendages difficult (Lawrence 1935; Beier 1955) but would be useful to detect if they are somehow elongated – another important troglomorphic trait for pseudoscorpions (Viana & Ferreira 2021). When compared to *S. serratidentatus*, the new species exhibits a slender palpal femur (4.0 times longer than wide in *S. serratidentatus* and 5.9–6.8 times in *S. naledi* sp. nov.) (Lawrence 1935).

Currently, *S. serratidentatus* and *S. heterodentatus* are only found in epigean environments, thus not presenting any subterranean-adapted traits (Ellingsen 1912; Chamberlin 1929, 1962; Beier 1932, 1964), whilst the species encountered inside subterranean environments (*S. cavernicola* and *S. naledi* sp. nov.) exhibit strong troglomorphisms such as depigmented integument and the absence of eyes/eyespots. This supports their status as troglobitic (Lawrence 1935; Chamberlin 1962). However, this classification may be confirmed or disregarded following future surveys aimed at generating additional information on the distribution of epigean species, especially those associated with cave entrances.

Conservation issues

The external area surrounding the caves in the Cradle of Humankind is highly altered, especially by deforestation. The caves' entrances are usually associated with small bush patches surrounded by grass (Fig. 5A–D). There are several farms in the area and a large road network including both paved and unpaved roads. Furthermore, potentially polluting activities take place in the region, such as an asphalt factory located approximately 70 meters from the entrance of Vila Louise Cave. It is important to note that this area is located within what is internationally known as the "Cradle of Humankind" where many hominid fossils were recovered, especially from caves (Berger et al. 2015). Even so, the area is heavily impacted by anthropogenic activities, such as farms and quarries (Fig. 1C).

The caves in the surrounding region are also heavily impacted. For example, the calcite deposits in many of the caves were previously mined. Vila Louise Cave is highly altered due to past removal of calcite. As a result, the cave's conduits and floor were severely changed in part by walls that were built inside the cave (Fig. 5B) and tires that were installed to serve as a staircase in the entrance chamber (Fig. 5C). Even today the cave still receives local visitors with signs of religious use present (e.g. candles and jars). Yom Tov Cave is more preserved, probably due to the difficulties in accessing the deeper sections of the cave that can only be reached via very narrow and vertical passages. Furthermore, there is evidence of a gate that was once installed to prevent local people from accessing the cave.

A major concern related to this species' conservation is the risk of contaminants originating from the farms and small factories in the surrounding area entering the cave systems. Furthermore, it is important to visit other caves in the area to search for additional specimens and determine, with accuracy, the actual distribution of this species.

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