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Original paper

A new *Euscorpius* species (Scorpiones: Euscorpiidae) from a Dinaric cave - the first record of troglobite scorpion in European fauna

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Summary. A troglobite, *Euscorpius studentium* n. sp. is described based on a single immature male specimen from Skožnica, a relatively small cave in the coastal region of Montenegro. The characteristics of the new species are compared with the characteristics of an immature male specimen of troglophile *Euscorpius feti* Tropea, 2013 of the same size, from another cave in Montenegro. Some identified differences indicate evolutionary changes that are the result of the process of adaptation of troglobite scorpions for life under conditions found in underground habitats: reduced eyes, depigmentation, smooth teguments with reduced granulation and tubercles, elongated sharp and thin ungues of the legs and narrowed body. The settlement of limestone caves by large troglobionts such as scorpions follows karstification processes. Lithophilic forms that evolved under these conditions possess the necessary climbing abilities that are prerequisite for settlement of hypogean habitats. Uncontrolled visits by tourists in recent years have seriously threatened the fauna of Skožnica cave, including this new and first recognized troglobite scorpion species among European fauna.

Keywords: edaphomorphic, Montenegro, troglobite, troglomorphic, troglophile.

INTRODUCTION

Dinaric karst is famous as a global hot spot of subterranean fauna. It is a huge, intensely karstified mountainous area of the Balkan peninsula, inhabited by numerous and heterogeneous subterranean fauna. Scorpiones are one of the rare animal groups widely present in Dinaric epigean fauna but not recorded as present in the corresponding subterranean environment with troglobites, till this finding. There are records of troglophile species (*Euscorpius croaticus* Di Caporiacco, 1950, *E. feti* Tropea, 2013[1] and *E. biokovensis* Tropea and Ozimec, 2020) that hinted at the possibility of the existence of troglobites. I think there are two reasons that cave scorpions have not been recorded to date in Dinaric karst. First, almost all findings of troglobite scorpiones so far have been based on individual findings, often made on the basis of one individual. This speaks to the extremely small populations of these predators, which are difficult to spot in rare cave visits. Actually, for humans, caves and sinkholes are the only available parts of far more spacious underground areas inhabited by troglobites. Second, living in cave conditions requires agility, dexterity and rapid locomotion in any spatial plane. Scorpions are not ideally built for the demands of that kind of life. Therefore, they are represented by a small number of species in the world of cave fauna. Based on critical reviews of the list of species of troglobite and troglomorphic scorpions by Volschenk and Prendini (2008) and later described troglobites (Lourenço and Pham 2010, 2015;

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[1] In Tropea (2013b) for an immature specimen collected on locality Petrina, Trebinje on 6 June 2004 the data that was collected in Arensdorfova pećina Cave by D. Pavićević is missing. I was present then.

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Santibanez Lopez et al. 2014; Lourenço et al. 2018), only 24 troglobitic scorpion species are known to the world, mostly from Mexico. These are mainly depigmented, eyeless species, with the exception of a few species that have to some extent reduced pigments and eyes.

The only known eyeless scorpion species among European fauna are from the genus *Belisarius* Simon, 1879 (family Belisariidae). This genus consists of two species, *B. xambeui* Simon, 1879, from the Pyrenees of Spain and France and *B. ibericus* Lourenço, 2015 from south Spain (Lourenço 2015). Fet (2010) designated *B. xambeui*, as an endogean, hygrophile lapidicolous species found in mountain forests, which may be applied to both species of the genus. *Belisarius xambeui* is noted as troglophile too. Recently, another troglophile species from the same family, *Sardoscorpius troglophilus* Tropea et Onnis, 2020 was described from two smaller caves located in a small area of eastern Sardinia (Tropea and Onnis 2020). *Sardoscorpius troglophilus* has reduced pigmentation, but well-developed eyes.

Here I describe a new species of the genus *Euscorpius*, which contains 57 described species. Recently, two subgenera of this genus were elevated to generic status, *Alpiscorpius* with 16 and *Tetratrichobothrius* with one species (Kovařík et al. 2019).

Euscorpius studentium n. sp. is a troglobite, and was described based on an immature male from a relatively small cave in the coastal part of Montenegro. An immature male of troglophile *Euscorpius feti* from an inland Montenegro Cave is also included in this study, for the purpose of comparison of the characteristics of two species of the same genus that represents two life forms of animals present in caves. Both specimens have similar body dimensions.

MATERIALS AND METHODS

Specimens were examined using a Leica M205C stereomicroscope equipped with a Leica DFC290 HD digital camera. The scanning electron microscopy (SEM) photographs were taken with a JEOL-JSM-64601v SEM microscope under high vacuum without previous preparation, to avoid damage. All specimens were collected by hand, searching thoroughly under stones, over the floors and walls of limestone caves.

The trichobothria notation follows Vachon (1974).

Material of *Euscorpius feti* examined and used for comparison with the *E. studentium* n. sp.: 1 ♂, Montenegro, Rijeka Crnojevića, Zaćirska pećina Cave, 27th April 2018, Leg D. Antić; 1 subad. ♂, 1 subad. ♀, ibid. 25th June 2018, Leg D. Antić; 1 juv. ♂, ibid. 16th February 2018, Leg I. Karaman; 1 immature ♂, 1 immature ♀, ibid. 18th October 2019, Leg I. Karaman.[2]

RESULTS

Euscorpius studentium n. sp.

(Figs 1-7, 11A)

Material examined

1 immature ♂ (holotype); Montenegro, Čanj, Spila Skožnica Cave, 7th May 2017, Leg I. Karaman; ibid. 1 juvenile ♀ (paratype), 2nd June 2017, Leg I. Karaman.

Depository

Holotype (Inv. No. SC1/01) and paratype (Inv. No. SC1/02) are deposited in the author's zoological collection (ZZDBE) at the Department of Biology and Ecology, University of Novi Sad (Serbia).

Etymology

The species is dedicated to the group of students who initiated the visit to the cave I had already explored several times before. They also noted the scorpion there. The finding occurred during regular marine fieldwork in Čanj, Montenegro, by our biology students from the Faculty of Sciences, University of Novi Sad.

Diagnosis

Blind, long-limbed *Euscorpius* species, with narrow body. Base color is white yellowish to orange. Tegument is smooth. Carapace slightly longer than wide, anteriory widely oval, truncated. Median and anterolateral eyes reduced, median ones without traces. Metasomal carinae reduced. Metasomal segment I slightly longer than wide. Sternum pentagonal, longer than wide. The pectinal teeth number is 7.

Pedipalp femur is slightly longer than patella; dorsal patellar spur long and sharp. Pedipalp manus ventral surface with 4 trichobothria (V1-3 + Et1); patella ventral surface with 7 trichobothria; external surface with: eb = 4, eba = 4, esb = 2, em = 4, est = 4, et = 6 trichobothria; ratio of metasoma/ carapace length 2.52.

Description of the holotype

Body length 26 mm. Base colour is light yellowish to orange (Fig. 1) with marbled infuscation, slightly marked on carapace. Carapace and pedipalps slightly darker. Legs pale, sternum, genital operculum, pectines and sternites yellowish. No patterns present.

Carapace lustrous, slightly elongated, oval (Fig. 2) with minute granulations on its antero-lateral edges; anterior edge straight; posterior three-fourths of carapace with parallel lateral margins. Carapace length/width ratio 1.05. Traces of

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[2] All specimens of *E. feti* were found in the deeper part of a large entrance hall and in a main canal of the cave, under conditions of constant temperature, humidity and complete darkness. In the part of the cave where some troglobionts were present as well as troglophiles. Most of the specimens of *E. feti* were present on the cave floor, some under stones or dried guano. Entrance part of the cave were not examined, but some scorpions were spotted there too, possibly of the same species.

Fig. 1. *Euscorpius studentium* n. sp., holotype, dorsal and ventral views (photos D. Savić).

reduced anterolateral eyes visible under higher magnification (Fig. 2C). Median eyes and tubercle reduced without visible traces (Fig. 2B).

Mesosomal tegument glossy. Stigmata small, last two pairs suboval (Fig. 3).

Metasomal segment I slightly longer than wide; all metasomal segments smooth with elongated sparse ventral and lateral setae. Dorsal carinae hardly noticeable on segments I–IV, without traces of granulation. All other carinae absent on all metasomal segments.

Telson vesicle moderately swollen (Fig. 4), smooth, with ventral seta of different size, some elongated, more numerous near the vesicle/aculeus juncture. Aculeus long, conspicuously curved.

Pectines shorter than coxae III (Figs 5C, 11A). Tooth counts 7/7; middle lamellae counts 2/2; numerous setae on proximal area of teeth and marginal lamellae, sparsely on middle lamellae and fulcra. Sensorial areas of teeth, covers approximately ¼ to ⅓ of surface.

Genital operculum: Short, with four pairs of macrosetae; subtriangular sclerites longitudinally divided with protruding genital papillae (Fig. 5B).

Sternum pentagonal in shape; longer than wide (length/width ratio = 0.92), posteriori emarginated (Figs 5B, 11A).

Chelicerae: Smooth (Fig. 5A), with darker apical portion of denticles. Movable finger dorsal distal denticle considerably shorter than ventral distal denticle; ventral edge smooth, covered with thick brush-like setae; dorsal edge with five denticles: one large distal, two small subdistal, one large median one small basal. Fixed finger with four denticles, normally configured.

Pedipalps (Figs 6, 7): Fingers weakly scalloped. Femur internal face with dorsal and ventral tuberculate carinae, median carinae formed by spaced conical tubercles and sparse granules; ventral face almost smooth with weakly granular external margin; dorsal face smooth (Fig. 7D); external face with dorsal and ventral tuberculate carinae and median carinae lightly serrulate, formed by wide tubercles. Patella smooth, dorsal internal carinae lightly crenate to rough tuberculate; dorsal external carinae weakly tuberculate (Fig. 7C); ventral external carinae weakly tuberculate; ventral internal carinae tuberculate to lightly serrulate (Fig. 7B); dorsal

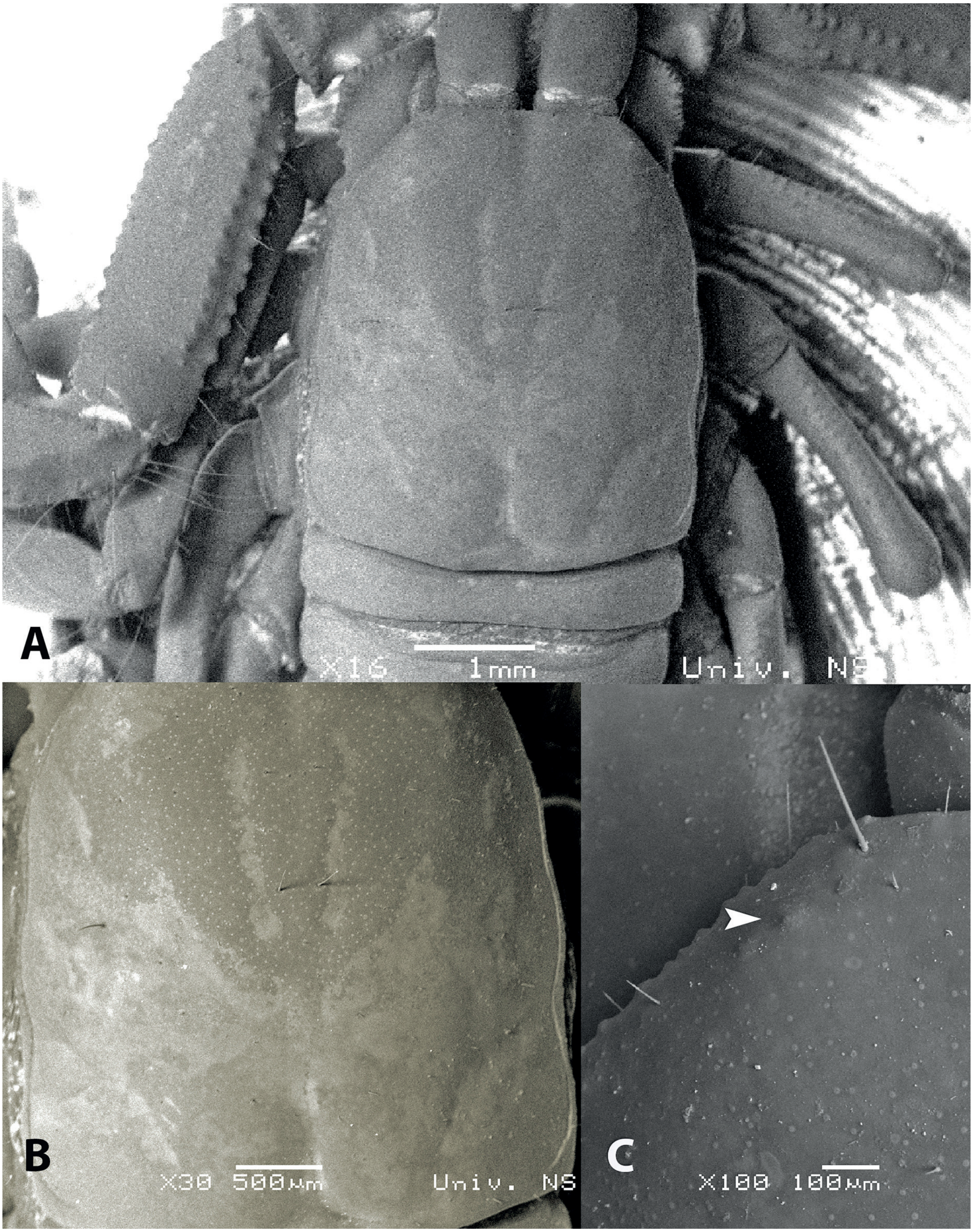

Fig. 2. *Euscorpius studentium* n. sp., holotype, carapace: **A**, dorsal view of the anterior part of the body; **B**, totally reduced median eyes and tubercle; **C**, antero-lateral edge with traces of reduced anterolateral eyes (arrow).

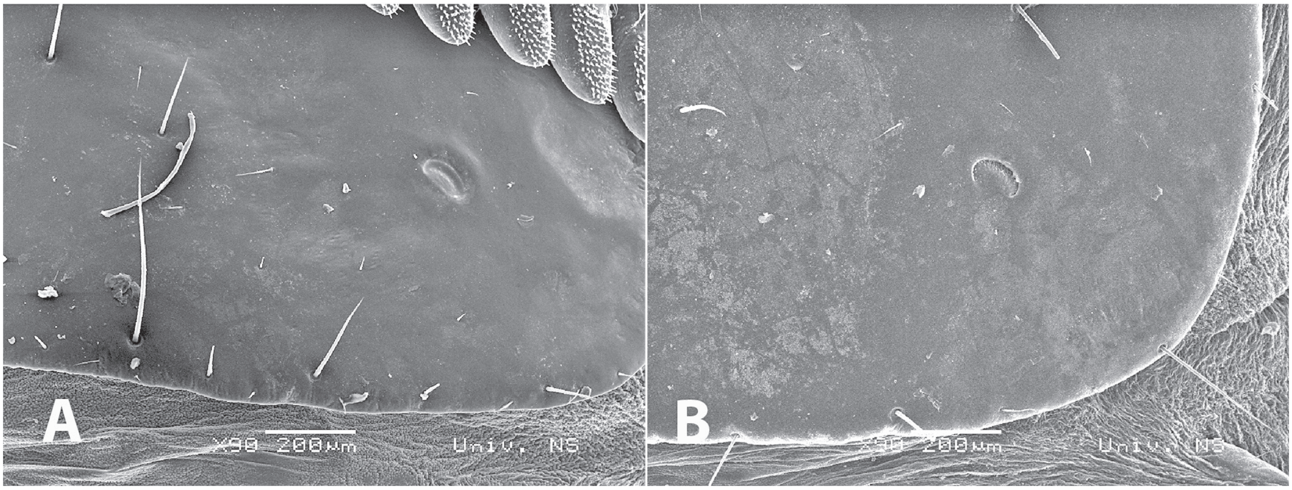

Fig. 3. *Euscorpius studentium* n. sp., holotype: **A**, stigma I; **B**, stigma IV.

patellar spur well-developed (Fig. 7C). Chela narrow, almost smooth, with moderately marked carinae (Figs 6A-C). Chelal carinae D1 and D4 are distinct and smooth, rough in basal part; V1 is distinct, tuberculated; V4 is distinct, rough and lightly granulate. Ventral face sparsely granulated. Typical *Euscorpius* chela finger dentition (Fig. 6D); L/W ratio of the chela 3.53; Lfem/Lpat ratio is 1.

Trichobothria patterns: Chela (Figs 6A-C): trichobothria on manus ventral surface is 4/4 (V1-3 + Et1); V4 on external surface to the ventral external carina. **Patella** (Figs 7A, B): ventral (Pv) is 7/7; external: eb = 4/4, eba = 4/4, esb = 2/2, em = 4/4, est = 4/4, et = 6/6. **Femur**: trichobothrium d is slightly proximal to i**,** whereas trichobothrium e is distal to both, situated on dorsal surface, to the external carina (Fig. 7D)**.**

Legs smooth, yellowish white**;** with two pedal spurs. Ungues elongate and sharp; unguicular spine well-developed and sharp. Tarsus III (Fig. 5D) with 8 ventral spinules.

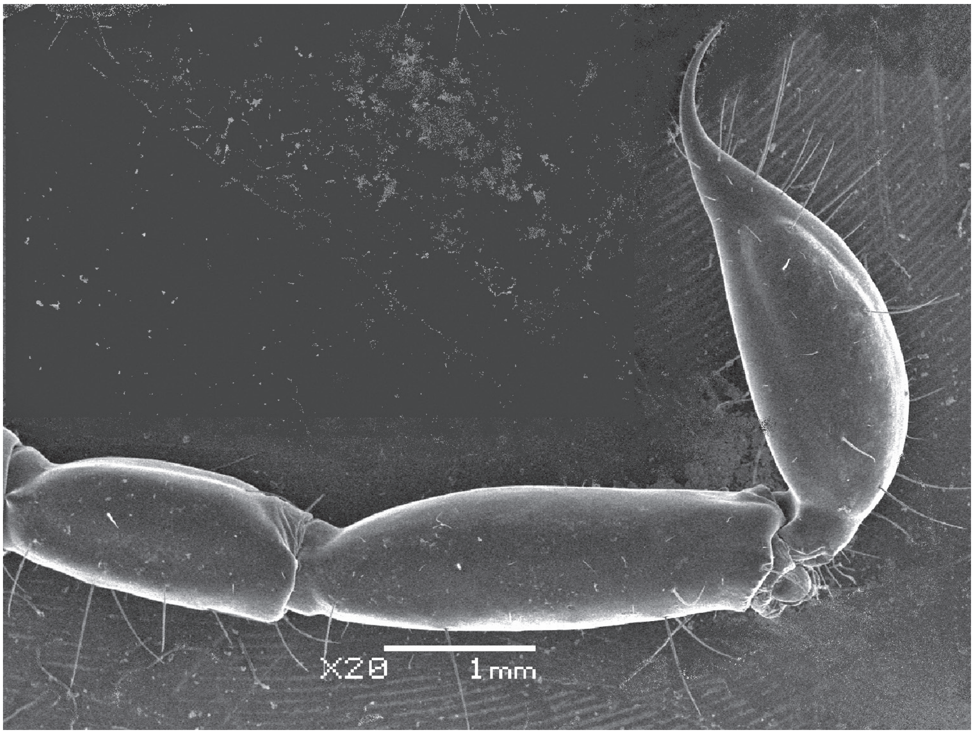

Fig. 4. *Euscorpius studentium* n. sp., holotype, lateral view of the telson with metasomal segments IV, V.

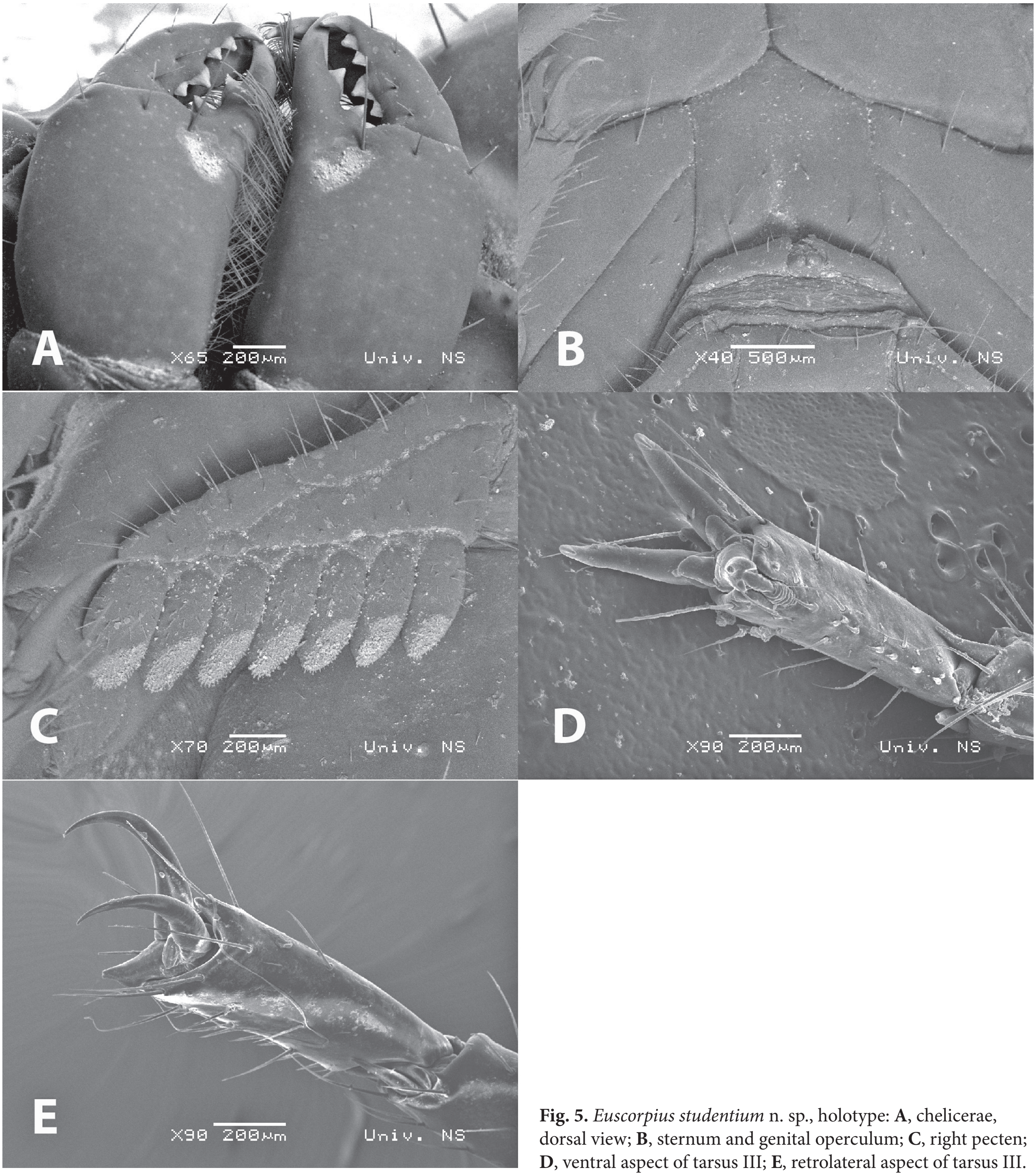

Fig. 5. *Euscorpius studentium* n. sp., holotype: **A**, chelicerae, dorsal view; **B**, sternum and genital operculum; **C**, right pecten; **D**, ventral aspect of tarsus III; **E**, retrolateral aspect of tarsus III.

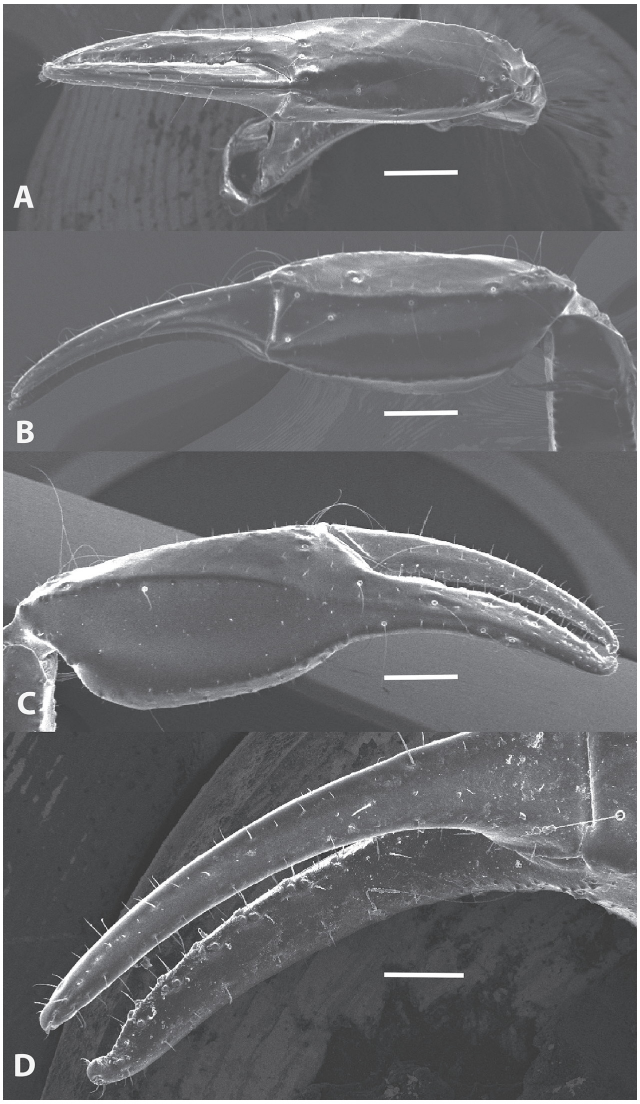

Fig. 6. *Euscorpius studentium* n. sp., holotype, pedipalp chela: **A**, external view; **B**, ventral view; **C**, dorsal view. **D**, detail of chela finger dentition (scale bar A-C = 1mm, D = 0.5 mm).

Short description of the juvenile paratype

Blind, body length 12 mm. Base colour is white to light yellowish. Carapace and pedipalps light yellowish. Legs pale, sternum, genital operculum, pectines and sternites white. No patterns present. Tegument glossy. Pectines tooth counts 7/7; Pedipalps patella trichobothria patterns: ventral (Pv) is 7/7; external: eb = 4/4, eba = 4/4, esb = 2/2, em = 4/4, est = 4/4, et = 6/6.

Remarks: The fact that during my numerous biospeleological visits to this cave so few individuals have been collected indicate the low population density of *E. studentium* n. sp.

Comparison of immature male specimens of *E. studentium* n. sp. and *E. feti*

The specimens compared are of the same size – 26 mm body length, possibly of the same age. Despite the fact that *E. studentium* n. sp. and *E. feti* are not closely related species, some differences among their immature specimens can be characterized as differences between the two life forms of scorpions represented in caves (Figs 1, 8). They concern regressive and progressive evolutionary changes that occurred in the process of adaptation of troglobites for life in the conditions of underground habitats. Regressive changes imply the development of so-called regressive characters, manifested from varying degrees of reduction to complete loss of a particular structure or organ as a result. Progressive changes include modifications that occur under strong selective pressure from the environment.

The regressive characteristics of troglobites that are also the most striking are reduced eyes and depigmentation of *E. studentium* n. sp. (Fig. 2) compared with *E. feti* (Fig. 9).

Progressive changes in troglobite specimens of *E. studentium* n. sp. compared to troglophile *E. feti* are more discrete than regressive ones. Those are the presence of a smooth tegument with reduced granulation and tubercles, elongated sharp and thin ungues of the legs and a narrowed body manifested by the profile of the sternum of troglobite *E. studentium* n. sp. compared to troglophile *E. feti*.

The smooth tegument with reduced granulation and tubercles of *E. studentium* n. sp. (Fig. 2B) compared with the sparsely granulated one of *E. feti* (Fig. 9B), is partly the result of regressive changes as well, usually reduced sclerotization of troglobite arthropods as a consequence of energy saving to survive in such an extremely nutrient-poor habitat. The progressive side of this change is reduced body friction when passing through narrow spaces in the underground cavities.

Sharp, elongated and thin ungues of the legs of *E. studentium* n. sp. (Fig. 5E) compared to the less elongated and thicker ungues in those of *E. feti* (Fig. 10) enable more efficient adhesion on the uneven and porous limestone surfaces and improve their climbing abilities. The almost identical form of this character in *E. feti* individuals of different ages indicates its stability and relevance.

The elongated body in troglobite *E. studentium* n. sp. (Fig. 1) is only an impression. Actually, it is narrowed as seen through the proportions of the sternum and the ratio of the sternum width and coxae III length (Fig. 11A) compared to the *E. feti* immature male (Fig. 11B). A narrowed body can be considered an adaptation that facilitates squeezing through tight spaces and at the same time reducing overall bodyweight, but not in proportion to leg span, which makes the animal more suitable for climbing – lithophily.

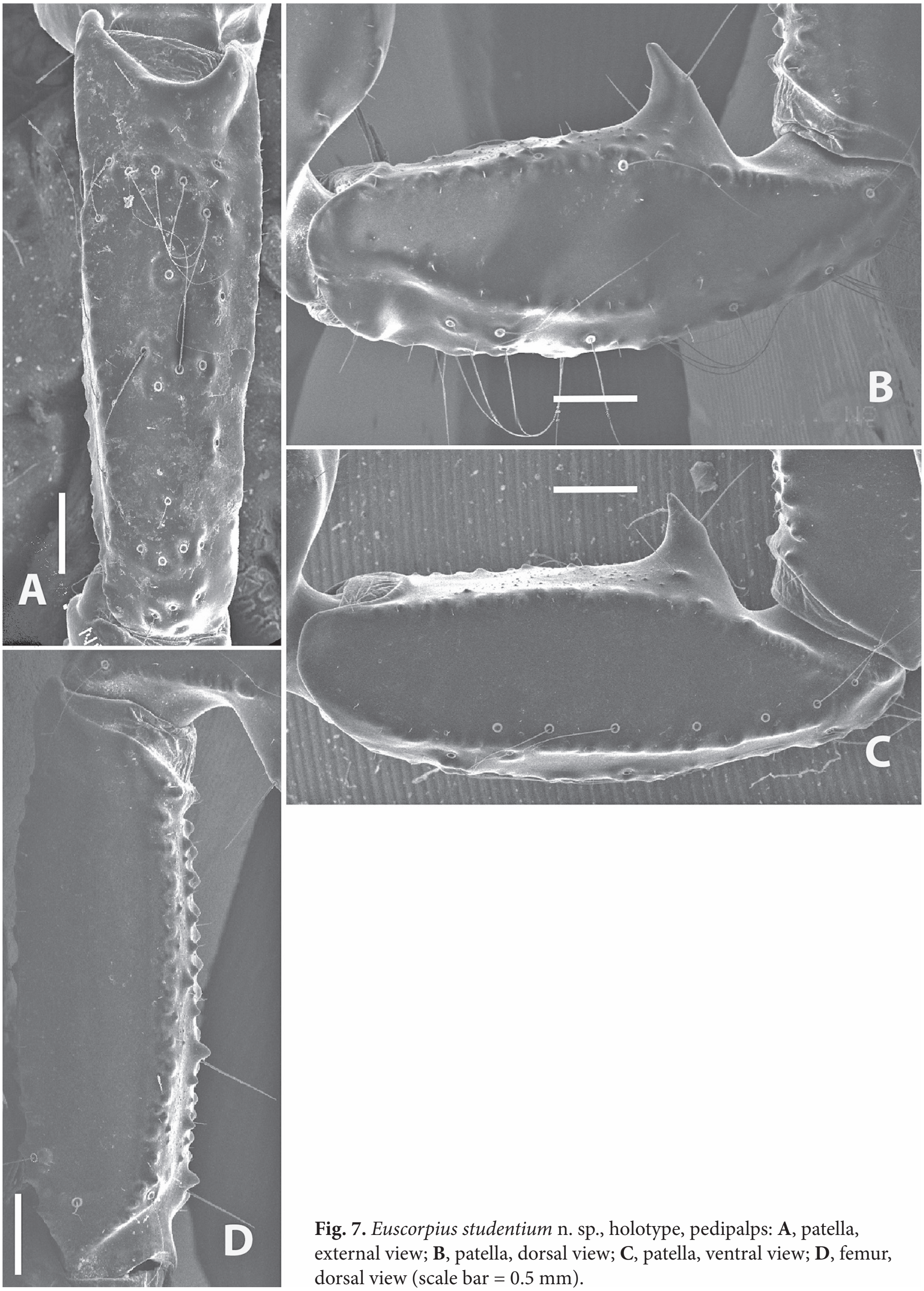

Fig. 7. *Euscorpius studentium* n. sp., holotype, pedipalps: **A**, patella, external view; **B**, patella, dorsal view; **C**, patella, ventral view; **D**, femur, dorsal view (scale bar = 0.5 mm).

Fig. 8. *Euscorpius feti*, immature male (dorsal and ventral view) (photos D. Savić).

The observed differences in stigmata shape between *E. studentium* n. sp. and *E. feti* (Figs 3, 12) probably are not a reflection of differences for the life forms to which they belong.

DISCUSSION

For humans, caves are fascinating but inhospitable places. For many animal groups present in such an environment, they are not. Still, there is limited energy input which limits troglobite diversity, population size and forces a K-strategy. For the vast majority of arthropods whose eyes are not the primary sense for orientation, the absence of light is not a handicap. Stable humidity and temperature favours the cave species of temperate zones whose epigean ancestors lived in similar conditions during the Tertiary. Caves are also a pleasant habitat for some cryophilic species whose ancestors lived during glacial episodes as mountain epigean forms in conditions of increased and stable humidity caused by the proximity of glaciers and constant snow cover. With respect to physical conditions, caves are a very pleasant environment. However, it is a space that is quite demanding in the sense that it cannot be inhabited by organisms that have limited vagility under the given conditions. One prerequisite for being habitable is that cave inhabiting organisms must have pronounced climbing abilities (Karaman 2019): a feature that is not widespread among scorpions.

The climbing abilities of lithophile species are implied. Life on open rocky surfaces implies almost all the challenges of life in caves, while probably being less hospitable. Food may also be infrequently available. Karstification processes in limestone, often preceded by erosion processes, gives rise to characteristic structures on its surface that provide conditions for the development of lithophiles. The same process happens beneath the surface of limestone, producing underground cavities, successively connected to the surface through cracks, fissures and ducts. This provides opportunities for lithophile species to become troglophile and in appropriate circumstances troglobite.

Both *Euscorpius* species presented here live in caves whose main entrances and halls, where they are present, are located just below the tops of hills. The cave, Spila Skožnica, which contains troglobite *E. studentium* n. sp., is surrounded with karren bedrock surface (škrapa) and rare small fragments of superficial deposits with vegetation (Fig. 13). Life under such conditions is almost impossible, particularly for fauna that originated from ancestors of primarily mesophilic

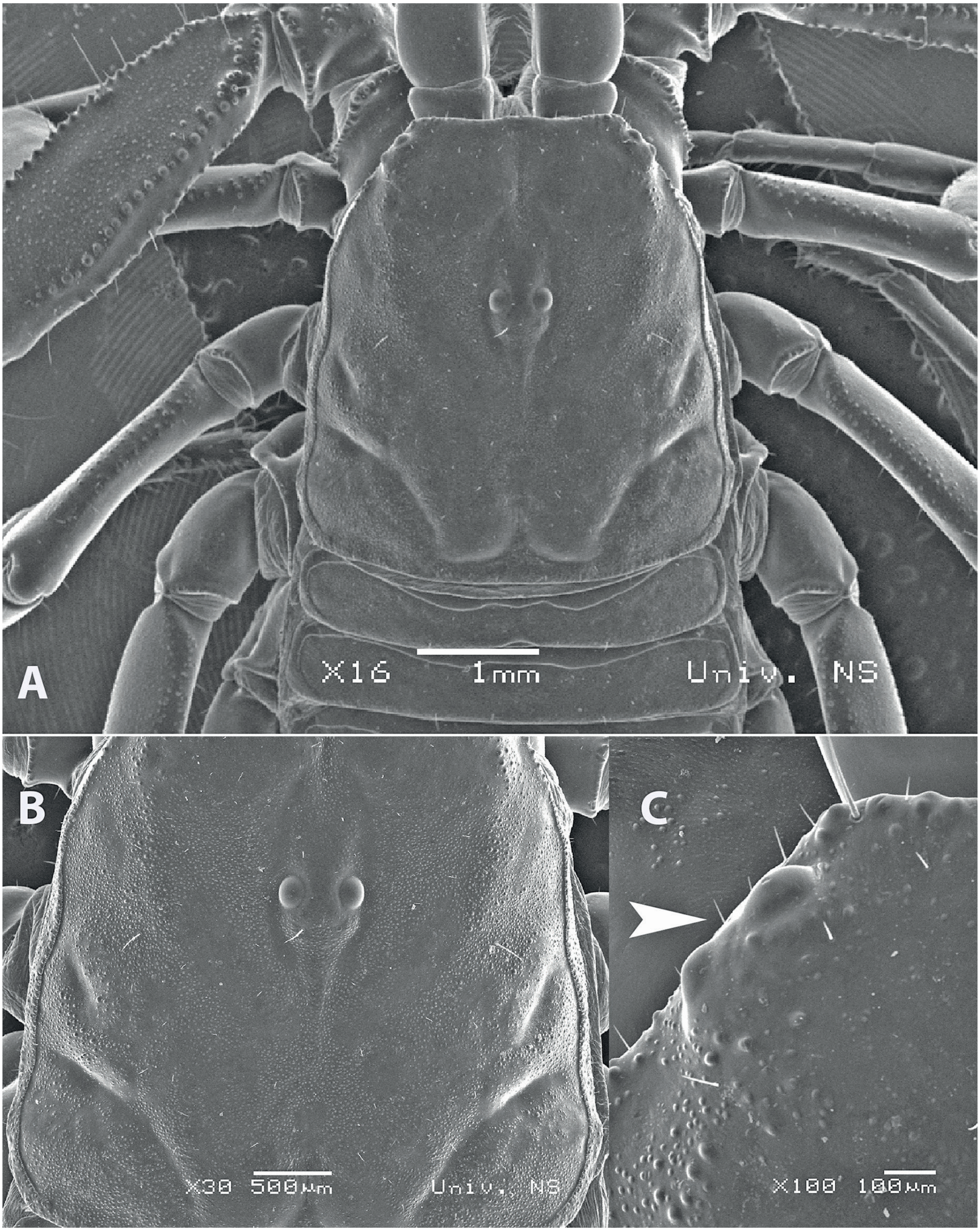

Fig. 9. *Euscorpius feti*, immature male: **A**, dorsal view of the frontal part of the body; **B**, granulated carapace with median eyes and tubercle; **C**, antero-lateral edge with anterolateral eyes (arrow).

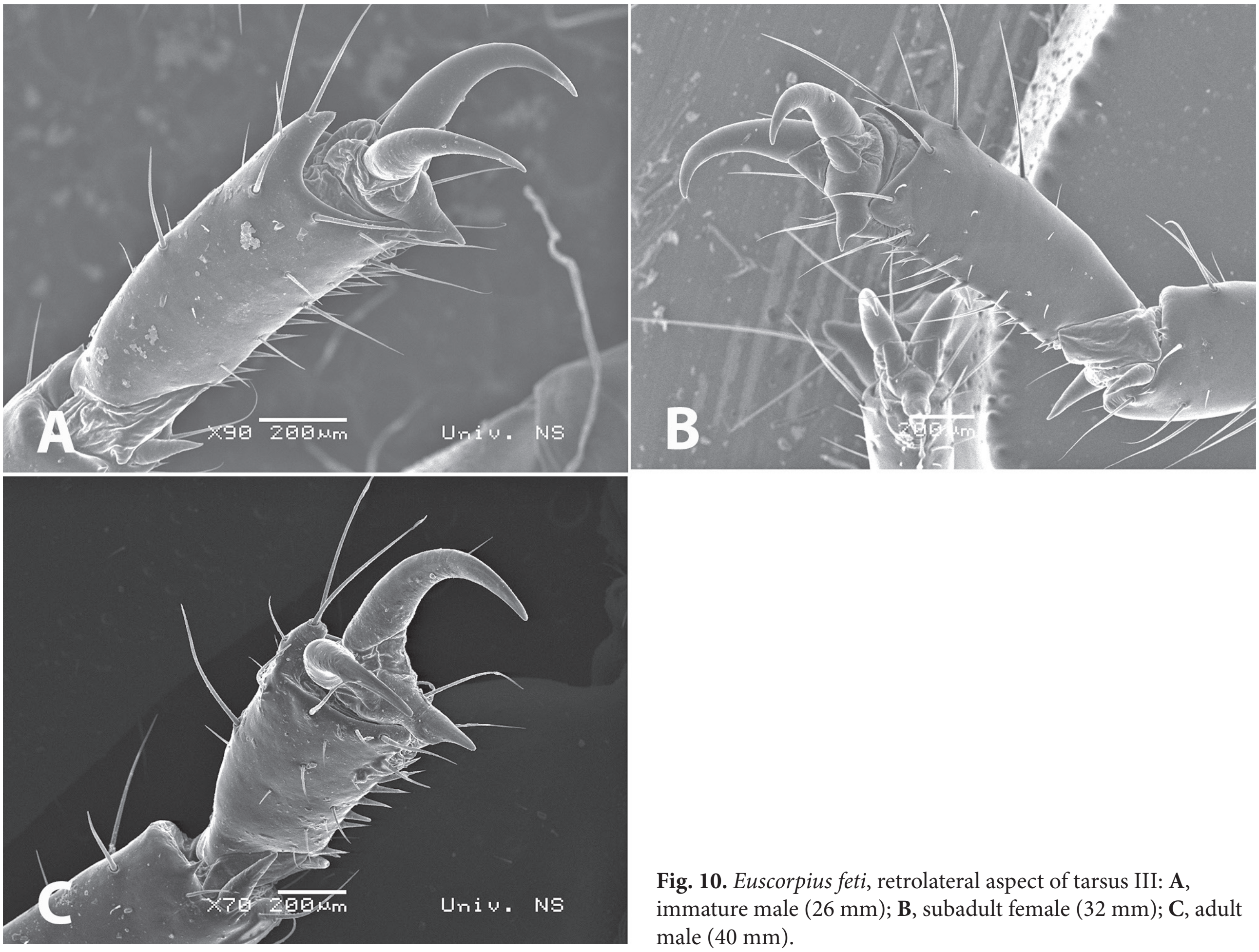

Fig. 10. *Euscorpius feti*, retrolateral aspect of tarsus III: **A**, immature male (26 mm); **B**, subadult female (32 mm); **C**, adult male (40 mm).

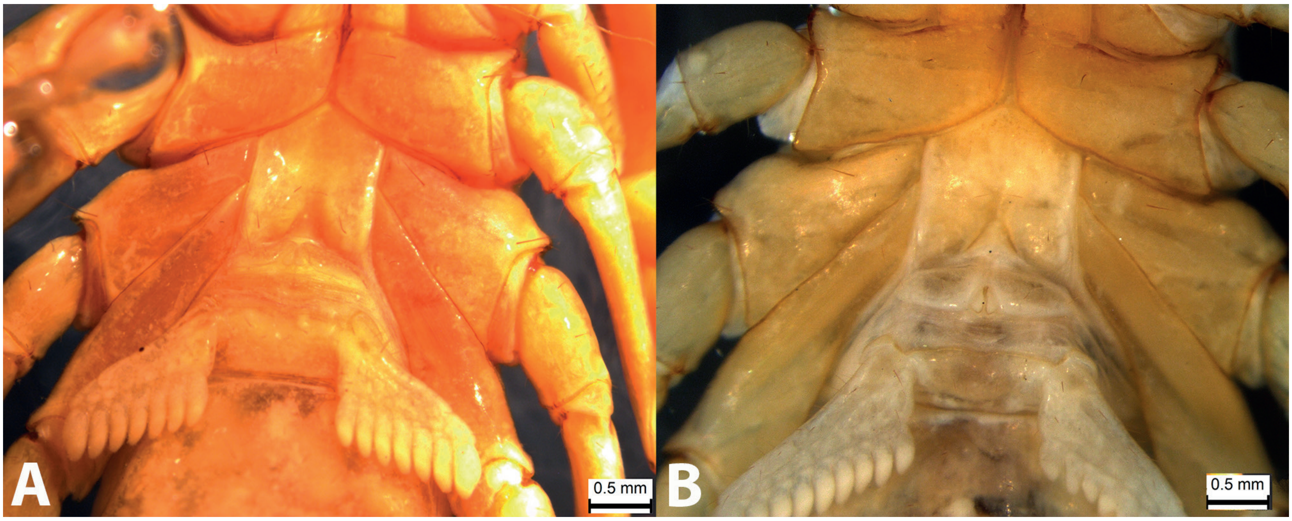

Fig. 11. Ventral aspect of sternum and coxae II-IV: **A**, *Euscorpius studentium* n. sp., holotype; **B**, *Euscorpius feti*, immature male (26 mm).

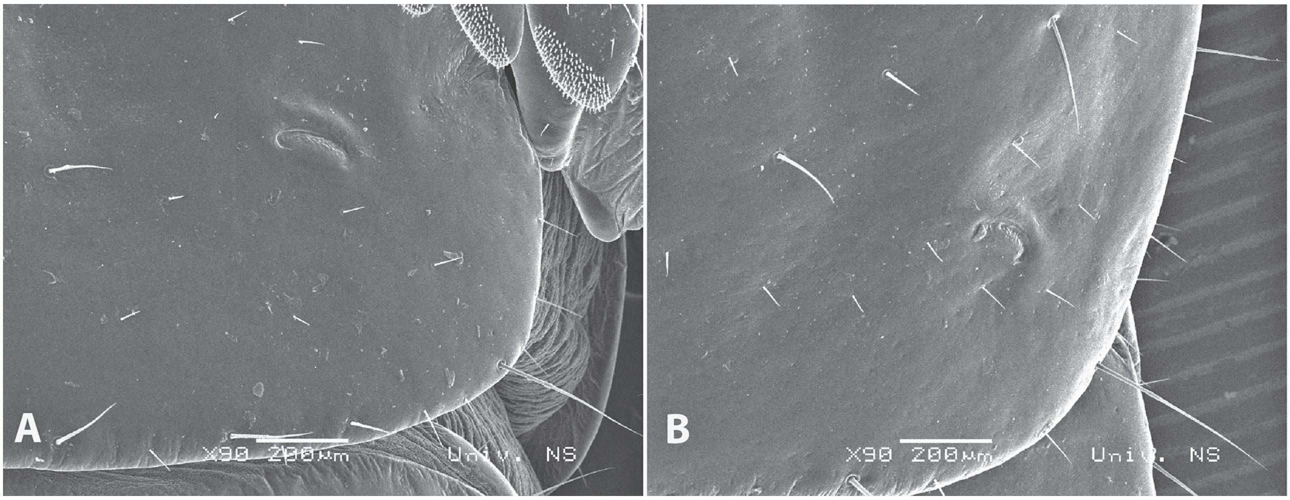

Fig. 12. *Euscorpius feti*, immature female (26 mm): **A**, stigma I; **B**, stigma IV.

character. Transitioning to subterranean life was the only option that obviously happened some time before the erosion and corrosion processes brought this terrain to its present state. Similarly, the cave Zaćirska pećina, which contains troglophile *E. feti*, is surrounded by a karst terrain dominated by superficial deposits under forest vegetation and bedrocks with deep clefts and cracks (Fig. 14). The entrance hall where I found specimens of this species is located just below such terrain. I believe that deep crevices provide similar conditions to those in the cave and are also a habitat for this species, and that there is communication between these spaces that provides gene flow between the epigean and subterranean segments of the population.

Volschenk and Prendini (2008), in the introductory part of their paper, correctly assumed that "Lithophily is probably a precursor to troglophily." For larger troglobites, I think that this is an obvious and dominant way of inhabiting subterranean spaces. However, it seems that the second author of this paper appears to have abandoned that position in his later studies. The paper of Prendini et al. (2010) deals with this issue and deserves special attention and comment here. Based on their cladistic analysis of morphological characters of a scorpion family Typhlochactidae, endemic to eastern Mexico, they concluded that "*Troglobitism is not an evolutionary dead-end: endogean scorpions evolved from hypogean ancestors on more than one occasion*." This kind of conclusion contradicts the opposing, more common opinion of which I myself am an advocate. The troglobites of Dinarides and other karstic regions of the former Yugoslavia I have been studying, are relicts, descended from Tertiary epigean fauna when they either inhabited subterranean spaces or settled them later, during the glacial episodes of the Pleistocene. They have in common the requirement for high relative humidity, which they mostly carry from their epigean ancestors. Tolerance to certain variability in relative humidity in caves is reserved only for troglophiles, which can often be found in all parts of them and outside in suitable habitats. Therefore, troglophiles have much wider distributions than troglobionts. When it comes to other characteristics common to troglobites, first of all those of morphological nature, it is difficult to specify any to be universal. Most often mentioned, anophthalmy and depigmentation are common features, but there are exceptions: mostly in younger troglobites. Elongated legs are a prerequisite for climbing abilities, a feature that epigean ancestors must have possessed before settling in underground spaces. Certainly, selective pressures in underground conditions continue to potentiate this feature.

Reduction of sclerotization in addition to anophthalmy and depigmentation is another frequent regressive evolutionary change associated with life in subterranean environments, as a consequence of the selective pressure of the resource-poor environment. The carrier of regressive evolution in cave organisms is energy economy, which is more pronounced in habitats that are extremely poor in nutrients. It is manifested by the reduction of characters and structures that are absolutely non-functional. Other aphotic environments also produce these regressive "troglomorphic" characteristics as well. Living in complete darkness is not only a peculiarity of cave life. It occurs in the marine depths of the aphotic zone, as well as in soil, among *endogean fauna*. The soil is an aphotic environment that is partly inhabited by fauna adapted to underground life, often accompanied by depigmentation and partial to complete reduction of the eyes. This fauna inhabits micro-cavities whose size is determined by the structure of the soil itself. The soil structure of the vertical profile shows successive steps in the decomposition of the bedrock and the biodegradation of plant remains of vegetation cover from the surface. In the decay layer of plants debris there is a spe-

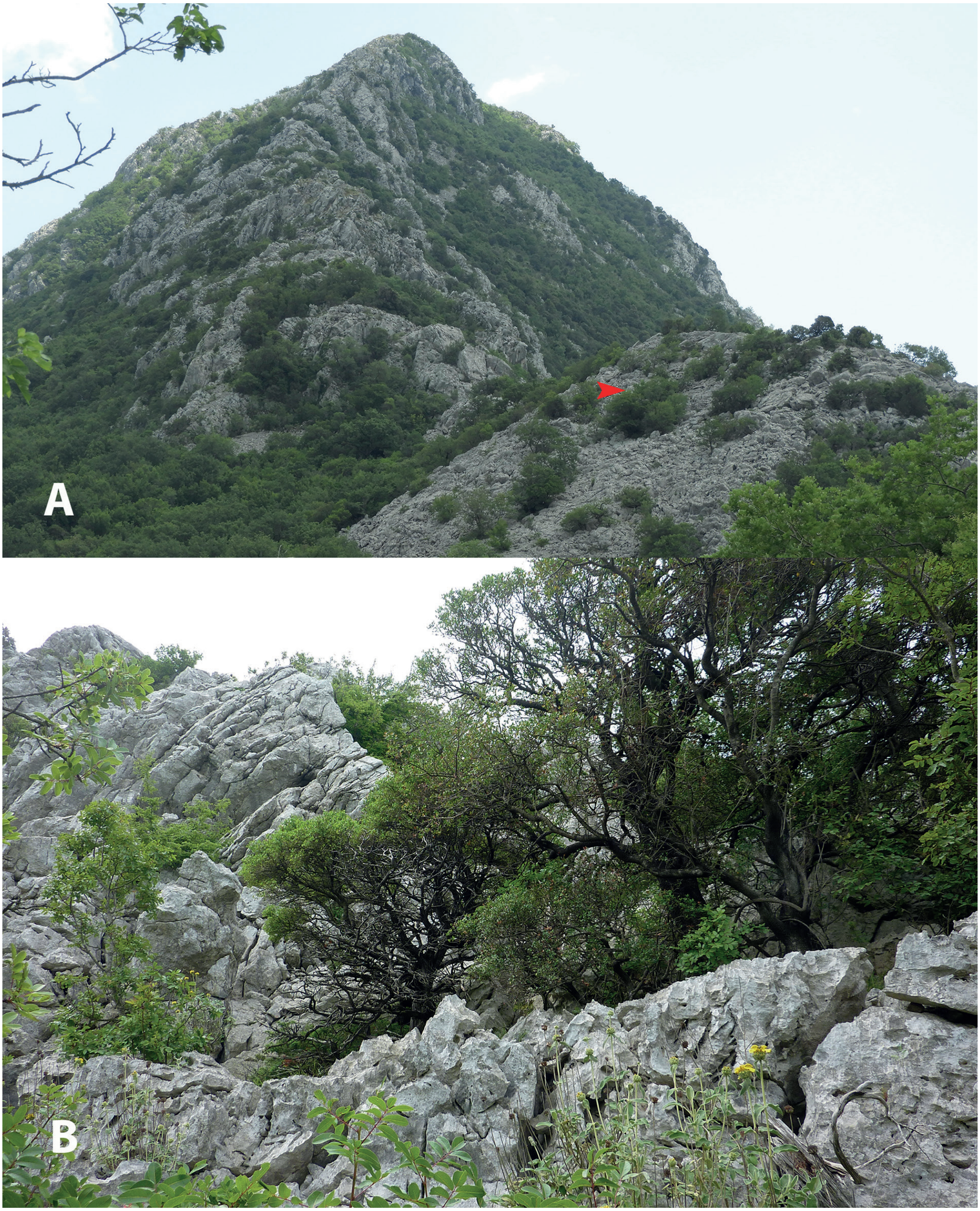

Fig. 13. A, Northern slope of the hill Velji grad (spring aspect). Arrow indicates the position of the entrance of the Cave Spila Skožnica, locus typicus of *Euscorpius studentium* n. sp. (photo M. Karaman); **B,** Karren bedrock surface in front of the Cave Spila Skožnica (spring aspect) (photo L. Barsi).

Fig. 14. Terrains surrounding the entrance to Zaćirska pećina cave (with *Euscorpius feti*), winter aspect: **A,** Karst terrain dominated by superficial deposits under forest vegetation, in front of the cave entrance (northern slope of the hill); **B,** Open bedrock surface (western slope of the hill); **C,** deep clefts of bedrock (photos M. Karaman).

cific fauna that we call *humicoles.* Between the bedrock and the plant remains is soil that is inhabited by characteristic - *edaphic fauna*. Often there is no sharp boundary between it and humicole fauna. The small dimensions of the soil cavities limit the body dimensions of the edaphic fauna and encourage the development of so-called edaphomorphic traits (Zacharda 1979), which include a smaller, more compact body (often narrowed and flattened), shortened, stocky and strong appendages. Edaphomorphic traits include the already mentioned depigmentation and reduction of the eyes. In contrast to the appendage structure of edaphic organisms, which is often proclaimed as a highly troglomorphic feature, appendage elongation is found in troglobites. It is clear that edaphomorphic features have evolved under strong selective pressure from the environment they inhabit. The question remains whether the visibly elongated extremities of most troglobites are indeed troglomorphic features. Edaphomorphic traits (as well as frequent close phyletic relationships of hypogean and edaphic fauna) suggest an alternative possibility. That elongated appendages are a plesiomorphic feature of terricolous forms, which remained functional in the subterranean environment, while being lost in epigean (after the onset of climate change) and edaphic conditions. Significant climate changes at the end of the Tertiary and in the Pleistocene, resulted in pronounced seasonal changes in humidity and temperature regimes, creating a strong selective pressure on a part of the epigean and humicole fauna, which in unfavourable conditions had to shelter in cavities of the substrate. Elongated extremities are a ballast in these conditions. Organisms that have settled larger subterranean spaces such as caves were not exposed to the selective pressure of appendage shortening. I think that it is the case with representatives of the east Mexican family Typhlochactidae. Throughout their long evolutionary history, they must have been stenotopes, as is indicated by the current distribution of this family. They had a long history of cryptobionts related to mesophile habitats. Under these conditions, their eyes were completely reduced, as is the case with the genus *Belisarius* in Europe. The common ancestor of Typhlochactidae had to be an endogean humicole or hygrophile lapidicolous species (as it is today, *Typhlochactas sissomi* Francke, Vignoli & Prendini, 2009) whose descendants were forced to settle deeper substrate or underground cavities due to climate changes. *Typhlochactas mitchelli* Sissom, 1988 and *T. sylvestris* Mitchell & Peck, 1977 exhibits clear edaphomorphic features of organisms that have inhabited smaller cavities in the substrate. *Typhlochactas rhodesi* Mitchell, 1968, *T. reddelli* Mitchell, 1968 and *T. cavicola* Francke, 1986 are possible troglophiles which occupied the "Milieu souterrain superficiel" (mesovoid shallow substratum - MSS). MSS is subterranean habitat rich in relict fauna, but seems neglected by many researchers. All types of this habitat as well as sampling techniques have been shortly reviewed in Mamola et al. (2016). Karst areas abound in this type of habitat. MSS in karst as a subterranean network of voids and cavities in deposits of rock fragments and vegetation debris often is connected with the deeper and larger hypogean bedrock fissures network and cavities, such as caves. The clear boundary between the endogean and troglobite fauna is lost in this space. It is probably in most cases transitional (ecotone) and a phase in the settlement of larger underground cavities. Movement through MSS is not accomplished by walking on a horizontal surface and through narrow spaces, but through a three-dimensional network of more or less spacious cavities, which also requires some climbing skills i.e. certain anatomical predispositions as in troglobites. In any case, it is not an environment that will exert strong selective pressure in the direction of elongation or shortening of the extremities. However, deep narrow cracks and crevices in bedrock and exposed sides of bare rocks and cliffs in rocky terrains and mountainous regions favour the adaptive features that characterize lithophilic species. Scorpion species that successfully inhabit such habitats have certain traits (Prendini 2001) that we find in troglobite species, as well as climbing abilities expressed as elongated legs and highly curved telotarsal ungues, elongated pedipalps and metasoma. *Sotanochactas elliotti* (Mitchell, 1971), *Typhlochactas granulosus* Sissom and Cokendolpher, 1998 and all three species of the genus *Alacran* are troglobites which had to have shorter or longer histories as lithophiles. Three species of the genus *Alacran* have acquired their distinctive "troglomorphic" traits as lithophiles from their common ancestor, which was also a lithophile. It is hard to believe that in an area extending nearly 70 km (air distance between the outermost caves with *Alacran* species) (Santibanez Lopez et al. 2014) there was a cave system that (in spatial or temporal continuity) was inhabited by a panmictic ancestral population that was fragmented due to the advanced karstification process. As an example of the existence of such a vast cave system, the authors cite the Sistema Sac Actun in Yucatan Peninsula, which has passages with a total known length of over 340 km. However, they neglect the fact that this large cave system covers an area that extends only about 15 km in length. It is similar to world longest Mamoth cave system, with more than 640 km of known passages.

It is much more likely that *Alacran* were litophiles from the tropical highland, which were forced to inhabit deeper subterranean habitats at the end of Pliocene and in Pleistocene when they become troglobites. Vicariance and dispersal of epigean lithophile common ancestors occurred in such an environment in conditions of intensive karstification.

I think that a key omission in the study of Prendini et al. (2010) is in the use of and definition of the term *troglomorphism*, which often (as in this study) indicates any degree of reduction of eyes and pigments in cryptobionts. Indeed, the authors point out that "*Troglomorphism… does not constitute unequivocal evidence of troglobitism*". But regardless, the use of this inadequate term results in an inevitable next step - to label species with such "troglomorphic" traits as troglobite, even though they were found in a completely different environment (as in Vignoli and Kovarik 2003). The term itself suggests that. Such troglomorphism in scorpions that were found in caves automatically characterizes them as troglobites (as *Troglocormus willis* Francke, 1981; *Troglorhopalurus translucidus* Lourenço Baptista & Giupponi, 2004; *Alloscorpiops troglodytes* Lourenço et Pham, 2015 etc.) although it is obvious that they are troglophiles. Such a widely understood and used term - troglomorphism, equalizes two life forms which are the results of different selection pressures: troglobites vs edaphobionts.

Prendini et al. (2010) hypothesizes the phylogenetic relationship among Typhlochactidae based on cladistic analysis of morphological characters. The final conclusions of these analyses are that the hypogean condition is ancestral among Typhlochactidae. But, phylogenetic reconstruction cannot automatically imply the reconstruction of life forms that taxa have undergone in their long history. Early branching off of the troglobite *Alacran tartarus* from the remaining analyzed Typhlochactidae does not suggest the troglobite nature of their common ancestor. My view is that the hypogean condition in Typhlochactidae evolved independently as many times as there are troglobite species within this family.

The question arises as to why Mexico has such a rich fauna of troglobite scorpions (almost 3/4 of all known species so far) and Dinaric karst (as a subterranean hot spot) does not? The answer lies in the fact that the diversity of epigean scorpion fauna in Mexico is far greater, and the fauna more heterogeneous (Santibanez-Lopez et al. 2016) than in the Dinarides. Lithophile scorpions are numerous as basic forms able to settle subterranean spaces. The Dinarides, as well as the entire Balkans in general, are inhabited by an indigenous lineage of scorpions, members of a terricole lineage of family Euscorpiidae and subfamily Euscorpiinae (*Euscorpius* and *Alpiscorpius*), primarily related to forest habitats and whose adaptation to other habitat types is on-going. But considering the extraordinary richness of the subterranean fauna of the Dinarides and its' under-exploration, I believe that *E. studentium* n. sp. is not the only troglobite scorpion in this karstic area. Moreover, more troglophiles should be expected because most explorers in the past did not pay attention to troglophiles in general and particularly to scorpions, since there were no interested experts. The distribution of presently known troglophile and troglobite scorpion species in the southern Dinaric region (a hot spot of subterranean fauna) is presented as a map (Fig. 15).

Besides the three previously mentioned Dinaric *Euscorpius* species (*E. biokovensis*, *E. croaticus* and *E. feti*), *E. aquilejensis* (C.L. Koch, 1837) from Italy, Slovenia and Croatia, *E. birulai* Fet et al., 2014 from Euboea in Greece, and *E. giachinoi* Tropea & Fet, 2015 from Central Greece, are another troglophile species in the genus (Tropea 2013a, b; Fet et al. 2014; Tropea and Fet 2015; Tropea and Ozimec 2019, 2020).

Despite the pronounced preferences for a particular type of habitat (Colombo 2006), species of the genus *Euscorpius* can be considered to be mostly eurytopic terricole animals. In this respect, it is worth noting the finding of a population of *E.* cf *tergestinus* (C. L. Koch, 1837) (Fig. 16) (identified by V. Fet) in the extreme south of Montenegro. The population of this species is adapted to life in the supralitoral zone (the splash zone) and the upper zone of the mediolitoral along the Adriatic coast. A number of mainly juveniles were found (in May), and were not rare, appearing as fast moving when disturbed among and beneath stones and coarser gravel, which are present in the thicker layer on that part of the shore. The rich supralitoral fauna there, with populations of several halophile terrestrial isopod species and particularly scaly cricket - *Pseudomogoplistes squamiger*, certainly are the main source of food for this population.

Spila Skožnica cave, where *E. studentium* n. sp. was found, was until a few years ago known only to local people who did not visit it at all. Probably to provide additional attractions for tourists, a few years ago somebody paved a road leading to the cave, and traces of frequent visits are now visible in it. This in particular has affected the large bat population that I came across during my first visits, when the cave was difficult to reach. The last two years have seen a dramatic decline in the bat population, which has been re-

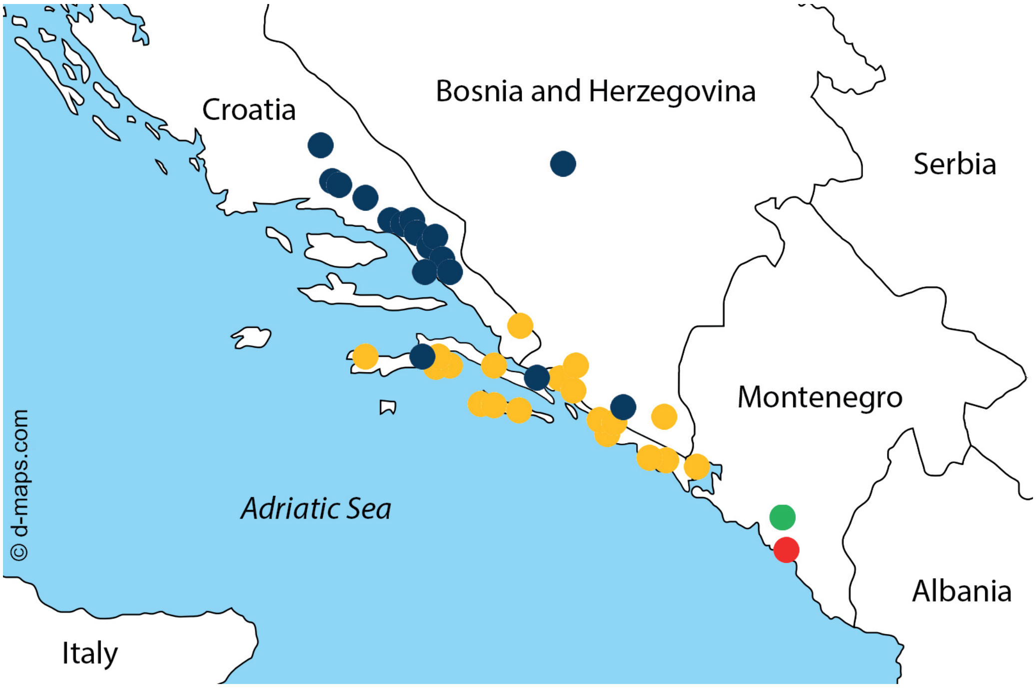

Fig. 15. Distribution map of troglophile and troglobite species of the genus *Eusorpius* in southern Dinarides: red cyrcle - *E. studentium* n. sp.; green cyrcle - *E. feti* Tropea, 2013 population from Zaćirska pećina Cave; jelow cyrcles - *E. feti* Tropea, 2013; blue cyrcles - *E. biokovensis* Tropea and Ozimec, 2020.

Fig. 16. *Euscorpius* cf. *tergestinus* (C. L. Koch, 1837) female, supralitoral population from Valdanos (Montenegro) (photo Ž. Lukač)

duced to less than 1/3 of the previously rich population. I am afraid that this finding of a troglobite scorpion will further motivate uncontrolled visits by tourists and collectors. It is very important that the cave does not remain unprotected, as it is now. In the current conditions, the species *E. studentium* n. sp. must be recognized and designated as Critically Endangered (CR) according to the International Union for Conservation of Nature (IUCN) criteria.

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