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Geographical variation in the tropical cave cockroach *Paratemnopteryx stonei* Roth (Blattellidae) in North Queensland, Australia.

David Paul Slaney and Philip Weinstein *

**SUMMARY**

Observations of cave dwelling organisms in both tropical and temperate caves often reveal morphological modifications, which may reflect various stages of adaptation to cave life. From April 1994 to June 1995 a number of adult *Paratemnopteryx stonei* were collected from 7 caves in tropical North Queensland to investigate the degree of geographical variation in such troglomorphies between cave populations. Results of morphometric analyses showed the occurrence of a morphological discontinuity between cave populations from the different geographic regions. The body dimensions particularly important in discriminating between each cave population were tegmen length (both sexes), and secondly, tegmen width and tarsus length for males and females respectively. Morphological differences between populations are discussed in relation to stages of adaptation to cave life.

**INTRODUCTION**

Cave organisms often demonstrate degrees of morphological modification (troglomorphy), for example, reduced or lost eyes, wings and bodily pigmentation, and attenuation of appendages (Christiansen, 1961; Barr, 1968; Culver, 1982; Kane and Richardson, 1985). These troglomorphic characters may reflect various stages of adaptation to cave habitats, induced through different regimes of selective pressures, and or genetic factors such as the accumulation of neutral mutations (Poulson, 1985; Wilkens, 1992; Culver et al., 1994). The highest morphological modification occurs in those populations which have been isolated (ie subject to no gene flow) the longest, have experienced stronger selective pressures, or have a greater fixation rate of genetic mutations within a population. Thus, one would expect isolated cave populations to demonstrate varying degrees of troglomorphy.

Important factors which determine the degree of isolation or otherwise of cave populations are the presence of geological barriers and/or interstitial
voids within cavernous strata (Barr, 1968; Howarth, 1982; Barr and Holsinger, 1985; Kane and Brunner, 1986). The occurrence of such barriers and voids influences the dispersal ability of cave dwelling organisms, and in turn determines the geographic extent and degree of gene flow between cave populations. For example, *Neaphaenops tellkampfi*, a troglobitic (obligately cave dwelling) trechine carabid beetle, in west central Kentucky contains isolated populations which have been allocated subspecies status by Barr (1979). He recognised four subspecies, based on morphological differentiation of the populations which coincides with the presence of faults and rivers between groups of morphological forms.

In contrast, cave populations that are subject to intercave gene flow would have a lower degree of morphological variation. In a study of the distribution and evolution of *Ptomaphagus* beetles in the southeastern United States, Peck (1984) compared 61 separate cave populations. The caves were located in a continuous limestone belt that would be expected to contain abundant subterranean avenues for dispersal. Morphological comparisons between these cave populations showed little variation, although each population was found to contain only one form of spermatheca. Peck suggested that the spermathecal forms are an indicator of species level taxonomic categories, and speciation has occurred despite the presence of subterranean dispersal routes.

In North Queensland tropical caves, comparison of two populations of *Undarana*, a cave dwelling cixiid (Hemiptera), from lava tubes 30 km apart, revealed significant differences in external and genital morphology (Hoch and Howarth, 1989). Although the populations were from distant lava tubes of separate origin, individuals may be able to disperse between caves because the lava fields are connected by other basaltic flows. Hoch and Howarth interpreted these differences as indicators of interrupted gene flow between the populations, and therefore surmised the existence of two separate biological entities. In contrast, they found populations of another cixiid, *Solonaima*, to be morphologically similar in the same lava systems.

Early examination of cockroaches we have collected from these lava tubes and other tropical caves in North Queensland indicated that there are morphological differences between populations of *Paratemnopteryx stonei* Roth (Blatto-dea: Blattellidae). This genus is distributed widely over Australia, with different species living in epigean and cave habitats (Roth, 1990). So far, three of the four cave species within the genus have been found only in North Queensland (*P. stonei*, *P. howarthi*, and *P. sp4*). The aim of this study was to investigate the degree of geographic variation in troglo-morphies between populations of *P. stonei* in North Queensland caves.
MATERIALS AND METHODS

From April 1994 to June 1995 *P. stonei* adults were collected from 7 caves in North Queensland: Bauhinia (8 males, 5 females) and Clam (16 males, 8 females) caves at Chillagoe, Barkers (16 males, 25 females) and Bayliss (21 males, 27 females) lava tubes at Undara, Frig cave (3 males, 4 females) at Broken River, and Rope Ladder (13 males, 12 females) and Bat cave (3 males, 3 females) at Fanning River (Fig. 1). As cockroaches do not continue to grow once they are adults morphometric analyses were carried out only on adults, avoiding sample bias in the growth stage. In addition, both sexes were analysed separately to investigate sexual dimorphism.

From these collections morphological measurements were made on 11 body dimensions using a stereo-dissecting microscope and ocular micrometer. The body dimensions were body length; femur, tibia, and tarsus length of hind leg; cercus length; eye length and width; tegmen length and width; and pronotum length and width.

Fig. 1 – Map of North Queensland indicating the four cave regions and cave study sites.
Fig. 2 - Variation in body length (mm) ± SE for males (circles) and females (squares) from the seven cave study sites.

The statistical analysis used to investigate geographic variation between populations was Canonical Discriminant Analysis (CDA), using the SAS program package (SAS Institute, 1987). CDA is an ordination technique for displaying and describing the differences between group centroids, i.e., for each population, by extracting the eigen vectors from the pooled within-group variance-covariance matrix. The analysis was carried out on ratio transformed data, with respect to body length, to remove the influence of body size on other body characters.
One-way ANOVA’s were carried out on body length and the morphological characters defined by the CDA’s as being particularly important in discriminating between cave populations. Based on these characters a Tukey Studentized Range (HSD) Test was carried out to define which populations were significantly different from each other (Sokal and Rohlf, 1982).
RESULTS

Initial exploratory data analysis of the raw data using plots of the mean of each of the measured body dimensions indicated that there were 2 main differences between males and females both between and within cave populations. These were body length and tegmen length (Figs. 2 and 3). Figure 2 shows that females had greater body length than males at each of the 7 caves, with populations from Chillagoe and Undara having greater body length than those from Broken River and Fanning River. Figure 3 indicates that females have shorter tegmina than males in populations from Chillagoe, Undara and Broken River.

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Fig. 4 – Radio transformed tegmen length data ± SE for males (circles) and females (squares) from the seven cave study sites.
Ratio transforming the tegmen length data produced different results to those shown in figure 3 (Fig. 4). In figure 4 females have shorter tegmina than males in populations from Chillagoe, Undara and Broken River, which is opposite to the relationship shown in figure 3. This reversal is due to the effect of body size (females are larger than males) supporting the decision to carry out further statistical analyses on ratio transformed data.

Figure 4 indicates that males had longer tegmina than females, and that sexual dimorphism in tegmen length is most pronounced in the cockroach populations from Fanning River caves. Based on tegmen length, the graph shows 3 morphological groups, these being a long wing morph at Chillagoe (males and females), a short wing morph at Undara and Broken River (males and females), and a long/short wing morph at Fanning River (males and females respectively).

Fig. 5 – Canonical discriminate analysis plots of males with 95% confidence intervals around centroids for Bauhinia (1), Clam (2), Barkers (3), Bayliss (4), Frig (5), Rope Ladder (6), and Bat (7) caves.
Plots of the CDA’s for males and females (Figs. 5 and 6 respectively) show a clear separation of the populations with respect to geographic location, and to a lesser degree between caves. For males the canonical variables 1 and 2 summarised 97.7% (87.3% and 10.4% respectively) of the total variation between groups, and 93.8% (67.2% and 26.6% respectively) for the females. Table 1 gives the coefficients for the first canonical variable, and indicates that the body dimensions which are particularly important in discriminating between cave populations are tegmen length (for both sexes), and secondly, tegmen width and tarsus length for males and females respectively. The distinctiveness between populations was confirmed by multivariate F-statistic analysis (Pillai’s Trace = 2.860, F = 6.647, p = 0.0001 for males; Pillai’s Trace = 2.643, F = 6.376, p = 0.0001 for females).
Table 1 – Coefficients for the first canonical variable from the CDA analyses carried out on males and females, ranked in order of importance in discriminating between cave populations.

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Plots of tegmen width and tarsus length (Figs. 7 and 8 respectively) indicate that male cockroaches from Bat Cave at Fanning River had the widest tegmina and female cockroaches from Bauhinia Cave at Chillagoe had the longest tarsi. Results from the one-way ANOVA’s and Tukey Studentized Range (HSD) Tests on body, tegmen and tarsus length, and tegmen width indicated that these characters were significantly different from each other in some populations (Results of which can be obtained from the authors).

DISCUSSION

Previous morphological work on *P. stonei* has been carried out by Roth (1990). He described *P. stonei* from caves at Chillagoe and Undara, but did not carry out any detailed morphometric analyses. He noted that specimens taken from different caves varied in size of tegmina, and reduction in pulvilli. However, comparison of male genitalia were similar enough that he considered the specimens to be races of the same taxon. He classified specimens found in Clam cave at Chillagoe, and those from Bayliss, and Barkers caves as 3 different races. Specimens have not been reported or described from either Broken River or Fanning River caves, and our specimens therefore constitute new locality records for *P. stonei*. Of further interest was the striking sexual dimorphism in tegmen length in individuals from Fanning River caves which has not been found in any other population of *P. stonei*. Sexual dimorphism in wing length is not unique to individuals of *P. stonei*, as it has been recorded in numerous other insects (Thayer, 1992).
The multivariate analyses indicate that there are morphological variations between cave populations which can be resolved into 4 major groups, representing the 4 geographic regions, Chillagoe, Undara, Broken River, and Fanning River (Figs. 5 and 6). There is a degree of variation within each population, where some individuals from caves in the same geographic region, ie Bauhinia and Clam at Chillagoe, Barkers and Bayliss at Undara and Rope Ladder and Bat at Fanning River, fall within each others' data cloud. However, the intracave region variation does not exceed the intercave region variation observed between the four cave regions.

Observations of cave dwelling organisms in both tropical and temperate caves often demonstrate troglomorphy, although the pattern and degree of morphological modification is not universal (Christiansen, 1961; Barr,
1968; Culver, 1982; Kane and Richardson, 1985; Peck, 1990). All individuals of *P. stonei*, except males from Fanning River, were found to have brachypterous tegmina with females having shorter tegmina than males (Fig. 4), and all individuals had vestigial hind wings. Reduction in tegmen width was also noted between males, with both intra and intercave region variation (Fig. 7). Peck and Roth (1992) have documented tegmina and wing reduction in surface dwelling *Chorisoneura* cockroaches from the Galápagos Islands. They concluded that during wing diminution the tegmina are less affected than the hind wings, and within a population the wing is more regressed in females. Wing loss has also been found in a number of other cockroaches, with flightlessness being more frequent among females than males, and there was a higher than average frequency in species inhabiting caves (Roff, 1990). The reduction in wing and tegmen size has been explained as a response to an increased specialisation for a more homogeneous environment, such as caves.

![Fig. 8](image_url)  
**Fig. 8** - Ratio transformed tarsus length data ± SE for females from the seven cave study sites.
Elongation of appendages is a further troglomorphic feature found in cave species. Females from Bauhinia cave at Chillagoe had longer tarsi than females from the other caves (Fig. 8). Leg attenuation in cockroaches has also been reported in species of *Nocticola* from caves at Undara (Stone, 1988). Peck (1986) found a tendency for appendage elongation in cavernicolous *Ptomaphagus* beetles, with *P. cavernicola* having especially long tarsi. Attenuation of legs and antennae may provide a selective advantage by increasing the searching ability of cave organisms in an environment where there is little to no light (Peck, 1973).

Tarsal structure in cockroaches is a highly adaptive character, showing distinctive, nonphylogenetic features above the species level (Roth and Willis, 1952; Arnold, 1974). Roth (1990) noted variation in pulvillus reduction in and between populations of *P. stonei* from Chillagoe. Reduction of pulvilli and increased dependance on tarsal claws is an adaptation for walking on muddy cave surfaces (Roth and Willis, 1952; Christiansen, 1961 and 1965). Inter and intraspecific variation in tarsal structure in North Queensland cave *Paratemnopteryx* is currently being investigated by us in populations from caves with different substrate surfaces and humidity levels.

Troglomorphic characters may reflect various stages of adaptation to cave life. The degree of which may be influenced by various factors. Firstly, the selective regimes operating, as body size and allometrically related morphological characters are affected by environmental factors. Thus, variability in morphology between cave populations can be a result of ecological differences between the caves. Secondly, the length of time and degree to which organisms have been isolated can affect morphological variability. Increased variability in troglomorphic characters has been proposed as resulting from intercave gene flow and hybridisation with extant surface species (Avise and Selander, 1972). As the cave regions in this study are over 150 km from each other it is unlikely that there is any gene flow between cave regions, but one would expect intercave connections within regions. Thus, both direct environmental induction, reflecting phenotypic plasticity, and genetic adaptation to current selection pressures may be important in contributing to the observed morphological variation (Atchley, 1983; Allegrucci et al., 1992; Bilton, 1993). Thirdly, non-selectionist origins for troglomorphy have been considered, with morphological variation occurring as a result of the accumulation and fixation of neutral mutations within a cave population (Poulson, 1985; Wilkens, 1992). This also would be influenced by the degree of intercave gene flow. Considering these points, one may expect that populations of one species showing increased troglomor-
phy, such as the males from Bauhinia Cave at Chillagoe and the females from Barkers Cave at Undara, represent populations that have experienced the greatest isolation or experienced greater selective pressure, and or a greater fixation rate of genetic mutations within a population.

Alternatively morphological variability may reflect phylogenetic differences between cave populations. However, it is important not to rely on morphological characters that may be adaptive for use in inferring phylogeny. To resolve these issues we are currently making microenvironmental comparisons between caves, and molecular, morphological and behavioural studies at the population and species level within Paratemnopteryx. Given the similarities of the cave environment in the caves studied, it is difficult to believe that the morphological variations reflect different degrees of troglomorphy resulting from different selection pressures at each site. The morphological differences exhibited by isolated cave populations are more likely to have resulted from the fixation of characters modified by genetic drift.

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REFERENCES


A recent colonization of Dolichopoda cave crickets in the Poscola cave (Orthoptera, Rhaphidophoridae).

Camilla Bernardini *, Claudio Di Russo *, Mauro Rampini **, Donatella Cesaroni * and Valerio Sbordoni *

SUMMARY

We report a series of investigations carried out on a Dolichopoda population recently discovered in the Poscola cave and in some small caves nearby (Lessini Mountains, Vicenza). This population is located north of Po river, outside the present known geographic range of this genus in Italy. Morphology of the epiphallus corroborated by chromosome and allozyme analysis indicated that this population belongs to D. laetitiae. Study of the genetic structure of population in the Poscola area revealed high gene flow levels between Poscola and the other minor caves, suggesting the occurrence of a single expanding population. This finding as well as mark-recapture data on population size, migrations, age structure and habitat type strongly suggest that the Poscola population is the result of a recent colonization due to anthropocore dispersal.

INTRODUCTION

Colonization, i.e. the successful invasion of a new area (or habitat) by a species, is a process with important evolutionary consequences. Particularly, the study of colonization events of isolated habitat, such as caves or islands, because of their simplified ecology, represents a good opportunity to investigate any detectable evolutionary changes in animal and plant populations both from the ecological and the genetic point of view. However, for the cave habitat, only few experimental transplantations have been reported in the last forty years. These experiments include the transplantation of Amphipod Crustacean Niphargus virei in the Balme cave in French (Ginet, 1965), of the Cholevid beetles Speonomus longicornis, S. diecki, S. stygius and Bathysciola derosasi introduced respectively in the

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Ramioul cave in Belgium (Bouillon & Hubart, 1982; Tercafs & Brouwir, 1991) and in the Patrizi cave in Italy (Patrizi, 1956) and of *Dolichopoda linderi* populations in two caves of southern France (Di Russo, 1993). *Dolichopoda* cave crickets were recorded in the Poscola cave for the first time in 1991 by one of us (M. Rampini). Previous records of cave crickets from this cave included *Troglophilus cavicola* and *T. neglectus* only (Bartolomei, 1957). The location of this cave, which is largely outside of the presently known range of *Dolichopoda* (Fig.1), and the low vagility of these crickets, usually limited to hypogean habitats, led us to hypothesize that the population presently inhabiting Poscola cave is the result of a recent colonization. In order to test this hypothesis and to detail the biology of this population, genetic and ecological studies were carried out throughout periodical sampling.

![Fig. 1 - Geographic location of Poscola cave and distribution range of *D.ligustica* and *D.laetitiae*.](image-url)
MATERIAL AND METHODS

Geographical location and cave description.

Poscola cave (cave register number: 136 V/VI) belongs to a Karst system located at 275 m asl on the eastern slope of the Faedo-Casaron mountain near Priabona village (Lessini Mountains, Vicenza). The cave develops horizontally for 325 m, showing two entrances. The main entrance opens near the garden of the Priabona church, while the smaller one is surrounded by a thick wood. Furthermore a stream springs near the secondary entrance and flows through the cave (Fig. 2).

Fig. 2 – Map of the Poscola cave: A, the main entrance; B, secondary entrance; 1, 2, 3, and 4, the different sectors for samplings.
The checklist of the fauna of this cave, compiled by Fabiani (1904) and later completed by Bartolomei (1957), is here reported: Gastropoda (*Oxychilus* sp.); Copepoda (*Speocyclops* sp.); Isopoda (*Androniscus dentiger*, *Armadillidium* sp., *Monolista berica*); Amphipoda (*Niphargus stigius costozzae*, *Gammarus balcanicus*); Decapoda (*Astacus fluviatilis*); Chilopoda (*Lithobius* sp.); Pseudoscorpionida (*Chthonius* sp.); Opiliones (*Gyas* sp.); Orthoptera (*Troglophilus cavicola*, *T. neglectus*); Coleoptera (*Neoba-thyscia fabianii*, *Antisphodrus* sp.); Lepidoptera (*Scoliopteryx libatrix*); Diptera (*Culex* sp.); Chiroptera and Rodentia.

Following our first record of *Dolichopoda* in 1991, several other small caves near the main Poscola cave were periodically checked for *Dolichopoda* occurrence. Out of 12 only 6 caves were inhabited by *Dolichopoda*: Poscola I (PSC 1), Poscola II (PSC 2), Poscola III (PSC 3), Poscola IV (PSC 4, n°1528 V/Vi), Marchiori cave (n° 579 V/Vi), Buco sopra la cava (n°2254 V/Vi) (Fig. 3).

**Epiphallus morphology**

Morphology of the epiphallus is the taxonomic character usually utilized to identify species in *Dolichopoda* (Baccetti & Capra, 1959, 1970). Samples of *D. laetitiae* and *D. ligustica* were therefore examined for comparative analysis. These two species were considered because of their geographic distribution and their overall similarity.

Study samples were from Bunker near Muratone pass (LIG), Pigna-Liguria (*D. ligustica*) and Zigolo cave (ZIG), Castel dei Britti-Emilia; Drago cave (DRA), Apecchio-Marche; Bella cave (FSS1), Genga-Marche; Tana Termini cave (TER), San Marcello Pistoiese-Toscana; Nebbia cave (FUN), Fungaia-Toscana; Etruscan Mitreo (SUT), Sutri-Lazio (*D. laetitiae*).

After dissection the epiphallus was treated with KOH solution (0.5N) and dehydrated in graded ethanol series. These structures, mounted on stubs, were coated with a thin layer of gold in a sputtering unit (MEDOIO sputter coater, Balzer Union). Observations were carried out with a Stereo Scan Cambridge 200 scanning electron microscope operating at 15 kV. Micrographs were taken on 120 Agfapan 25.

**Chromosome analysis**

Mitotic chromosomes were obtained from male nymph crickets. After dissection in a proper solution (NaCl 0.7%, CaCl2 0.02%), testes were iso-
lated, fixed in methanol-acetic acid 3:1 for 30 sec., then incubated in a drop of acetic acid for 1 min. Tissues were squashed under a siliconized coverslip which was removed with a razor blade after immersing the cytological preparation in liquid nitrogen. Chromosomes were stained with nucleophilic Giemsa solution (5% in deionized water for 20 min.) and
observed with a Leitz Laborlux 12 microscope equipped with a 100/50W mercury lamp.

**Allozyme analysis**

The degree of genetic similarity between Poscola cave population and other populations of *D. laetitia* was evaluated by means of allozyme polymorphisms. Samples of two *D. laetitia* populations, from Pitigliano cave (PIT) in Tuscany and S. Giacomo cave (GIA) in Umbria, were collected and analysed for comparative purpose. On a narrower geographic scale, samples from some small caves near the Poscola cave (PSC1, PSC3 and PSC4) were also considered to investigate population genetic structure (Fig. 3). All samples were assayed electrophoretically for genetic variation at 19 gene loci: acidphosphatase (*Acp*), aldolase (*Aldo*), diaphorase (*Dia*), esterase (*Est-1, Est-2*), glutamate-oxaloacetatetrasaminase (*Got*), glucose-phosphateisomerase (*Gpi*), isocitratedehydrogenase (*Idh-1, Idh-2*), leucino-aminopeptidase (*Lap-1, Lap-2*), malatedehydrogenase (*Mdh-1, Mdh-2*), mannose-phosphateisomerase (*Mpi*), peptidase (*Pep*), phosphoglucomutase (*Pgm*), pyruvate-kinase (*Pk*), proteins (*Pt*). The methodology essentially followed technical procedures reported in Allegrucci et al. (1992) with minor modifications.

Allele frequencies, observed and expected heterozygosities, and genetic distances were calculated using the BIOSYS-1 program of Swofford and Selander (1981). Genetic distance indices were calculated using the Nei's (1978) algorithm.

F-statistics (Wright, 1951) was used to investigate the genetic structuring of *Dolichopoda* samples from the Poscola area, by using the procedure of Weir and Cockerham (1984) and the FSTAT program (ver1.2) developed by Jérôme Goudet, University of Losanna, Switzerland. The extent of gene flow was evaluated by means of *Nm* values, i.e. the average number of migrants exchanged per generation, estimated from the relationship: \[ F_{ST} = 1/(4Nm+1). \]

**Estimation of population size by seasonal samples**

Poscola cave was divided in four sectors (Fig. 2) to relate the spatial distribution of *Dolichopoda* to thermal condition of the cave and trophic resources availability. Air temperature of the four sectors was recorded seasonally by a digital thermometer (± 0.1).
A RECENT COLONIZATION OF DOLICHOPODA CAVE CRICKETS

Population size was estimated by mark-recapture method (Lincoln, 1930) modified for small population by Bailey (1951). This method was previously tested in several Dolichopoda populations (Carchini et al., 1983; Rampini et al., 1983).

According to Bailey (1951), population size \( N \) was calculated by \( [N = M(T+1)/(R+1)] \), where \( M \) is the number of marked individuals, \( T \) is the total number of recaptured individuals and \( R \) is the total number of recaptured individuals previously marked.

Variance of the estimates was calculated as follow: \( [V(N) = M^2(T+1)(T-R)/(R+1)^2 (R+2)] \) and confidence limits (C.f.) are given by the relation \( [C.f. = \pm t \times \sqrt{V(N)}] \) with \( t = 1.96 \) for \( \alpha = 95\% \). Samplings were carried out every three months starting from March '94 to June '95. Additional samplings, conducted on December '92, June '93 and March '96, were also available. In order to record displacements inside the cave and migration outside the cave, crickets were marked with different colours in different sectors. Age structure of each sample was studied by means of individual metatibial length recorded with a vernier caliper.

RESULTS

Taxonomic assessment of Poscola cave population

The inspection of the epiphallus of Poscola specimens showed substantial differences from \( D. ligustica \), because of its deep incision at the basal part of the structure, while its shape appeared to fall within the variation of \( D. laetitiae \) (Fig.5). Morphological similarity to \( D. laetitiae \) was also revealed by other structures as male X uroterga, subgenital plate and ovipositor in the female. However, because of a wide range of variation in these morphological structures within \( D. laetitiae \) (Sbordoni et al., 1979), chromosome and allozyme analyses were carried out to support taxonomic assignment.

Figure 4 illustrates mitotic chromosomes obtained from a nymph of Poscola population. A diploid number equal to 31 was established, with sex determination XX, XO. As found in other Dolichopoda species (A.P. Bianchi, pers. com.) a supernumerary chromosome occurred. Number and morphology of chromosomes appeared to match to \( D. laetitiae \) (Baccetti, 1958). On the contrary the Poscola karyotype differed from that of the geographically closest species, \( D. ligustica \), which presents a diploid number of 30 chromosomes (Baccetti, 1982).
Furthermore allozyme polymorphisms analysis showed a low level of genetic divergence between the Poscola population (PSC) and the two *D. laetitiae* populations (PIT and GIA), as indicated by D values (Nei, 1978) ranging from 0.031 to 0.054. These values in *Dolichopoda* are usually found between conspecific populations (Sbordoni et al., 1985; Allegrucci et al., 1992). On the basis of these analyses we can safely assign the Poscola population to *Dolichopoda laetitiae*.

![Mitotic plate from a male nymph of Poscola cave. The X-chromosome is indicated.](image)

**Population size**

Table 1 lists the number of cave crickets in Poscola cave estimated by mark-recapture method since December 1992 until March 1996. Estimates ranged between a minimum of 496 individuals (c.l. ± 127) in June 1995 and a maximum of 1988 individuals (c.l. ± 588) in October 1994. Population size showed strong variation apparently not related to any seasonal trends.
Fig. 5 – Scanning electron microscope photographs of the epiphallus: 1 = *D. ligustica* (LIG); 2 = *Dolichopoda* from Poscola cave; 3-8 = *D. laetitiae*, (3=ZIG, 4=DRA, 5=FSS1, 6=TER, 7=FUN, 8=SUT; for population symbols see text).
Table 1 – Population size (N) estimated in Poscola cave by mark-recapture method. M = marked individuals; T = total individuals recaptured; R = marked individuals recaptured; V = variance; C.l. = confidence limits

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>T</th>
<th>R</th>
<th>N</th>
<th>V</th>
<th>C.l.(+/-)</th>
</tr>
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<tr>
<td>Dec-92</td>
<td>256</td>
<td>283</td>
<td>79</td>
<td>909</td>
<td>7330</td>
<td>166</td>
</tr>
<tr>
<td>Jun-93</td>
<td>188</td>
<td>283</td>
<td>32</td>
<td>1618</td>
<td>67520</td>
<td>509</td>
</tr>
<tr>
<td>Mar-94</td>
<td>183</td>
<td>163</td>
<td>37</td>
<td>790</td>
<td>12252</td>
<td>215</td>
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<tr>
<td>Jun-94</td>
<td>182</td>
<td>252</td>
<td>40</td>
<td>1123</td>
<td>25070</td>
<td>310</td>
</tr>
<tr>
<td>Oct-94</td>
<td>259</td>
<td>283</td>
<td>36</td>
<td>1988</td>
<td>90154</td>
<td>588</td>
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<tr>
<td>Jan-95</td>
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<td>98</td>
<td>1870</td>
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<td>116</td>
<td>1887</td>
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<td>105</td>
<td>36</td>
<td>496</td>
<td>4209</td>
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<tr>
<td>Mar-96</td>
<td>167</td>
<td>144</td>
<td>22</td>
<td>1053</td>
<td>7644</td>
<td>171</td>
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</table>

Age structure and sex-ratio

Figure 6 reports the frequency distributions of metatibia length obtained from individual measures in seasonal samples. Individual growth showed a clear seasonal trend, resulting from the occurrence of different age groups in different periods of the year.

Adults start to emerge at the beginning of summer and show a frequency peak in autumn, while in winter they disappear. During the winter, the population is composed only by nymphs of different age which stop growing because of dormancy. In autumn, two distinct choorts of individuals are clearly identifiable. A first one is mainly formed by adults, and a second by youngs and nymphs. The sex ratio for each of the samples was not statistically different from the ratio 1:1.

Spatial distribution and migration

Temperature variation in space and time is summarized in Table 2. The sector 1 and 4 appeared rather variable with seasonal ΔT ranging from 7.7°C to 9°C. On the contrary sectors 2 and 3 appeared relatively more stable, with a ΔT ranging between 4.6°C and 5.5°C. Sector 1 showed a mean temperature relatively low (10.2°C), while sector 4, with a mean temperature of 13.5°C, was close the optimum temperature (15°C) of Dolichopoda life cycle (Di Russo & Juberthie, 1995). According to these data sector 1 was seldom inhabited by Dolichopoda, most of which occurred in the sector 4 in every season. Only in winter the spatial distribution of crickets appeared more heterogeneous as a consequence of displacement of Dolichopoda inside of the cave, particularly in the sectors 2 and 3. Mark-recapture data also confirmed these observations. In fact, several crickets,
marked in autumn and winter and coming from the sectors close to the entrances (1 and 4), were recaptured in the sectors 2 and 3. On the contrary, 10 individuals, marked in winter in the two inner sectors, were found in the sector 4 on spring and summer.

*Dolichopoda* were also discovered in the small caves near Poscola cave. Migration between these caves can occur, as established by recapture in PSC1 of one individual previously marked in the main cave. Apparently only one out of these small caves (PSC3) showed a stable population. This was estimated by periodical counts ranging between 200 and 400 individuals. In the summertime, occasional sights of *Dolichopoda*, were also recorded outside caves.

Table 2 – Summary of thermal condition in the four sectors of Poscola cave

<table>
<thead>
<tr>
<th>sector</th>
<th>min °C</th>
<th>max °C</th>
<th>mean °C</th>
<th>ΔT (°C)</th>
</tr>
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<td>sector 1</td>
<td>5</td>
<td>14</td>
<td>10.2</td>
<td>9</td>
</tr>
<tr>
<td>sector 2</td>
<td>7.7</td>
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<td>sector 3</td>
<td>11</td>
<td>15.6</td>
<td>12.8</td>
<td>4.6</td>
</tr>
<tr>
<td>sector 4</td>
<td>11.6</td>
<td>19.3</td>
<td>13.5</td>
<td>7.7</td>
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</table>
Genetic structure

Allele frequencies at 19 loci calculated for the four population samples (PSC, PSCI, PSC3 and PSC4) are reported in Table 3. Different samples showed allele frequencies quite similar at most loci, and genetic distance values were very low in any pairwise comparison, ranging from 0.000 to 0.003.

The analysis of the genetic structuring for these nearby populations was performed by using θ (Weir and Cockeram, 1984) as \( F_{ST} \) estimator. The global θ value was 0.009, suggesting absence of population heterogeneity in the study area, and the deriving \( Nm \) product was 27.52. Accordingly, \( Nm \) values for single pairwise comparisons between samples appear rather high (all of the six values > 14), suggesting that several migrants are exchanged per generation between these four population units. In Table 3 estimates of genetic variability at 19 gene loci in all study samples are also reported. On the whole, expected heterozygosity (He) ranged from 0.111 to 0.174.

Table 3 – Allele frequencies, observed (Ho) and expected (He) heterozygosities for the 4 population samples from Poscola area; n refers to the number of assayed individuals.

<table>
<thead>
<tr>
<th>Locus</th>
<th>PSC</th>
<th>PSCI</th>
<th>PSC3</th>
<th>PSC4</th>
<th>Locus</th>
<th>PSC</th>
<th>PSCI</th>
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<td>Acp</td>
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<td>33</td>
<td>28</td>
<td>Lap-1</td>
<td>n. 14</td>
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<td>34</td>
<td>27</td>
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<td></td>
<td>A 0.969</td>
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<td>1.000</td>
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<td>0.452</td>
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<td>0.296</td>
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<tr>
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<tr>
<td></td>
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Ho 0.181 0.098 0.126 0.124 He 0.174 0.111 0.138 0.139
DISCUSSION AND CONCLUSIONS

The present genetic and morphological investigations carried out on Dolichopoda from the Poscola area allowed us to assign them to D. laetitiae, a species whose northern limit is represented by Po river (Baccetti, 1982). The occurrence of this species to the north of Po river was never reported in the literature. In addition, the absence of Dolichopoda from Poscola cave was witnessed by earlier investigations (Bartolomei, 1957). As a consequence, a quite recent colonization of the Poscola cave seems highly realistic. Concerning the mechanism of colonization, the most plausible hypothesis should imply an anthropocore dispersion. Unintentional transplantation of eggs, nymphs or even adults is a likely event in Dolichopoda. This mechanism has been hypothized to explain the occurrence of Dolichopoda schiavazzii in cellars and other artificial caves in the Argentario Promontory, where D. baccettii diverged and speciated in insular allopatric condition. Since the present spread of D. schiavazzii in this area is limited to the neighbouring of the Passionisti Abbey in the inner part of the Promontory, the occurrence of this species in this area has been explained with anthropocore dispersion (Allegrucci et al., 1982). Alternative hypotheses implying active colonization by Dolichopoda appear unlikely, because of lack of records within a wide area north and south of Po river, which apparently represents a geographic barrier for these crickets. Previous studies on geographic variation of molecular and morphological traits proved that both geographic distribution and speciation processes in Dolichopoda have been strongly affected by such river barriers (Sbordoni et al., 1991; Cesaroni et al., 1996).

If only few individuals, or even a single female, founded the Poscola cave population, an expected consequence could be a reduction in genetic variability of the present population. The allozyme survey showed that heterozygosity in PSC (He= 0.174) is comparable to the levels of genetic variability reported for other Dolichopoda populations (Sbordoni et al., 1985, 1991). However, these findings do not necessarily conflict with the hypothesis of a small propagule founding the Poscola population. In fact, several other factors can counterbalance the loss of genetic diversity due to founder effect. Particularly, Nei et al. (1975) developed a general model concerning the effects of bottlenecks on the heterozygosity in respect to the intrinsic rate of growth (r) of the populations. According to this model, for any given mutation rate, a r value ≤ 0.1 should correspond to a high decrease of genetic variability in the population. On the contrary for r values ≈ 1 the average heterozygosity appears weakly affected by
bottleneck. Being estimated r value ranging between 0.7 and 1 in *Dolichopoda* spp. including *D. laetitiae* (Di Russo, 1993), it is reasonable to argue that founder effect, whichever number of founders was, did not played a significant role in changing the level of genetic variability of the Poscola cave population.

Mark-recapture experiments proved that present *Dolichopoda* population is abundant and wealthy, confirming the successful achievement of the cave colonization. Population size reached a maximum value of 2000 individuals. This estimated size is probably close to the carrying capacity of the cave. However, relevant variations in population size, observed in various periods of the year, were probably due to either migration outside the cave or winter grouping. In fact crickets were commonly found in suitable habitats (either small caves or wood floor) surrounding the main cave. These migrations, chiefly occurring to search food outside the cave, can represent the main reason for *Dolichopoda* dispersal across other small caves in the area. The very low $F_{ST}$ estimate ($\theta = 0.009$) calculated for the four population samples indicates complete lack of genetic structuring of population units which actively exchange individuals and genes. The degree of genetic structuring between samples from Poscola area is comparable to that found between subpopulations of *D. laetitiae* within a single cave (Cappellani, unpublished data) or in adjacent artificial hypogea (Sansotta, 1993). Since we expect that $F_{ST}$ is positively related to the age of the populations and to the occurrence of extrinsic barriers to migration, the value obtained for the Poscola populations also supports a recent colonization and present active dispersion of crickets in this area.

Short distance active dispersion of *Dolichopoda* in other areas of foothills of the Alps appears to be favoured by the prevailing mesophilic bioclimatic conditions. This is clearly showed by recent records of new population units of *D. ligustica septentrionalis* near Bergamo whose settlement may have not occurred before 1980 (Comotti, 1982; pers. com.).

Population age structure showed a typical seasonal trend as often found in *Dolichopoda* populations inhabiting artificial caves with trophic resources largely represented by vegetable matters seasonally available outside caves. This kind of age structure might be unexpected in a natural limestone cave as Poscola, relatively rich in bat guano deposits. In similar situations a costantly heterogeneous age structure is generally found as an adaptation to exploit resources inside cave and to reduce intraspecific competition (Di Russo et al., 1987; Carchini et al., 1991; De Pasquale et al., 1995). However, preliminary data on feeding habits of these crickets indicated a diet mainly based on vegetable matters (L. De Pasquale,
Even the spatial distribution of crickets inside the cave supports dependence upon external resources. In fact, in spring and summer, most of crickets were located near the secondary entrance surrounded by mesophilic wood, a suitable environment to move and search food. These findings suggest that the seasonal age structure revealed in this population might be the consequence of both recent colonization of the Poscola area and bioclimatic conditions that favour exploitation of trophic resources outside the cave.

Since *Dolichopoda* cave crickets show a typical semivoltine life cycle (Boudou Saltet, 1971; Di Russo et al., 1987), it could be expected that a single colonization event might determine lack of mobile individuals during 6-9 months, corresponding to the embryonic development, and emergence of adults every two years. On the contrary, observed phenology clearly showed the occurrence of two choorts formed by individuals of different age overlapping each other in autumn and the emergence of adults every summer. This finding suggests that choort overlap can arise in a few generations, as a possible consequence of variability in the duration of embryonic diapause, nymphal dormancy and asynchrony in laying eggs. Di Russo (1993) described a similar situation in two experimentally transplanted populations of *Dolichopoda linderi* in France, which, starting from a little number of founders, showed choort overlap arised in less than 10 generations.

**ACKNOWLEDGEMENTS**

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A RECENT COLONIZATION OF DOLICHOPODA CAVE CRICKETS


A new genus and species of troglobitic Trechinae (Coleoptera, Carabidae) from southern China

Augusto Vigna Taglianti *

SUMMARY

Guizhaphaenops zorzini n.gen.n.sp. is described from Anjia Yan Cave, Shuicheng County, Guizhou (China). This highly specialized troglobite species is easily recognizable from the other cave dwelling Trechini from China for the main morphological external characters, but its true relationships remain uncertain, the male being still unknown. Similar in habitus to Cathaiaphaenops and to Sinotroglodytes, the new taxon is much more related to the latter, being dorsally glabrous and having the mentum fused with the submentum, with a deep oval fovea, but it differs in its elongated head, with incomplete frontal furrows and without posterior frontal setae.

Only few years ago an extraordinary new genus and species, Sinaphaenops mirabilissimus Ueno & Wang, 1991, was discovered in Guizhou (Libo County), in Southeast China; it was the first record of an anophthalmic trechine beetle from mainland China (Ueno & Wang, 1991). None of the eyeless trechine species, quite abundant in the temperate zones, especially in Northern Hemisphere and also in Eastern Asia, with many genera and species described from Taiwan, Korea and especially Japan (see also Vigna Taglianti & Casale, 1996), was previously known from China. Another new genus and species, Dongodytes fowleri Deuve, 1993, was described two years later from Guangxi, collected by an expedition organized by Chinese and British speleologists.

Recently, in a paper by Deuve (1996), three other anophthalmic cave-dwelling trechines were described from Northwest Hunan, collected in the karst of Longshan in August 1995, by French and Chinese speleologists of the expedition “Xiangxi 95”; they were ascribed to two new genera (Cathaiaphaenops and Sinotroglodytes) and to one new subgenus (Cimmeritodes) of the Japanese genus Gotoblemus Ueno, 1970.

One year before, in August 1994, also “China Caves ’94”, the third speleological Italian expedition to China (Zorzin & Melotti, 1995; see also Vigna Taglianti, 1995, for the “Sichuan ’93 Project”), visited some karstic areas in Guangxi and Guizhou provinces. This expedition was organized by dr Roberto

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Zorzin, geologist at the Museo Civico di Storia Naturale di Verona, Department of Geology and Paleontology (for the scientific aspects), and dr Silvano Melotti, of the Centro Ricerche Naturalistiche Monti Lessini, Verona (for the speleological aspects), and carried out in cooperation with the Guizhou Normal University. Among the few zoological samples collected in Chinese caves, and given to prof. Sandro Ruffo, former Director of the Museo Civico di Storia Naturale di Verona, for sorting and studying, there was also one carabid beetle, that was subsequently kindly and friendly forwarded to me. This specimen belongs to a new genus and species of highly specialized eyeless Trechinae, whose description is the object of the present note.

**Guizhaphaenops** n.gen.

*Diagnosis*

An highly specialized, but not aphaenopsoid, trechine genus, with very elongated antennae and legs, round pronotum and large ovate elytra, with serrulate shoulders. Similar to the genus *Sinotrogloodytes* Deuve, 1996, in the general shape of the body and appendages, and in having the mentum fused with submentum, with a deep oval fovea, the new taxon clearly differs in elongated head, with incomplete frontal furrows, and without posterior frontal setae, in the right mandible strongly bidentate, in the labial tooth clearly bifid, in the outer prebasilar setae longer and stronger, in the presence of the posterior lateral setae on pronotum, in the clearly keeled protibiae and in the pubescent ventral surface.

Known only on a female specimen, the true relationships of the new genus are still uncertain, the male remaining unknown.

*Type species*

*Guizhaphaenops zorzini* Vigna Taglianti, n.sp.

*Description*

A trechine genus, showing a high morphological adaptive modification to the cave environment. Medium sized, with very elongated antennae and legs, round pronotum and large ovate elytra (Fig. 1); surface completely glabrous on dorsum, except the thin pubescent genae, but well pubescent on abdominal sternites. Inner wings totally reduced. Colour reddish brown, relucnt and shiny.

Head elongated, longer than prothorax, narrow, with a clear neck constriction; frontal furrows incomplete, divergent and obsolete posteriorly; eyes completely vanished; genae parallel, with very short, thin and sparse hairs; only one
A NEW GENUS AND SPECIES OF TROGLOBITIC TRECHINAE

pair of frontal setae (the anterior ones), behind the level of ocular oblique suture; two pairs of short setae above the antennal base; clypeus with right margin,
and with four setae, the outers being much longer and stronger; labrum gently
emarginate at the apex, with six setae, the outers much longer, the inner ones
very short and thin. Mandibles slender, feebly arcuate, acute at apices; the right
mandible strongly bidentate (Fig. 2), the left one with straight cutting edge. La-
bium (Fig. 3) completely fused, without trace of labial suture; mentum with a
porrect tooth in apical emargination, half as long as lateral lobes, bifide at the
tip; in the middle, the mentum shows a depressed round-oval fovea, deep, be-
hind the apical setae (two, lined with the deeper emarginations) and before the
semicircular series of nine prebasilar setae. Of these setae, the inner (five, at the
apex of submentum) and the apical ones (two, at the basal sides of mentum) are
similar in length and size, the outer (at the side angles of submentum) are much
more longer and stronger. Ligula triangularly produced, octosetose (the apical
two setae are longer and stronger); paraglossae moderately arcuate, extending
much beyond the ligula; labial palpus long and slender, penultimate segment
slightly curved and dilated at the apex, with two setae at the apex and one, lon-
ger, at half the length, on the anterior side; apical segment about four-fifths as
long as the penultimate. Maxillae slender, with lacinia gently curved and provi-
ded with recurved spines and hairs on the inner margin; maxillary palpus (Fig.
3) long and slender, glabrous, with only three short setae at the apex of penulti-
mate segment; penultimate segment long, subcylindrical in the basal half and si-
nuately dilated towards the apex; apical segment about eight-ninths as long as
the penultimate. Antennae long and slender, reaching the four-fifths of the
eytral length; scape is the thickest of all segments, and the less setose, while the
penultimate is the shortest and segment 3 the longest.

Prothorax short; pronotum round-ovate, as long as head (without labrum)
and slightly wider than long, with the maximum width at the half of the lengh;
sides gently arcuate, more gradually narrowing towards the base than towards
the apex; front angles obtusely rounded, hind angles completely rounded, con-
tinuous with the base; lateral fine borders continuing onto apex and base, gently
and gradually enlarged behind the basal third; basal foveae indistinct, superfi-
cial, extending anteriorly with the side borders. Marginal setae present, the apic-
als one being the longest; the apical ones situated before the first-fifth of the
length, the basal ones at the posterior tenth, before the hind angle. Scutellum di-
stinct.

Elytra ovate, much wider than prothorax, with maximum width at basal
third, gently narrowing towards the apex; slightly convex, with flattened basal
and humeral area; oblique prehumeral borders, distinct shoulders, narrowly
rounded apices; side borders complete from basal peduncle to apex, serrulate at
shoulders, with short setae at the apex of each denticulation (10-12, in the basal
fourth); striae shallow, vanishing at the sides, at the base and at the apex; the in-
nner four striae more complete and deeper; basal pore present; two setiferous
dorsal pores present on stria 3, the anterior one before the fore sixth, the poste-
rior one clearly before the middle; preapical pore absent; two apical pores pre-
sent, slightly internal to the recurrent stria; marginal series of umbilicate pores
not aggregate, as in Fig. 1: the first pore a little distant from marginal gutter, the
second (at the level of the fore discal pore) adjoining the marginal gutter, the
third a little distant from gutter, like the first one; all three anterior pores very
close to each other, equidistant; the fourth widely distant (three time the distan-
ce between the previous), displaced from the gutter; fifth and sixth also very
close to each other, the sixth adjoining the gutter; seventh and eighth at a similar
distance to each other, at the apical sixth of elytron, the eighth adjoining margi-
nal gutter.

Ventral surface with sternites 4-7 bearing a relatively thick and long pube-
scence; 4-6 with one pair of median setae along the posterior margin; in female,
stermite 7 with two pair of similar setae, the outer being a little longer than inner
ones.

Legs very long and slender; fore legs with clearly sulcate tibiae, with thick
apical pubescence on inner side; tibiae of median and hind legs thin sulcate on
the entire inner side, with pubescence on inner face, thicker towards the apices;
tarsi slender, pubescent on dorsal side.

Female genital appendages (Figs 4-5) without peculiar features; penulti-
mate segment of gonostyli with two subapical spines on dorsal surface; apical
segment elongate, gently curved, with two dorsal (inner and outer) spines and
ventral sensorial fovea, with two thin hairs.

Derivatio nominis

The generic name is composed by “Guizhou” (the Province toponym) and
“aphaenops”, to recall the name of the classic, specialized, speciose and wide-
spread genus of cave-dwelling Trechini, Aphaenops, meaning “without visible
eyes”.

Guizhaphaenops zorzini n.sp.

Diagnosis

A medium sized trechine, included in Guizhaphaenops n. gen., with elon-
gated head, neck constriction clearly visible, shortened frontal furrows, frontal
posterior seta lacking, right mandible strongly bidentate, labial tooth clearly bi-
fid, outer prebasilar setae longer and stronger, hind lateral setae of pronotum
present, clearly keeled protibiae and pubescent ventral surface.
Figs 2-5 - *Guizhaphaenops zorzini* n.gen. n.sp., holotype: right mandible (2), labium and maxillary palpi (3), genital appendages (4) and left gonostylus, at major magnification (5).

**Type material**

Description

Complete description as for the genus.
Total length 6.12 mm from apical margin of clypeus to apices of elytra.
Head a little longer than wide: length (from apical margin of clypeus to apical margin of pronotum) 1.25 mm, greatest width (behind level of the frontal setae) 0.9 mm. Antennae 5.1 mm long. Microsculpture reticulate, in fine polygonal meshes.
Pronotum round-oval; length (along the mid-line) 1.18 mm, greatest width (at mid length) 1.18 mm. Microsculpture reticulate, with fine meshes transversely stretched.
Elytra ovate, narrowing towards apices; greatest length 3.67 mm, greatest width (behind level of the 4 marginal umbilicate pore) 2.24 mm. Microsculture clearly transverse.
Legs slender, elongated; length of hind tibia 2.55 mm.

Derivatio nominis

It is a pleasure to dedicate this new species, the sixth specialized cave dwelling trechine so far known from China, to its collector, dr Roberto Zorzin, a good friend of the author and organizer of the “China Caves '94” Italian speleological expedition.

Ecological notes

The type locality, Anjia Yan cave, whose name is from a nearby little village in the Shuicheng County (Guizhou, China), lies in the locality Show Ga, about 50 km northwestwards from Shuicheng, 2160 m above sea level.

This cave, open inside limestone aged between Devonian and Triassic, of fossil type, with only few pools with dropping water, is about 300 m long, with 65 m of difference in height from entrance to the end. The cave is shortly described by Zorzin & Melotti (1995), and the map and section were made by the “China Caves '94” expedition (not yet published). The cave has a wide entrance, lengthened horizontally, with an enormous rock slab above large masses of slides. The vault develops sub-horizontally and has a rather regular configuration, while the floor is covered by slide masses. Many concretions are present, occasionally very large. A narrow meander (7-8 m deep on average, at some points 20 m deep) runs along the entire length, with pools of dropping water on the bed.

The cave, from the ecological point of view, is of the temperate type: the temperature of the air into the cave was 10.8°C (outdoor 18.6°C), of the water 10.6°C.
First record of Parastenocarididae (Crustacea, Copepoda, Harpacticoida) from subterranean freshwater of insular Greece and description of two new species.

Vezio Cottarelli and Maria Cristina Bruno *

SUMMARY

The genus Parastenocaris, new for Greece, has been discovered in the hyporheic habitat of Kos and Kythira Island with two new species, that are described and discussed in this work. Parastenocaris aesculapii n. sp. shares some characters with P. nollii from Germany and P. italica from Italy, Macedonia and Turkey. Parastenocaris aphroditis n. sp belongs, according to the Authors, to a group of species living exclusively in estuarine interstitial habitats, which are all characterised by peculiar morphology and ecology, that are as well considered and interpreted.

INTRODUCTION

The large genus Parastenocaris Kessler, 1913, is almost exclusive of subterranean waters from all over the world; according to Dussart & Defaye (1990), it is widely distributed in Southern Europe except, strange enough, in Greece. For this area there is only one dubious report on the presence of Parastenocaris (see above), even if subterranean habitats have been recently investigated (Bruno & Cottarelli, in press; Forniz et al., 1990; Pesce, 1981, 1985; Pesce & Maggi, 1983). This gap has now been filled with the record of two new species from the Greek Islands of Kos and Kythira, that are described and discussed here. Some remarks on relationship, biogeography and ecology of these Parastenocaris, will also be considered.

MATERIAL AND METHODS

Samples were collected using the Karaman-Chappuis method, fixed in 5% buffered Formalin. Specimens were mounted in permanent slides with Faure’s medium and drawn at 1250X, with an oil immersion lens, using a * Dipartimento di Scienze Ambientali, Università della Tuscia. Via San Camillo de Lellis 10100 Viterbo, Italy.
VEZIO COTTARELLI and MARIA CRISTINA BRUNO

drawing tube mounted on a Zeiss Axioskop phase contrast microscope. The following abbreviations are used, when required, throughout the text and figures: A1= antennula; A2= antenna; Bsp= basipodite; Enp= endopodite; Exp= exopodite; Fu= furcal rami; Ga= genital field; Gsg= genital somite; Md= mandible; Mx= maxilla; Mxl= maxillule; Mxp= maxilliped; Op= anal operculum; P1-P5= thoracic appendages; R= rostrum.


For both species, the material of the typical series is temporarily deposited at the “Dipartimento di Scienze Ambientali, Università della Tuscia”, Viterbo (senior author’s collection) except for the holotype and one female paratype, deposited in the collection of the “Museo Civico di Storia Naturale A. Doria”, Genoa (Italy).

Fam. PARASTENOCARIDIDAE Chappuis, 1933
Gen. Parastenocaris Kessler, 1913
Parastenocaris aesculapii n. sp.

Type material

Holotype: 1 male, V. Cottarelli leg., 5-04-1992, hyporheic water of a small stream near the Asklepeion, in Kos, Dodecanese Islands, dissected and mounted on a slide labelled: Kos - Parastenocaris aesculapii ht. Paratypes: 1 male and 5 females from the same station, V. Cottarelli leg., 23-03-1989; 24-02-1990, 5-04-1992, also mounted on slides numbered from 1 to 6, labelled: Kos - Parastenocaris aesculapii pt.

Description of the holotype

Body cylindrical and elongate, unpigmented, eyeless; length, from the rostrum to the distal apex of the furcal rami: 0.387 mm.

Anal operculum (Fig. 2): rounded, with a row of spinules near the distal margin.

Furcal rami (Fig. 2): rounded, with a row of spinules near the distal margin.

Rostrum and antennule (Fig. 3): rostrum as in figure. Antennule: first segment bare, second segment with five distal setae, one is plumose; third segment with four setae. Fourth segment enlarged, has a seta and a tipped
apophysis on the proximal margin, a distal tubercle with two setae and an aesthetasc that reaches in length the end of the last segment. Fifth segment partially merged with the previous one, without armature, as the sixth segment, which is lengthened in a strong curved tip. Seventh segment with eight setae and an aesthetasc.

Antenna (Fig. 4): one-segmented exopodite with a slender apical seta; allobasipodite with a row of cuticular spinules at about half of the inner lateral margin. Endopodite bearing distally three geniculated setae, three one-side barbed setae. Remaining ornamentation as in figure.

Mandible (Fig. 7): one-segmented palp, with two distal setae.

Maxillule (Fig. 8): arthrite of the praecoxopodite with three distal curved spines and some spinules; a curved seta is inserted at about half length of the arthrite. Coxopodite with a distal seta, basipodite with two apical setae.

Maxilla (Fig. 9): syncoxopodite with two endites, one bears a normal and a leaf-like setae. The other one with a barbed seta. Basipodite prolonged into an apical curved and spinulose tip with a lateral normal seta. Endopodite reduced to a small tubercle with two setae.

Maxilliped (Fig. 10): slim and elongate; basipodite unarmed, first segment with some small distal spinules; second segment unarmed, with a long, curved and pennate apical spine.

P1 (Fig. 11): exopodite three-segmented, almost as long as the endopodite. Third segment with two geniculate apical setae, an apical and a sub-apical spines. Endopodite two-segmented; second segment with a long and geniculate and a barbed setae on the apex.

P2 (Fig. 12): exopodite three-segmented, armature shown in figure. Endopodite shorter than 1/3 of the first segment of the corresponding exopodite, represented by a little cylindrical segment, with some apical spineles and one seta.

P3 (Fig. 16): squat, basipodite with a row of spinules and a long seta; a row of very small spinules near the lateral inner margin. Endopodite is missing. First segment of the exopodite ending in a strong and long apophysis with a group of four cuticular spinules inserted on the outer margin. Second segment represented by a leaf-like appendix, almost as long as the apophysis, with undulating margins.

P4 (Fig. 15): Exopodite three-segmented, chaetotaxy as shown in figure. Endopodite as long as half of the first segment of the corresponding exopodite, outer margin with a row of spinules decreasing in length proximally to distally. On the basipodite, near the insertion of the endopodite, a short barbed seta.
P5 (Fig. 13): represented by a sharpened plate of approximately triangular shape, prolonged in a strong tip. About half way along the distal margin are one long and two short setae.

Description of the paratype (female)

Length: 0.396 mm. Rostrum, antenna, oral appendages, maxilliped, P1, P2 and P4 exopodite, anal operculum, as in the male. Genital somite provi-
ded ventrally with an undulated row of spinules, below the genital field (Fig. 1).

Furcal rami (Fig. 5): with the same armature as in the male, but shorter. Length/width ratio: 2.6.

Figs. 7-19 – Parastenocaris aesculapii n. sp. 7,8,9,10,11,12,13,15,16: holotype male. 14,17,18,19: paratype female. 7, Md; 8, Mxl; 9, Mx; 10, Mxp; 11, P1; 12, P2; 13, P5; 14, Enp P4; 15, P4; 16, P3; 17, P5; 18, Enp P2; 19, P3.
Antennule (Fig. 6): seven-segmented, second segment with a plumose composite seta and four distal setae; third segment with five distal setae. Fourth segment with a distal tubercle bearing two long setae and an aesthetasc. Seventh segment with an aesthetasc on the apex and seven marginal setae.

P2 endopodite (Fig. 18): similar to the male’s one but longer, with the same ornamentation.

P3 (Fig. 19): endopodite represented by a sharp barbed spine, longer than 2/3 of the corresponding two-segmented exopodite, which is armed as in figure.

P4 endopodite (Fig. 14): a little shorter than the first segment of the corresponding exopodite, with sharp apex and some apical spinules.

P5 (Fig. 17): similar to the male’s one, but with longer setae.

Derivatio nominis

The species name has been chosen since the species has been collected near the Askleipeion, the famous temple dedicated to Aesculapius, the Greek God of Medicine.

Variability

The features described above appear to be constant in all the specimens of the typical series, except for some small variations in the total length values.

Relationships

Parastenocaris aesculapii n. sp. is well characterised by the morphology and ornamentation of P3 and P4 endopodite in males and of furcal rami in both sexes, but its arrangement of features makes difficult to identify the affinities. The simple structure of P4 endopodite in males, accompanied by a single seta near its insertion, is not so frequently occurring at least between the European Parastenocaris. The same features are shared, for example, by P. budapestiensis Török, 1935, from Budapest and by P. nolli Kiefer, 1938 from Germany. The male’s P3 of P. aesculapii also resembles to the same appendix of P. nolli and P. italica Chappuis, 1953, a species distributed not only in Italy, but also in Macedonian and Turkey. Moreover, another species, still in study, from Turkey shows some morphological affinities with P. aesculapii.
Parastenocaris aphroditis n. sp.

Type material

Holotype: 1 male, M.C. Bruno and V. Cottarelli legg., 3-04-1996, hyporheic water of a small stream mouth in Kastraki beach, near Paleopolis, in Kythira Island, dissected and mounted on a slide labelled: Kythira - Parastenocaris aphroditis ht. Paratypes: 21 males and 32 females from the same station, also mounted on slides numbered from 1 to 53, labelled: Kythira - Parastenocaris aphroditis pt.

Description of the holotype

Body cylindrical and elongate, unpigmented, eyeless; length, from the rostrum to the distal apex of the furcal rami: 0.354 mm.

Anal operculum (Fig. 25): with smooth, rounded margin.

Furcal rami (Fig. 20): subcylindrical, shorter than the last abdominal segment; length/width ratio: 2.2. Armature consisting of a subapical composite dorsal seta, a long main apical seta flanked by two shorter ones of different length, two short subapical outer setae.

Rostrum and antennule (Fig. 21): rostrum as in figure. Antennule: first segment bare, second segment with four normal and a plumose seta; third segment with five apical setae. Fourth segment enlarged, brings distally one seta near the origin of a tubercle bearing a seta and an aesthetasc that reaches in length the end of the last segment. Fifth segment partially merged with the previous one, with no armature, as the sixth segment which is lengthened in a strong curved tip. Seventh segment with seven setae and an aesthetasc.

Antenna (Fig. 30): one-segmented exopodite with a slender apical seta; allobasipodite unarmed. Endopodite bearing distally two geniculate and three barbed setae. Remaining ornamentation as in figure.

Mandible (Fig. 26): one-segmented palp, with two distal setae.

Maxillule (Fig. 27): arthrite of the praecoxopodite with four distal curved spines; a long and curved seta is inserted at about half length of the arthrite. Coxopodite with a long distal seta, basipodite with two apical setae.

Maxilla (Fig. 28): syncoxopodite with two endites, one bears a normal and a geniculate setae, the other endite bears one normal seta. Basipodite prolonged into an apical curved and distally spinulose tip, with a lateral seta. Endopodite represented by a small tubercle with two setae.
Maxilliped (Fig. 29): slim and elongate; basipodite and first segment unarmed, second segment with an apical long, curved and one-side barbed spine.

P1 (Fig. 31): basipodite with a hook near the endopodite insertion. Exopodite three-segmented, almost as long as the endopodite. Third segment with two geniculate, an apical and a subapical spines. Endopodite
two-segmented, second segment with a long and geniculate and a barbed setae on the apex.

P2 (Fig. 32): exopodite three-segmented, armature shown in figure. Endopodite almost as long as half of the first segment of the corresponding exopodite, represented by a cylindrical segment with some apical spinules and one seta.

P3 (Fig. 23): quite squat, basipodite with a row of spinules and a long seta; endopodite represented by a seta. First segment of the exopodite with a proximal spine near the lateral outer margin and a group of four spines on the same margin, ending in a leaf-like apophysis with undulating margin and a spine on the apex. Second segment longer than the end of the apophysis, represented by a thin, elongate appendix.

P4 (Fig. 34): exopodite three-segmented, chaetotaxy as shown in figure. Endopodite as long as the second segment of the corresponding exopodite, with the first third smooth and a roundish lateral apophysis. The remaining terminal part of the endopodite is leaf-like, sharpening to the top, with small lateral tubercles and spinules. Near the insertion of the endopodite are inserted a thick spine with curved tip, almost as long as 1/3 of the endopodite itself and a shorter and thinner spine.

P5 (Fig. 33): represented by a plate of approximately rectangular shape, prolonged in a distal inner tip. Four setae of different length along the distal margin.

_description of the paratype (female)_

Length: 0.363 mm. Furcal rami, rostrum, antenna, oral appendages, maxilliped, P1, exopodite P2 and P4, anal operculum, as in the male.

Furcal rami (Fig. 24).

Antennule (Fig. 22): seven-segmented, second segment with three normal and a plumose setae; third segment with five distal setae. Fourth segment with a distal tubercle bearing two setae and a long aesthetasc. Sixth segment with a distal short seta; seventh segment with an aesthetasc on the apex and eighth terminal setae.

P2 endopodite (Fig. 37): similar to the male’s one, with the same ornamentation.

P3 (Fig. 35): endopodite transformed in a strong spine with curved tip, a little longer than the first segment of the corresponding two-segmented exopodite, which is armed as in figure.

P4 endopodite (Fig. 38): a little longer than the first segment of the corresponding exopodite, ending in a tip, with some small distal spinules.
P5 (Fig. 36): with the same ornamentation as in the male, but slimmer and longer.

**Derivatio nominis**

The species name has been chosen since Kythira is the island were the cult of Aphrodite, in the ancient time, has started.

**Variability**

The features described above appear to be constant in all the specimens of the typical series, except for some small variations of the total length values in the paratypes.

**Relationships**

*Parastenocaris aphroditis* n. sp. belongs to the *minuta* group Lang 1948, and shows the closest affinities with some of the species of this group: *P. andalusica* Enckell, 1965, *P. hera* Cottarelli, 1969, *P. stellae* Cottarelli, Saporito & Puccetti, 1981, *P. rivi* Cottarelli & Bruno, 1994, *P. oligoalina* Cottarelli, Bruno & Venanzetti, 1995, *P. etrusca* Cottarelli, Bruno & Venanzetti, 1995. All of these species, as well as *P. aphroditis* n. sp., have been collected in the estuarine hyporheos of streams and rivers and in the Mediterranean area; all of them share a similar ecology and a peculiar habitus, expressed mainly in male's P3, in furcal rami, in endopodite P2 and P5 in both sexes. However, the new species is easily distinguishable by the ornamentation of the first segment of male's P3, by the presence of both the long and hooked and the short and straight spines near the insertion of endopodite P4 in males, by the remarkable length of this endopodite, by the shape and size of endopodite P4 in females. In particular, the morphology of endopodite P4 in males of *P. aphroditis* n. sp., *P. andalusica* and *P. etrusca* is similar (Cottarelli et al., 1995b; Rouch, 1990). As regards male's P3, only in *P. stellae* the spines on the first segment of the exopodite are arranged in two groups (one group is made of two spines at about 1/3 of the length, the other one of a distal row of five spines); in all the *Parastenocaris* mentioned before there is only a distal raw composed by a variable number of spines.

The morphology and ornamentation of P5 is quite constant in all the *Parastenocaris* so far discussed: in *P. hera*, *P. stellae*, *P. oligoalina*, *P. etrusca* it is an approximately rectangular plate, prolonged distally in an inner tip with four marginal setae of different length, in *P. rivi* the inner tip is
Figs. 26-38 – *Parastenocaris aphroditis* n. sp. 26, 27, 28, 29, 30, 31, 32, 33, 34: holotype male. 35, 36, 37, 38: paratype female. 26, Md; 27, Mxl; 28, Mx; 29, Mxp; 30, A2; 31, P1; 32, P2; 33, P5; 34, P4; 35, P3; 36, P5; 37, Enp P2; 38, P4.

substituted by a spine. *P. andalusica* differs because P5 has a triangular shape and bears only three setae.

In previous works Cottarelli & Bruno (1994), Cottarelli et al. (1995b) had already noticed that it can be useful, in order to distinguish species with a very close morphology, as in this case, to use features such as maxillules and maxillae, that are not usually considered in the taxonomy of this genus. Accordingly, we summarise in the following list the data regarding all the *Parastenocaris* of Mediterranean rivermouths.
<table>
<thead>
<tr>
<th>Species</th>
<th>Maxillules</th>
<th>Maxillae</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. andalusica</em></td>
<td>Not described</td>
<td>Not described</td>
</tr>
<tr>
<td><em>P. aphroditis</em></td>
<td>Arthrite: 4 distal spines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 lateral seta</td>
<td>Endopodite: 2 setae</td>
</tr>
<tr>
<td></td>
<td>Coxa: 1 seta</td>
<td>Endite 1: 2 setae</td>
</tr>
<tr>
<td></td>
<td>Basipodite: 2 setae</td>
<td></td>
</tr>
<tr>
<td><em>P. etrusca</em></td>
<td>Arthrite: 3 distal spines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 lateral seta</td>
<td>Endopodite: 2 setae</td>
</tr>
<tr>
<td></td>
<td>Coxa: 1 seta</td>
<td>Endite 1: 2 setae</td>
</tr>
<tr>
<td></td>
<td>Basipodite: 2 setae</td>
<td></td>
</tr>
<tr>
<td><em>P. hera</em></td>
<td>Arthrite: 2 distal spines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 lateral seta</td>
<td>Endopodite: 1 seta</td>
</tr>
<tr>
<td></td>
<td>Coxa: 1 seta</td>
<td>Endite 1: 2 setae</td>
</tr>
<tr>
<td></td>
<td>Basipodite: 2 setae</td>
<td></td>
</tr>
<tr>
<td><em>P. oligoalina</em></td>
<td>Arthrite: 3 distal spines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 lateral seta</td>
<td>Endopodite: 2 setae</td>
</tr>
<tr>
<td></td>
<td>Coxa: 1 seta</td>
<td>Endite 2: missing</td>
</tr>
<tr>
<td></td>
<td>Basipodite: 3 setae</td>
<td></td>
</tr>
<tr>
<td><em>P. rivi</em></td>
<td>Arthrite: 3 distal spines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coxa: 1 seta</td>
<td>Endopodite: 2 setae</td>
</tr>
<tr>
<td></td>
<td>Basipodite: 2 setae</td>
<td></td>
</tr>
<tr>
<td><em>P. stellae</em></td>
<td>Not described</td>
<td>Endopodite: 1 seta</td>
</tr>
<tr>
<td></td>
<td>Endite 1: 1 seta</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Endite 2: 2 setae</td>
<td></td>
</tr>
</tbody>
</table>

**DISCUSSION**

The discovery of these Greek *Parastenocaris* fills a gap in the distribution of *Parastenocaris* in the Mediterranean area. In particular the already mentioned relationships between *P. aesculapii* n. sp. and a Turkish congeneric species can be explained by the occurrence of past links between Kos Island and Turkey. Kos is nowadays only five kilometres distant from Bodrum, on the Turkish Coast and the two lands were connected during Tortonian-Messinian, (Sondaar et al., 1986; Dermitzakis, 1990) and even for a long time in Pleistocene, (Audisio & De Biase, 1990).

The discovery of *P. aphroditis* n. sp. allows to better trace the distribution of the species group *minuta*, confirming that the group is widely represented in Southern Europe and in the Mediterranean Islands. It has been
collected not only on large islands such as Sicily (Pesce et al., 1988) and Sardinia (Cottarelli et al., 1995a), but also on little islands such as Kos, Kythira, San Pietro (Sardinia) (Cottarelli & Bruno, 1994); in Montecristo (Tuscan Archipelago) have been collected (Cottarelli & Torrisi, 1976) only female specimens of a species probably belonging to the same group.

As regards continental Greece, there are not data concerning the presence of Parastenocaris: Pesce & Maggi (1983), report of a Parastenocaris sp. from Northern Greece that has never been mentioned in further papers. Anyway, it will be probably possible to demonstrate a wide distribution for this genus in continental Greece too, if some peculiar habitats, such as hyporheos and lacustrine psammon, will be sufficiently investigated.

The researches on the interstitial meiofauna adapted to the estuarine ecotone that we have been carrying out for several years, allow us to identify the group of six Parastenocaris in the minuta species group, (P. andalusica, P. etrusca, P. hera, P. oligoalina, P. rivi, P. stellae) that share peculiar morphological affinities. These species are the only ones tipically living in Perimediterranean Europe in estuarine habitats, where the ecological factors have a wide variability, to which the Parastenocaris discussed here seem to be the only adapted species. In fact P. hera, distributed in Central and Southern Italy, has been found only in sandbanks from the mouth of Sele River to 450 meters upriver, where this species is replaced by other Parastenocaris. P. hera shows the same spatial distribution in Voltorno and Garigliano Rivers; the same pattern has been detected for P. etrusca and P. stellae, collected from Fiora River (Central Italy) and Cedrino River (Sardinia) respectively, that are replaced upriver by other species of Parastenocaris. When the streams are short and small, as those where P. oligoalina (from a small stream in Sardinia), P. rivi (from a small stream in S. Pietro Island, near the Sardinian Western Coast) and P. aphroditis (from a small stream mouth) live, only these species, typical of estuarine habitats, have been collected. In any case, all the species mentioned here have been often found together with harpacticoids of the genus Psammopsyllus Nicholls, 1945 and Ichnusella Cottarelli, 1971. P. andalusica has been collected in Rio Fuengirola, Malaga, Spain, in “sandbank 300 meters from the river mouth. Freshwater interstitial habitat, hardly affected by sea waters” (Enckell, 1965).

Two hypotheses can be proposed about the origin of these related taxa: according to the first one, some ancestors already adapted to life in subterranean freshwater would have from this habitat “re-colonised” the estuaries. In this case, the observed morphological and ecological similarities could reflect strong evolutionary convergence in a discrete number of species, di-
distributed on a wide area. According to the second hypothesis, that seems to us more convincing, it can be assumed a common origin of these Paraste-

necaris from an ancestor adapted to life in the river mouths around the Me-

diterranean Sea, which would have colonized continental hyporheic habitats afterwards. The ancestor should have already had those morphological cha-

racters, probably in a plaeismorphic state, that are still shared by this group of Parastenocaris.

ACKNOWLEDGEMENTS

These researches have been supported by grants from M.U.R.S.T (40%) and C.N.R; some samples have been collected (1989) during researches carried out with the Oceanographic Ship Bannock, belonging to the Italian "Consiglio Nazionale delle Ricerche".

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graphy and Ecology of Greece and adjacent Regions. Iraklion, Crete: 75.


Lithobius nuragicus n. sp., a new Lithobius from a Sardinian cave (Chilopoda Lithobiomorpha)

Marzio Zapparoli *

SUMMARY

A new species of Lithobius from a Sardinian cave (Cagliari, Santadi, loc. Su Benatzu, Grotta “Pirosu”, 631 Sa/Ca, m 270) is described. Lithobius nuragicus n. sp. belongs to the subgenus Lithobius s. str. and is related to Lithobius variegatus Leach, 1814, occurring in the British Isles, Brittany, Channel Isles, Iberian Peninsula, Maghreb, Sicily and Southern Italy. This new species is differentiated from L. variegatus by the number of prosternal teeth (3+3), the number and arrangement of ocelli (1+3; little, depigmented, not contiguous to each other, in the center of a depigmented area, posterosuperior ocellus larger than the other ocelli), the size of the organ of Tömösváry (larger), the number of antennal articles (79-86), the number of dorso-lateral and dorso-median setae and the shape and size of the claw of the female gonopods (4-5; 10-11; short, with a small lateral denticle on the internal side).

INTRODUCTION

The species of troglobitic centipedes known to date are very few and most of them belong to the order Lithobiomorpha (Negrea & Minelli, 1994). One of the most important world areas in terms of number of species is the Mediterranean basin, and Sardinia, W Liguria and NE Alps are the most interesting and more characterized Italian regions (Minelli, 1982). The most specialized centipedes in Italy occur in Sardinia, such as the two endemics Lithobius sbordonii Matic, 1967, a troglobitic species whose affinities are uncertain, and Lithobius doderoi Silvestri, 1907, with a lower degree of cave adaptations than L. sbordonii and apparently close to some cavernicolous Lithobius from the Pyrenees. In Sardinian caves we can also find Lithobius cerii Verhoeff, 1942-43, also found in a cave in Capri Island (Thyrrenian Sea); the affinities of this species are unclear but certainly it is not close to the two species mentioned before.

About twenty centipedes are to date known in Sardinian caves (Puddu & Pirodda, 1974; Minelli, 1985; Grafitti & Zapparoli, 1992). In the present article a description of a new species of cave Lithobius, collected in the

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Sulcis area in the framework of the biospeological campaigns carried out in Sardinia by the Gruppo Speleo-Archeologico “G. Spano”, from Cagliari in 1994, is given. The new species, which shows clear morphological adaptations to cave habitat, is not close to other Sardinian cave *Lithobius* already known, but it seems close to some forms occurring in W-Europe and in the Maghreb.

**Diagnosis**

A large sized *Lithobius* s. str. (20.0 mm long), morphologically close to *Lithobius variegatus* Leach, 1814; antennae of 79-86 articles, 1+3 ocelli on each side, organ of Tömösváry larger than the ocelli, prosternum with 3+3 conical teeth, porodont spiniform; tergites 9, 11 and 13 with broad triangular posterior projections, increasingly larger from T. 9 to T. 13; coxal pores 6-8, VaC absent, 15th legs without accessory apical claw; female gonopods with 2+2 short, cylindro-conical spur and a short claw with a small lateral denticle on the internal side. Male unknown.

The new species differs from *L. variegatus* especially for the lower number of prosternal teeth, and for the shape of the apical claw of the female gonopods; female gonopods also shows a lower number of dorsolateral setae on the first article and a lower number of dorsomedian setae on the second article and on the apical claw.

**Material examined**


**Description**

Female. Body 20.0 mm long, 2.5 mm broad at T. 10, tergites pale chestnut, head dark chestnut, legs slender and long, spines long.

Head feebly wrinkled, broader than long, as broad as T. 1, posterior border straight, median thickening of marginal ridge very distinct; antennae 14.5-15.0 mm long, with 79-86 articles as broad as long, terminal article about two times longer than broad; ocelli (Fig. 1) 1+3 on each side, little, not contiguous each other, in the middle of a depigmented area, posterosuperior ocellus larger than the other ocelli, organ of Tömösváry (Fig. 1) larger than ocelli; prosternum (Fig. 2) with 3+3 conical teeth, porodont spiniform, shoulders asymmetrical, absent on the right side, very feebly on the left side.
A NEW LITHOBIUS FROM A SARDINIAN CAVE

*Lithobius nuragicus* n. sp.

(Figs. 1-4)

Figs. 1-4 – *Lithobius nuragicus* n. sp., Holotypus. Head, lateral (1); prosternum, ventral (2); left female gonopod, ventral (3), dorsal (4).
Tergites feebly wrinkled and long; T.1 trapeziform, larger than T.3, with posterior angles rounded and posterior border feebly concave; lateral borders parallel in TT. 3, 5 and 7, feebly convergent to the posterior end and almost straight in TT. 8 and 10, feebly convergent to the posterior end and feebly arcuated in TT. 12 and 14; posterior angles rounded in TT. 3 and 5, angulated in TT. 7, 8, 10, 12 and 14; posterior border straight in T. 3, feebly concave in T. 5, concave in TT. 8 and 10, feebly emarginate in TT. 7, 12 and 14; intermediate tergites with lateral borders almost arcuate in TT. 2, 4 and 6, parallel in TT. 9, 11 and 13; posterior angles blunt in T. 2, angulated in TT. 4 and 6, with broad, short and increasingly larger triangular projections in TT. 9, 11 and 13, the triangular projections in T. 13 are longer and sharper than in T. 9 and T. 11; posterior border straight in all the intermediate tergites.

Coxal pores 6, 7, 8, 7, the proximal pores are circular and little, the distal pores are oblong. Legs 14th and 15th are 9.5 mm and 13.0 mm long respectively, with femur, tibia and tarso with numerous glandular pores on the internal side, 15th legs without accessory apical claw. VaC absent, see Tab. 1 for spinulation.

Female gonopods (Figs. 3-4) with 2+2 short, cylindro-conical spurs especially those on the external side, claw short, with a little denticle on the internal side; first article with a group of 10-11 dorsomedian setae proximal to the insertions of the spurs; second article with 4-5 dorsolateral setae in a line and one dorsomedian seta; apical claw with 4-5 shorter dorsolateral setae in a line.

<p>| Table 1 – Lithobius nuragicus n. sp. Spinulation of legs. C = coxa, t = trochanter, P = prefemur, F = femur, T = tibia, a = anterior spine, m = median spine, p = posterior spine. |</p>
<table>
<thead>
<tr>
<th>legs</th>
<th>Ventral</th>
<th>Dorsal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>amp</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>amp</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>amp</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>amp</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>amp</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>amp</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>amp</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
<td>amp</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>amp</td>
</tr>
<tr>
<td>10</td>
<td>-</td>
<td>amp</td>
</tr>
<tr>
<td>11</td>
<td>-</td>
<td>amp</td>
</tr>
<tr>
<td>12</td>
<td>-</td>
<td>m</td>
</tr>
<tr>
<td>13</td>
<td>-</td>
<td>m</td>
</tr>
<tr>
<td>14</td>
<td>-</td>
<td>m</td>
</tr>
<tr>
<td>15</td>
<td>-</td>
<td>m</td>
</tr>
</tbody>
</table>
**Derivatio nominis**

After the culture of nuraghi, characteristic of Sardinian prehistory.

**Affinities**

The new species is morphologically close to *Lithobius variegatus* s.l., an epigeic species distinct in two subspecies, *L. v. variegatus* Leach, 1814, known from S Scotland, England, Galles, Ireland, Channel Islands (introduced ?), Brittany, NW Spain and N Portugal, and *L. v. rubriceps* Newport, 1845, recorded in Central and Southern Iberian Peninsula, Morocco, Tunisia, Sicily and Calabria (Eason, 1964; Eason & Minelli, 1976; Eason & Serra, 1986). The British populations of *L. v. variegatus* show preference especially for mesophilous woodlands and seem not to tolerate low winter temperatures (Eason, 1964; Eason e Serra, 1986); the habitat preferences of other populations of *L. variegatus* s.l. are unknown.

*L. variegatus* s.l. and *L. nuragicus* n. sp. share the following morphological characters: the large general size, especially as regards the body length, between 16-24 mm in *L. v. variegatus* and up to 40 mm in *L. v. rubriceps*; the number of prosternal teeth, more than 2+2; the shape of T. I, trapezioidal; the presence of triangular projections in the posterior angles of TT. 9, 11 and 13; the absence of VaC; the absence of accessory apical claw on 15th legs; the general shape of the female gonopods with 2+2 spurs and no tridentate claw; the general arrangement of spinulation.

The new species differs from *L. variegatus* s.l. by the presence of 3+3 prosternal teeth instead of 6+6 or 7+7; by the claw of the female gonopods with a distinct lateral denticle, instead of quite simple without denticulations as in *L. v. rubriceps*, or with small and irregular lateral denticle as in *L. v. variegatus*. *L. nuragicus* n. sp. and *L. variegatus* s.l. also differ from one another in the arrangement of the setae of the female gonopods: in *L. nuragicus* n. sp. dorsolateral setae of the second article and those of the apical claw are arranged on a longitudinal line of 4-5 setae, whereas in *L. variegatus* s.l. dorsolateral setae of the same articles are arranged on a band of 2-3 lines and their number is very higher than in *L. nuragicus* n. sp. (about 20 on the second article); *L. nuragicus* n. sp. also shows about 10-11 dorsomedian setae arranged in a small area of the first article proximal to the insertion of the spurs, instead of more numerous setae arranged on a larger area as in *L. variegatus* s.l.

*L. nuragicus* n. sp. also differs from *L. variegatus* s.l. in characters, such as the lower number and different arrangement of ocelli, 1+3 in the center of a depigmented area insetad of 13-20 in 4-5 irregular rows, and in
the higher number of antennal articles, 79-86 instead of 35-52, obviously as a result of morphological adaptations of the new species to the cave habitat.

For differential characters of *Lithobius variegatus* Leach, 1814 s.l. and *Lithobius nuragicus* n. sp. see Tab. 2.

Table 2 - Differential characters of *Lithobius variegatus* Leach, 1814 s.l. and *Lithobius nuragicus* n. sp.

<table>
<thead>
<tr>
<th></th>
<th><em>L. v. variegatus</em></th>
<th><em>L. v. rubriceps</em></th>
<th><em>L. nuragicus</em> n. sp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>body length (mm)</td>
<td>16-24 (British Isles) 24-30 (Iberian Peninsula)</td>
<td>40-42</td>
<td>20</td>
</tr>
<tr>
<td>body colour</td>
<td>pale brown with variegated markings (in live specimens)</td>
<td>uniform dark brown</td>
<td>uniform pale brown (in preserved holotype)</td>
</tr>
<tr>
<td>n° ocelli</td>
<td>1+13-18</td>
<td>1+15-20</td>
<td>1+3</td>
</tr>
<tr>
<td>n° prostellar teeth</td>
<td>6+6, 7+7</td>
<td>48-52</td>
<td>79-86</td>
</tr>
<tr>
<td>n° antennal articles</td>
<td>35-46</td>
<td>48-52</td>
<td>79-86</td>
</tr>
<tr>
<td>triangular projections on T. 7</td>
<td>small but distinct</td>
<td>very small or absent</td>
<td>absent</td>
</tr>
<tr>
<td>glandular pores on 15th legs</td>
<td>sparse or absent</td>
<td>very numerous</td>
<td>very numerous</td>
</tr>
<tr>
<td>15th legs/body length ratio</td>
<td>ca. ½</td>
<td>ca. 1/3</td>
<td>ca. 1/2</td>
</tr>
<tr>
<td>n° coxal pores</td>
<td>5-7 (British Isles) 7-10 (Iberian Peninsula)</td>
<td>7-10, occasionally 3-5</td>
<td>6-8</td>
</tr>
<tr>
<td>claw of female gonopods</td>
<td>with small or irregular lateral denticles</td>
<td>simple, without lateral denticles</td>
<td>with a lateral denticle</td>
</tr>
<tr>
<td>1st article of female gonopods</td>
<td>ca. 15</td>
<td>ca. 10</td>
<td></td>
</tr>
<tr>
<td>dorsomedian setae on female gonopods</td>
<td>ca. 15</td>
<td>ca. 10</td>
<td></td>
</tr>
<tr>
<td>dorsolateral setae 2nd article of female gonopods</td>
<td>ca. 20 on a band of 2-3 lines</td>
<td>4-5 on a line</td>
<td></td>
</tr>
<tr>
<td>dorsolateral setae claws of female gonopods</td>
<td>ca. 10 on a band of 2-3 lines</td>
<td>4-5 on a line</td>
<td></td>
</tr>
</tbody>
</table>

**Distribution and ecology**

The new species is only known from the type locality, the Grotta “Pirosu”, 631 Sa/Ca, Su Benatzu, Santadi (Sardinia, Cagliari province), in the Sulcis. The cave develops in Cambrian limestones and dolomias, it has a length of about 475 m and a difference of level of -52 m. The cave has three entrances leading to a large main hall, from which some short galleries start; for a map of the cave see Maxia (1972). “Pirosu” cave was used during the nuragic age as a holy place and today, because of important ar-
archaeological findings, is one of the most important Sardinian prehistoric sites (Todde, 1972). Due to this, entrance to the cave is limited.

The holotypus of *L. nuragicus* n. sp. has been collected among organic debris on a stalagmite (Grafitti pers. com.). In the cave a rich fauna is present, including also troglobitic species, with some Sardinian endemics (see Argano & Rampini, 1973; Puddu & Pirodda, 1974; Strasser, 1974; Mahnert, 1976; Gardini, 1980): *Oxychilus* sp. *opressus* (Fisher & Studer, 1878) (Gastropoda Sylommatophora Zonitidae), troglophilic; *Chthonius siculus* Beier, 1961 (Arachnida Pseudoscorpionida Chthoniidae), troglophilic; *Roncus puddui* Mahnert, 1976 (Arachnida Pseudoscorpionida Neobisiidae), troglobitic, Sardinian endemic; *Catalauniscus puddui* Argano, 1973 (Crustacea Isopoda Trichoniscidae), troglobitic, Sardinian endemic; *Blaniulus eulophus* Silvestri, 1903 (Diplopoda Iulida Blaniulidae), troglophilic, Sardinian endemic; *Paranchus albipes* (Fabricius, 1796) (Insecta Coleoptera Carabidae), trogloxene; *Catopomorphus orientalis* Aubé, 1850 (Insecta Coleoptera Cholevidae), troglobitic; *Aglenus brunneus* (Gyllenhal, 1813) (Insecta Coleoptera Othniidae); *Nycteribia vexata* Westwood, 1835 (Insecta Diptera Nycteribiidae), ectoparasite on Chiroptera.

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REFERENCES


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