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First record of troglobitic Fulgoromorpha from Italy (Hemiptera, Auchenorrhyncha, Cixiidae)

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Abstract

A new genus and a new species of a troglobitic Cixiidae from Sicily are described. *Ibleocixius* gen. n. differs from *Cixius* and related taxa in a different arrangement of several characters which are also present in other taxa. Characters at genus level lie in the peculiar morphology of the aedeagus which has only one movable spine, a longitudinal sclerotized ridge on the right side and the characteristic sclerotized areas along the margins and on the left side; in females the transition between the wax plate and the lateral abdomen is very peculiar, forming a rather rounded angle; tergite IX bearing a wax plate partially divided in two portions. The new species, *Ibleocixius dunae* sp. n., has strongly reduced eyes, the forewings are slightly and the hind wings strongly reduced; the body is partially covered by wax granules that pile up waxflakes mainly along the wing margins. Special characters pertain to the structure of the male and female genitalia. The new species up to now is known only from a single limestone cave of the South-eastern Sicily.

Introduction

Among the taxa traditionally classified as "Auchenorrhyncha", namely Fulgoromorpha and Cicadomorpha, only the first group contains endogean (interstitial soil species) or cave-dwelling species. In particular, more than 50 cavernicolous species belonging to the families Hypochthonellidae, Delphacidae, Kinnaridae, Meenoplidae and Cixiidae, are known from different regions of the world. Up to now, no species of Cicadomorpha is known to complete its full life cycle underground (Hoch 2002; Hoch et al. 2006).

Among the taxa belonging to the Fulgoromorpha living underground, there are troglophilic (facultative soil and cave-dwellers), endogean (obligatory soil dwellers), troglobitic (obligatory cavernicoles) species (Hoch et al. 2006). The only endogean species known are two Delphacidae and the one Hypochthonellidae (see the taxonomic distribution of hypogeic species in Hoch et al. 2006 for more details).

Adaptation to underground life happened in several Fulgoromorpha lineages but the most cave-dwelling species belong to the families Cixiidae and Meenoplidae. These taxa are soil-dependent during part of the life cycle because immature stages are root feeders and live underground or close to the soil (Remane & Hoch 1988).

Adaptation to hypogeic life of the immature stages is considered a preadaptation that, when suitable conditions prevail, could lead to a complete life cycle underground; in this case, adults and immature stages share the same habitat and the same food resources.

The adaptation to the special conditions of the subterranean environment (essentially uniform temperature, darkness, in general high humidity) in Auchenorrhyncha (like in other arthropod taxa) is accompanied by morphological alterations, called troglomorphies. The most striking troglomorphies are depigmentation of the cuticle, reduction or complete loss of the compound eyes and the ocelli, reduction of the fore and hind wings. The degree of reduction of these structures may vary (Hoch 1994).

In continental Europe, there is only one (unpublished) record of an apparently cave-dwelling Cixiidae from a single cave in Southern France (Hoch & Asche, personal communication); also this species has not been formally described, as only eyeless nymphs could be found.

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In the Mediterranean-Macaronesian area, the Canary Islands and the Azores are comparatively rich in cavernicolous Fulgoromorpha: three species of Meenoplidae and nine species of Cixiidae from the Canary Islands (Remane & Hoch 1988; Hoch & Asche 1993), and two species of Cixiidae from the Azores (Hoch 1991) are known. Racovitza (1907) mentions the occurrence of a "troglobitic cixiid" from a cave on Mallorca (Baleares), however, the species was never formally described and the specimens could not be retrieved by later workers (Hoch 1994).

During biospeleological explorations carried out in some Sicilian caves, a new troglobitic species of Cixiidae was found and is described here.

Material and methods

Specimens were collected in a limestone cave in South-eastern Sicily, in the Iblei Mountains.

Photos of live specimens were made using a Nikon Coolpix 5600 digital camera. Some specimens were preserved dry and others in 70% ethanol. The male and female genital segments were macerated in 10% KOH for 10 hours at room temperature, washed in distilled water, dissected and transferred to glycerine for drawings. A camera lucida mounted on a Zeiss stereomicroscope was used for drawings. For the scanning electron microscope (SEM) studies, specimens were macerated in 10% KOH at room temperature overnight, washed in distilled water with a drop of tensioactive chemical substance for 36 hours, fixed in 2.5% glutaraldehyde and then post-fixed in 2% osmium tetroxide, dehydrated in increasing series of ethanol and in HMDS (hexamethyldisilazane), mounted on aluminium stubs with colloidal silver paste, coated with gold-palladium. Observations were made with a Hitachi S4000 scanning electron microscope. The morphological terminology of the female genitalia is used according to Bourgoin (1993).

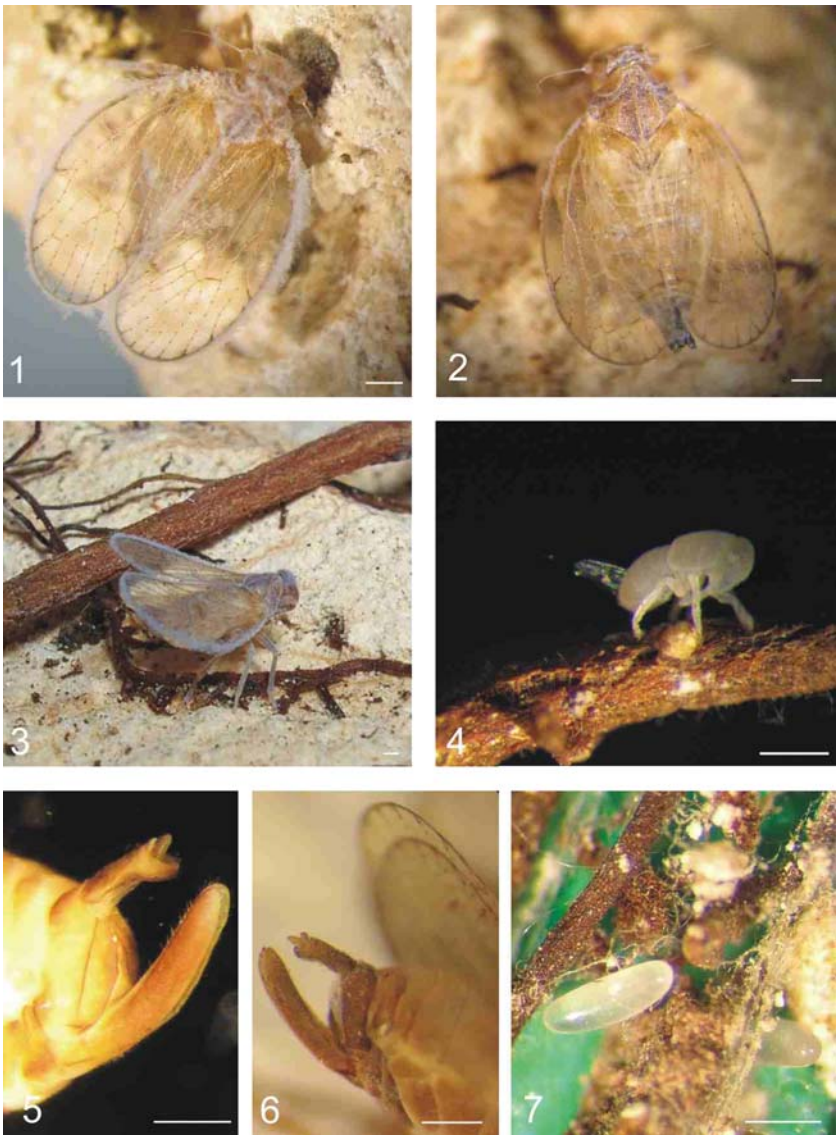
The holotype and the paratypes are deposited in D'Urso collections, University of Catania.

Taxonomy

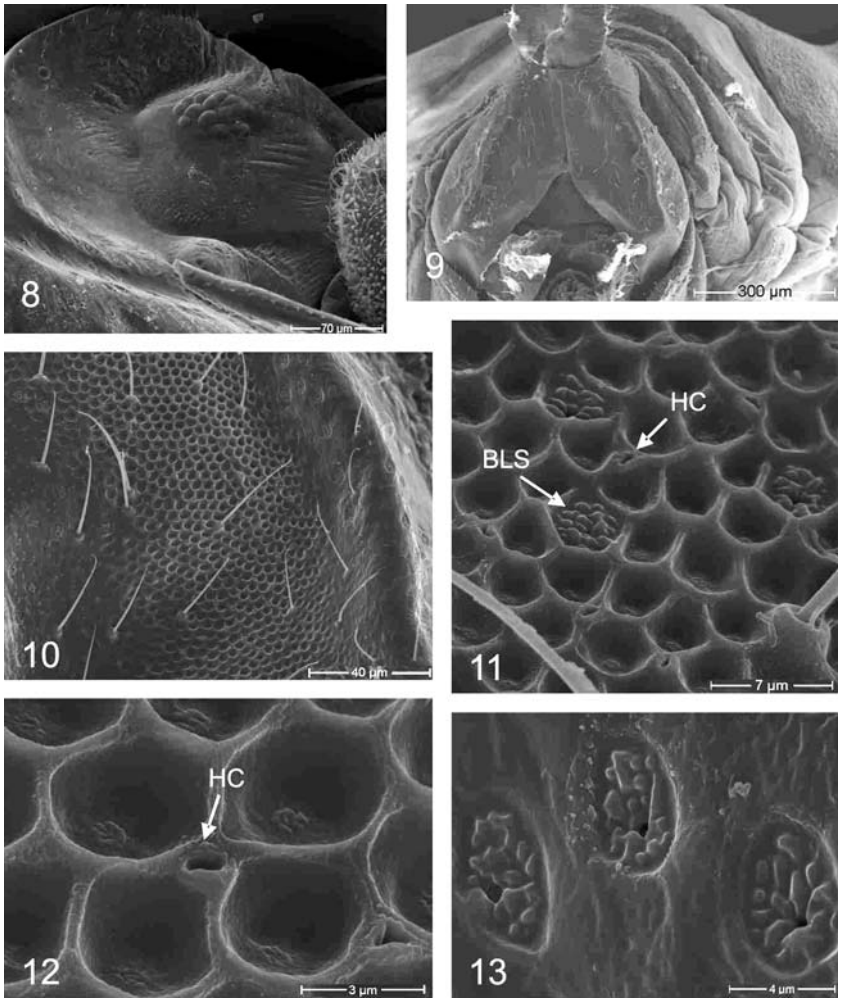
Ibleocixius D'Urso & Grasso, gen. n.

Type species. Ibleocixius dunae D'Urso & Grasso, sp. n.

Description. Moderately large cixiids (5–6 mm). Body in dorsal view heart-shaped in males (Figs 1, 3), ovate in females (Fig. 2). Frons (Fig. 15) longer than wide,



Figures 1–7. *Ibleocixius dunae* gen. n., sp. n. from Iblei Mountain (Sicily). **1.** Male, habitus. **2.** Female, habitus. **3.** Male (another specimens) on the roots. **4.** First instar. **5.** Female (specimen in alcohol), genital and anal blocks. **6.** Female (dry specimen), genital and anal blocks. **7.** Eggs. Scale bar: 0.5 mm.



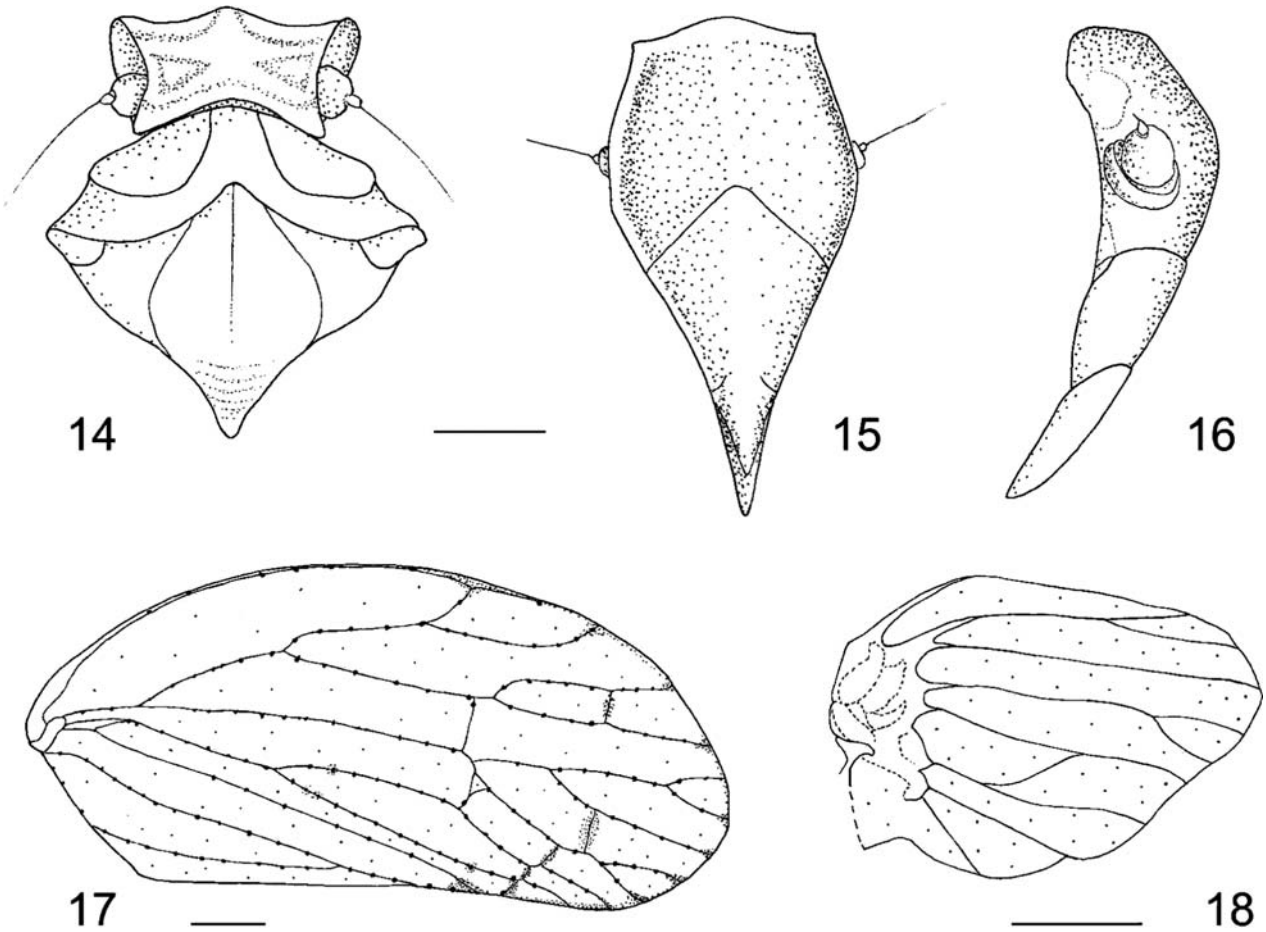
Figures 8–13. *Ibleocixius dunae* gen. n., sp. n. (SEM). **8.** Male, head, lateral view. **9.** Female, posterior view of wax plate on the tergite IX. **10.** Characteristics of the wax plate. **11.** Particular of the wax pores. **12.** High magnification of wax pores. **13.** Bubbles-like structures on the lateral portion of IX segment. BLS = bubbles-like structure; HC = ellipsoidal crack.

widest at the level of the antennae and prominent medially, with strongly carinated lateral margins and a weak median carina. In lateral view (Fig. 16), frons with an evident convexity at the level of the antenna. Clypeus shorter than frons, with carinated lateral margins. Vertex (Fig. 14) rectangular, about two times wider than long, strongly ridged laterally. Eyes reduced (Fig. 8). Pronotum (Fig. 14) short and wide, with posterior margin medially strongly notched; lateral carinae prominent and arcuate, reaching the lateral margin. Pronotum slightly longer medially than vertex. Mesonotum (Fig. 14) nearly 4 times longer than pronotum, with a weak medial carina posteriorly disappearing and lateral carinae strongly arched. Fore wings (Fig. 17) rather ovate with rounded posterior apex; marginal tubercles absent between the veins (exceptionally only 1 or 2), tubercles with long hairs especially on the anal veins, on the claval suture, on the basal portion of the main longitudinal veins. CuA bifurcation at the same level of the Sc + R, on the proximal half of the wing. The transversal subapical vein between R and M is absent. Hind wings reduced (Fig. 18). Posterior legs with 3 lateral spines and 6 apical spines on the tibia; first and second tarsomere apically with 5 small spines.

Male. Genital segment (Figs 19–21) subrectangular in lateral view, about 1.7 times higher than wide, with a triangular medioventral process. Anal segment about 3 times longer than wide, distal portion (Fig. 23) bent ventrally with laterodistal margins produced into two small lobes directed ventrolaterally. Styles spoon-shaped (Fig. 22). Aedeagus (Figs 24–27) with basal portion compressed, only one movable spine on the right side, ventral margin winding basally forming a small tooth, dorsal margin with two sclerotized convexities on the apical half, a prominent sclerotized longitudinal ridge on the right side. Distal part of the aedeagus reflected basally, folded in a nearly right angle at near half length, with a longitudinal dorsal ridge forming a small spine at apex.

Female. Abdomen (Fig. 29) distally truncate (Figs 5, 6, 9, 28): tergite IX raised nearly perpendicular to the longitudinal body axis, ovipositor only slightly curved dorsally. Anal tube cylindrical, shorter than ovipositor. Tergite IX bearing a wax plate (Figs 5, 6, 9) partially divided dorsoventrally into two portions. The transition between the wax plate and the lateral abdomen forming a rounded angle. Wax plate with "*Cixius*-like" wax pores (Holzinger et al. 2002) and scattered setae (Figs 10–12).

Distribution. Ibleocixius seems to be restricted to south-eastern Sicily where it was found in a single



Figures 14–18. *Ibleocixius dunae* gen. n., sp. n., male. **14.** Head and torax, dorsal view. **15.** Head, anterior view. **16.** Head, lateral view. **17.** Fore wing. **18.** Hind wing. Scale bar: 0.5 mm.

limestone cave. It displays a strong degree of troglomorphy, and is thus likely an obligate cavernicole (troglobite).

Derivatio nominis. The genus is named for the area in which it was first discovered, the Iblei Mountain.

Ibleocixius dunae D'Urso & Grasso, sp. n.

Holotype male. Italy: Sicily, Priolo Gargallo (SR), Contrada Morghella, Di Natale's cave, EO 15°08′36,2″, N 37°07′03,9″ (WGS84), n. SI7178 in "Catasto Nazionale delle Grotte d'Italia" (Speleological Society of Italy), 222 m, 18.2.2007, R. Grasso & M. T. Spena leg. Paratypes: 4 males, 4 females, same data as holotype.

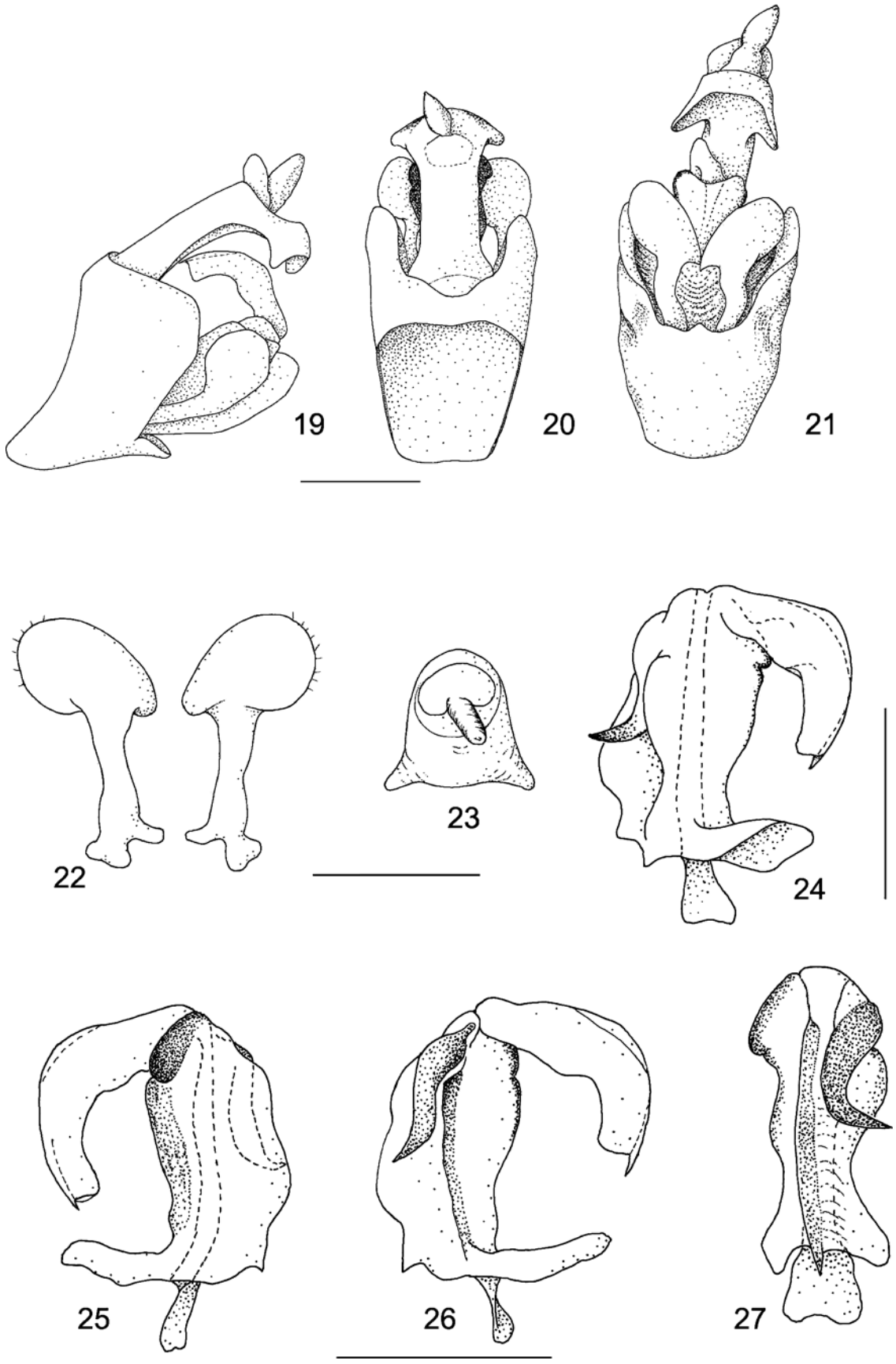
Dimensions. Male. Body length: 5.0–6.0 mm; length of vertex: 0.2–0.3 mm; width of vertex: 0.6–0.7 mm; length of pronotum: 0.2 mm; width of pronotum: 1.3–1.6 mm; length of pronoto plus mesonotum: 1.2–1.4 mm; width of mesonotum: 1.4–1.5 mm; length of fore wings: 4.3–5.0 mm; width of fore wings: 2.0–2.3 mm.

Female. Body length 5.6–6.3 mm; length of vertex: 0.3–0.4 mm; width of vertex: 0.6–0.7 mm; length of pronotum: 0.2 mm; width of pronotum: 1.6–1.7 mm; length of pronotum plus mesonotum: 1.2–1.4 mm; width of mesonotum: 1.3–1.6 mm; length of fore wings: 4.6–5.0 mm; width of fore wings: 2.0–2.2 mm.

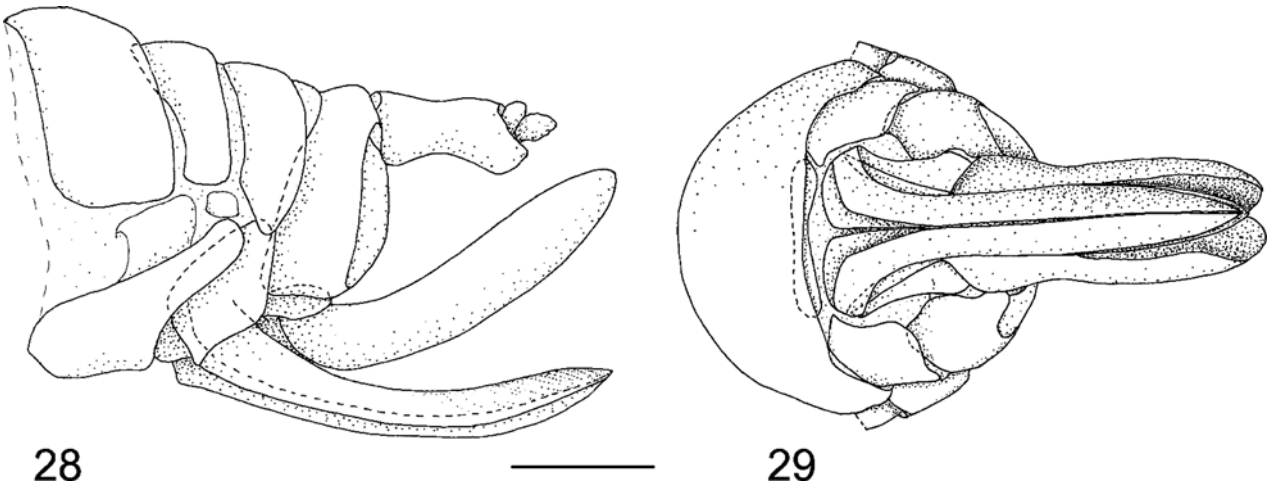
Description. Male. The "heart-shaped" appearance is due to the configuration of the fore wings which are weakly tilted above the abdomen and distally directed dorsally. Body pale yellow. Wings transparent and iridescent. Body partially covered by wax granules which pile up waxflakes mainly along the fore wing margins and the hind wing posterior margin (Figs 1, 3).

Head with eyes very reduced to only 10–15 ommatidia (visible only at the SEM) on a convex vaulted area (Fig. 8); in the position of the ocellus (not visible at the compound microscope) it is possible to observe at the SEM a "median ocellus rudimentary". Antenna with a comparatively large pedicel with several types of sensorial structures. Fore wings (Fig. 17) slightly reduced, barely attaining the tip of the abdomen; apical cells reduced; veins concolorous, light brownish on the distal end of CuP, on the distal end of the longitudinal veins, on the transversal veins which mark the apical cells. Hind wings (Fig. 18) reduced, less than half as long as the fore wings.

Male genitalia. Styles (Fig. 22) with narrow at base, distally spoon-shaped. Aedeagus (Figs 24–27) with the movable spine on the right side sturdy and with apex directed ventrolaterally; ventral margin forming an accentuated convexity in the middle portion; longitudinal



Figures 19–27. *Ibleocixius dunae* gen. n., sp. n., male. **19.** Genital and anal block, lateral view. **20.** Genital and anal block, dorsal view. **21.** Genital and anal block, ventral view. **22.** Right stylus in ventral and dorsal view. **23.** Anal tube, posterior view. **24.** Aedeagus, latero-dorsal view. **25.** Aedeagus, left side. **26.** Aedeagus, right lateral aspect. **27.** Aedeagus, ventral view. Scale bar: 0.5 mm.



Figures 28–29. *Ibleocixius dunae* gen. n., sp. n., female. **28.** Genital and anal blocks, lateral view. **29.** Genital blocks, ventral view. Scale bar: 0.5 mm.

sclerotized ridge on the right side arising near the spine and with basal portion very sturdy; dorsal margin, on the left side view, appears strong and well sclerotized in the apical portion and less sclerotized in the others portions; a small membranous velum is present in the upper portion of the distal part of the aedeagus.

Female. Habitus similar to male but more ovate, less heart-shaped (Fig. 2). Forewing not reaching the tip of the abdomen.

Female genitalia. The two areas of the wax plate on the tergite IX are in contact in the upper part by a median ridge (Fig. 9); at the SEM, the triangular area between the two portions appears uniformly covered with tubercles; wax plate covered with similar wax pores regularly arranged and with dispersal setae (Figs 10–12). In the cuticular areas among 4 wax pores, ellipsoidal cracks irregularly arranged are present. In the peripheral portions of the wax plate scattered bubble-like structures are present; the latter have an opening in the center and are similar to those more abundant, at least, on the other parts of the abdomen (Fig. 13). The function of these structures is unknown.

The internal female genitalia show an irregular shaped spermatheca (receptaculum seminis): a large proximal portion with four windings (ductus receptaculi) followed by a long thin portion (diverticulum ductus) ending into the twisted spindle-like pars intermedialis; the latter is followed by a short glandula apicalis.

Immatures. In the same habitat of the adults, immatures were found (Fig. 4). The description of the five instars and the life cycle will be provided elsewhere.

Eggs. ca. 500 micron in length, ellipsoidal in shape and slightly arcuate, with rounded anterior and posterior poles (Fig. 7); chorion surface smooth and shiny, except at the cephalic pole where a specialized area showing a polygonal pattern with raised outlines is present; this pattern is very accentuated on the micropylar area.

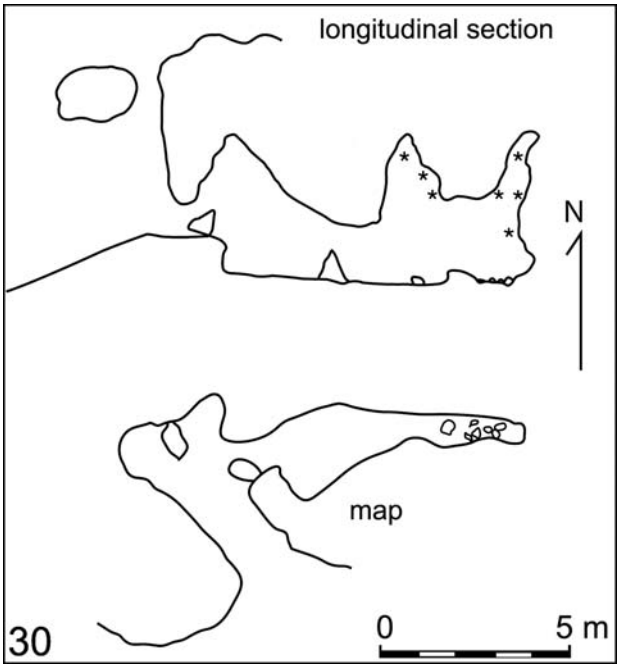


Figure 30. Topography of the Di Natale's cave. The asterisks indicate the spots where *Ibleocixius dunae* were collected.

Distribution. Up to now, the new species is known from a single cave on the Iblei Mountains although further caves in the same area and belonging to the same geological unit which potentially could host the new species were explored, but hitherto no specimens were found. It is conceivable that the absence of the new species in these caves could be due to the fortuitous causes (e.g. frequent fires during summer) which destroyed the epigean vegetation resulting in the disappearance of roots inside these caves, rendering them unsuitable for planthopper colonization, or were the cause for their extinction. On the other hand, the Iblei area holds numerous caves still unexplored (or too small to be explored by man) which may house *Ibleocixius dunae*.

Ecology. Limestone cave with roots of typical plants of the Mediterranean undergrowth like *Pistacia lentiscus* L., *Rhamnus alaternus* L., *Euphorbia dendroides* L., *Olea europea* var. *oleaster* L. The roots are hanging along the rock walls. Both adults and immatures feed on the roots. The eggs are laid on the roots, and not inserted into plant tissue (personal observation). Yearly thermohygrometer data taken at the spot where the cixiid was collected: temperature: 20.2–14.9 °C range; 18.1 °C media of monthly max.; 16.7 °C media of monthly min.; 17.4 °C media; relative humidity: 100–74.1 % range; 99.9 % media of monthly max.; 92.9 % media of monthly min.; 98.4 % media. The specimens live in complete darkness, in the terminal part of a cave about 12 m long (at least the portion that can be explored by men) (Fig. 30).

Derivatio nominis. The species is dedicated to Duna, representative of humans' best friend and faithful companion during many years.

Discussion

Ibleocixius dunae sp. n. belongs to the tribe Cixiini, and although resembles *Cixius* Latreilles, displays a unique combination of characters which does not allow its placement into this genus. Thus, a new genus is erected to accommodate the new species.

Ibleocixius is the first record of an obligately cave-dwelling taxon of Auchenorrhyncha in Italy.

The limestone cave where the new genus were found is on the Iblei Plateau; this latter consists of a massive Meso-Caenozoic carbonate succession and of clastic Neogenic-Quaternary deposits, interrupted by minor volcanic sequences.

The valleys, carved in Oligo-Miocene carbonate succession, show a fluvial-karstic morphology produced by water mechanical erosion and chemical corrosion of limestone rocks. The widespread karstification occurs both with surface forms and with the development of underground channels. In particular, in the valleys sinkholes are common, often buried below alluvial blankets, or caves that may be fossil or even affected by water circulation. The lifting of the whole Iblei region from the upper Miocene led to emersion of marine carbonate deposits. On the basis of the latest marine outcropping sediments in the area where the Di Natale's cave is, dated to the medium Pleistocene, it can be deduced that the definitive emersion of the area started about 0.7 Ma (Grasso et al. 1987).

Ibleocixius differs from *Cixius* and related taxa (*Trirhacus, Sardocixius, Neocixius, Simplicixius, Nanocixius, Apartus, Sphaerocixius, Tachycixius*) of the tribe Cixiini Spinola, 1839, in a particular combination of characters, each of which is also present in other taxa (see Holzinger 2002) (apical margin of fore wings without granules between veins – except for 1 or 2 –, posterior tibia with 3 lateral spines, number and shape of the carinae of pro- and mesonotum, shape of the styles, the aedeagus and anal tube, shape of the female IX tergite and wax plate). Characters at genus level are the morphology of the aedeagus which displays only one movable spine, a longitudinal sclerotized ridge on the right side and with the characteristic sclerotized areas along the margins and on the left side; in females, transition between the wax plate and the lateral abdomen forming a rather rounded angle intermediate between the rounded one in *Trirhacus* and the more or less right-angled one as in *Cixius* and *Tachycixius*. Wax plate covered with similar wax pores and scattered setae. This pattern is similar to the one present in other Cixiini with uniform "sieve-plate" wax pores and dispersal setae (Holzinger 2002; Holzinger et al. 2002). Up to now only the troglobitic *Cixius ariadne* Hoch & Asche, 1993 from the Canary Islands has only one movable spine on the aedeagus but associated with a ventrally massive bifurcate projection (Hoch & Asche 1993).

The phylogenetic relationship among the taxa of Cixiini is still not fully clear. Concerning the position of the new genus within other Cixiini from western Palaearctic, it seem closely related to *Cixius*, namely to the species of the subgenus *Ceratocixius*, for the shape of the aedeagus; the upper sclerotized portion of the dorsal margin in *Ibleocixius* could be the residue of a second disappeared spine. The latter character and the prominent sclerotized longitudinal ridge on the right side of the aedeagus, are interpreted here as autapomorphies of the new genus.

The female genitalia resemble the configuration of *Trirhacus* and *Sphaerocixius* but tergite IX bears a wax plate, partially divided into two portions like in *Apartus* and in some *Cixius* species from the Azores and the Canary Islands.

Despite the strong reduction of the hind wing, the end of the Cu-veins seems to show a trace of the incision that is typical for *Trirhacus* and closely related taxa but not present in *Cixius* and *Tachycixius.*

The new genus shows a combination of characters, like the symmetrical anal tube (plesiomorphie) and the female IX tergite with wax plate (apomorphie) but divided in two areas, which place *Ibleocixius* among the Cixiini.

The fine structure of the wax plate might be a "good" character from the phylogenetic point of view, however, more species from different Cixiini genera need to be examined.

The biggest genus among Cixiini is *Cixius*; it is a worldwide distributed genus with more than 260 described species (Holzinger et al. 2002) but has never been proven as monophyletic (Hoch 1988); many times, in areas far from each others, epigean species often not clearly recognizable, have been originated cave-dwelling taxa: 6 species in the Canary Islands (Hoch & Asche 1993), 2 species in the Azores (both species belonging to *C. azoricus* Lindberg group) (Hoch 1991), 2 species in Mexico (Fennah 1973; Hoch 1988).

According to Howarth (1980, 1986), the presence of the terrestrial troglobitic taxa is expected in all regions

of the world where there are caves that are sufficiently old and large, in communication with the surface, with suitable food and adequate levels of humidity.

Such caves could be colonized by epigean populations due to an adaptative process, e.g. under the stimulus of the utilization of a not yet exploited food resource. In contrast, according to Vandel (1965) and Barr (1968), the colonization of the hypogeic environment is due to modifications of the surface conditions that have become incompatible with life. The adaptative shift hypothesis *sensu* Howarth is founded on his observations in the volcanic caves of the tropical oceanic islands of Hawaii. Here, obligately cavernicolous, strongly troglomorphic cixiid species of the genus *Nesoliarus* occur while on the surface, close epigean relatives are still extant. In the caves, troglobitic *Nesoliarus* feed on roots of the native *Metrosideros polymorpha* (Myrtaceae), a pioneer on young lava flows. Howarth (1986) postulated that the driving force for the colonization of lava tubes by planthoppers was the exploitation of this food resource which is not utilized by many other species.

The new genus displays some characters (reduction of the eyes and wings, cuticle depigmentation, abundant wax production, etc.) that show a degree of troglomorphy due to the cave-dwelling life. It is possible to suppose that the new genus could have arisen from an epigean species of *Cixius*, nowadays extinct, that colonized the hypogeic habitat to exploit new rich food resources represented by the roots. But it is not possible to exclude that the driving force leading to the adaptation to the hypogeic life could be the deterioration of the epigean habitat.

In Sicily, the epigean fauna of Cixiidae (within the tribe Cixiini) belongs to the genera *Cixius* (*C.* cf. *distinguendus*, *C. nervosus*, *C. pallipes*) and *Tachycixius* (*T. remanei*: Sicily and Central Italy, *T. osellai*: endemic to Sicily, *T. desertorum* known by us only from literature but never personally collected in Sicily).

Considering the recent emersion of the area whit the cave in which *Ibleocixius dunae* has been found, it very probably originated before, in a different area; only subsequently the species reached the current location through the cracks and caves network of the karstic Iblei Plateau.

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