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The Occurrence of the Genus *Marmocandona* (Ostracoda, Candoninae) in Italy, with the Description of Two New Species

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The genus *Marmocandona*, established in 2012 to encompass species formerly attributed to the *Pseudocandona zschokkei* species group, currently includes five subterranean species distributed across the Western Palearctic region. The presence of *M. zschokkei*, the most widely distributed species and the only one with a documented fossil record in the genus, has previously been reported in Italy, albeit without conclusive evidence. This study substantially enhances the known diversity of *Marmocandona* through the description of three species from northern Italy: two collected from the hyporheic zone of streams and one from a spring, the latter currently left in open nomenclature. Additionally, the occurrence of *M.* sp. aff. *zschokkei* has been documented in a cave in Central Italy. Morphological analyses of these newly described taxa, along with previously recognized species, revealed a combination of plesiomorphic and apomorphic traits in their chaetotaxy. This study also offers preliminary insights into the potential timing and mechanisms underlying the colonization of subterranean habitats by this new species.

Keywords: Candoninae, Morphology, Subterranean ostracods, Taxonomy, Distribution

BACKGROUND

Ostracods are a class of small bivalve crustaceans with an extensive fossil record, making them a primary focus of paleontological studies. Regarding extant species, most inhabit marine environments; however, non-marine forms—all belonging to the order Podocopida Sars, 1866—have experienced a remarkable evolutionary diversification, successfully colonizing a broad spectrum of aquatic and semi-terrestrial ecosystems, including subterranean habitats. A considerable proportion of subterranean ostracod species belong to the family Candonidae Kaufmann, 1900, which accounts for approximately 21% of all accepted species of extant non-marine ostracods (Meisch et al. 2024). Over time, this family has undergone extensive taxonomic revisions, initially based on morphological considerations and, more recently, on molecular studies. The latest revisions have led to the proposal of eight subfamilies. Among them, the subfamily Candoninae Kaufmann, 1900 includes 19 genera (Wysocka et al. 2019; Meisch et al. 2024). Some of these genera were described as early as the late 19th and early 20th centuries, while the majority were established from the late 1960s onward. One of the most recently recognized genera is *Marmocandona* Danielopol, Namiotko, & Meisch, 2012.

The genus *Marmocandona* was established to accommodate species previously belonging to *Pseudocandona* gr. *zschokkei*, namely, *M. zschokkei* (Wolf, 1920), *M. delamarei* (Danielopol, 1973), *M. rouchi* (Danielopol, 1973), *M. serfozoi* (Gidó, 2010),

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and *M. pescei* (Karanovic, 2005), the latter of which was originally included in the genus *Typhlocypris* Vejdovský, 1882 (Danielopol et al. 2012). These species are characterized by a trapezoidal carapace in lateral view, with the left valve overlapping the right one and featuring a dorsal hump, valves possessing shallow pits in the central area, and the setal group on the second podomere of the mandibular palp with three setae (Danielopol and Hartmann 1986; Namiotko and Danielopol 2004; Danielopol et al. 2012). In addition, all these species occur in the Western Palearctic and exclusively inhabit subterranean aquatic environments.

The potential occurrence of *Marmocandona* in Italy has remained extremely scarce to date. *Pseudocandona zschokkei* was reported in by Ghetti and McKenzie (1981) in lakes of the northern Apennines, although without precise details on the collection sites. However, this habitat does not correspond to other known occurrences of this species (Meisch 2000). The lack of illustrations cast significant doubt on the reliability of this report, along with the inability to locate specimens in collections for taxonomic verification. Moreover, *P. zschokkei* did not appear in the list of ostracod species recorded during surveys conducted in the 385 lakes and temporary pools of the northern Apennines (Moroni 1967).

A single valve collected from a limnocrene spring in the lowlands of the province of Parma (northern Italy) and initially identified as ?*Mixtacandona* sp. (Mazzini et al. 2017, fig. 8C, D) must be regarded as a new species of *Marmocandona* (Danielopol, pers. comm.). Unfortunately, further samplings failed to yield additional specimens necessary for formal description. As a result, it remains in open nomenclature.

Here, we present detailed descriptions of two new species of the genus *Marmocandona*, also from northern Italy. The first was previously identified as *Pseudocandona* gr. *zschokkei* in an unpublished undergraduate thesis (Zanichelli 2009), and the second one as *Schellencandona* sp. in Pieri et al. (2009, Plate 5, A–C).

MATERIALS AND METHODS

The ostracods examined in this study were collected through surveys conducted in Italy between 2001 and 2009. The samples were collected using a hand net, except for a well where a trap was employed, which consisted of a plastic bottle filled with gravel and baited with meat. All samples were preserved in ethanol.

The sorting and dissection of the ostracods were conducted under a stereomicroscope. Valves were preserved dry in micropaleontological slides, while the dissected appendages were mounted in glycerin on microscope glass slides and sealed with nail varnish. Digital images of carapaces and valves were acquired using Scanning Electron Microscopy (SEM), and line drawings of soft parts were produced with a camera lucida-equipped microscope. The chaetotaxy of the soft parts follows that of Smith (2025).

The codes GR and VP, followed by a number, indicate the classification of the examined specimens within the first author's collection and correspond to those appearing in previous publications. An additional code (MZUF, followed by a number) was assigned to all studied specimens, identifying the location of the material deposited in the crustacean collection of the La Specola Museum of Natural History, Zoology Section, Florence, Italy.

RESULTS

Taxonomic account (after Meisch et al. 2024)

Class Ostracoda Latreille, 1802
Subclass Podocopa G.O. Sars, 1866
Order Podocopida G.O. Sars, 1866
Suborder Cypridocopina Baird, 1845
Superfamily Cypridoidea Baird, 1845
Family Candonidae Kaufmann, 1900
Subfamily Candoninae Kaufmann, 1900
Genus *Marmocandona* Danielopol, Namiotko & Meisch, 2012

Diagnosis of the genus based on adult specimens (modified from Danielopol et al. 2012).

Cp of medium L (0.7–1.1 mm), shape approximately trapezoid or rectangular in lateral view, greatest H in the middle third of dorsal margin, H/L > 0.5. LV higher and dorsally overlapping RV. Valves entirely covered with large, deep fossae. Anterior calcified inner lamella 10–15% of valve length, about twice as wide as posterior one. Anterior peripheral valves with numerous medium-sized marginal canals. Weakly expressed sexual dimorphism; male carapace slightly larger, more rounded postero-ventrally than in female. A1 7-segmented; A2 in both sexes with exceptionally long apical claws; in female G1 ≥ 2.6 (in most species) and GM ≥ 2.2 (usually 2.7–2.9) the length of the anterior margin of the penultimate segment, in males G2 ≥ 2.2 (usually > 2.7) GM ≥ 1.5 (commonly > 2.1) the length of the anterior margin of second and third endopodal segments combined, z1 claw either subequal to G2 or distinctly shorter. Except one species (*M. serfozoi*), male A2 lacks male bristles (transformed

t2 and t3 setae) and En2 undivided. Setal group of the inner margin of the second segment of Md-palp with three setae, externo-distal g seta on the same segment smooth (not plumose). Exopodial branchial plate of L5 rudimentary with two plumed setae. L6 with one d seta on protopodite and (? always) two unequal g1 and g2 setae on penultimate segment. L7 with protopodite bearing three setae (d1, d2, dp), penultimate segment missing medial f seta, penultimate segment with long distal g seta, last segment with two long h2 and h3 setae and one short, hook-like h1 seta. CR with posterior seta present. Female genital lobe moderatley convex, with one or two blunts and shallow folds. Hemipenis with three lobes (a, b, h) well developed, the middle h lobe often two-folded (h1 and h2 lobes, the latter striated); M-process only partially sclerotised; bursa copulatrix cornet-shaped. Zenker organ with five wreaths of spines and two terminal cap-like structure.

***Marmocandona zanichellii* n. sp.**

(Figs. 1–3)
[non] *Schellencandona* sp. Pieri et al. 2009
(Plate 5, A–C)
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Type locality: Drinking well, municipality of Salsomaggiore Terme, province of Parma, Emilia Romagna region, latitude 44°49'20"N, longitude 10°00'14"E, elevation: 140 m a.s.l.

Type material: *Holotype*: adult ♂ (GR558-MZUF-CRU-E00733) with soft parts dissected in glycerine in a sealed slide, valves stored dry in a micropalaeontological slide.

Paratype: adult ♂ (GR557-MZUF-CRU-E00734) with soft parts dissected in glycerine in a sealed slide, valves stored dry in a micropalaeontological slide. Specimens collected by F. Zanichelli using a baited trap positioned on 29 April and retrieved on 7 May 2009.

Etymology: The new species is named after Fabio Zanichelli, who collected the specimens described here during his undergraduate thesis project.

Measurements: GR557-MZUF-CRU-E00734, LV: L = 822 µm, H = 508 µm, H/L = 0.62; RV: L = 803 µm, H = 453 µm, H/L = 0.56. GR558-MZUF-CRU-E00733, LV: L = 807 µm, H = 496 µm, H/L = 0.61; RV: L = 787 µm, H = 457 µm, H/L = 0.58.

Description: Cp and valves (Fig. 1). Cp subtrapezoidal, stout in lv. Greatest H at the posterior cardinal angle, greater L within the ventral half. Dorsal margin almost straight approximately parallel to the ventral margin (RV, Fig. 1 A) to slightly concave in the middle (LV, Fig. 1 B), sloping posteriorly and with a subtle concavity anteriorly. LV overlaps RV on both ends, LV exceeds RV in H and L. Cp in dv anteriorly beak shaped. Surface of valves entirely covered with shallow smooth fossae (Fig. 1C), becoming foveolate towards the anterior and posterior margins (Fig. 1D) bounded by polygonal muri forming a reticulate pattern. Normal pore canals simple or trifoliate (Fig. 1D). On the anterior margin of the RV, small tubercles may occur (Fig. 1G–H). In iv, hinge adont (Fig. 1E, F, I, J). Both anterior and posterior margins rounded, anterior more widely than posterior. Selvage peripheral. Width of anterior marginal zones more than double the posterior marginal zones. RV ventral margin markedly concave (Fig. 1E, I). Marginal pore canals straight, more abundant anteriorly than posteriorly.

Soft parts

A1 (Fig. 2A): seven-segmented-limb; first segment with two unequal dorsal setae and two shorter setae on the ventral margin; second segment with a short ventro-apical seta; third segment with one apical seta slightly exceeding the distal margin of the next segment; fourth and fifth segments with a short dorsal seta and two long ventral setae; sixth segment with four ventral setae, the innermost exceeding the distal margin of the last segment by 1/5 of its length, a very short a seta and the two very long setae; seventh segment bearing three long setae and aesthetasc ya equal in length to the segment itself.

A2 (Fig. 2B): coxa with two ventral setae; basipodite with a long ventral, sub-apical seta; exo with one long seta nearly reaching the distal margin of En1 and two short, unequal setae, the most ventral one widened at the base; endopodite three-segmented (second segment undivided); En1 bearing aesthetasc Y placed at approximately 2/5 of the ventral margin, with its proximal part widened, and two ventro-apical setae, the longer one exceeding the distal margin of En3 and about 2.2 times the length of the shorter one; En2 with aesthetasc y1, a seta t1 (no male bristles), and apically aesthetasc y2 on the ventral margin; at 3/5 of the dorsal margin, a seta slightly surpassing En3, in the distal position two setae z, two short unequal apical claws G1 and G3 in a 1.8 ratio, and more dorsally a very long claw G2, serrated along the central part and approximately equalling the combined lengths of the three endopodal segments; En3 with two claws, one (GM) about 30% the length of the other (Gm), the latter with serrulation as in G2, and ventro-apically aesthetasc y3 with its companion seta, both surpassing the tip of GM.

Md (Fig. 2C): four-segmented palp; first segment externally carrying the respiratory plate (not shown), internally with two apical setae of which one longer

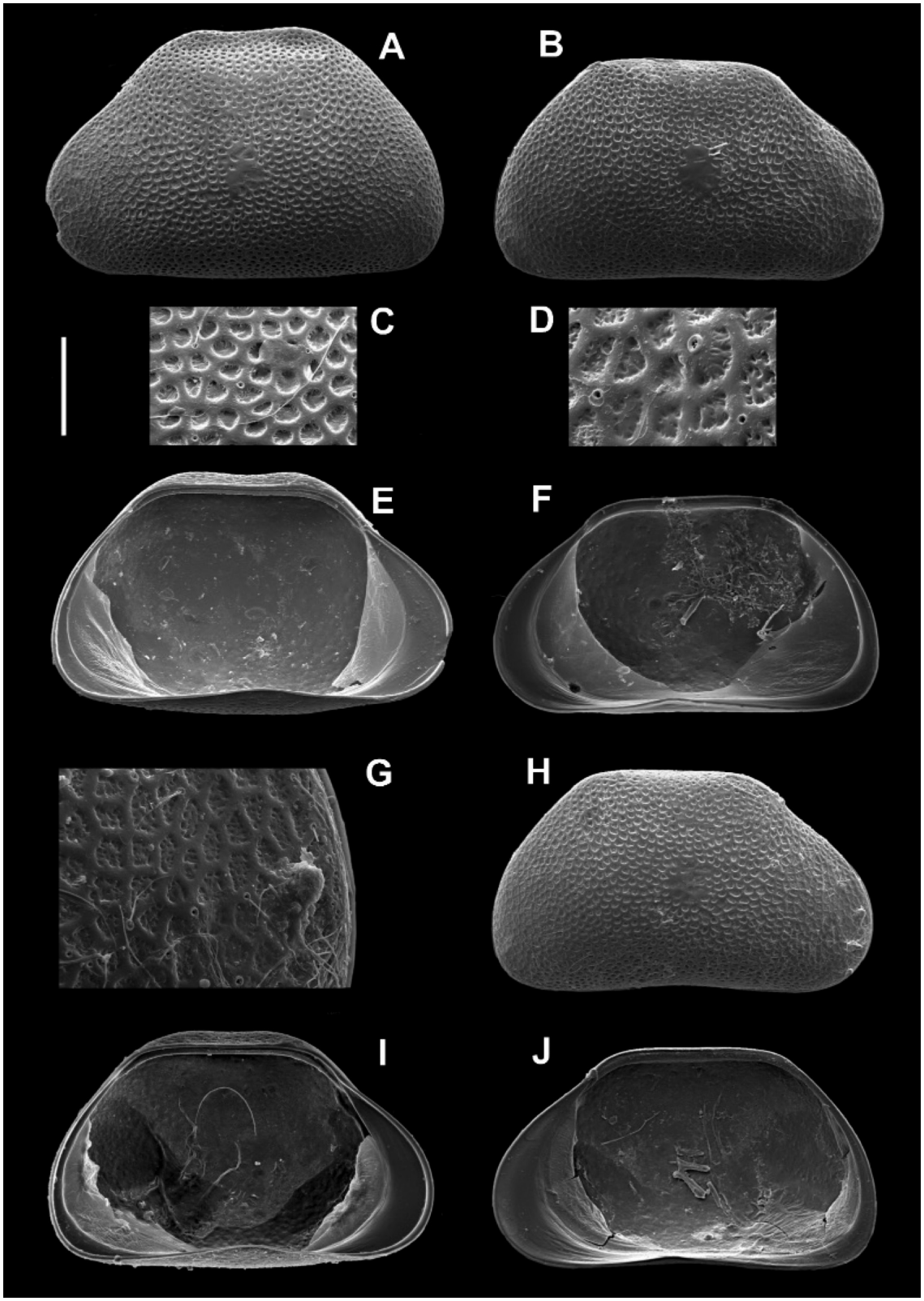

Fig. 1. A–F: *Marmocandona zanichellii* n. sp. adult ♂ (GR557-MZUF-CRU-E00734); *Marmocandona zanichellii* n. sp. G–J: adult ♂ (GR558-MZUF-CRU-E00733). A, left valve, external view. B, right valve, external view. C, detail left valve, external view. D, detail left valve, external view. E, left valve, internal view. F, right valve, internal view. G, detail right valve, external view. H, right valve, external view. I, left valve, internal view; J, right valve, internal view. Scale bars: A, B, E, F, H–J = 200 μm; C = 70 μm; D = 28 μm; G = 44 μm.

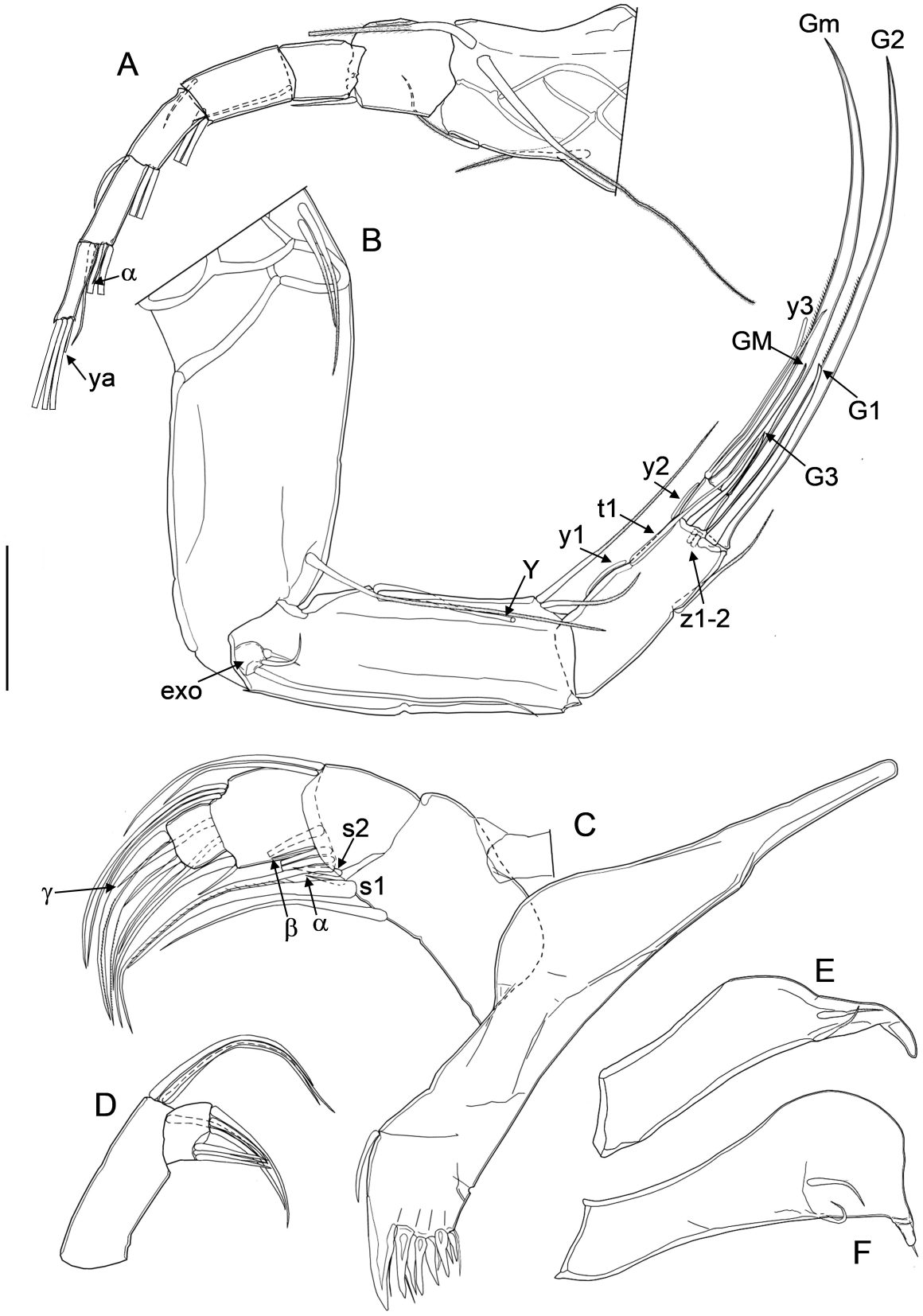

Fig. 2. A, *Marmocandona zanichellii* n. sp. adult ♂ (GR557-MZUF-CRU-E00734); B–F, *Marmocandona zanichellii* n. sp. adult ♂ (GR558-MZUF-CRU-E00733). A, A1. B, A2. C, Md. D, Mx1-palp. E, left L5-palp. D, right L5-palp. Scale bars: A–D = 50 μm; E, F = 35 μm.

and hirsute (s1), a tiny a seta, and a short and stout seta s2; second segment bearing two external, apical setae of unequal length, a group of five internal, apical setae of different length, the β seta being the shortest of all; third segment with a group of three subapical setae externally, centrally two setae, the shorter one being the g seta, and internally two apical setae, one of which very short; fourth segment short, with four visible apical setae, the most external ones robust and finely hirsute; masticatory process slender and distally with a series of strong teeth.

Mx1 (Fig. 2D): two-segmented palp; first segment with three setae of similar length and a shorter sub-apical seta; second segment short, bearing two long and one short apical setae, and three sub-apical setae.

L5 (Fig. 2E, F): male palps transformed into strongly asymmetric clasping organs, the left one more slender and distally beak-shaped, the right one distally swollen with a rounded margin and ending in a thin protuberance bearing a small spine; both palps with two sub-terminal setae, one along the palp margin and the other positioned more internally.

L6 (Fig. 3A): a walking leg consisting of a protopodite carrying seta d1 and a four-segmented endopodite; En1 and En2 with a sub-apical ventral seta (e and f, respectively); En3 with two sub-apical setae (g1 and g2) of unequal length, the latter distinctly shorter; En4 short, with terminal claw h2 c. 1.7 times the combined lengths of the three distal endopodal segments, prominently serrated along its central portion, and flanked by minute setae h1 and h3.

L7 (Fig. 3B): a cleaning leg consisting of a protopodite and of a four-segmented endopodite (En2 subdivided); protopodite with sub-equal setae d1 and d2, and seta dp slightly longer than the next segment; En1 and En2a without setae; En2b with sub-apical seta g; En3 short, bearing three apical setae, the first (h1) small, hirsute and distinctly curved, the second (h2) also curved and claw-like, slightly shorter than the combined lengths of the last three endopodal segments and finely serrated in its distal two-thirds, the third (h3) notably longer with a robust proximal part and hirsute over its distal 5/8, the three seta with relative length ratios of approximately 1:5.7:8.5 respectively.

CR (Fig. 3C): relatively slender, with long seta Sp inserted at approximately 5/6 of the posterior margin and reduced seta Sa; distal claws robust and curved, strongly serrated except at the basal portion and the tip; Ga about 1.3 times the length of Gp and slightly less than 2/3 the length of the ramus.

Hemipenis (Fig. 3D): compact in shape, slightly longer than wide; inner margin gently curved at the basal part; lobe a large and sub-rectangular; lobe b with a distal margin forming a blunt triangle; lobe h1 small and seemingly unstriated; lobe h2 slightly smaller than lobe b, with a distal margin marked by a slight central depression.

Zenker organ (Fig. 3E) with 5+2 whorls of spines.

Eye absent.

Differential diagnosis: *Marmocandona zanichellii* n. sp. can be distinguished from other species in the genus by its unique combination of morphological traits in the valves and appendages.

The morphology and dimensions of the carapace and the valves, of *M. zanichellii* differ from that of *M. zschokkei* in the proportions (H/L 0.61 and 0,47 respectively) (Wolf 1919). The dorsal margins of *M. zschokkei* are almost straight compared to the sinuous dorsal margins of *M. zanichellii*, and the heavy ornamentation of fossae and muri displays a pattern different from that of *M. zanichellii*: the rounded fossae are foveolate in the central anterior part and become smooth and smaller towards the anterior and posterior ends (Wolf 1919, Table III, fig. 1-5-6). The adult male LV of *M. delamarei* illustrated by Danielopol et al. (1978, fig. 47A) shows a different outline, with an almost straight dorsal margin, gently tapering towards anterior. The external ornamentation of *M. delamarei* displays a pattern of small, rounded fossae clustered inside smooth muri in the antero-dorsal area (Danielopol et al. 1978, fig. 32D). *M. rouchi* exhibits an external ornamentation with small smooth oval fossae arranged around large simple pores (Danielopol et al. 1978, fig. 33B); it is shorter (0.73 mm) with a symmetrical trapezoidal carapace (Danielopol et al. 1978, fig. 45E). The outline of the valves of *M. rouchi* is extremely similar to that of *M. serfozoi*, although the surface ornamentation is stouter as stated by Gído (2010). *Marmocandona pescei* displays a small flange on the LV, with a straight dorsal margin tapering towards anterior end, with shallow rounded pits covering the surface and densely covered with setae (Karanovic 2005, figs. 1–4). The length ratios between setae and claws and between these and their appendages differ from those of congeners. In male A2, the aestheasc Y is tapering distally rather than expanding as in other species of *Marmocandona*; En2 has two z-setae (as in *M. zschokkei*) but only one seta t (there are three setae t in *M. zschokkei*). L7 has a four-segmented endopodite (En2 subdivided), a trait observed only in *M. pescei*. The hemipenis has h1 and h2 lobes, a feature shared only with *M. delamarei*; however, in the latter species these lobes result from the folding of the lobe h and are not distinct as in *M. zanichellii* n. sp.

Remarks: *Marmocandona zanichellii* sp. nov. is formally described here, despite the availability of only two male specimens. This decision was made as both valve and soft morphological characters could be clearly

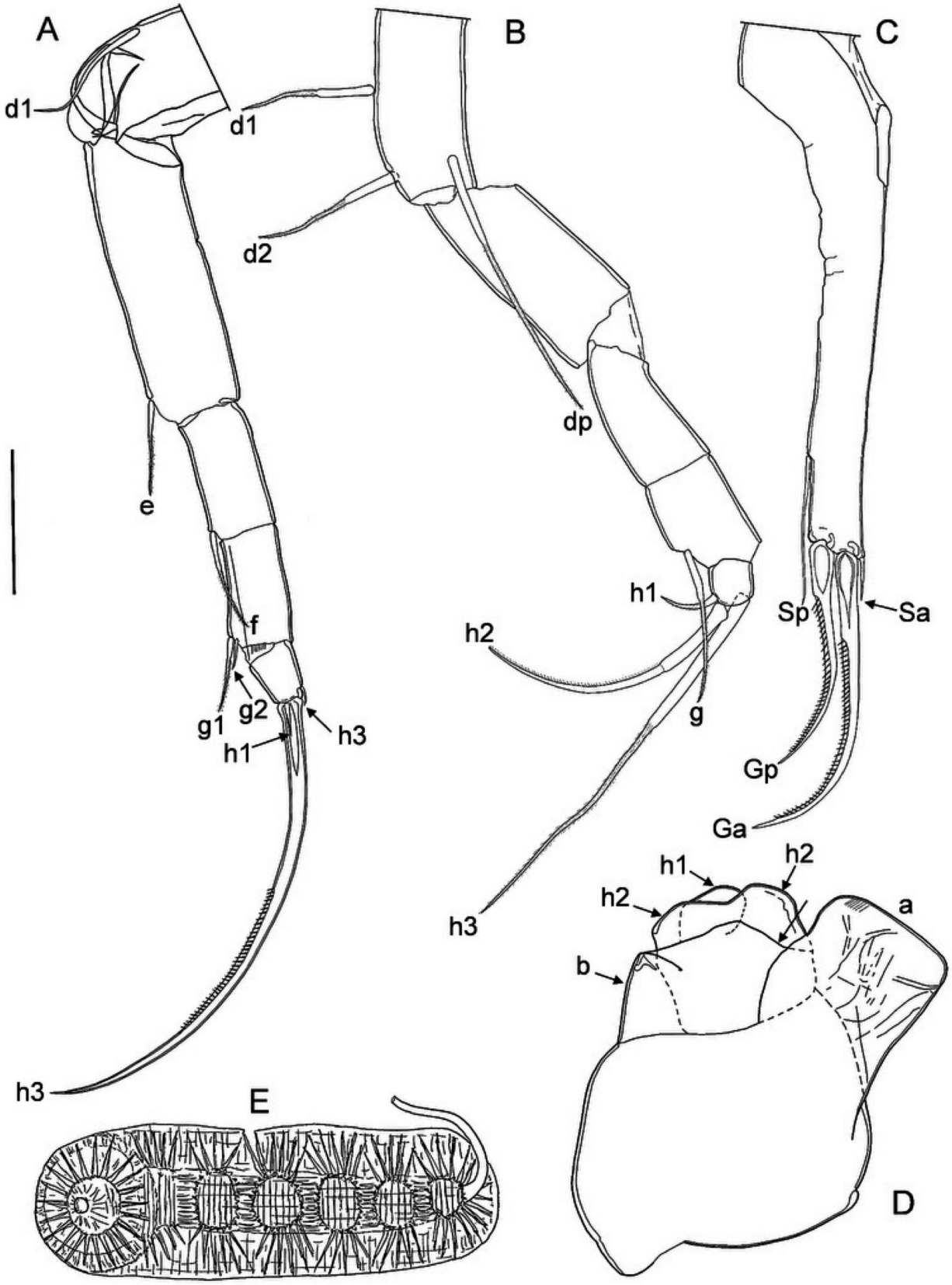

Fig. 3. A, D, E: *Marmocandona zanichellii* n. sp. adult ♂ (GR558-MZUF-CRU-E00733); B, C: *Marmocandona zanichellii* adult ♂ (GR557-MZUF-CRU-E00734). A, L6. B, L7. C, CR. D, hemipenis. E, Zenker organ. Scale bars: A = 63 μm; B, C = 50 μm; D, E = 100 μm.

documented, enabling a distinct differentiation of the new species from its congeners.

***Marmocandona valentinae* n. sp.**

(Figs. 4–6)

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Type locality: Risorgive di Flambro, municipality of Talmassons, province of Udine, Friuli Venezia Giulia region, latitude 45°54'59"N, longitude 13°04'48"E, elevation 21 m a.s.l. Samples collected by FS on 15 February 2001 (VP0602-MZUF-CRU-E00735) and 7 June 2002 (VP0630-MZUF-CRU-E00736). Alkaline peat bog fed by resurgences along the lower boundary of the "springs line" in the Friuli Venezia Giulia lowplain. Vegetation is characterized by communities dominated by *Cladium mariscus*, along the edges of springs and on the bottom of the lowlands, by *Schoenus nigricans*, and by damp meadows dominated by *Molinia caerulea* (Zapparoli, 2011).

Type material: *Holotype*: adult ♂ (VP0602-MZUF-CRU-E00735) with soft parts dissected in glycerine on a sealed slide, valves stored dry on a micropaleontological slide.

Allotype: adult ♀ (VP0630-MZUF-CRU-E00736) with soft parts dissected in glycerine on a sealed slide, valves stored dry on a micropaleontological slide.

Etymology: The new species is dedicated to Valentina Pieri in recognition of her significant contribution to the study of non-marine ostracods in Italy.

Measurements: VP0602-MZUF-CRU-E00735. VP0630-MZUF-CRU-E00736, LV: L = 676 µm, H = 476 µm, H/L = 0.70; RV: L = 651 µm, H = 406 µm, H/L = 0.62.

Description: Carapace and valves (Fig. 4). Cp subtrapezoidal. Greatest H around the middle in LV (Fig. 4A, C), towards the anterior in the RV (Fig. 4B, D). Greater L within the ventral half. Marked cardinal angles. Dorsal margin slightly convex (RV, Fig. 4A, C) to slightly straight (LV, Fig. 4B, D). Anterior margin rounded, with a subtle concavity at mid-height, posterior margin obtuse. LV overlaps RV on both ends, LV exceeds RV in H and L and markedly overlaps RV on the dorsal margin with a flat flange. Cp in dv anteriorly beak shaped. Surface of valves generally smooth, with shallow foveolate rounded fossae in the central area. In iv, hinge adont (Fig. 4E, F), narrow marginal zone. Internal dorsal margin of LV with a characteristic protuberance. Posterior margins sloping steeply into an obtuse postero-ventral angle. Anterior margin rounded. Selvage peripheral. Width of anterior marginal zones more than double the posterior marginal zones. Ventral margins with evident additional closing mechanism in the middle (Fig. 4E, F). Marginal pore canals straight.

Soft parts

A1 (Fig. 5A): seven-segmented; first segment with two long dorso-apical setae and two subequal shorter setae ventrally; second and third segment with one ventro-apical seta, respectively slightly shorter and exceeding by about half its length the distal margin of the next segment; fourth and fifth segments with two long ventral setae; sixth segment with three (check) apical setae, one slightly exceeding the distal margin of the last segment, a short a seta and more ventrally a long seta; seventh segment with three long setae and aesthetasc ya.

A2. Male (Fig. 5B): coxa with two ventral setae of different length; basipodite with a ventral seta slightly exceeding next segment; exo with three setae of different length, the median one very long (approximately 5.6 times and 1.4 times the length of the other two setae) and extending beyond the distal margin of En1; endopodite three-segmented (second segment undivided); En1 with aesthetasc Y positioned proximally along the ventral margin and consisting of three parts, with the intermediate one narrow, and two ventro-apical setae, the longer about 3.7 times the length of the other; En2 ventrally bearing aesthetasc y1, three setae t, none of which modified into male bristles, and apically aesthetasc y2; just beyond the midpoint of the dorsal margin, a seta slightly surpassing En3; distally two setae z, two short apical claws G1 and G3 of similar length, and a very long claw G2 serrated in its distal third and exceeding the length of the endopodite; E3 with two terminal claws, of which Gm about 3.2 times the length of GM, the former serrated distally and with its tip ending close to that of G2; in a ventro-distal position, aesthetasc y3 accompanied by a slightly longer seta, the former approximately half the length of Gm. Female (Fig. 5C): En2 with aesthetascs y1 and y2 and a single visible seta t along the ventral margin, one seta on the dorsal margin, and distally two setae z, claw G2 approximately equal to the combined lengths of En2 and En3, two long claws G1 and G3, serrated along one-third of their length, about 3.8 times the length of G2; En3 bearing apically aesthetasc y3 with its companion seta and claws GM and Gm, the former ending near the tips of G1 and G2, and approximately 1.6 times the length of Gm.

Md (not illustrated): setal group of the inner margin of the second segment of Md-palp with three setae.

L6 (Fig. 6A): protopodite with seta d1; four-segmented endopodite; En1 and En2 carrying a sub-

apical ventral seta each (e and f); En3 with two subapical setae (g1 and g2), the latter very tiny; En4 with terminal claw h2 slender, gently curved and serrated distally, slightly shorter than endopodite length, and setae h1 and h3 with a length ratio of 1:0.7.

L7 (Fig. 6B): protopodite with seta d1 and dp, the latter distinctly longer; seta d2 possibly lost during dissection (discontinuity noticeable at the insertion site on the protopodite margin); three-segmented endopodite (En2 not subdivided); En1 without setae; En3 with sub-

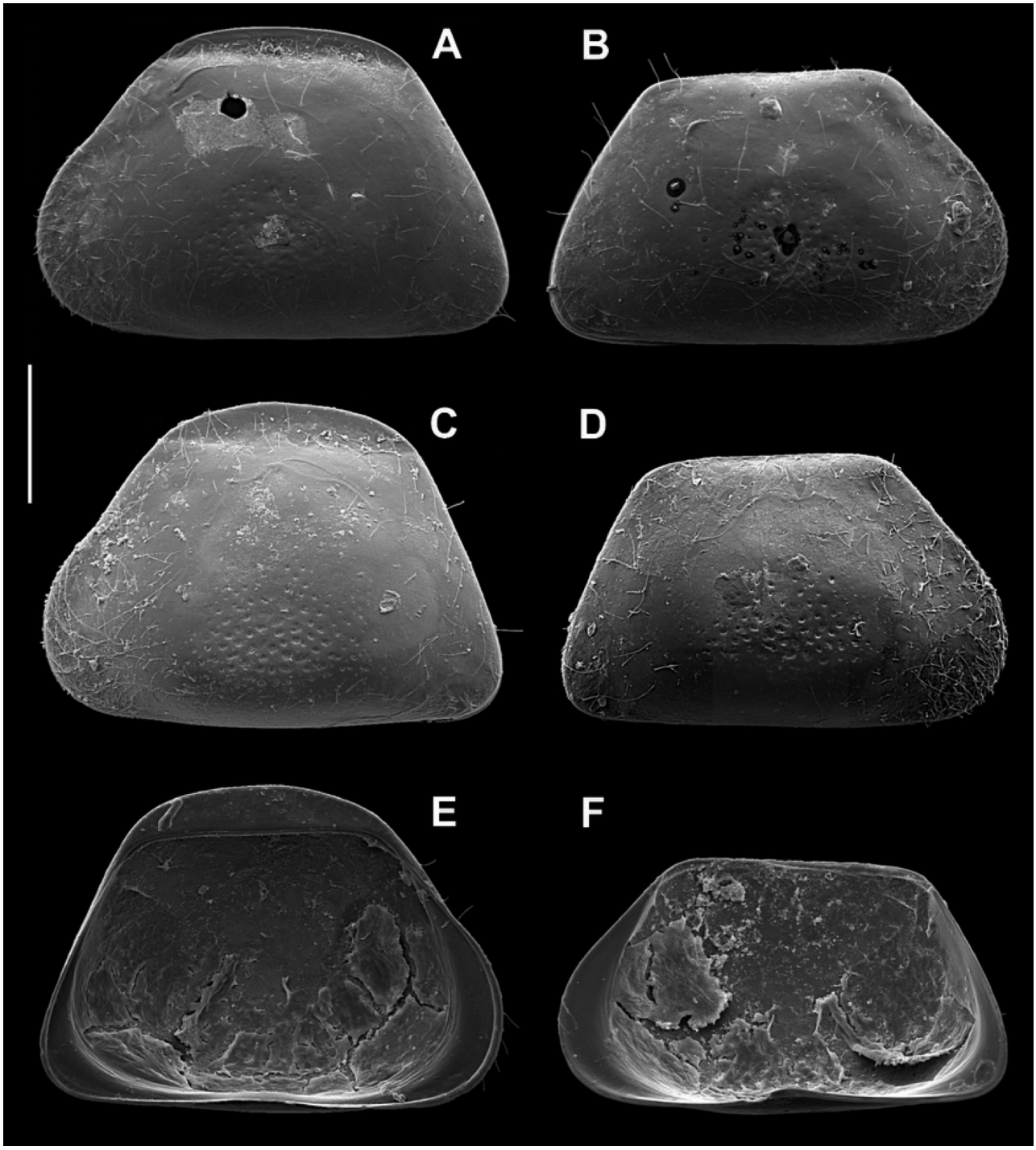

Fig. 4. A and B, *Marmocandona valentinae* n. sp. adult ♂ (VP0602-MZUF-CRU-E00735); C–F, *Marmocandona valentinae* n. sp. adult ♀ (VP0630-MZUF-CRU-E00736). A, left valve, external view. B, right valve, external view. C, left valve, external view. D, right valve, external view. E, LV iv. F, right valve, internal view. Scale bar = 200 μm.

apical seta g approximately 80% the length of segment; En3 sub-quadrate, with h1 short and curved, h2 a finely serrated and curved claw, and h3 longer and hirsute, with relative length ratios of approximately 1:2.8:3.8.

CR (Fig. 6C): seta Sp inserted at about 7/8 of the posterior margin of the ramus; seta Sa strongly reduced; terminal claws Ga and Gp serrated and curved distally, sub-equal in length, corresponding to roughly 75% of the anterior margin of the ramus.

Hemipenis (Fig. 6D): inner margin nearly straight, outer margin rounded; lobe a projecting laterally, rectangular with rounded corners; lobe b with curved margin, sloping more markedly toward the inner side; lobe h digitiform, slightly smaller and extending a little farther than the previous one.

Mx1, L5 and Zenker organ lost or severely

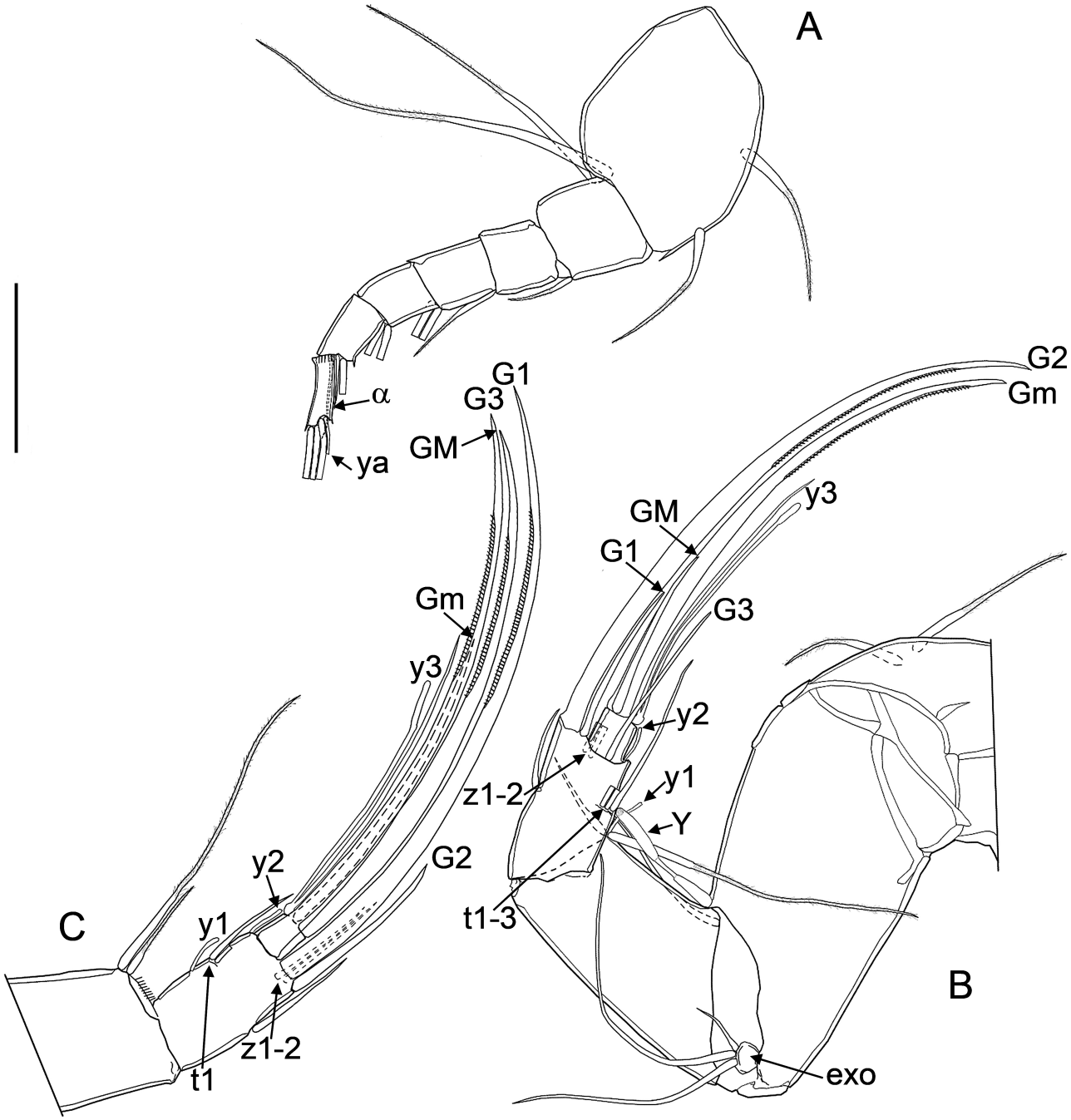

Fig. 5. A and C, *Marmocandona valentinae* n. sp. adult ♀ (VP0630-MZUF-CRU-E00736); B, *Marmocandona valentinae* n. sp. adult ♂ (VP0602-MZUF-CRU-E00735). A, A1. B, A2. C, terminal part of A2. Scale bar = 50 μm.

damaged during dissection.

Eye absent.

Differential diagnosis: *Marmocandona valentinae* n. sp. differs from other species of the genus due to a distinct set of morphological characteristics of both valves and appendages.

Marmocandona valentinae is the only species within the genus *Marmocandona* known to exhibit a distinctively flat and smooth dorsal flange on LV and a smooth surface, which features rounded foveolate fossae only in the central area. These traits clearly distinguish it from the five other *Marmocandona* species described to date. The relative proportions of setae and claws, as well as their relationship with the corresponding appendages, differ from those observed in other species of the genus. Additionally, in male A2, unlike all other congeners, the median seta of the exopodite is exceptionally long.

Remarks: Despite the recovery of only two

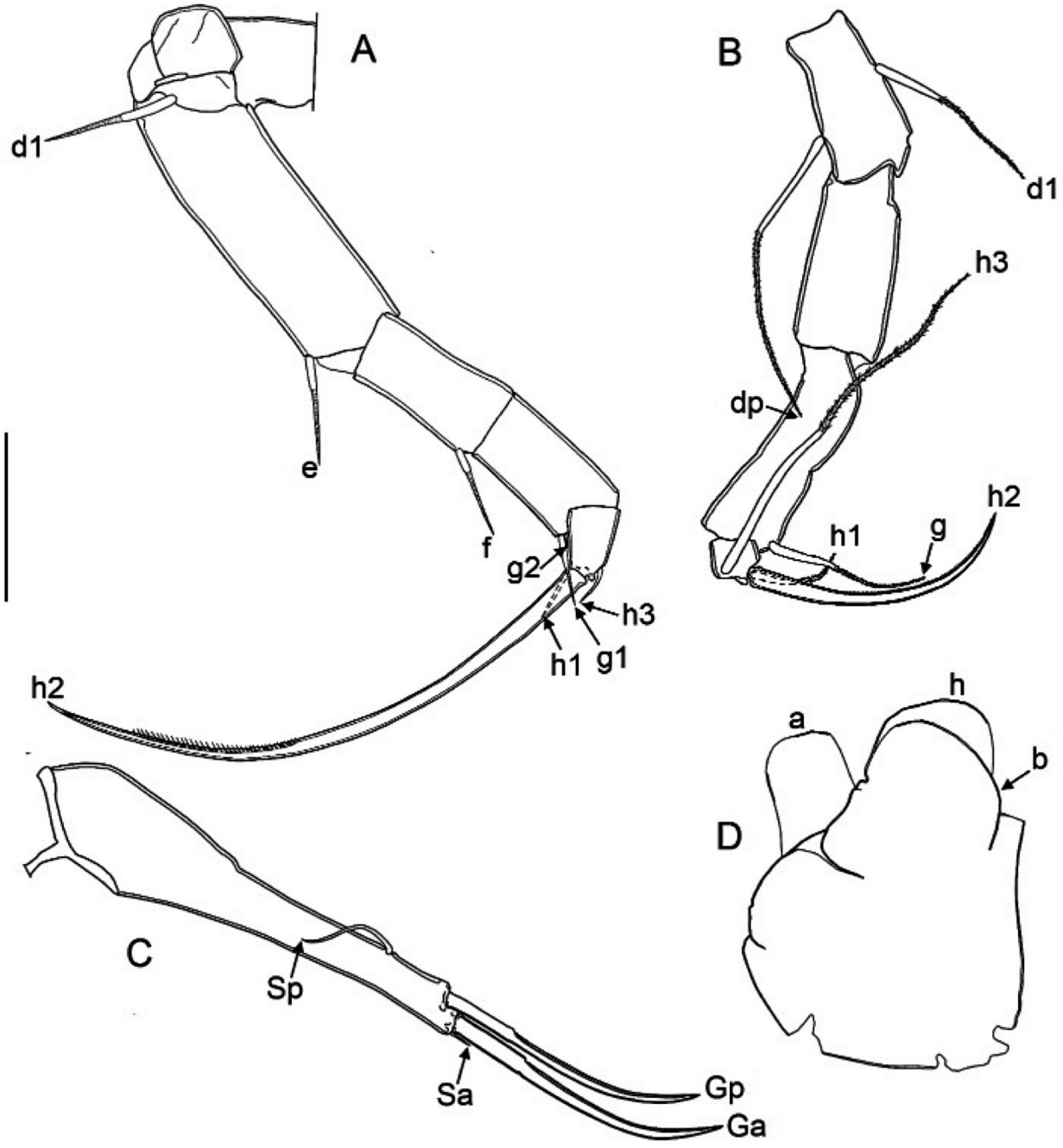

Fig. 6. A, C, and D, *Marmocandona valentinae* n. sp. adult ♂ (VP0602-MZUF-CRU-E00735); B, *Marmocandona valentinae* n. sp. adult ♀ (VP0630-MZUF-CRU-E00736). A, L6. B, L7. C, CR. D, hemipenis. Scale bars: A–C = 50 μm; D = 100 μm.

specimens, *Marmocandona valentinae* n. sp. is formally described here as the description of the valves, and the most important diagnostic characters of its soft parts provide substantial support for its unequivocal recognition as a new species.

Additional sampling in the Risorgive di Flambro during 2001–2002 led to the identification of *Pseudocandona lobipes* (Hartwig, 1900) and *Candonopsis scourfieldi* Brady, 1910 (det. V. Pieri, unpublished), but no specimens of *Marmocandona valentinae* n. sp. were found.

***Marmocandona* sp. A**

[non] ?*Mixtacandona* sp. Mazzini et al. 2017
(Fig. 6C, D)

Sampling locality: Limnocrene spring La Commenda, municipality of Sissa-Trecasali, province of Parma, Emilia-Romagna region, latitude 44°53'15" N, longitude 10°16'55"E, elevation: 31 m a.s.l. Sample collected by GR on 16 April 2009. The spring is located within the Torrile and Trecasali Nature Reserve, where examples of natural resurgences remain. The aquatic vegetation consisted of *Potamogeton natans*, *Lemna minor*, *Vallisneria spiralis*, *Samolus valerandi*, *Riccia fluitans*, and *Groenlandia densa*.

Examined material: Adult ♀ (GR564-MZUF-CRU-E00737): one isolated LV (L = 735 µm, H = 458 µm, H/L = 0.62), no soft parts.

Description (from Mazzini et al. 2017): LV with a scalene trapezoidal shape. Maximum H at anterior cardinal angle, maximum L below the muscle scars. Slightly convex dorsal margin with marked dorsal protuberance and cardinal angles. Anterior margin rounded, posterior margin slightly pointed. Ventral margin straight, with slight convexity posteriorly. Central dorsal area characterised by a horizontal depression. Surface covered by a pattern of pits (fossae) on the whole surface. Internally, marginal zone narrow; vestibules equally developed; marginal pore canals not observed.

Remarks: The valve of *Marmocandona* sp. A differs from *M. zanichellii* for external ornamentation, valve morphology, and internal structure. Although both taxa display comparable relative height (H/L ≈ 0.59–0.63), they differ in absolute size and carapace sculpture. *Marmocandona* sp. A in absolute length (735 µm) is distinctly larger than *M. zanichellii* (LV 686 µm; RV 667 µm). Height is also greater in *Marmocandona* sp. A (458 µm) compared to both valves of *M. zanichellii* (432 µm LV; 395 µm RV). *Marmocandona* sp. A shows a finer and more uniformly organized punctation, with evenly distributed pore pits and consistent interspaces. In contrast, *M. zanichellii* exhibits coarser, slightly less regular punctation, with greater variability in pit diameter and spacing. *Marmocandona* sp. A appears slightly more inflated dorsally, whereas *M. zanichellii* shows a somewhat lower dorsal curvature, particularly in the right valve. The ventral posterior margin of *Marmocandona* sp. A is markedly inflated and blunty pointed and this is evident in internal view where the posterior vestibulum of *Marmocandona* sp. A is much larger and well developed than in *M. zanichellii*. However, it cannot be ruled out that it may belong to a female specimen of *M. zanichellii*, a species for which only males have been recorded so far (see above). It is also worth noting that the sampling sites for *Marmocandona* sp. A and *M. zanichellii* were separated by only ~23 km. The recovery of further specimens is required to either substantiate or reject this hypothesis.

Several additional surveys at La Commenda Spring revealed the presence of *Pseudocandona lobipes* (Hartwig, 1900), *Cypria ophthalmica* (Jurine, 1820), *Cyclocypris laevis* (O.F. Müller, 1776), *Prionocypris zenkeri* (Chyzer & Toth, 1858), and *Herpetocypris reptans* (Baird, 1835) (Rossetti et al. 2005 2006 2020; E. Bellavere, pers. comm.), but no specimens of *Marmocandona* sp. A were collected.

***Marmocandona* sp. aff. *zschokkei* (Wolf, 1920)**

(Fig. 7)

Sampling locality: Lago del Granduca, Punta degli Stretti Cave (cadastral code 250 GR/T), municipality of Monte Argentario, province of Grosseto, Tuscany region, latitude 42°25'54"N, longitude 11°10'17"E, elevation: 5 m a.s.l. The Punta degli Stretti Cave is an anchialine cave, close to a coastal lagoon; water conductivity of 'Lago del Granduca' at the date of sampling was 1954 µS/cm.

Among the subterranean water crustaceans, the Punta degli Stretti Cave has been found to host interesting species such as *Tethysbaena argentarii* (Stella, 1951), *Salentinella angelieri* Delamare-Deboutteville & Ruffo, 1952, *Diacyclops cosanus* Stella & Salvadori, 1954, as well as *Trichoniscus baschierii* Brian, 1953, an isopod endemic to this cave (Cavanna, 1998). Other ostracod species previously found in the cave include *Notodromas monacha* (O. F. Müller, 1776) and possibly *Cavernocypris subterranea* (Wolf, 1920) (Stella & Baschieri Salvadori, 1953).

Material examined: Adult ♀ (VP1825–MZUF-CRU-E00738): dissected soft parts kept on a sealed slide and valves used for SEM stored on a micropaleontological slide; adult ♀ (VP1831–MZUF-CRU-E00739): undissected and used for SEM. Specimens collected by FS, G. Tomasin, and D. Vagaggini on 9 May 2003. In addition to *M.* sp. aff.

zschokkei, *Fabaeformiscandona* cf. *alexandri* (Sywula, 1981) was present in the same sample (det. V. Pieri).

Measurements: VP1825–MZUF-CRU-E00738, LV: L = 755 µm, H = 427 µm; RV: L = 734 µm, H = 385 µm, H/L = 0.52. VP1831–MZUF-CRU-E00739, Cp: L = 765 µm.

Remarks: For *Marmocandona* sp. aff. *zschokkei*, the valve and soft part morphology closely resembled that of *M. zschokkei*. However, neutral nomenclature is currently preferred. This is due to the fact that the site where *Marmocandona* sp. aff. *zschokkei* was discovered is biogeographically atypical when compared to the known distribution of the nominal species, which is restricted to the Rhine, Rhone, and Danube drainage basins. As noted in the Introduction, previous records of *M. zschokkei* from Italy should be regarded as questionable.

Discussion: The growing number of subterranean taxa recently described across various zoogeographic regions (*e.g.*, Iepure et al. 2023; Külköylüoğlu et al. 2023; Hotèkpo et al. 2024; Issartel and Marmonier 2025a b; Rossetti et al. 2025; Zhai et al. 2025) has expanded our knowledge. However, available information on groundwater ostracod faunas remains limited, and the known diversity likely represents only the tip of the iceberg (Mori et al. 2025).

Several hotspots of subterranean ostracod diversity have been identified (see Hutchins et al. 2025), where geological, climatic, and ecological factors may have favored evolutionary radiation. However, our understanding of species diversity patterns and distribution is strongly affected by the "ostracodologist effect," analogous to the "rotiferologist effect" described by Fontaneto et al. (2012). This bias is further exacerbated by various impediments, particularly the so-called Racovitzan impediment (Ficetola et al. 2019), which imposes significant limitations on research conducted in groundwater environments.

Recent studies in Italy have provided more detailed insights into the distribution of subterranean ostracods, and in several cases, have led to the discovery of new species (Mazzini et al. 2017; Rossetti et al. 2022; Rossetti et al. in prep).

The two new species of subterranean ostracods belonging to *Marmocandona*, discovered in Italy and described here, have significantly increased the number of species in this genus. Notably, two of these species were initially assigned to other genera, in one case because the genus *Marmocandona* had not yet been established, but primarily due to taxonomic issues when identification relies predominantly on valve morphology. These structures can exhibit homoplastic traits in different lineages because of strong selection on adaptive traits to subterranean habitats (Iepure et al. 2023). For example, various Candoninae genera include species characterized by triangular or trapezoidal valves. In contrast, the morphological characteristics of soft parts are generally more informative and stable, although their use is exclusively limited to neontological research.

However, the species accommodated to the genus *Marmocandona* exhibit some variability in limb morphology, namely in chaetotaxy, for instance in the arrangement and length of setae and claws on appendages, as the number of t and z setae and the presence/absence of male bristles on A2. Further morphological differences may occur in the subdivision of En2 on A2 and L7, as well as in the shape of lobe h in the hemipenis. These traits represent a combination of plesiomorphic and apomorphic characters, resulting in a mosaic-like structural pattern.

It remains unclear whether such variability reflects substantial morphological plasticity within the lineage, combined with the isolation of species and populations and the resulting limited gene dispersal, or whether it implies the existence of distinct evolutionary branches. Interestingly, valve morphology and chaetotaxy appear to be highly variable, even within a single species, as demonstrated by the results of a morphological study of different populations of *Marmocandona zschokkei* (P. Marmonier, pers. comm.).

One of the most remarkable morphological traits is the presence of exceptionally long setae on the exopodite of A2 in *Marmocandona valentinae* n. sp. (Fig. 6B), a feature that, to our knowledge, has not been previously documented in candonids. This feature, rather that representing an adaptation to subterranean life (as these setae are not sensory structures), may instead reflect a plesiomorphic condition. Although only two specimens—one adult male and one adult female—were available for examination, the presence of this trait in both sexes (here only illustrated for the male) confirms that it is not a teratological anomaly.

Similarly, the Tuscan material assigned to *Marmocandona* sp. aff. *zschokkei* closely matches *M. zschokkei* in carapace outline, ornamentation pattern, chaetotaxy of A2, and general hemipenis structure, but differs in its smaller size (0.73–0.76 mm vs. 0.78–0.85 mm reported for females of *M. zschokkei*). This size reduction may represent geographic isolation from the main Rhine–Rhône–Danube populations and subsequent morphological divergence, or it may indicate the presence of a closely related but distinct lineage within a broader species complex. Moreover, the Punta degli Stretti Cave is an anchialine cave, charactreised by a fauna typical of transitional environments. This further supports the view that the habitat is not only biogeographically distinct from the German species, but

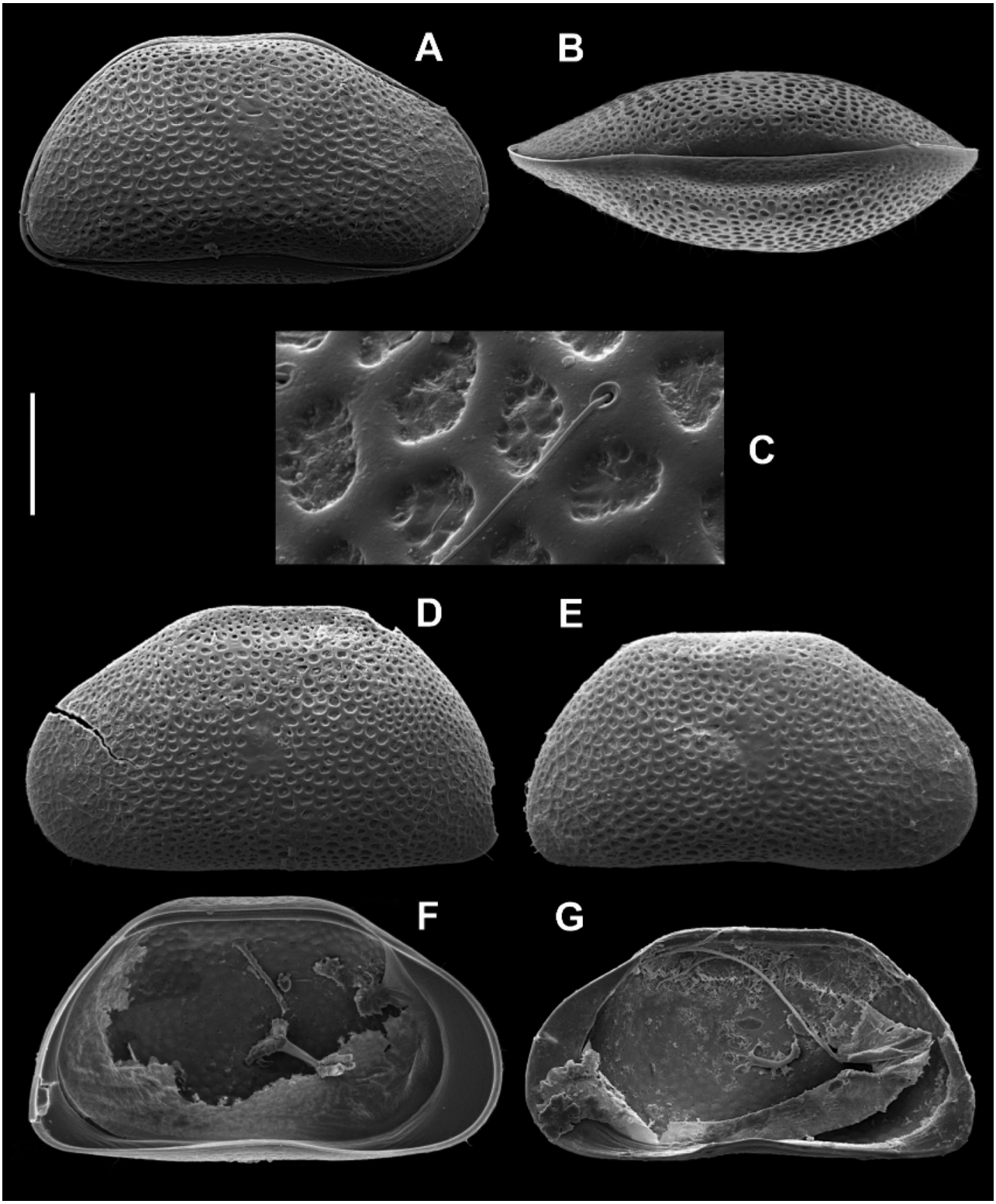

Fig. 7. A–C, *Marmocandona* sp. aff. *zschokkei* adult ♀ (VP1831–MZUF-CRU-E00739); D–G, *Marmocandona* sp. aff. *zschokkei* adult ♀ (VP1825–MZUF-CRU-E00738). A, carapace, right lateral view. B, carapace, ventral view. C, detail carapace, right lateral view. C, left valve, external view. D, right valve, external view. F, left valve, internal view. G, right valve, internal view. Scale bars: A, B, D–G = 200 μm; C = 20 μm.

is clearly Mediterranean and anchialine in character—thus far more atypical than one might assume based solely on its geographic location. Given the limited material available and the biogeographical disjunction, a conservative taxonomic approach is currently considered preferable. The taxonomic interpretation of *Marmocandona* sp. A and *Marmocandona* sp. aff. *zschokkei* warrants further consideration.

The single valve assigned to *Marmocandona* sp. A was recovered from a site geographically close to that which yielded the two male specimens of *M. zanichellii* n. sp. The single LV of *Marmocandona* sp. A shares with *M. zanichellii* a comparable trapezoidal outline and similar H/L ratio (0.62 vs. 0.61–0.62 in the LV of *M. zanichellii*), as well as a dorsal protuberance. However, it differs in the more pronounced convexity of the dorsal margin, the presence of a marked central dorsal depression, and differences in vestibule development. Because only males are currently known for *M. zanichellii*, whereas *Marmocandona* sp. A is represented by a single valve likely belonging to a female, these differences may reflect sexual dimorphism rather than species-level divergence. The close geographic proximity of the two sampling sites (~23 km) within the same hydrological district further supports this possibility, although confirmation requires additional material, in particular to study soft-part morphology.

Marmocandona zschokkei is widespread across several major European drainage basins, mainly inhabiting the hyporheic zones of large rivers and, more rarely, springs and wells (Meisch 2000; Prié et al. 2024). Although the valve and soft part morphology of the material here referred to as *Marmocandona* sp. aff. *zschokkei* closely resembles that of *M. zschokkei*, we refrain from assigning it to the nominal species. In addition to the biogeographical inconsistency mentioned above, the specimens are distinctly smaller than previously reported, with females of *M. zschokkei* ranging from 0.78 to 0.85 mm in length (Meisch 2000). This size difference may reflect long-term geographic isolation from the main Rhine–Rhône–Danube populations, potentially leading to morphological divergence, or it may indicate the presence of a closely related but distinct lineage within a broader species complex. Given the limited material available, which precludes a robust assessment of within-population variability and detailed morphometric comparison with confidently identified populations of the nominal species, a conservative taxonomic approach is therefore considered preferable. This caution is also warranted in line with evidence from molecular studies demonstrating that nominal ostracod species may conceal cryptic diversity (Karanovic 2015). Future integrative taxonomic studies may clarify whether the Tuscan material is conspecific with *M. zschokkei*, thus representing the southernmost record and a significant extension of its known distribution, or whether it belongs to a distinct lineage within a broader species complex.

Currently, the two new species and one putatively new species of *Marmocandona* from Italy are restricted to their type localities. This is also the case for the other species described in the genus, with the sole exception of *M. zschokkei*, as noted above. The occurrence of both endemics in geographically limited areas and widely distributed species is a shared feature among various subterranean genera of Candoninae (*e.g.*, *Mixtacandona* and *Schellencandona*). However, at least part of the high endemicity rate observed in these ostracod genera may be attributed to the scarcity of studies in groundwater environments.

Marmocandona zschokkei is the only species in its genus with documented fossil records, limited to the Holocene and to the following environments: spring calcareous tufa in Belgium (Van Frausum and Wouters 1990; Seret and Wansard 2022) and interstitial waters within sandy sediments of river channels in France (Muller et al. 2008; Salel et al. 2019; Lachenal et al. 2020). This considerably narrows the scope for reconstructing the colonization dynamics of subterranean waters by this group of ostracods.

CONCLUSIONS

The discovery of two new Italian species of *Marmocandona*, together with an additional putatively new taxon, highlights both the underestimated diversity of subterranean ostracods and the taxonomic challenges posed by morphological variability within the group. These findings expand the known morphological range of the genus, most notably through the identification of exceptionally long A2 exopodite setae, and underscore the limitations of valve-based taxonomy in groundwater taxa. Because most species appear narrowly endemic and molecular data are still lacking, our understanding of evolutionary patterns, biogeography, and species boundaries in *Marmocandona* remains incomplete. This study thus provides a crucial baseline for future integrative taxonomic work and emphasizes the need for more comprehensive sampling of groundwater habitats to reveal the true diversity and evolutionary history of subterranean ostracods.

List of abbreviations

Abbreviations and symbols used in the text and figures.

Valves

Cp: carapace.
RV: right valve.
LV: left valve.
L: length.
H: height.
W: width.
iv: internal view.
ev: external view.
lv: lateral view.
dv: dorsal view.

Soft parts

A1: antennule.
A2: antenna.
Md: mandible.
Mx1: maxillula.
L5: fifth limb (maxilliped).
L6: sixth limb (walking leg).
L7: seventh limb (cleaning leg).
CR: caudal ramus.
exo: exopodite.
En1-4: endopodal segments.
En2a and En2b: segments resulting from division of En2.
ya: aesthetasc on A1.
a: seta on A1 and Md-palp.
t1-3 and z1-2: setae on A2.
Y and y1-3: aesthetascs on A2.
G1-3, GM, Gm: claws on A2.
b, g, s1 and s2: setae on Md-palp.
f, and h1-3: setae and claws on L6 and L7.
g1 and g2: setae on L6.d1-2, dp and g: setae on L7.
Sa and Sp: anterior and posterior setae on CR.
Ga and Gp: anterior and posterior claws on CR.
b, h (h1 and h2), a: inner, middle and outer lobes of hemipenis.

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Availability of data and materials: This work and the new species name will be registered with ZooBank upon acceptance of the manuscript.

Consent for publication: All the authors consent to the publication of this manuscript.

Ethics approval consent to participate: Not applicable.

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