TAXONOMIC POSITION OF *HELICELLA (JACOSTA) SYRENSIS CARINATOGLOBOSA* HAAS, 1934

MARCO T. NEIBER[1] & KEVIN A. SCHLEGEL[2]

[1]Centre of Natural History, Zoological Museum, Universität Hamburg, Martin-Luther-King-Platz 3, 20146 Hamburg, Germany; [2]Hengstrücken 52, 37520 Osterode am Harz, Germany

Abstract *The taxonomic position of the insufficiently known nominal taxon* Helicella (Jacosta) syrensis carinatoglobosa *Haas, 1934 is discussed on the basis of genital morphology. Our results show that the taxon is a separate species that ought to be classified in the genus* Xerocrassa *Monterosato, 1892 and not in the genus* Trochoidea *Brown, 1827 as proposed in several recent publications.* Xerocrassa carinatoglobosa *is a narrow-range endemic restricted to the Akrotiri Peninsula in southern Cyprus.*

Key words Xerocrassa, Trochoidea, *Cyprus, systematics, genital system.*

INTRODUCTION

The as yet insufficiantly known nominal taxon *Helicella* (*Jacosta*) *syrensis carinatoglobosa* Haas, 1934 from Cyprus was originally described as a subspecies of the nominal taxon *Helix syrensis* Pfeiffer, 1846 and included in the subgenus *Jacosta* Gray, 1821 (supressed by ICZN Opinion 431 (1956)) of the genus *Helicella* Férussac, 1821 (type species by ICZN Opinion 431 (1956): *Helix itala* Linnaeus, 1758) on conchological grounds (Haas, 1934). Subsequently, Fuchs & Käufel (1936) regarded *Helix syrensis* (incl. *Helix syrosina* Bourguignat, 1876, *Helix eugoniostoma* Bourguignat, 1876, *Helix eminens* Westerlund, 1889, and *Helix syrensis* var. *exserta* Martens, 1889) from Syros Island (Cyclades, Greece) as the nominate subspecies of a 'Rassenkreis' widespread in the Eastern Mediterranean region (Euboea, Cyclades, Crete, Rhodes, Cyprus, Palestine). Based on genital characters of a single specimen of the nominal species *Helix* (*Jacosta*) *siphnica* Kobelt, 1883 from Sifnos Island (Cyclades), Fuchs & Käufel (1936) placed all taxa of the 'Rassenkreis' in *Trochoidea* Brown, 1827 (type species by monotypy: *Trochus terrestris* Pennant, 1777 (= *Helix elegans* Gmelin, 1791)) considered by these authors as a subgenus of *Helicella*. However, already Schuberth (1892) showed that *Helix syrensis* (sub *Helix* (*Xerophila* (*Jacosta*)) *syrosina*) has a dart apparatus consisting of a single dart sac and two bunches of mucus glands, a result confirmed by Mylonas *et al*. (1995). This configuration of the dart apparatus is shared by members of the genus *Candidula* Kobelt, 1871 (type species by absolute tautonymy: *Glischrus candidula* Studer, 1820 (= *Candidula unifasciata* Poiret, 1801)), in which the nominal taxon *Helix syrensis* is currently included (Triantis *et al*., 2008; Cuttelod *et al*., 2011).

Gittenberger (1991), in his revision of the Cyprian xerophilous hygromiids, showed that the "so-called" Cyprian subspecies of '*Helix*' *syrensis* can be divided into three groups, two of which were included in the genus *Helicopsis* Fitzinger, 1833 (type species by monotypy: *Helix striata* Müller, 1774) based partly on anatomical, but also on conchological and distributional data. The third group, including only the nominal taxon *Helicella* (*Jacosta*) *syrensis carinatoglobosa*, could not be classified with any genus by Gittenberger (1991) because preserved soft parts were unavailable to the author. Gittenberger (1991, p. 124) conjectured however that the taxon "most probably represents a separate species".

In the present study we propose that *Helicella* (*Jacosta*) *carinatoglobosa* should be placed in the genus *Xerocrassa* Monterosato, 1892 (type species by monotypy: *Helix seetzeni* Pfeiffer, 1847) and not in the genus *Trochoidea* as proposed in the recently published works by Cuttelod *et al*. (2011), Welter-Schultes (2012) and Vardinoyannis *et al.* (2012). Only Richardson (1980), without giving reasons or an explanation, previously affiliated the species with *Xerocrassa*, regarded by that author, however, as a subgenus of *Trochoidea*.

MATERIAL AND METHODS

This study is based on material kept in the following collections: FW, private collection of Frank Walther, Essen, Germany; MCZ, Museum

Contact author : mneiber@hotmail.de

of Comparative Zoology, Havard University, Cambridge, U.S.A.; MN, private collection of M.T. Neiber, Sehnde, Germany; SMF, Naturmuseum Senckenberg, Frankfurt a. M., Germany; ZMH, Zoological Museum, Universität Hamburg, Hamburg, Germany.

Living specimens were killed by immersing the crawling animals for 10–15 s in boiling water. Foot muscle tissue was conserved in 100% isopropanol and stored at -20 °C. The remaining soft parts were conserved in 70% ethanol. Shell measurements were taken using a digital calliper and measurements of the soft parts were taken with an ocular micrometre. The terminology of the individual parts of the genitalia follows Hausdorf & Sauer (2009). Shell whorls were counted according to the method described in Kerney *et al*. (1983).

Systematics

The family level classification follows Razkin *et al*. (2015).

Geomitridae Boettger, 1909

Helicellinae Ihering, 1909

Trochoideini Nordsieck, 1987

Xerocrassa Monterosato, 1892

Type species by monotypy *Helix seetzeni* Pfeiffer, 1847

Xerocrassa carinatoglobosa (Haas, 1934)

Helicella (Jacosta) syrensis carinato-globosa Haas, 1934: 18–20, fig. 2–4
Helicella (Trochoidea) syrensis carinato-globosa Fuchs & Käufel, 1936: 632
Trochoidea (Xerocrassa) syrensis carinatoglobosa Richardson, 1980: 245
'Helicella' carinatoglobosa Gittenberger, 1991: 101, 123
Trochoidea carinatoglobosa Cuttelod *et al*., 2011: 69
Trochoidea carinatoglobosa Welter-Schultes, 2012: 514, Q71
Trochoidea carinatoglobosa Vardinoyannis *et al*., 2012: 32

Holotype "Zypern, Akrotiri-Wald" (= Cyprus, Akrotiri forest), leg. G.A. Mavromoustakis, 21.04.1933, SMF 6709/1.

Paratypes 4 sh, "Akrotiri-Wald", leg. G.A. Mavromoustakis, SMF 6710 (only the three adult shells were designated as paratypes by Haas (1934)); 6 sh, "Zypern, zw. Kap Gata u. Kap Zevgari" (= Cyprus, between Cape Gata and Cape Zevgari), leg. G.A. Mavromoustakis, 20.04.1933, SMF 6711/6.

Material examined 2 sh, "Zypern, Kap Gata" (= Cyprus, Cape Gata), leg. G.A. Mavromoustakis ex coll. A. Zilch, 1937, SMF 64372/2; 8 sh, "Zypern, Akrotiri Wald," leg. G.A. Mavromoustakis ex coll. K.L. Pfeiffer, 1938, SMF 97538/8; 3 sh, Cyprus, Akrotiri forest, leg. G.A. Mavromoustakis, Dec. 1935, leg. G.A. Mavromoustakis ex coll. T. van Benthem Jutting, MCZ 64467; 7 sp and 1 sh, Cyprus, Akrotiri, near the shore of the salt lake close to Agios Georgios (34°36'15'' N, 32°56'25'' E), leg. H.N. Büscher, 01.10.2011, ZMH 79331; 27 sp and 7 sh, Cyprus, Akrotiri, Agios Georgios (34°36'11'' N, 32°56'23'' E), leg. B. Hausdorf, 30.06.2012, ZMH 79636; 6 sp and 1 sh, Cyprus, Akrotiri, near the shore of the salt lake close to Agios Georgios (34°36'15'' N, 32°56'25'' E), leg. H.N. Büscher, 01.10.2011, MN GEO-58.

Shell (Figs 1–2, Tab. 1) Depressed-conical, conical to conical-globular, sometimes scalarid; with 4.25–5.75 convex whorls; protoconch smooth, 1–1.25 whorls, corneous; teleoconch irregularly ribbed, whitish to cream-coloured, usually with brown bands that may be fused and that are (if present) always interrupted by the whitish coarse radial ribs; body whorl with a crenulated

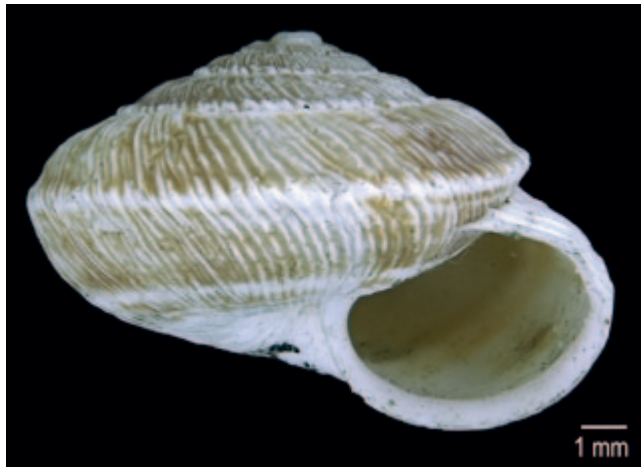

Figure 1 Holotype of *Xerocrassa carinatoglobosa* (Haas, 1934). "Zypern, Akrotiri-Wald" (= Cyprus, Akrotiri forest), leg. G.A. Mavromoustakis, 21.04.1933, SMF 6709/1.

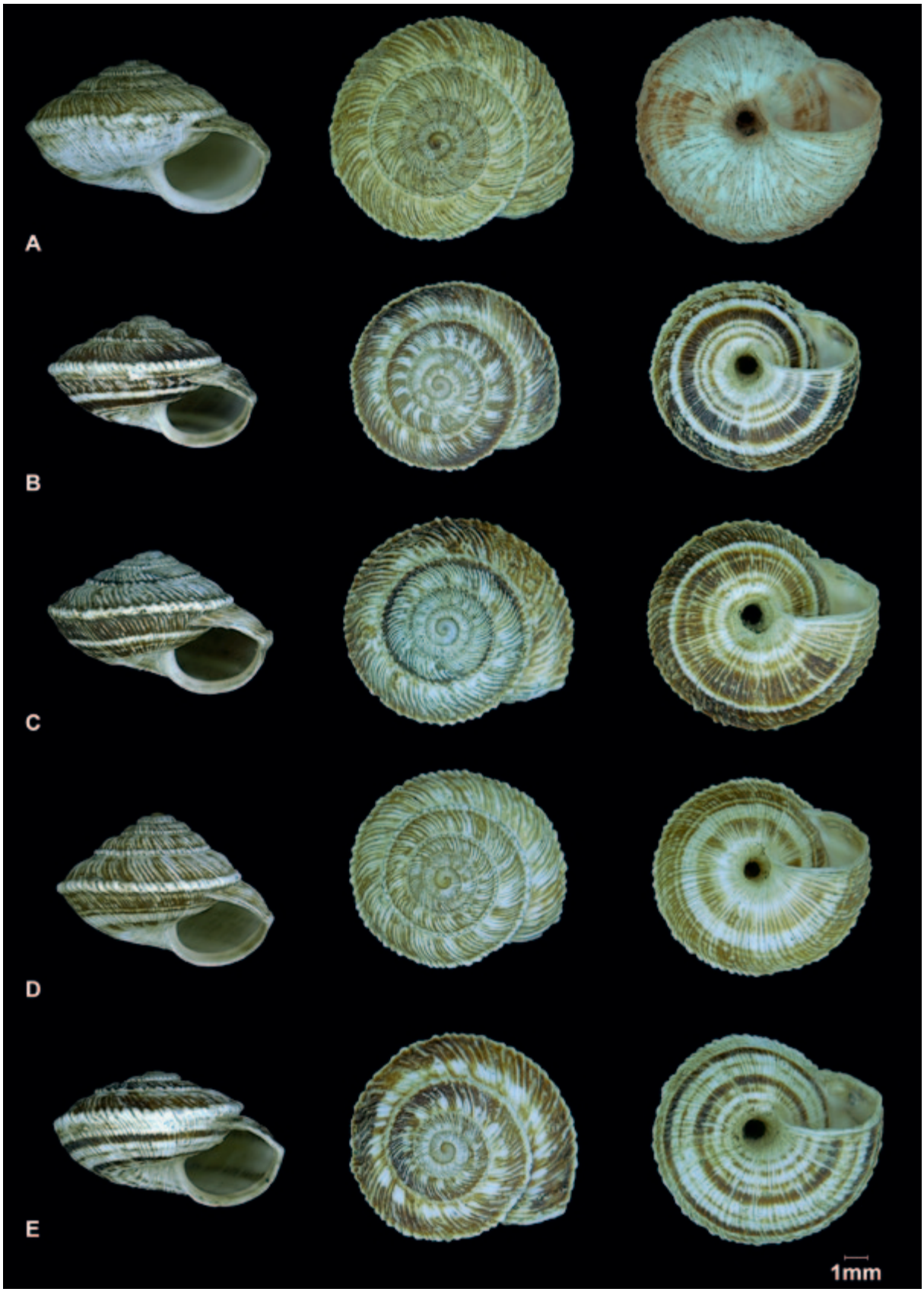

Figure 2 **A–E** Shell variability of *Xerocrassa carinatoglobosa* (Haas, 1934). All specimens from Cyprus, Akrotiri, near the shore of the salt lake close to Agios Georgios (34°36'15'' N, 32°56'25'' E), leg. H.N. Büscher, 01.10.2011, MN GEO-58.

Table 1 Shell measurement (in mm) and proportions of *Xerocrassa carinatoglobosa* (Haas, 1934).

Voucher	D		H		DU		D/H		DU/D	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
SMF 6709/1 (Holotype)	14.28	–	9.88	–	1.58	–	1.45	–	0.11	–
SMF 6711b (Paratype)	10.51	–	7.71	–	1.25	–	1.36	–	0.12	–
SMF 6711c (Paratype)	10.75	–	7.16	–	1.42	–	1.50	–	0.13	–
SMF 6711d (Paratype)	10.56	–	5.71	–	1.33	–	1.85	–	0.13	–
SMF 6711e (Paratype)	8.92	–	5.57	–	1.17	–	1.60	–	0.13	–
SMF 6711f (Paratype)	8.97	–	5.90	–	1.17	–	1.52	–	0.13	–
SMF 6711h (Paratype)	8.48	–	5.32	–	1.00	–	1.59	–	0.12	–
SMF 64372 (n=2)	12.22–12.94	12.58	9.47–10.45	9.96	1.58–1.17	1.38	1.24–1.29	1.27	0.09–0.13	0.11
SMF 79636 (n=34)	7.37–13.12	10.16	4.36–9.72	6.72	0.67–1.58	1.14	1.34–1.72	1.52	0.08–0.15	0.11
MN GEO-58 (n=7)	9.35–11.07	10.03	5.59–7.17	6.47	0.75–1.42	1.08	1.38–1.72	1.56	0.08–0.14	0.11

Abbreviations: D, maximum shell diameter; DU, diameter of umbilicus; H, shell height, n, number of specimens.

keel that sometimes almost disappears towards the aperture; aperture elliptical (slightly notched if keel reaches the aperture); upper insertion of the peristome slightly to distinctly descending; peristome sharp, upper margin not, basal and columellar margins slightly expanded, internally with a whitish rib; umbilicus moderately narrow (8%–15% of maximum shell diameter), hardly obscured by columellar margin.

Genitalia (Fig. 3, Tab. 2) Right ommatophoral retractor passing outside penioviducal angle. Penis innervated from the right cerebral ganglion. Dart apparatus symmetrical, consisting of two small accessory sacs (slightly shifted to one side of vagina) inserting just distal of the four mucus glands (each with 2–4 terminal branches), which are about twice as long as the accessory sac. Internal wall of vagina with several irregular longitudinal folds. Free Oviduct 0.23–0.34 times the length of vagina; vagina 1.12–1.43 times the length of penis; stalk of bursa copulatrix adhering to spermoviduct in situ, 0.57–0.64 times the length of flagellum and epiphallus together; bursa copulatrix ovoid-spherical, reaching albumen gland. Vas deferens (in situ) loosely attached by connective tissue to angle between female and male parts of genitalia. Flagellum somewhat shorter to about as long as epiphallus, penis retractor muscle inserting in the distal fifth to fourth of its total length. Penis/epiphallus boundary well-visible from the outside, marked by a slight constriction; penis translucent, wider than epiphallus, about 0.3 times the length of epiphallus. Penial papilla elongate-ovoid, with a subapical pore, towards its base with rugose annular streaks, circular in crossection, lumen between outer wall and wall of seminal duct filled with rather loose connective tissue, inner wall of seminal channel with longitudinal folds. Genital atrium short, sometimes laterally with an indistinct, small bulge-like dilatation with a single fold inside, inner wall with irregular folds, some of which running along the wall into the penis, some finer and a prominent fold into the vagina.

Habitat Reported from open forests and Mediterranean (xerophilous) shrub land. The specimens for this study were collected close to Agios Georgios church, aestivating on low

sclerophylous/halophilous shrubs growing on sandy soils (Fig. 4).

Geographic range Only known from the Akrotiri Peninsula, Sovereign Base Area Akrotiri (British Overseas Territory), Cyprus.

Remarks and comparisons According to Hausdorf & Sauer (2009), the genus *Xerocrassa* is characterised by possessing a symmetric dart apparatus consisting of two small accessory sacs (possibly homologous to the accessory sacs of other Hygromiidae) and usually four branched

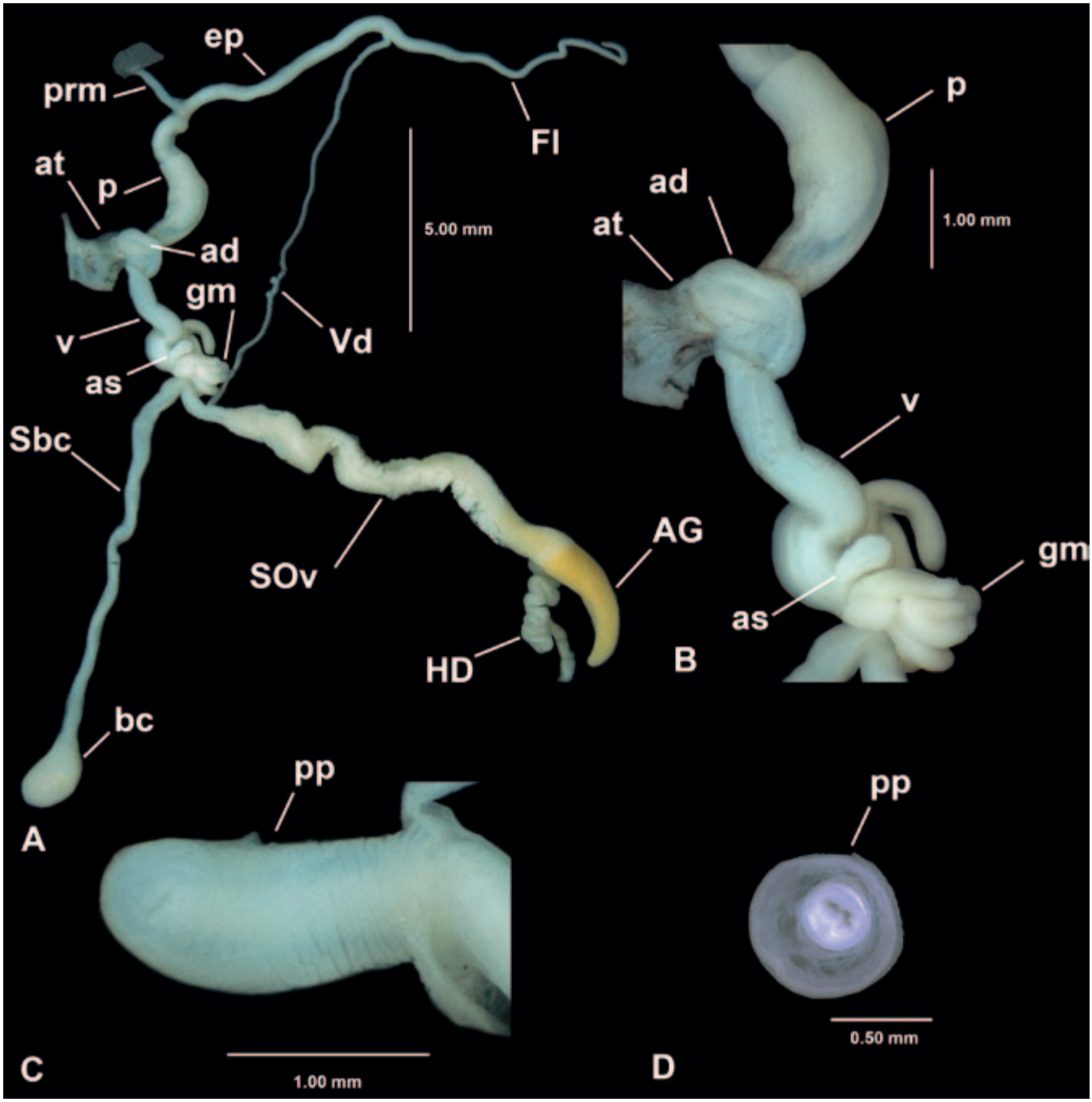

Figure 3 Genital system of *Xerocrassa carinatoglobosa* (Haas, 1934). Cyprus, Akrotiri, Agios Georgios (34°36'11'' N, 32°56'23'' E), leg. B. Hausdorf, 30.06.2012, ZMH 79636. **A–B** distal parts of male and female sections of genitalia. **C** penial papilla. **D** cross section through penial papilla. Abbreviations: ad, dilatation of genital atrium; AG, albumen gland; as, accessory sac; at, genital atrium; bc, bursa copulatrix, ep, epiphallus; Fl, flagellum; gm, mucus glands; HD, hermaphroditic duct; p, penis; pp, penial papilla; prm, penis retractor muscle; Sbc, stalk of bursa copulatrix; SOv, spermoviduct; v, vagina; Vd, vas deferens.

Table 2 Measurements of some parts of the genital system (in mm) of *Xerocrassa carinatoglobosa* (Haas, 1934).

Voucher	p	ep_d	ep_p	Fl	v_{ap}	v_{gm}	v_t	Sbc	fOv
ZMH 79636/1	2.8	2.1	7.2	7.1	4.0	4.2	4.5	10.5	1.1
ZMH 79636/2	2.6	1.8	6.6	8.3	3.7	4.0	4.9	10.1	1.1
ZMH 79636/3	2.5	2.0	6.4	6.0	3.2	3.8	4.2	8.2	1.4
ZMH 79636/4	2.6	2.0	6.6	6.4	2.9	3.2	3.9	9.3	1.1

Abbreviations: ep_d, epiphallus distal of the insertion of the penis retractor muscle; ep_p, epiphallus proximal of the insertion of the penis retractor muscle; Fl, flagellum; fOv, free Oviduct; p, penis; Sbc, stalk of bursa copulatrix; v_{ap}, vagina up to the base of vaginal appendiculae; v_{gm}, vagina up to the mucous gland; v_t, total length of vagina.

Figure 4 **A** Habitat of *Xerocrassa carinatoglobosa* (Haas, 1934) near the church Agios Georgios (34°36'15'' N, 32°56'25'' E), Akrotiri Peninsula, Cyprus.
B Aestivating specimens on sclerophilous/halophilus shrubs (Chenopodiaceae) (B). Photographs by H. N. Büscher (Belgium).

mucus glands inserting into the lumen of the vagina. An appendix on the genital atrium is missing or weakly developed, and the internal wall of the vagina is equipped with irregularly arranged folds. The genus *Trochoidea* differs from *Xerocrassa* by the presence of a well-developed appendix on the genital atrium, and four strong longitudinal folds on the internal wall of the vagina, two of which each surround the opening of an accessory sac, and fuse at their proximal and distal ends, respectively (Hausdorf & Sauer, 2009). The anatomical findings presented in this study (i.e. the structure of the dart apparatus, the absence of an atrial appendix and the arrangement of folds in the vagina) clearly indicate a placement of the nominal taxon *Helicella* (*Jacosta*) *syrensis carinatoglobosa* Haas, 1934 in the genus *Xerocrassa*.

Table 3 Ratios of some parts of the genitalia of *X. carinatoglobosa* (Haas, 1934) (*n*=4 individuals). For abbreviations see Table 2.

ep_p:p	ep_p:ep_d	ep_p:Fl	ep_p:v_t	v_t:p	v_t:v_{ap}	v_t:v_{gm}
2.5–2.6	3.2–3.7	0.8–1.1	1.3–1.7	1.6–1.9	1.1–1.3	1.1–1.2

Two other congeneric species, *X. cretica* (Férussac, 1821) and *X. nicosiana* (Gittenberger, 1991), also occur in Cyprus. Both are easily distinguished from *X. carinatoglobosa* by their rather finely striated to smooth shells, usually with a rounded distal half of the body whorl. Furthermore, *X. nicosiana* differs from *X. carinatoglobosa* according to Gittenberger (1991) and Fuchs & Käufel (1936) (mentioned as a transitional form between *X. cretica* and *X. seetzeni*) by possessing a vagina that is twice as long or more than twice as long as the penis, whereas this ratio does not exceed a value of 1.9 in *X. carinatoglobosa* (Tab. 3). *Trochoidea liebetruti* (Albers, 1852) and *T. pyramidata* (Draparnaud, 1805), the only other Trochoideini reported from Cyprus do not resemble *X. carinatoglobosa* conchologically and can easily be saparated from it by the presence of a well-developed atrial appendage (Hesse, 1934; Giusti *et al*., 1995). Some forms of *Xeropicta ledereri* are conchologically similar to *X. carinatoglobosa*, anatomically *Xeropicta* differs by the presence of two symmetrically arranged dart-bearing sacs with accessory sacs on the vagina and a large atrial appendage (Gittenberger, 1991).

Several *Xerocrassa* species from the eastern Mediterranea region possess a keeled shell (Brandt, 1959; Forcart, 1976; Mylonas *et al*., 1995; Welther-Schultes, 1998, 2012; Hausdorf & Sauer, 2009; Heller, 2009; De Mattia & Páll-Gergely, 2014). *Xerocrassa picardi* (Haas, 1933) from Israel is easily distinguishable from *X. carinatoglobosa*

by its pagoda-shaped shell and *X. tuberculosa* (Conrad, 1852) from Israel and Sinai differs from *X. carinatoglobosa* e.g. by its conical shell and much narrower umbilicus. *Xerocrassa pseudojacosta* (Forcart, 1976) has a wider umbilicus, a flatter lenticular shell and a less coarse radial sculpture, while *X. davidiana* (Bourguignat, 1863) has a hardly elevated spire, which is conical or sometimes step-like to slightly scalariform in *X. carinatoglobosa*. Among the keeled species from Crete, *X. franciscoi* Hausdorf & Sauer, 2009 differs by its much flatter shell, a finer radial sculpture and a much wider umbilicus. Anatomically *X. franciscoi* differs by the lower length ratios of proximal epiphallus/penis (ep_p/p), proximal epiphallus/distal epiphallus (ep_p/ep_d) and proximal epiphallus/flagellum (ep_p:Fl) (Tab. 3 and Hausdorf & Sauer, 2009). The shell of *Xerocrassa siderensis* (Maltzan, 1883) usually is rather blutly angled than keeled or rounded at the periphery, and the radial sculpture is much less prominent. Anatomically this species is easily distinguished by the significantly greater ep_p:Fl ratio (Tab. 3 and Hausdorf & Sauer, 2009). *Xerocrassa amphiconus* (Maltzan, 1883) differs from *X. carinatoglobosa* by the more depressed shell, finer radial sculpture and the very narrow, prick-like umbilicus and the greater ep_p:Fl ratio (Tab. 3 and Hausdorf & Sauer, 2009). The very variable *X. mesostena* (Westerlund, 1879) cannot be distinguished from *X. carinatoglobosa* on the basis of genital ratios, however in keeled populations of this species the radial sculpture is much finer in this species. *Xerocrassa lasithiensis* Hausdorf & Sauer, 2009, *X. subvariegata* (Maltzan, 1883) and *X. heraklea* Hausdorf & Sauer, 2009 from Crete may have an angulated body whorl, but the narrow umbilicus and the much more weakly developped radial sculpture readyly distinguish these species from *X. carinatoglobosa*. *Xerocrassa heraklea* differs anatomically in the lower ep_p/p ratio, *X. subvariegata* in the greater ep_p/ep_d ratio and *X. lasithiensis* in the greater ep_p/v_t ratio from *X. carinatoglobosa* (Tab. 3 and Hausdorf & Sauer, 2009). *Xerocrassa claudiconus* Hausdorf & Welter-Schultes, 1998 from Gávdos island has a flatter shell and finer radial sculpture, and a distinct widening of the flagellum towards its insertion point into the epiphallus (Welter-Schultes, 1998) is not observed in *X. carinatoglobosa*. Keeled forms of *X. siphnica*, endemic to Siphnos Island, have a flatter shell with a less coarse radial sculpture (Mylonas *et al*. 1995) and a comparatively well-developed atrial appendage, which is at most rudimentary in *X. carinatoglobosa*.

Most of the numerous species and subspecies of the tribe Trochoideini reported by Brandt (1959) from Libya are in need of revision. The taxa assigned to the subgenera *Xeroregima* Brandt, 1959, *Ereminella* Pallary, 1919, *Xeroptyca* Monterosato, 1892 and *Xeroamanda* sensu Brandt, 1959 not Monterosato, 1892 differ from *X. carinatoglobosa* anatomically in the markedly shorter flagellum (except for the nominal taxon *T.* (*Xeroregima*) *liebetruti klemmi* Brandt, 1959 which has a high, conical shell). In *Xerobarcana* Brandt, 1959 the flagellum is even rudimentary. All of the taxa from Libya assigned to *Xerocrassa* by Brandt (1959) have a rounded or at most slightly angled and finely striated body whorl, characteristics distinguishing all these forms readily from *X. carinatoglobosa*.

Although the endemic *Xerocrassa* radiation on Crete (Hausdorf & Sauer, 2009; Sauer & Hausdorf, 2009, 2010a, b, 2012; Sauer *et al*., 2013) and the phylogeography of *X. geyeri* (Soós, 1926) (Pfenninger *et al*., 1996; Pfenninger *et al*., 2003b) have been intensively studied and individual species have been included in various molecular studies (Pfenninger & Magnin, 2001; Pfenninger *et al*. 2003a; Steinke *et al*. 2004; Manganelli *et al*. 2005; Groenenberg *et al*., 2011; Razkin *et al*., 2015), the phylogenetic relationships within Trochoideini are, at present, not well understood. Brandt (1959) separates several groups as subgenera of *Trochoidea* including *Xerocrassa* mainly on the basis of differences in the length of the flagellum in relation to the epiphallus and shell ornamentation. Hausdorf & Sauer (2009), Sauer & Hausdorf (2009, 2010a, b, 2012) and Sauer *et al*. (2013) have shown that these characters are widely variable among species of the Cretan *Xerocrassa* radiation. Even a rudimentary flagellum, which is an autapomorphy of *Xerobarcana*, may be variable among species in the same genus (Gittenberger & Ripken, 1987). The anatomical characters of *X. meda* (Porro, 1840) and *X. gharlapsi* (Beckmann, 1987), the only two species widely accepted to belong to the subgenus *Xeroclausa* Monterosato, 1892 (type species: *Helix meda* Porro, 1840), fall into the limits of the generic concept of *Xerocrassa* as presented by Hausdorf & Sauer (2009). Aside from the separation of *Trochoidea* and *Xerocrassa*, which can be founded

anatomically as discussed above, we regard any further subdivision into genera or subgenera as premature until a detailed revision or molecular genetic analysis becomes available that ought to include the North African taxa along with the groups from the Near East, the Mediterranean region and Central to Western Europe.

Acknowledgements

We would like to thank Dr. H.N. Büscher (Halle-Zoersel, Belgium), Prof. Dr. B. Hausdorf (ZMH, Hamburg, Germany), Dr. R. Janssen (SMF, Frankfurt a. M., Germany) and A.J. Baldinger (MCZ, Cambridge, MA, U.S.A.) for the donation or loan of material and F. Walther for taking the photograph of the holotype.

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