NEW RECORDS OF NON-INDIGENOUS MOLLUSCS IN THE MEDITERRANEAN BASIN: TWO ENIGMATIC ALIEN GASTROPODS FROM THE TUSCAN ARCHIPELAGO (ITALY)

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Abstract *Two alien gastropod species, an assimineid and a succineid, were found in a plant nursery on Elba Island during field research aimed at gathering information on non-native terrestrial molluscs in the Tuscan Archipelago (central Italy). Neither species has been recorded in the Euro-Mediterranean area but their identification is not easy because of taxonomic uncertainty and the absence of a modern revision of these gastropod groups. Details of their anatomy are given for the first time and identification is attempted. The assimineid belongs to the Asian genus* Solenomphala *Martens 1883, but its specific identification could not be ascertained. The succineid is presumably an invasive species recorded from nurseries in North America, Hawaii and Australia, tentatively identified as* Succinea tenella *Morelet 1865. Both species were probably introduced with plants imported from tropical Asia. Since alien species are a potential threat to native biodiversity, their settlement in the National Park of the Tuscan Archipelago and other parts of Italy and Europe should be prevented.*

Key words *introduced species, plant nurseries,* Solenomphala, Succinea

INTRODUCTION

The National Park of the Tuscan Archipelago (northern Tyrrhenian Sea, Italy) has promoted activities aimed at maintaining or restoring ecosystem function, including LIFE projects focused on conserving nesting colonies of marine birds and eradicating introduced predators, such as rats and feral cats. The National Park recently joined a partnership of public authorities, universities and research centres that cooperate on a strategic project called Co.R.E.M. (Cooperation of Ecological Networks in the Mediterranean), financed by the European Union and focused on nature conservation and enhancement of sustainable activities and tourism. In this framework, the Park promoted field research on xenodiversity aimed at knowing the number and distribution of allochthonous plants and animals introduced to the seven major islands: primary aim of these activities was to define policy documents and guidelines to reduce the impact of alien on autochthonous species and on natural habitats.

Non marine molluscs were among the groups investigated. Fieldwork was carried out in the archipelago from 2010 to 2013 to gather information on the distribution and status of alien snails and slugs. This research was based on qualitative sampling in all available terrestrial and freshwater habitats, including plant nurseries and greenhouses: samplings included visual search and litter analysis. At least 15 of the 102 species occurring in the archipelago are not native (Table 1): six are extra-Palaearctic or non-Mediterranean species; seven are European or Mediterranean snails or slugs not native to the northern Tyrrhenian area or to the Tuscan islands; one is of uncertain origin; and one has unknown distribution pending specific identification (Manganelli *et al.*, 2014). Another eight species are suspected to be allochthonous: although they occur naturally in the northern Tyrrhenian area, they are found mainly in or near anthropogenic habitats in the islands of the Tuscan Archipelago. Because the information obtained about them is not definitive, their native presence in the archipelago could not be excluded. Finally, *Oxyloma elegans* is a native species that became extinct on Elba in the 20th century: the populations recently discovered on the island near plant nurseries are certainly derived from introduced specimens.

Nine alien gastropods are naturalised and occur in natural and semi-natural habitats, while the others were mainly collected in urban or non-natural habitats (gardens, greenhouses). Seven out of 15 alien species are reported for the first time from the archipelago. They include an assimineid and a succineid not hitherto recorded in the Western Palaearctic. We therefore devoted particular attention to these two species in order to clarify their identity and origin. However,

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Table 1 Checklist of alien (**A**), putative alien (**?A**), cryptogenic (**C**) and re-introduced (**R**) non-marine molluscs of the Tuscan Archipelago. CAP Capraia, ELB Elba, GIA Giannutri, GIG Giglio, GOR Gorgona, MON Montecristo, PAL Palmaiola, PIA Pianosa. Species with asterisks are of extra-Palaearctic origin; species occurring in anthropogenic habitats (A); species present in natural/seminatural habitats (N).

status	species	CAP	ELB	GIA	GIG	GOR	MON	PAL	PIA
	Family Assimineidae								
A*	*Solenomphala* sp.		A						
	Family Physidae								
A*	*Physella acuta* (Draparnaud 1805)		N						
	Family Succineidae								
A*	*Succinea* sp.		A						
R	*Oxyloma elegans* (Risso 1826)		A, N						
	Family Valloniidae								
A	*Vallonia costata* (Müller 1774)		A						
?A	*Vallonia pulchella* (Müller 1774)		A, N						
	Family Enidae								
?A	*Chondrula tridens* (Müller 1774)							A	
	Family Clausiliidae								
?A	*Papillifera papillaris* (Müller 1774)	A	A		A	A			A
	Family Ferussaciidae								
?A	*Cecilioides janii* (De Betta and Martinati 1855)	A	A			A			
?A	*Hohenwartiana hohenwarti* (Rossmässler 1839)		A						
A	*Ferussacia carnea* (Risso 1826)								A, N
	Family Punctidae								
A*	*Paralaoma servilis* (Shuttleworth 1852)	A	A, N		A, N	A, N	A, N		
	Family Helicodiscidae								
C	*Lucilla scintilla* (Lowe 1852)		A, N		A, N		A		
A*	*Lucilla singleyiana* (Pilsbry 1890)		A						
	Family Pristilomatidae								
A*	*Hawaiia minuscula* (Binney 1840)		A						
	Family Gastrodontidae								
A	*Zonitoides* sp.		A						
	Family Milacidae								
?A	*Milax nigricans* (Philippi 1836)	A, N	A	A		A	A		A
	Family Limacidae								
?A	*Lehmannia melitensis* (Lessona and Pollonera 1892)	A	A	A	A	A			A
A	*Lehmannia nyctelia* (Bourguignat 1861)		A						
	Family Cochlicellidae								
?A	*Cochlicella conoidea* (Draparnaud 1801)							A	
	Family Hygromiidae								
A	*Microxeromagna lowei* (Potiez and Michaud 1838)	A				N			
A	*Trochoidea elegans* (Gmelin 1791)			A					
A	*Monacha parumcincta* (Menke 1828)		A						
	Family Helicidae								
A	*Murella muralis* (Müller 1774)		A		A		A		

present uncertainty about the taxonomy of the two genera and the difficulty of obtaining well-preserved specimens of several species from a wide geographical range for more thorough research limited this study to a preliminary description of these alien species to facilitate their identification in the event of further findings.

Materials and Methods

Live specimens were drowned in water, then fixed and preserved in 75% ethanol buffered with $NaHCO_3$. Snail bodies were isolated by crushing the shells (*Solenomphala*) or simply by removing them from their shells (*Succinea*). They

were dissected under the light microscope (Wild M5A) using very fine pointed watchmaker's tweezers. Anatomical details were drawn using a Wild *camera lucida*.

Shell dimensions (number of whorls; shell diameter; shell height; aperture diameter; aperture height) were measured with a micrometer or calipers.

Radulae were extracted manually from the buccal bulbs, washed in pure 75% ethanol, mounted on copper stubs with electronconductive glue, sputter-coated with gold and photographed using a Philips 505 SEM.

Voucher specimens are kept in the F. Giusti Collection at Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente, University of Siena (Siena, Italy).

Key to acronyms used in figures: A anus; AG albumen gland; BC bursa copulatrix; BW body wall; DBC duct of bursa copulatrix; E epiphallus; ES eyestalk with eye; F foot; FC fertilization chamber; FG female gonopore; FHD first hermaphrodite duct; FO free oviduct; GA genital atrium; GAR genital atrium retractor muscle; I intestine; ME mantle edge; O operculum; P penis; POS prostatic portion of ovispermiduct; PP penial papilla; PR penial retractor muscle; PS penial sheath; RO renal oviduct; S snout; SR seminal receptacle; UOS uterine portion of ovispermiduct; V vestibule; VD vas deferens; VO vaginal outgrowth.

SPECIES DESCRIPTIONS

Clade Littorinimorpha Golikov & Starobogatov 1975

Superfamily Truncatelloidea Gray 1840

Family Assimineidae Adams & Adams 1856

***Solenomphala* sp.**

Material examined Elba Island: Portoferraio, Vivai dell'Elba S.r.l. (Portoferraio, Livorno) 32TPN0739, A. Benocci & M. Bianchi leg. 24.06.2011 (10 specimens and 1 shell), A. Benocci, G. Manganelli & L. Manganelli leg. 11.10.2011 (many specimens and 6 shells), A. Benocci, D. Barbato, G. Manganelli & L. Manganelli leg. 14.02.2013 (1 specimen and 2 shells)

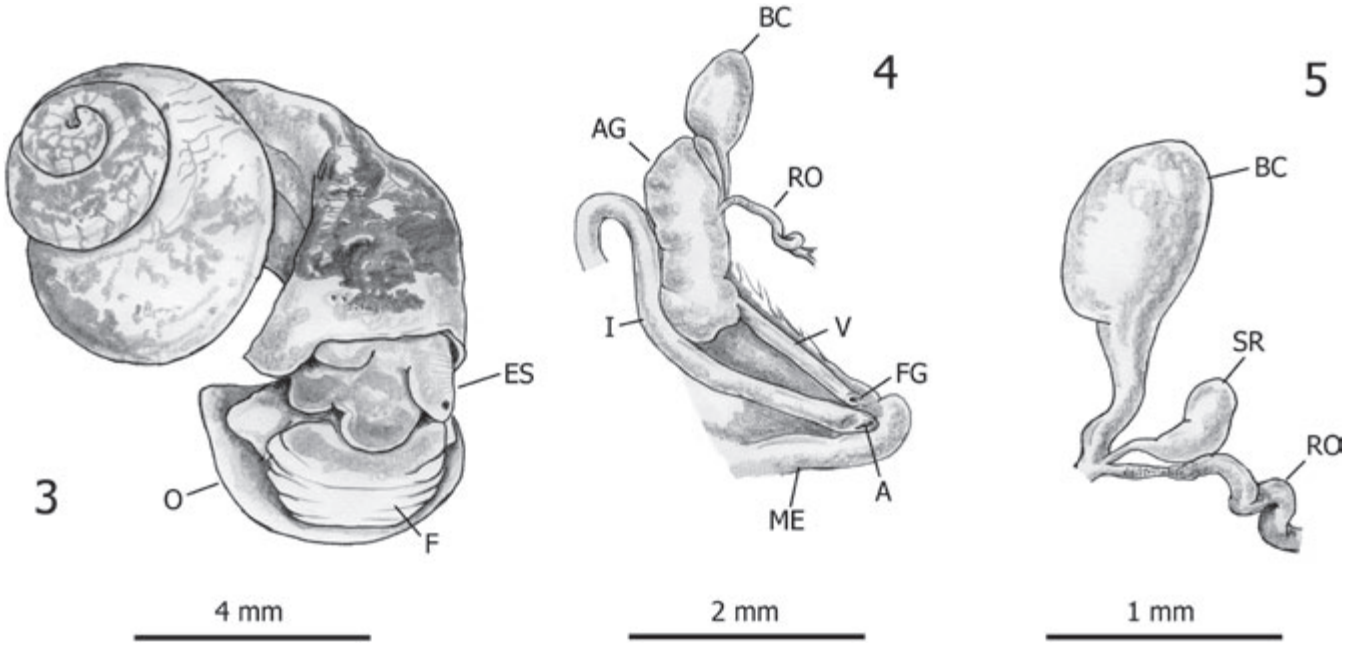
Shell (Figs 1–2): small, conical, robust, reddish yellow with about six slightly convex whorls separated by rather superficial sutures; last whorl about 2/3 of shell height; protoconch finely malleated; teleoconch finely ribbed and with distinct spiral microscopic cords; aperture pyriform; peristome slightly thickened; umbilicus punctiform. Maximum size: shell height, 5.9 mm; shell diameter, 3.9 mm; aperture height, 2.7 mm; aperture diameter, 2.2 mm; maximum number of whorls, 6.5 (7?).

Operculum Thin, pyriform, yellowish, paucispiral, internal side with simple muscle scar.

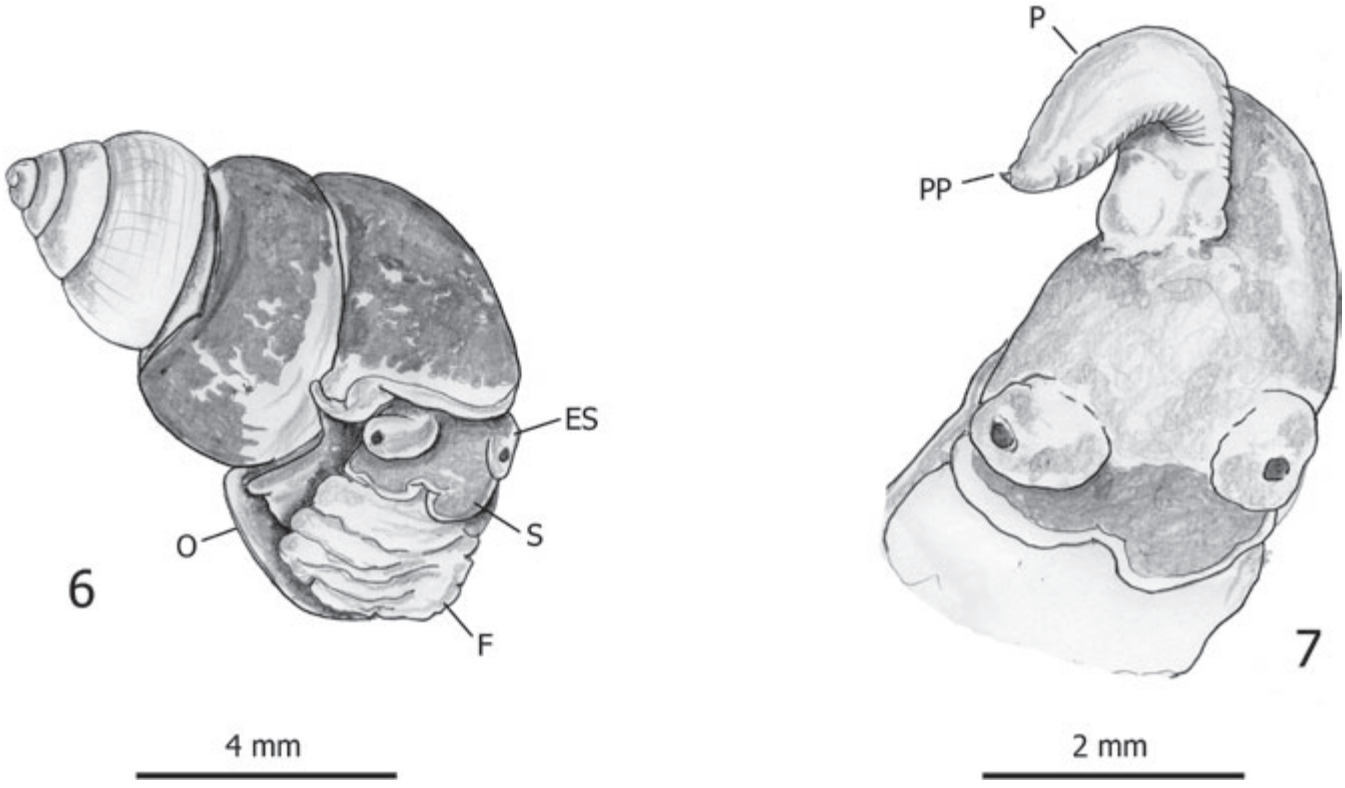
Body (Figs 3, 6) Preserved specimens show greyish head and sides; foot wide with simple whitish sole; external surface of pallial cavity and visceral sac more or less intensely black; head with eyestalks bearing eyes; pallial cavity with four gill filaments.

Female genitalia (Figs 4–5) Renal oviduct thin, forming loop with sometimes lobate walls

Figures 1–2 Two shells of *Solenomphala* sp. from Elba Island (Vivai dell'Elba S.r.l., Portoferraio), A. Benocci, G. Manganelli and L. Manganelli leg. 11.10.2011.

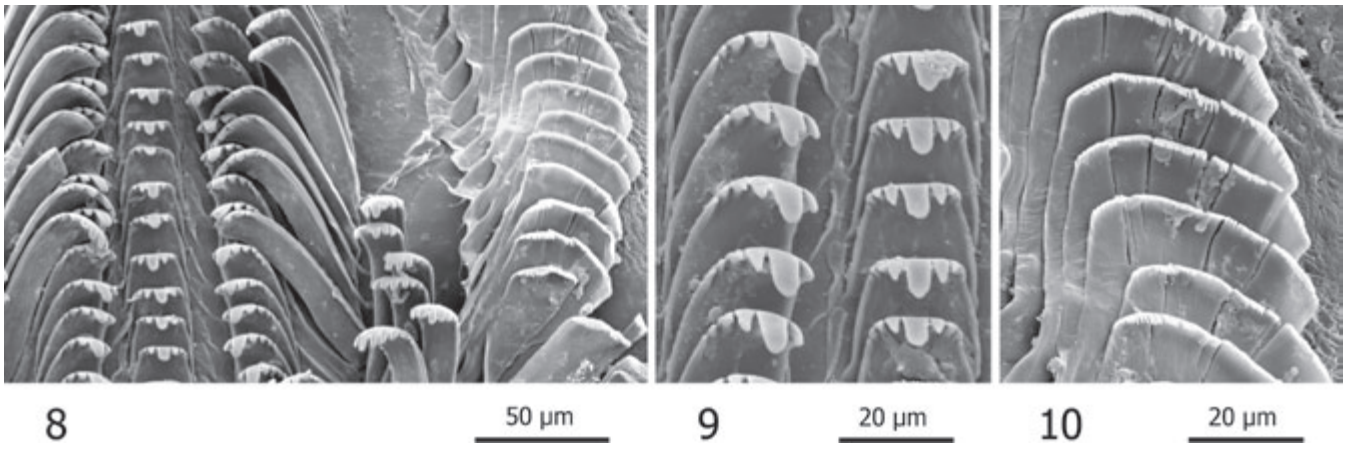


Figures 3–5 Female body and genitalia of *Solenomphala* sp. from Elba Island (Vivai dell'Elba S.r.l., Portoferraio), A. Benocci, G. Manganelli and L. Manganelli leg. 11.10.2011; female body (3); distal female genitalia (4–5).



Figures 6–7 Male body and genitalia of *Solenomphala* sp. from Elba Island (Vivai dell'Elba S.r.l., Portoferraio), A. Benocci, G. Manganelli and L. Manganelli leg. 11.10.2011; male body (6); penis (7).

near its end in pallial oviduct: bursa copulatrix very large, oval, its rather short duct arising from posterior portion of albumen gland, side by side with renal oviduct and ending flared in right side of anterior portion of bursa; seminal receptacle small sac-like with long slender duct arising from final portion of renal oviduct; pallial oviduct rather large with posterior



Figures 8–10 Radula of *Solenomphala* sp. from Elba Island (Vivai dell'Elba S.r.l., Portoferraio), A. Benocci, G. Manganelli and L. Manganelli leg. 11.10.2011; overall view (8); lateral and central teeth (9); second marginal teeth (10).

albumen gland and anterior capsule gland continuing in long slender vestibule with genital pore at tip.

Male genitalia (Fig. 7) Spermiduct thin, very long, convoluted; prostate gland rather large, bean-shaped, plurilobate; vas deferens thin; penis variably large and long, conical, with penial duct (penial portion of vas deferens) inside its left side and very small, apical penial papilla.

Radula (Figs 8–10) Taenioglossan with central teeth trapezoidal, lacking basal cusps and having cutting edge with seven denticles (large central and three on both sides progressively decreasing in size); lateral teeth longer than central, curved centre-wards, their cutting edge with seven denticles (large central; two on inner and four on outer side progressively decreasing in size); first marginal teeth rake-shaped, slightly curved centrewards, with long body and cutting edge with seven denticles; second marginal teeth as long as first marginal, very wide at apex and having long cutting edge with more than 50 very small denticles.

Remarks According to Dr. H. Fukuda (Okayama University, Japan; pers. comm.), this species belongs to the genus *Solenomphala* Heude 1882 (type species: *Assiminea* (*Solenomphalae* [sic]) *scalaris* Heude 1882) which, due to the absence of cephalic tentacles (only cephalic eyestalks with eyes present) and basal cusps on central teeth of radula, belongs to assimineid "Group 2" of Fukuda & Ponder (2003).

A definitive specific identification is impossible, due to lack of a modern revision of this group of assimineids. The Elban species is similar to *S. debilis* (Gould 1859) from Japan, *S. scalaris* (Heude 1882) from China and *S. taiwanensis* (Habe 1942) from Taiwan, having shell with reddish apex, but slightly larger and thicker than in these species, so that it is "probably not conspecific with them" (H. Fukuda, pers. comm. 30.07.12). Among these species, *S. debilis* and *S. scalaris* appear more closely related to the species from Elba due to the fact that they share with it a very long vestibule of the pallial oviduct, a rather short albumen and capsule gland and a wide and oval bursa copulatrix with wide, muscular duct. Only conspecificity with *S. taiwanensis* can therefore be categorically excluded, due to penis which in this species has a hooded tip (Pace, 1973: 44, pl. 9, fig. 6).

The species may have been introduced from somewhere in Asia with tropical plants. In line with what is known of the ecology of the genus *Solenomphala* ("they live in wet situations near small freshwater streams, e.g. small drains or crop fields": Fukuda & Ponder, 2003), our species lives in soil or litter and therefore seems to be substantially terrestrial, albeit limited to the frequently watered plant nursery in which it was discovered.

The species only occurs at high densities in a plant nursery at Portoferraio. Living specimens (including hundreds of juveniles) are found on the ground, at the base and on the sides of plant pots, and tend to gather in recently or frequently irrigated sites. Empty shells are found throughout in the nursery.

Figures 11–12 Two shells of *Succinea* sp. from Elba Island (Vivai dell'Elba S.r.l., Portoferraio), A. Benocci, G. Manganelli and L. Manganelli leg. 11.10.2011.

Clade Stylommatophora Schmidt 1855
Superfamily Succineoidea Beck 1837
Family Succineidae Beck 1837
***Succinea* sp.**

Material examined Elba Island: Portoferraio, Vivai dell'Elba S.r.l. (Portoferraio, Livorno) 32TPN0739, A. Benocci & M. Bianchi leg. 24.06.2011 (2 shells), A. Benocci, G. Manganelli & L. Manganelli leg. 11.10.2011 (2 specimens and many shells), A. Benocci, D. Barbato, G. Manganelli & L. Manganelli leg. 14.02.2013 (7 shells).

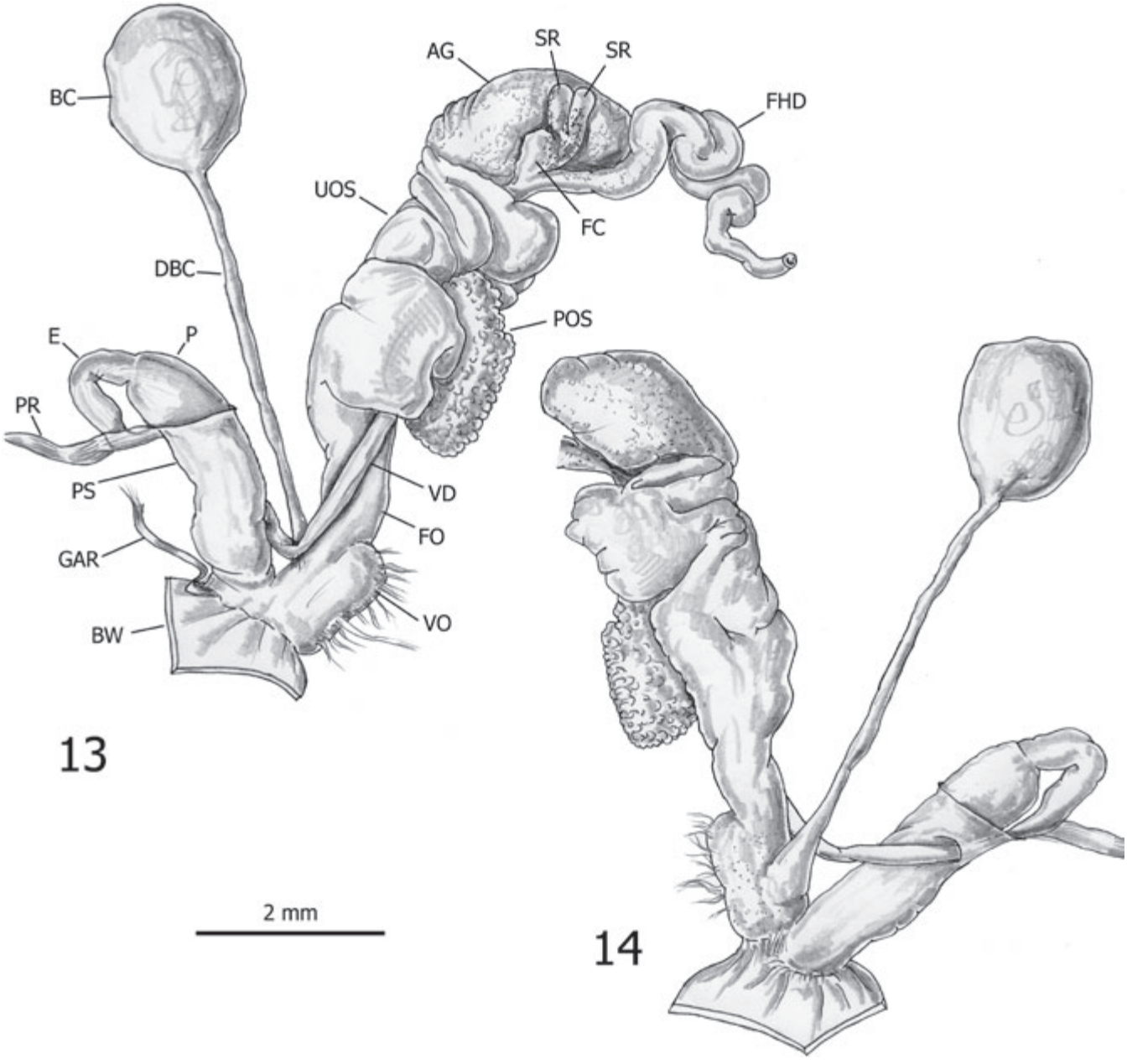
Shell (Figs 11–12): medium-sized, globose-conical, fragile, yellowish, transparent and glossy when fresh, with three-four rapidly expanding convex whorls, separated by rather deep sutures; last whorl about 3/4 of shell height; protoconch reddish, smooth; teleoconch with fine irregular collabral growth lines; aperture broad, ovate; peristome simple, slightly thickened; umbilicus closed. Maximum size: shell height, 13.9 mm; shell diameter, 8.8 mm; aperture height, 8.6 mm; aperture diameter, 5.7 mm; maximum number of whorls, 4.

Body Preserved specimens with sparse blackish pigmentation, foot greyish, pallial cavity and visceral sac intensely black.

Genitalia (two specimens dissected; Figs 13–16) gonad large, inside apical portion of visceral sac; first hermaphrodite duct wide in calibre and twisted; talon consisting of basal fertilization chamber and two large seminal receptacles with blackish external surface; second hermaphrodite duct (ovispermiduct) rather large.

Female distal genitalia Includes free oviduct, bursa copulatrix and vagina. Free oviduct short and wide. Bursa copulatrix rather large and round, with very long slender duct, initially flared. Vagina very short and wide. Last portion of free oviduct and vagina with lateral, sac-like to oblong outgrowth, on which many small tufts of muscle fibres end. Internal surface of vagina smooth.

Male distal genitalia Includes vas deferens, epiphallus and penis. Vas deferens long and slender entering penial sheath slightly before its end. Epiphallus short, slightly wider than vas deferens. Penis rather long and variably enveloped by an apically open penial sheath: in one case (not illustrated), penis and epiphallus completely enveloped while in the other (Figs 13–14), epiphallus free and penis enveloped for only 2/3 of its length; when enveloped by penial sheath, penis appears cylindrical, rather wide and as long as free oviduct and vagina; without



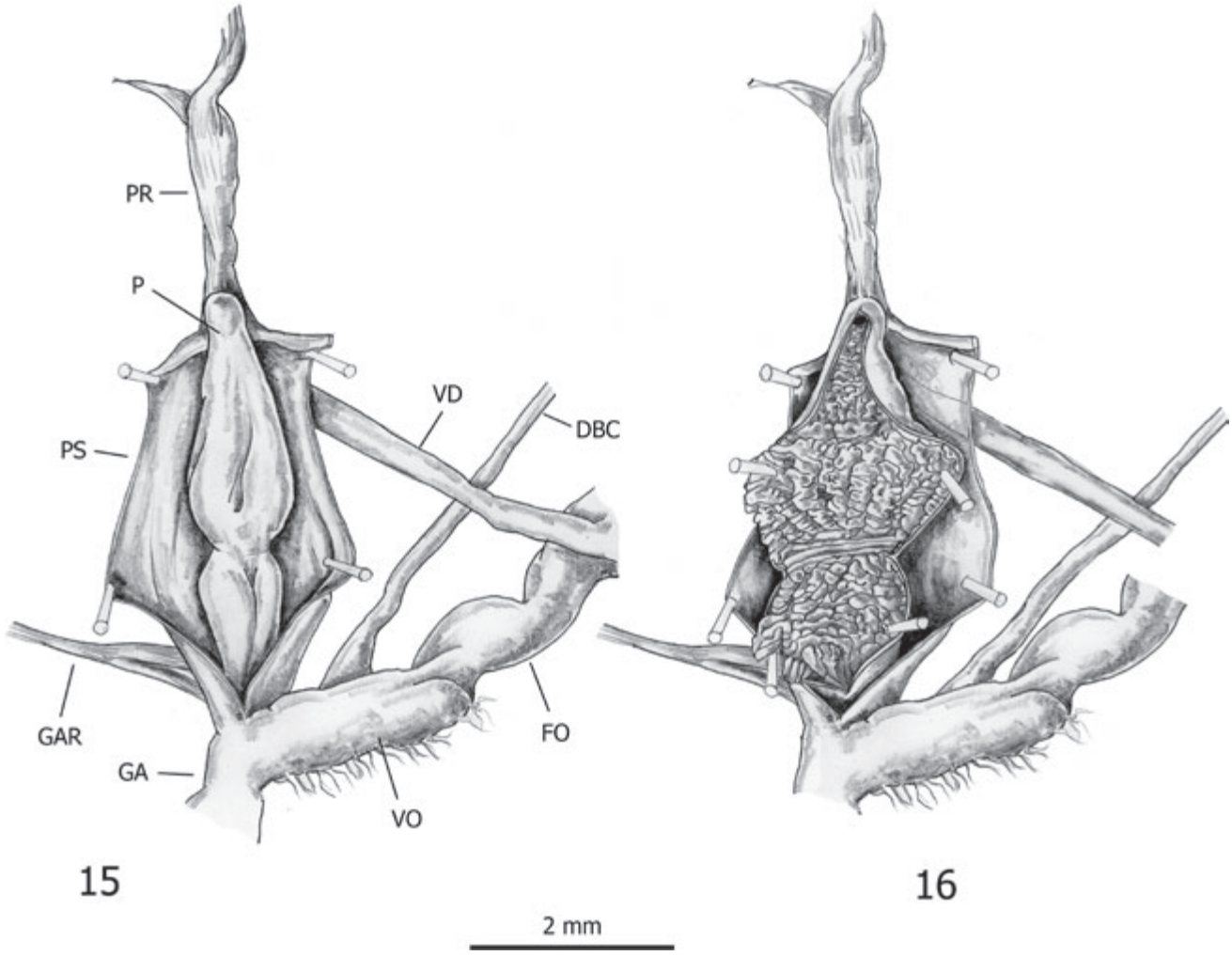
Figures 13–14 Distal genitalia of *Succinea* sp. from Elba Island (Vivai dell'Elba S.r.l., Portoferraio), A. Benocci, G. Manganelli and L. Manganelli leg. 11.10.2011.

penial sheath, penis reveals two cylindrical or pear-shaped parts, proximal slightly longer than distal, divided by constriction; entire internal penial surfaces irregularly corrugated with fringed pleats appearing as rows of irregularly shaped papillae. Penial retractor attached to vas deferens-epiphallus border and connected with penial sheath.

Genital atrium Very short.

Radula (two specimens examined; Figs 17–18) Consists of many rows of 59–61 teeth; central teeth with wide square basal plate from which longer mesocone and two shorter ectocones arise; lateral teeth with long large mesocone, very small, barely visible endocone and rather large ectocone; from about tenth lateral tooth of each row, ectocone splits into two cusps; from about fifteenth latero-marginal tooth of each row, ectocone splits into three or more (up to six) small cusps; extreme marginal teeth very small, rudimentary.

Jaw Elasmognathe: wide, robust and smooth, with median projection.

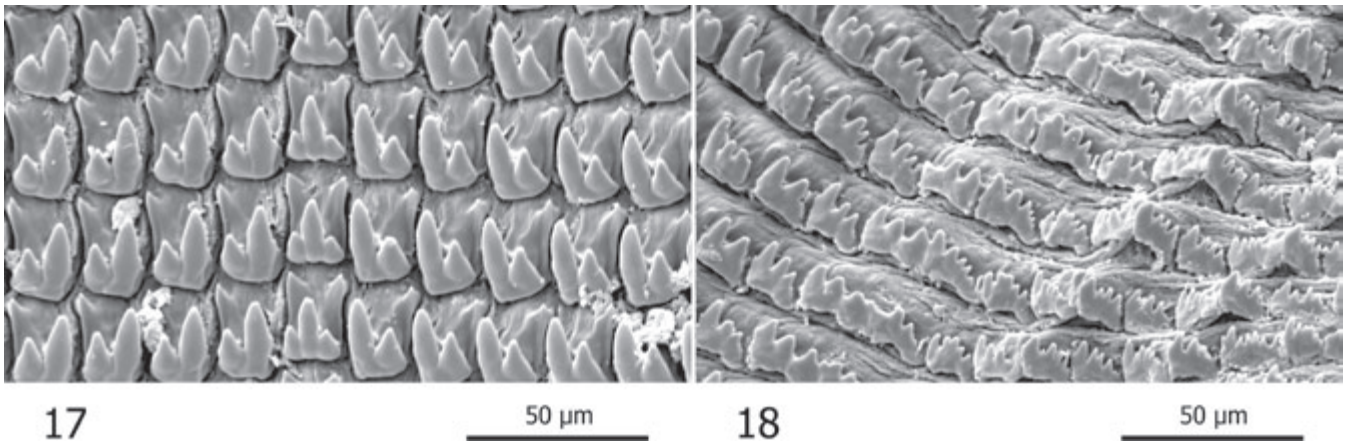


Figures 15–16 Distal male genitalia of *Succinea* sp. from Elba Island (Vivai dell'Elba S.r.l., Portoferraio), A. Benocci, G. Manganelli and L. Manganelli leg. 11.10.2011; penis with penial sheath open longitudinally (15); internal penial structure (16).

Remarks Robinson (1999) observed that succineids were extremely difficult to identify morphologically, especially if collected from locations beyond their native range and in the absence of knowledge of their native provenance. Indeed, many species have been described from all over the world, in most cases only on shell characters. Anatomy, when known in detail (very few cases), provides useful diagnostic characters, although some are subject to significant intraspecific variability.

Based on the features of their penial complex (epiphallus, penis, penial sheath and penial retractor), Elban specimens match species of *Succinea* Draparnaud 1801 (type species: *S. putris* Linnaeus 1758). Species assigned to this genus show a similar scheme of the distal genitalia, differing only in length and shape of vagina, epiphallus and penis and in relationships between penial sheath, epiphallus and penis (Schileyko, 2007). However, these features may even vary widely within single species, possibly due to different functional states and copulation (see, for example, the relationships between penial sheath, epiphallus and penis discussed in detail by Hoagland & Davis, 1987). This also happens in the Elban species: the two specimens dissected appeared quite different from each other: one showed epiphallus and penis completely enveloped by penial sheath (not illustrated); the other had a free epiphallus and a penis enveloped for only 2/3 of its length (Figs 13–14).

The Elban species is characterized by a lateral, sac-like to oblong outgrowth joined to the last portion of the free oviduct and the vagina. This structure has never been described in any



Figures 17–18 Radula of *Succinea* sp. from Elba Island (Vivai dell'Elba S.r.l., Portoferraio), A. Benocci, G. Manganelli and L. Manganelli leg. 11.10.2011; central and first lateral teeth (17); extreme marginal teeth (18).

anatomically studied succineid species and is a useful diagnostic feature for distinguishing the immigrant from European autochthonous species. Schileyko (2007) described a long tubular "atrial appendix" in two groups of East Asian succineids, namely *Boninosuccinea* Habe 1956 (type species: *Succinea punctulispira* Pilsbry 1901) and *Neosuccinea* Matekin 1956 (type species: *Succinea chinensis* Pfeiffer 1857) living in China and Japan and presumably spread to southern Asia, stating that this appendix "may be shifted to either male or female ducts" and that these two genera may be synonyms. There is no evidence that this appendix may be homologous to the structure described in Elban *Succinea*: the former is a long tubular organ with a sort of apical diverticulum, the latter is a lateral sac-like outgrowth of the distal female genitalia with many small associated tufts of muscle fibres.

Holyoak *et al*. (2013) reported an alien *Succinea*, very similar to the Elban species, from some mainly coastal sites in the Iberian Peninsula. They assigned it to an unidentified species of subgenus *Calcisuccinea* Pilsbry 1948 (type species: *Succinea campestris* Say 1817). It apparently lacks a vagina and vaginal outgrowth and has a long epiphallus, entirely wrapped by the penial sheath and almost forming a loop, because the penial retractor joins the terminal vas deferens with the penial sheath at the distal epiphallus. The two succineids therefore seem distinct, but prudence is appropriate in view of the high functional intraspecific variation in the genital structures of succineids.

Dr. G. M. Barker (Landcare Research, Hamilton, New Zealand), who is working on a monograph of succineids, hypothesized (pers. comm. 04.11.11) that the Elban species may correspond to an invasive species recorded from nurseries in North America (California and Florida: Holland & Cowie, 2006), Hawaii (Holland & Cowie, 2006; Hayes *et al*., 2007) and Australia (G.M. Barker in Hayes *et al*., 2007), often intercepted on horticultural products from Thailand (D.G. Robinson, in Hayes *et al*., 2007). Unfortunately, the taxonomy of this *Succinea* is still unclear: based on unpublished molecular genetic analysis, it has been considered conspecific with a species from the western Pacific by Holland & Cowie (2006), later only tentatively identified as "*Succinea tenella* Morelet" by Hayes *et al.* (2007) and "*Succinea tenella* Morelet, 1865" by Cowie *et al*. (2009). If the relationships between Elban *Succinea* and the invasive species reported by Holland & Cowie (2006), Hayes *et al*. (2007) and Cowie *et al*. (2009) are correct, our description is the first anatomical study of this succineid species.

This species seemed to be established in the plant nursery in which it was discovered, even if it did not seem as abundant as *Solenomphala* sp.. Only two living specimens were collected, but a large number of shells at various stages of growth were found all over the area, more or less in the same environment where *Solenomphala* specimens occurred.

CONCLUSIONS

Fragile animal communities such as those of islands may be considered at risk when new non-indigenous species arrive (Veitch & Clout, 2002; Genovesi & Carnevali, 2011). The latter do not

always have high invasive potential, but since it is impossible to estimate this potential *a priori*, it is a good rule to be alert as soon as the phenomenon is discovered (Genovesi & Shine, 2004). This is why we highlight the finding of the above two NIS: Elba Island is part of the National Park of the Tuscan Archipelago and therefore warrants maximum of attention to prevent the arrival and settlement of immigrants.

Another reason is to signal the arrival of the two immigrants in Italy. Indeed, it seems impossible that they are only on Elba Island, which is regularly supplied with every kind of merchandise from various parts of the Italian mainland. It is therefore extremely probable that the two species have already settled in other Italian regions, ready to invade other parts of the country and Europe.

Acknowledgements

Dr. F. Giannini (Parco Nazionale dell'Arcipelago Toscano) provided technical and financial support for the fieldwork and the project; Vivai dell'Elba S.r.l. consented to sampling in their plant nurseries; D. Barbato, M. Bianchi and L. Manganelli helped with fieldwork; Dr. G.M. Barker (Landcare Research, Hamilton, New Zealand), Dr. H. Fukuda (Okayama University, Japan) and Dr. W. Ponder (Australian Museum, Sydney, Australia) assisted with species identification.

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