

ON THE IDENTITY OF *HELIX DOHRNI* PAULUCCI 1882 AND *HELIX HILLYERIANA* PAULUCCI 1882, WITH THE DESCRIPTION OF TWO NEW *XEROSECTA* SPECIES (PULMONATA: HYGROMIIDAE) FROM SARDINIA (WESTERN MEDITERRANEAN)

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Abstract The genus *Xerosecta* (s.s.) is conchologically and anatomically investigated on the island of Sardinia (Western Mediterranean). *Xerosecta dohrni* (Paulucci 1882) is the most widespread and commonest species on Sardinia. Its reproductive system is characterised by a simple genital atrium without crests or knobs and a long penial flagellum. Paulucci (1882) described *Helix hillyeriana* from Decimomannu (in the province of Cagliari) and distinguished it from *H. dohrni* on the base of minor shell features such as a very weak keel and slightly more depressed shape. Nevertheless, no significant genital differences were found amongst keeled and depressed specimens and other populations elsewhere on Sardinia. Thus we consider these keeled populations as ecotypes of *X. dohrni* (i.e. form *hillyeriana*). Two new species are described by virtue of their distinctive conchological and anatomical features. *Xerosecta sandaliotica* n. sp. is easily distinguishable by its large genital atrium containing a large fungiform papilla. So far its distribution is restricted to the Sulcis-Iglesiente region (SW Sardinia). *Xerosecta brachyflagellata* n. sp. is known only from a single locality in the NE of Sardinia (Golfo Aranci, Olbia-Tempio province). It is distinguished by virtue of its remarkable short penial flagellum.

Key words *Xerosecta dohrni*, *Xerosecta sandaliotica* n. sp., *Xerosecta brachyflagellata* n. sp., Hygromiidae, Sardinia, Italy, nomenclature, taxonomy, systematics

INTRODUCTION

Xerosecta Monterosato 1892, is a genus of xerophilous Hygromiidae with Western-Mediterranean distribution: Algeria, Balearic Islands, French mainland, Italian mainland, Morocco, Sardinia, Spanish mainland, Portugal and Tunisia. It is represented by three subgenera (*Polloneriella* Alzona & Alzona Bisacchi 1940, *Xeromagna* Monterosato 1892, *Xerosecta* s.s.) and about 12 taxa of specific and subspecific rank (Alonso, 1975; Aparicio, 1982; Manganelli & Favilli, 1995). Most of them are locally endemic or have a strictly limited distribution, while only *X. (Xeromagna) cespitum* s.l. (Draparnaud 1801), is widespread, occurring throughout the greater part of the western Mediterranean, and also in Belgium where it is introduced (Puente, 1995).

In Sardinia (see Manganelli *et al.*, 1995) three taxa of *Xerosecta* are present: *Xerosecta cespitum arigonis* (A. Schmidt 1853), and the endemics *X. dohrni* (Paulucci 1882) and *X. hillyeriana* (Paulucci 1882). The latter two species, which were originally described by Paulucci as *Helix dohrni* and

H. hillyeriana, were doubtfully referred by subsequent authors to the genus *Ceruellia* Schlüter 1838 (Giusti & Castagnolo, 1983), and were eventually assigned to *Xerosecta* (Bodon *et al.*, 1995; Giusti & Manganelli, 1998). Additional information on their taxonomy, distribution, ecology and conservation status is not presently available (Falkner *et al.*, 2011a, 2011b).

Intensive collecting undertaken by the authors on Sardinia over the past eight years has provided sufficient specimens to allow us to investigate the taxonomy and systematics of the Sardinian taxa. As a result, the taxa introduced by Paulucci have been revised and two new species have been discovered and described.

MATERIAL AND METHODS

The snails were killed in water and then fixed in 75% ethanol. The body was removed from the shell and dissected under a Leica stereoscope. Anatomical details were drawn using a camera lucida. Empty shells were measured (n=15 for each population). The (type) material is deposited in the collections of the authors: Willy De

Mattia (WDM) and Francesco Mascia (FM), in the Malacological Collection of the Museum and Art Gallery of the Northern Territory (NTM), Darwin, Australia and in David Cilia collection (Santa Venera, Malta; DC). The number of dissected specimens (dsp) is also shown.

The following abbreviations are used for the anatomical parts: A, atrium; AG, albumen gland; BC, bursa copulatrix; CGA, crest-like structure of the genital atrium; DBC, duct of the bursa copulatrix; DG, digitiform glands; DSC, dart sac; DSO, dart sac opening; F, flagellum; FHD, first hermaphrodite duct; FO, free oviduct; G, glans or penial papilla; GA, genital atrium; LDL, left dorsal lobe; P, distal penis; PL, pleats; PN, pneumostoma; POS, prostatic ovispermiduct; PP, proximal penis; PR, penial retractor muscle; RLL, right lateral lobe; T, talon; SL, subpneumostomal lobe; UOS, uterine ovispermiduct; V, vagina; VD, vas deferens.

SYSTEMATICS

Family Hygromiidae Genus *Xerosecta* Monterosato 1982

The genus *Xerosecta* is well represented throughout the island of Sardinia and throughout a great variety of biotopes (Fig. 40). A taxon referred to *Xerosecta dohrni* proved to have a relatively variable shell morphology but consistent anatomical organisation and was found to be widely distributed across the island. During the anatomical analysis of *X. dohrni*, we unexpectedly came across a number of populations which were clearly separable from *Xerosecta dohrni* in terms of anatomical features.

Xerosecta dohrni (Paulucci 1882) (Figs 1–15, 41–45)

Helix dohrni Paulucci 1882

Helix hillyeriana Paulucci 1882

Cerनुella (?) *dohrni*: Giusti & Castagnolo, 1983

Cerनुella (?) *hyllieriana* [sic]: Giusti & Castagnolo, 1983

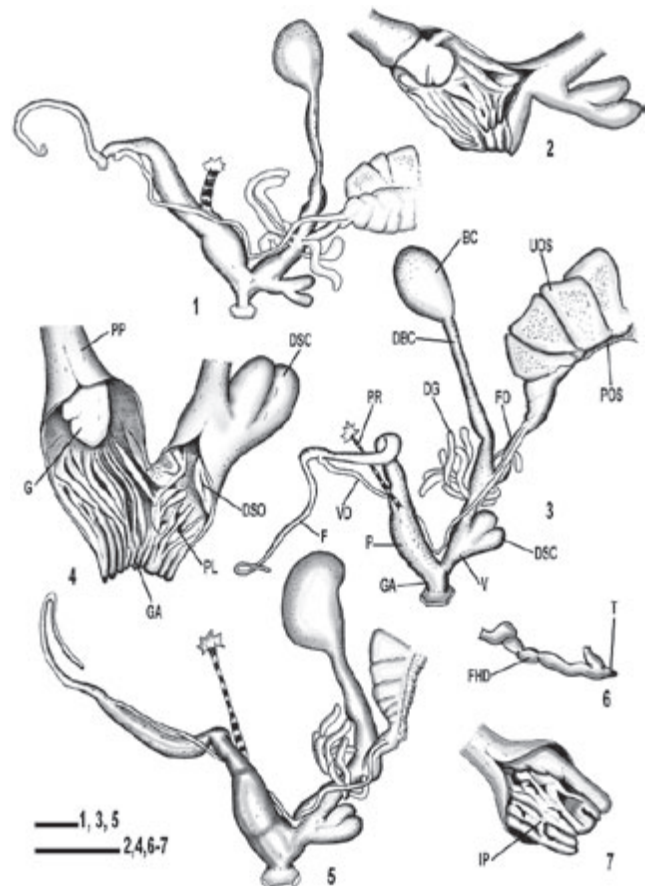
Xerosecta (s.s.) *dohrni*: Bodon *et al.*, 1995

Xerosecta (s.s.) *hillyeriana*: Bodon *et al.*, 1995

Xerosecta (s.s.) *dohrni*: Giusti & Manganelli, 1998

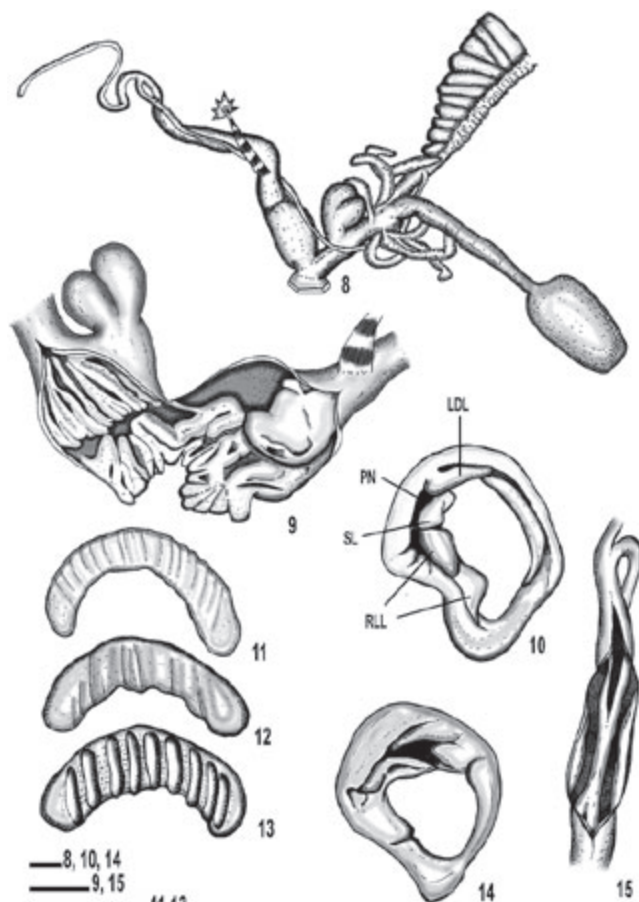
Xerosecta (s.s.) *hillyeriana*: Giusti & Manganelli, 1998

Xerosecta dohrni: Cianfanelli *et al.*, 2012



Figures 1–7 *Xerosecta dohrni* distal genitalia: 1 distal genitalia from San Gemilano (Sestu, Cagliari), 2 details of distal genitalia, 6 distal portion of first hermaphrodite duct with talon; 3 distal genitalia from Monte Corrasì (Oliena, Nuoro), 4 details of distal genitalia; 5 distal genitalia from Bosa Marina (Bosa, Oristano); 7 glans.

Material examined Cala Figu'era (Cagliari, province of Cagliari, Sardinia, Italy), 39°11'01.97"N 09° 09'39.91"E, 30 m asl, FM leg, 21.iv.2007, 2 dsp; Punta Sèbera (Domus de Maria, Cagliari), 39° 02'52.45"N 08°49'56.14"E, 947 m asl, FM leg, 14.iii.2008, 1 dsp; Coa Màrgini, Villagreca, (Nuràminis, Cagliari), 39°28'40.20"N 09° 00'28.08"E; 220 m asl., FM leg., 07.xii.2009 2 dsp; Monte Lora, (San Vito, Cagliari), 39°27'50.30"N 9°31'53.92"E; 370 m asl., FM leg., 14.xi.2010 6 dsp; Cala Regina (Quartu S. Elena, Cagliari), 39°10'58"N 09°21'7.95"E, 93 m asl, FM leg, 01.ii.2009, 1 dsp; Mari Pintau-Geremeas (Quartu S. Elena, Cagliari), 39°10'21.28"N 09°22'21.64"E, 11 m asl., FM leg., 01.ii.2009, 1 dsp; Simbiritzi (Quartu S. Elena, Cagliari), 39°15'44.91"N 09°13'9.90"E, 50 m asl, FM leg, 14.iii.2009, 1dsp; San Gemiliano (Sestu, Cagliari), 39°21'23.91"N 09°04'54.87"E, 130 m



Figures 8–15 *Xerosecta dohrni* distal genitalia, jaw and mantle edge: 8 distal genitalia; 9 details of distal genitalia; 13 jaw; 14 mantle edge from Rio San Giovanni Valley (Domusnovas, Carbonia-Iglesias); 10 mantle edge; 12 jaw from Monte Grighini (Siapiccia, Oristano); 11 jaw from San Gemiliano (Sestu, Cagliari); 15 inner structure of epiphallus from Pedru Saddu (Florinas, Sassari).

asl, FM leg, 14.iii.2009, 1 dsp; Mont' 'e Crèsia (Sinnai, Cagliari), 39°16'55.03"N 09°23'47.33"E, 673 m asl, FM leg, 01.ii.2009, 2 dsp; San Gregorio (Sinnai, Cagliari), 39°18'08.42"N 09°22'17.51"E, 328 m asl, FM leg, 01.ii.2009, 2 dsp; Sa Fogaia (Teulada, Cagliari), 38°53'49.19"N 08°38'32.87"E, 10 m asl, FM leg., 20.xi.2012, 2dsp; Marganai (Domusnovas, Carbonia-Iglesias), 39°21'41.20"N 08°34'11.25"E, 703 m asl, FM leg., 05.xi.2007, 1 dsp; Rio San Giovanni Valley (Domusnovas, Carbonia-Iglesias), 39°20'09" N, 08°37'54" E, 270 m asl, FM leg., 29.xi.2008, 12 dsp; Bolasci (Collinas, province of Medio Campidano, Sardinia, Italy), 39°39'38.06"N 08°50'16.68"E, 160 m asl. FM leg., 05.xii.2007, 3 dsp; Bruncu Masoni Bacas (Sanluri, Medio Campidano), 39°35'11" N 08°55'16"E, 170 m asl, FM leg, 20.xi.2012, 1 dsp; Monti Ollastu

(Segariu, Medio Campidano), 39°33'26.16"N 08°59'11.04"E, 168 m asl., FM leg., 05.xii.2008, 1 dsp; Conca Lada, (Villanovaforru, Medio Campidano), 39°36'54.28"N 08°53'08.80"E, 287 m asl., FM leg., 05.xii.2007, 2 dsp; Monte Arbu (Fonni, province of Nuoro, Sardinia, Italy), 40°03'34.79"N 09°19'53.56"E, 1450 m asl., FM leg., 20.V.2008, 1 dsp; Cala Fuili, Cala Gonone (Dorgali, Nuoro), 40°15'23.58"N 09°37'27.87"E, 15 m asl, WDM leg., 07.xi.2007, 4 dsp; Ispinigoli (Dorgali, Nuoro), 40°18'04"N 08°29'05"E, 130 m asl, WDM leg, 09.xi.2007, 3 dsp; San Giovanni Su Anzu (Dorgali, Nuoro), 40°19'16.18"N 09°36'58.30"E, 170 m asl, WDM leg., 16.xi.2007, 2 dsp; Monte Albo (Lula, Nuoro), 40°31'45.70"N 09°35'31.96"E, 730 m asl, WDM leg, 02.xi.2007, 2 dsp; Monte Corراسi (Oliena, Nuoro), 40°14'45"N 09°26'15"E, 1100 m asl, FM leg, 21.xi.2008, 2 dsp; Monte Gonare (Orani, Nuoro), 40°13'39.01"N 09°12'11.07"E, 1040 m asl, FM leg, 20.xi.2009, 3 dsp; Monte Novo San Giovanni (Orgosolo, Nuoro), 40°07'08.73"N 09°24'50.82"E, 1246 m asl, FM leg., 12.iii.2008, 1 dsp; Orboredu (Seui, province of Ogliastra, Sardinia, Italy), 39°41'58.15"N 09°21'55.51"E, 675 m asl, FM leg, 23.xii.2012, 1 dsp; Castello di Quirra (Tertenia, province of Ogliastra, Sardinia, Italy), 39°40'34.36"N 9°33'9.31"E, 655 m asl, FM leg, 18.x.2007, 5 dsp; Coddu Vecchju (Arzachena, province of Olbia-Tempio, Sardinia, Italy), 41°04'18.77"N 09°21'10.78"E, 100 m asl, FM leg., 12.iii.2010, 1 dsp; Isola Figarolo (Golfo Aranci, Olbia-Tempio), 40°59'15.20"N 09°38'37.88"E, 10 m asl, WDM leg., 14.xi.2008, 3 dsp; Santa Reparata (Santa Teresa di Gallura, Olbia-Tempio), 41°13'44.36" 09°10'3.69"E, 5 m asl, WDM leg, 14.xi.2008, 2 dsp; Bosa Marina (Bosa, province of Oristano, Sardinia, Italy), 40°18'04" N 08°29'05" E, 130 m asl, WDM leg, 11.xi.2007, 2dsp; Monte Grighini (Siapiccia, province of Oristano, Sardinia, Italy), 39°56'05.71"N 08°49'18.89"E, 617 m asl, FM leg., 08.x.2011, 1 dsp; Punta Lorio (Magomadas, Oristano), 40°15'19.88"N 08°29'20.75"E, 150 m asl, FM leg., 10.xii.2011, 1 dsp; Castel Medusa (Asuni, Oristano), 39°53'32.90"N 8°57'14.41"E, 150 m asl, FM leg., 11.xii.2011, 4 dsp; Sa Meliana (Nureci, Oristano), 39°49'32.67"N 08°59'10.73"E, 460 m asl, FM 05.xii.2007, 1 dsp; Pedru Saddu (Florinas, province of Sassari, Sardinia, Italy), 40°38'37.24"N 08°38'22.26"E, 440 m asl, FM leg., 10.ii.2010, 2 dsp; Pasciale (Padria, Sassari), 40°23'55.30"N 08°35'35.62"E, 217 m asl, FM leg. 13.ii.2010, 1 dsp.

Redescription Shell (Figs 46–50) dextral, conical and hairless. Protoconch pale brown to brown. Teleoconch brownish with 4–8 brown to dark brown bands either fragmented into spots and segments, or continuous. Some bands very strong and fused together or barely visible if not totally absent rendering shell almost uniform in colour. Traces of smaller, ill-defined bands present on lower part of last whorl. External, upper surface with variable sculpture, well-defined, irregularly spaced growth lines to almost smooth. Along last whorl growth lines, if present, clearly visible from suture as far umbilicus. Spire variable in height, from conical to almost globose, moderately conical to tectiform, almost lenticular in some populations, with 4.75 to 5.25 regularly increasing, rounded whorls separated by well-defined, more or less deep sutures. In some populations whorls display a very faint keel which may be strong and cord-like in some specimens. Protoconch consists of ca. 1 to 1.5 whorls. Final whorl large and rounded, more or less descending near aperture and contribution 0.75 of total shell height. Umbilicus open but narrow, wide, about 0.1 maximum, of shell diameter. Aperture rounded, slightly elliptical with faint thickening along inner side of last whorl. In strongly keeled populations, aperture elliptical with external margin angled at keel. Peristome interrupted, simple and thin, often with well-developed white-yellowish internal callous rib. Columellar margin reflected, somewhat thick.

Dimensions of shell Diameter 10.9 ± 0.8 mm (range 9.5–11.5 mm); height 8.2 ± 0.8 mm (range 7.4–10.5 mm) (n=20). Ratio D/H 1.3.

Body (Figs 10–14) Soft parts pale grey to brownish, slightly transparent. Mantle border (Figs 10, 14) pale slate grey with 5 lobes. Right lateral lobe triangular with a deep incision at half of its length; right dorsal lobe small and bean-like. Left dorsal lobe long and slender. Walls of pallial cavity colourless, without any stripes or spots; a strong pulmonary vein is visible. Jaw odontognathous, very variable in shape (markedly arched to almost straight), with many (10 up to 14) cross, smooth ridges (Figs 11–13). Right ommatophore retractor independent from both penis and vagina.

Genital anatomy (Figs 1–9, 15) General arrangement of genitalia semidiaulic monotrematic.

Convolute first hermaphrodite duct arises from multilobate gonad and ends laterally in a talon (Fig. 21). Albumen gland long and thin, connected to a wide ovispermiduct consisting of prostatic and uterine portions. Eventually, prostatic portion extends to a thin vas deferens terminating in the penial complex. Female portion of ovispermiduct joined distally to the free oviduct then turning into a vagina at the level of bursa copulatrix duct. Duct of bursa copulatrix usually wide, moderately long, uniform in diameter. This ends in a variable, oval to roundish, bursa copulatrix coloured greenish or occasionally orange in fresh specimens. Four tufts of digitiform glands arise from proximal portion of the vagina. These glands are variable in number (from 8–12), very rarely branched, and in shape and length also variable – from short and wide to long and slim. Proximal vagina (marked distally by its entrance to dart-sac complex) usually as long as free oviduct. Dart-sac complex arises from one side of vagina and is of the 0+2 type. It possesses a smaller, inner accessory sac and a larger, outer, dart-bearing stylophore. Outer stylophore has a thin wall, while inner stylophore possesses a thicker fibrous structure. Cavities of stylophores end side by side in a common opening into vagina and are bordered by 2 strong pleats. Other pleats, variable in number and depth, run longitudinally on inner surface of vagina reaching genital atrium as far aperture. No other inner structure present. Atrium funnel-like, but never swollen, and its walls are thin.

Penial complex consisting of flagellum, epiphallus (which extends from insertion of vas deferens to penial retractor muscle) and penis ending at atrium. Penial flagellum very long and slender, gradually narrowing towards tip. It is usually 1.2–1.3 times longer than epiphallus-penis complex as a whole. Epiphallus wide in diameter, but barely half length of flagellum; its internal walls show 3 parallel, longitudinal pleats which end at penial retractor level. Penis, without any muscular or glandular sheath, approximately $0.3 \times$ length of the epiphallus; swollen, thick-walled and housing the penial papilla. The *Xerosecta* (s.s.) type penial papilla (see Manganelli & Favilli, 1995: 342) is very variable in shape, from globose to elongated. Sometimes folded, with a subapical or apical opening emerging from the inner corpus cavernosus. External penial papilla sheath connects with penial inner walls by 2 thin frenula.

Ecology *Xerosecta dohrni* lives in a wide range of habitats which vary from basic limestone, marls and vulcanites (such as basalts) to acid substrates as hercynic granites. It is found from 0 to 1400 m asl. It colonises open fields and grassland usually associated with garigue or low-rise maquis, from seashores to mountains peaks. It is normally found grazing directly on grass and rarely on stems and branches or under stones and boulders. Strongly keeled populations are found on Palaeozoic limestone, under rocky debris at the foot of cliffs and slopes. These morphs seem to be directly related to these particular habitats, thus clearly adopting the status of ecotypes.

Its reproductive season seems to be strictly related to the rainy, humid period of late autumn where the chances to find living, active specimens are the highest. During the hot periods of the year the snails probably aestivate buried amongst roots and soil crevices totally disappearing from the surface. Mating behavior of *X. dohrni* has been recorded only in a range from mid october to mid december. During that period populations were composed of full-grown, mating specimens and immature, non-mating specimens. That being so, probably *X. dohrni* has a biennial life-cycle.

Distribution *Xerosecta dohrni* is endemic to Sardinia. It is widespread and common throughout the main Island, including most of the surrounding islets (Fig. 40).

Remarks Paulucci (1882) cited two depressed and keeled populations from "Monte Santo at 800 m asl" (Pula) and "San Pietro di Pula" (= Villa San Pietro) Sarroch (province of Cagliari) and assigned them, in a speculative way, to *Helix rozeti* Michaud 1833. This taxon is known to live in Algeria: "entre Mostaganem et les marabouts des Mesrah" (Michaud, 1833). Most probably Paulucci called this population *H. rozeti* because of its conchological similarity with the North African taxon which is also characterised by a depressed spire and a more or less keeled shape. Until now no data are currently available on topotypical *Helix rozeti* (Manganelli *et al.*, 1996: 356). Despite many recent collecting trips in the Sarroch-Monte Santo area, no markedly keeled and depressed *Xerosecta* specimens have been ever found. The nearest population found is from Punta Sèbera (Domus de Maria) about 3 km from

Monte Santo and it clearly possesses a rounded shell with the diagnostic anatomical features of *Xerosecta dohrni*.

Instead, four populations with depressed and keeled shells were found in other different localities on Sardinia: Rio San Giovanni Valley (Domusnovas, Carbonia-Iglesias) (Fig. 45); Monte Lora, 340 m asl, (San Vito, Cagliari); Castello di Quirra, 190 m asl, (Tertenia, Cagliari) and Castello di Medusa, 240 m asl (Asuni, Oristano). These localities are widely scattered along the mid-Southern Sardinian coast, more than 60 km separate each another, except for Monte Lora and Castello di Quirra (7 km). On these particular localities, characterized by an ecological gradient, *X. dohrni* has been collected all along a transept: from more shaded scrubby spots to xerophilous, open rocky slopes. The "keeling degree" of the shells followed exactly the same gradient: exclusively unkeeled specimens in the scrubby spots to exclusively markedly keeled specimens in open, limestone xerophilous slopes, with all the transition forms in the middle. As regards the anatomical features of genitalia (Figs 8–9, 13–14), no significant or consistent differences were ever found amongst keeled, depressed and unkeeled and conical specimens. Therefore, we refer these keeled, depressed populations/individuals as simple ecotypes of the widespread *X. dohrni*.

Paulucci (1882: 251) described and depicted *Helix hillyeriana* from Decimomannu (province of Cagliari) and *Helix dohrni* from the very generic location "prope Sassari" on the basis of a few empty shells. The lectotypes of both species, which are preserved in the Paulucci collection kept in the Museum of Natural History, University of Florence, were depicted by Giusti & Manganelli (1998: 329. Figs 25 and 26). The indications Paulucci gave about the localities are too general to allow an accurate field survey to collect topotypical specimens. Despite intensive collecting around Decimomannu, the nearest population of any *Xerosecta* species was at San Gemiliano (Sestu), 10 km ENE of Decimomannu in the Campidano Plain. Conchologically, this population perfectly matches the lectotype of *Helix hillyeriana* from Paulucci's collection (no. 11503): subglobose shell with a faint keel along last whorl. As regards the anatomical features of genitalia (Figs 1–2, 6) we found no significant difference with other populations elsewhere in Sardinia referable to *X. dohrni*. Therefore, we

propose *Helix hillyeriana* Paulucci as an ecotype, and thus a junior synonym of *Xerosecta dohrni*.

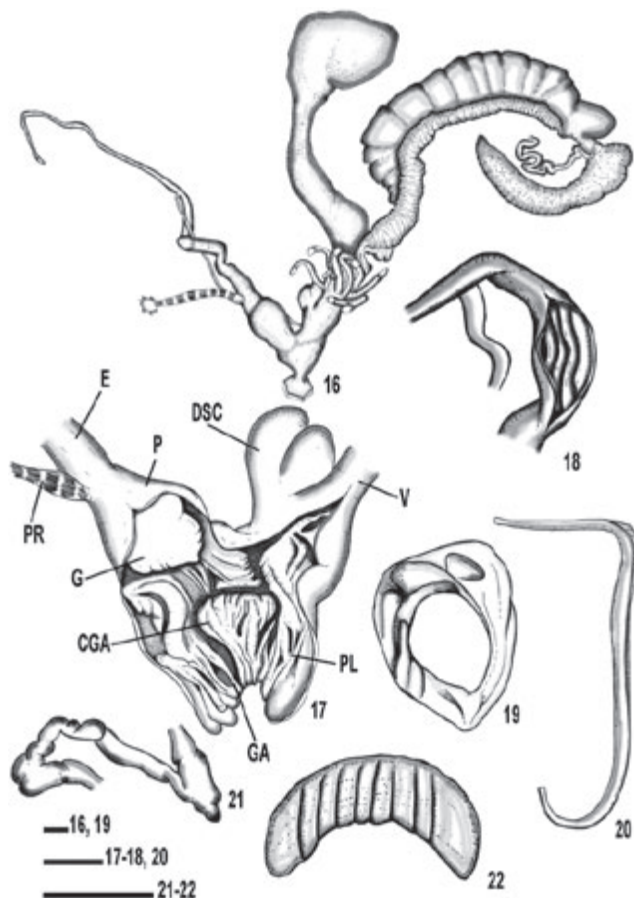
Our intensive collecting of material of *Xerosecta* brought to light many other populations all around Sardinia that share the same shell features that Paulucci indicated were unique of *Helix hillyeriana*. Despite this variability of the shell shape and its euryoecious ecology, the genitalia of *Xerosecta dohrni* are characterised by a lack of variation. This is the reason we also avoid any subspecific differentiation in nomenclature, often used for other extremely variable Mediterranean hygromiid species, such as *Trochoidea spratti* (Pfeiffer 1846) (see Giusti *et al.*, 1995: 395). Therefore, no definitive shell characters can explicitly distinguish between *dohrni* and *hillyeriana* at any rank.

Status and conservation Nonetheless being a widespread species all over Sardinia, its scattered and punctiform distributional pattern makes it Near Threatened as stated in Categories and Criteria of the IUCN Red List of Threatened Species (www.iucnredlist.org, Version 3.1).

Xerosecta sandaliotica new species
(Figs 16–31, 46–50)

Types Holotype (Figs 16–22, 46) and 4 paratypes all from Piscinas (Arbus, province of Medio Campidano, Sardinia, Italy), 39°32'24"N 08°27'10"E, 4 m asl, WDM & FM leg., 14.xi.2007, deposited in the NTM, registration numbers: P.53336 (Holotype) and P.53337 (Paratypes). Paratypes: 20 specimens (12 shells and 8 alcohol-preserved, 6 dsp) from Piscinas (Arbus) deposited in WDM collection; 20 specimens (10 shells and 10 alcohol preserved, 4 dsp) deposited in FM collection; 1 specimens deposited in DC collection.

Other (non-type) material examined (Figs 23–31, 48–50) Is Arenas (Arbus, province of Medio Campidano, Sardinia, Italy), 39°29'37"N, 08°24'51"E, 5 m asl, WDM & FM leg., 14.xi.2007, 15 shells and 4 dsp. Gùtturu Flùmini (Arbus, province of Medio Campidano, Sardinia, Italy), 39°36'13.68"N 08°28'14.17"E, 20 m asl., FM leg., 14.xi.2007, (12 shells and 8 alcohol-preserved, 3 dsp). Monte Linas (Gonnosfanàdiga, province of Medio Campidano, Sardinia, Italy), 39°26'53.12"N 08°37'7.21"E, 1200 m asl, FM leg., 19.xii.2007, (26 shells and 14 alcohol-preserved, 6 dsp).



Figures 16–22 *Xerosecta sandaliotica* n. sp. genitalia and anatomical parts of Holotype from Piscinas (Arbus, Medio Campidano): 16 genitalia (gonad excluded); 17 details of distal genitalia; 18 inner structure of epiphallus; 19 mantle edge; 20 spermatophore; 21 distal portion of first hermaphrodite duct with talon and 22 jaw.

Type locality Piscinas (Arbus, province of Medio Campidano, Sardinia, Italy), 39°32'24"N, 08°27'10"E.

Diagnosis *Xerosecta sandaliotica* is easily distinguishable from both the other Sardinian species of *Xerosecta* by virtue of both its conchological and anatomical features. Its genital atrium containing a large, crest-like structure is a unique feature among Sardinian *Xerosecta* species.

Shell (Figs 46–50) Dextral, conical and hairless. Protoconch pale brown to dark violet-brown. Teleoconch cream-white with 6–8 brown to dark brown bands; bands fragmented into spots and segments creating a zig zag pattern. Also traces of smaller, ill-defined bands on lower part of last whorl. External surface waxy with well-defined,

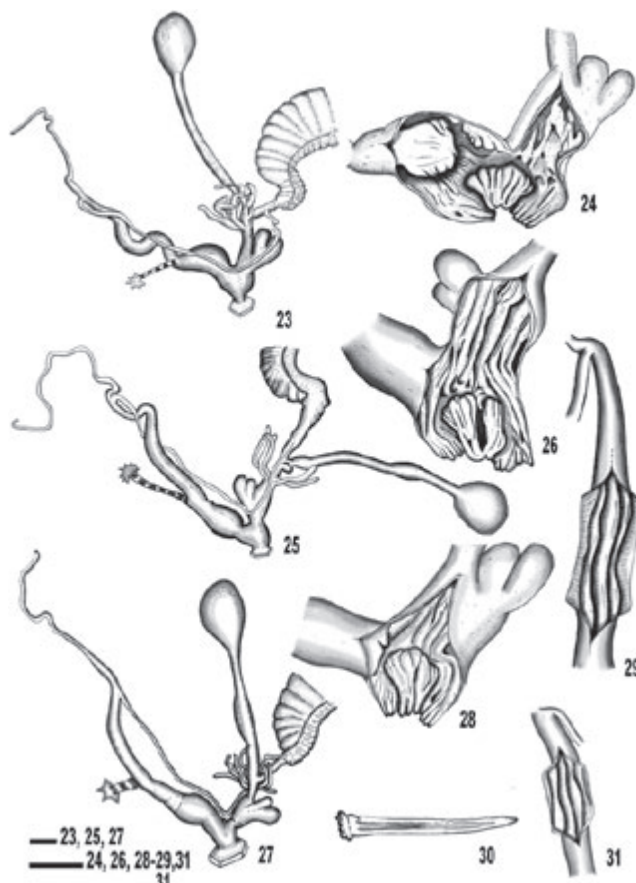
well-spaced growth lines. Along final whorl these growth lines are clearly visible from suture to umbilicus. High altitude populations (above 800 m asl) less waxy, with basic colouration dark brown on teleoconch thus suppressing usual band patterns. Spire conical to markedly conical with 5.3–5.75 convex, regularly increasing whorls separated by deep sutures. Protoconch consists of ca. 1.25 whorls. last whorl large and more or less descending near aperture and contributes 0.8 of total height of shell. High altitude populations have a relatively small final whorl (Fig. 49). Umbilicus is open but narrow and wide, about $1.15 \times$ maximum shell diameter. Aperture slightly elliptical with faint thickening along inner side of final whorl. Peristome interrupted and thin. Columellar margin somewhat thicker than peristome.

Dimensions of shell Diameter 15.2 ± 0.8 mm (range 14–16.2 mm); height 12.4 ± 0.7 mm (range 11.3–13.2 mm) (n=20). Ratio D/H: 1.2.

Body (Figs 19, 22) Soft parts dark grey to brownish; foot whitish. Mantle border (Fig. 19) pale slate grey with 5 lobes. Right lateral lobe triangular with a deep incision at half of its length; right dorsal lobe large. Left dorsal lobe long and slender. Walls of pallial cavity colourless with no stripes or spots, and pulmonary vein prominent. Jaw odontognathous, with many (8–10) cross ridges appearing squared in section (Fig. 22). Right ommatophore retractor independent from both penis and vagina.

Genital anatomy (Figs 16–18, 20–21, 23–31) General arrangement of genitalia semidiaulic monotrematic. Convolute first hermaphrodite duct arises from multilobed gonad and ends laterally in talon (Fig. 21). Albumen gland long and slim, and connected to wide ovispermiduct consisting of prostatic and uterine portions. Eventually, prostatic portion continues turning in thin vas deferens ending up in the penial complex.

Female portion of ovispermiduct joined distally to free oviduct, turning into vagina at level of duct of bursa copulatrix. Duct wide, moderately long, and uniform in diameter, ending in variable, oval to roundish, bursa copulatrix coloured greenish or sometimes orange in fresh specimens. A slender spermatophore has been found in bursa copulatrix (Fig. 20). This is "J" shaped with a small comb running from upper angle as far



Figures 23–31 *Xerosecta sandaliotica* n. sp. distal genitalia and dart: 23 distal genitalia from Is Arenas (Arbus, Medio Campidano); 24 details of distal genitalia; 25 distal genitalia from Gùtturu Flùmini (Arbus, Medio Campidano); 26 details of distal genitalia; 29 inner structure of epiphallus; 27 distal genitalia from Monte Linas (Gonnosfanàdiga, Medio Campidano); 28 details of distal genitalia; 30 dart; 31 inner structure of epiphallus.

as middle portion of main axis. Four to six tufts of digitiform glands arise from proximal portion of vagina; glands variable in number (6–8), long and slim, and never branched. Proximal vagina (distally marked by point of entry of dart-sac complex) usually as long as free oviduct. The 0+2 type dart-sac complex arises from one side of vagina, consisting of smaller, inner accessory sac plus larger outer, dart-bearing stylophore. Outer stylophore has a thin wall while inner stylophore shows a thicker fibrous structure. Cavities of stylophores end side by side in common opening into vagina and are bordered by 2 strong pleats. Other pleats, variable in number and depth, run longitudinally on inner surface of the vagina reaching the genital atrium. Moreover,

many pleats arise from internal walls of atrium, merging tightly together forming a very characteristic fungiform, crest-like structure (CGA) which occupies most of inner volume of atrium itself. Atrium always swollen, its walls thick and fibrous and provided with robust muscles.

Penial complex consists of flagellum, epiphallus (which extends from the insertion of vas deferens to penial retractor) and penis ending at atrium. Penial flagellum very long and slender, gradually narrowing at tip, usually 1.3–1.4×length of epiphallus-penis complex as a whole. Epiphallus wide in diameter and as long as half of flagellum; internal walls possess 3 parallel longitudinal pleats which end at penial retractor level. Penis, without any muscular or glandular sheath, approximately 0.5×epiphallus length, swollen, thick-walled, and housing penial papilla which is of *Xerosecta* (s.s.) type penial papilla (see Manganelli & Favilli, 1995: 342). Papilla often folded, with subapical or apical opening emerging from the inner corpus cavernosus. External penial papilla sheath connects with penial inner walls by 2 frenula.

Etymology Named after Sandalia, which is the ancient name for Sardinia.

Ecology *Xerosecta sandaliotica* has been found in two different habitats on Sardinia: along the coasts and on mountain peaks. The coastal populations are found in psammophilous environments consisting of huge systems of stable sand-dunes (Piscinas and Is Arenas of the Costa Verde, SW Sardinia) and amongst debris, under rocks and boulders, at the base of low coastal limestone cliffs (Gùtturu Flùmini). In the sand dunes, the species lives on the sand close to the roots of the dune herbaceous vegetation and its stems. These herbaceous spots are scattered as small islands in a “sea” of sand, and associated with dune scrubs, thickets and woods dominated by *Juniperus oxycedrus* L. subsp. *macrocarpa* (S. & S.) Neirl. and other sclerophyllous species. Probably the snails aestivate buried in the sand and among plant roots. *Xerosecta sandaliotica* shares the same habitat with other psammophilous snails such as *Ichnusomunda sacchii* Giusti & Manganelli 1998, *Ganula lanuginosa* (Boissy 1835) and the most widespread *Theba pisana* (Müller 1774). It is worthy of mention that the coastal dunes of Costa Verde from Scivu to Piscinas (Arbus, Medio

Campidano) are the widest coastal dunes anywhere in the Mediterranean, extending from the coast inland for about three kilometers, and hosting numerous botanical and zoological endemic taxa (Bacchetta & Pontecorvo, 2005; Angius *et al.*, 2011).

As mentioned above, *Xerosecta sandaliotica* has also been found in the pebbly orophilous garigue of Monte Linas, 1200 m asl. This mountainous region is also rich in rare botanical palaeoendemics such as *Castroviejoa montelinasana* Em. Schmid Galbany & al. (Asteraceae), *Anchusa montelinasana* Angius, Pontec. et Selvi (Boraginaceae), and characterised by a supramediterranean bioclimate, lower humid ombrotype (Bacchetta *et al.*, 2008).

Distribution *Xerosecta sandaliotica* is known only from the subsector Iglesiasiente of the Sulcitano-Iglesiente in the SW part of Sardinia where it occurs sympatrically with *X. dohrni* which has also been found in this region (Arbus, VS; Marganai, Iglesias, CI; Rio San Giovanni, Domusnovas, CI) (Fig. 40). *Xerosecta sandaliotica* seems to be restricted to this part of the Island. During the Tertiary this region was separated from the rest of the main island by marine intrusion and then, in the Quaternary, by alluvial floods along the eastern side by the Campidano plain and along the southern side by the Cixerri depression.

The Iglesiasiente has recently been recognised as biogeographic sub-sector because of the relatively high number of exclusive endemics occurring there (Bacchetta & Pontecorvo, 2005). As with *X. sandaliotica*, many palaeo-endemic taxa are present both in coastal environments as at the highest peaks of the sector e.g. the vascular plant *Genista sulcitana* Vals. (Fabaceae), which is distributed from 200 up to 1000 m asl and *Probatiscus ebeninus cassolai* Ardoin 1973 (Coleoptera: Tenebrionidae), which occurs from the dunes of Piscinas to the peaks of M. Linas.

Remarks *Xerosecta sandaliotica* shows a remarkable consistency in its anatomical features, which renders it easily distinguishable by virtue of its large genital atrium containing a large fungiform, crest-like papilla. Other Sardinian *Xerosecta* species have either a normally developed atrium without any supplementary structure (*Xerosecta dohrni*, *X. brachyflagellata*.) or a slightly developed atrium but containing only a delicate pleat

(*X. cespitum arigonis*). Nevertheless, *X. cespitum arigonis* is easily distinguishable from all the other Sardinian species by virtue of its colour patterns, larger shell, different shape and wider umbilicus.

The crest-like papilla has already been considered as an essential crucial taxonomic feature by other authors (Manganelli & Favilli, 1995). In fact *Xerosecta giustii* Manganelli & Favilli 1995 was mainly defined by the presence of a similar strong pleat-like papilla in the atrium. Although *X. sandaliotica* and *X. giustii* partially share this genital character, many other fundamental conchological, anatomical, biogeographical features separate the two species. For a comparative review of the eastern species of the genus *Xerosecta* (mainland Italy and southern Europe) see Manganelli & Favilli (1995: 347–351).

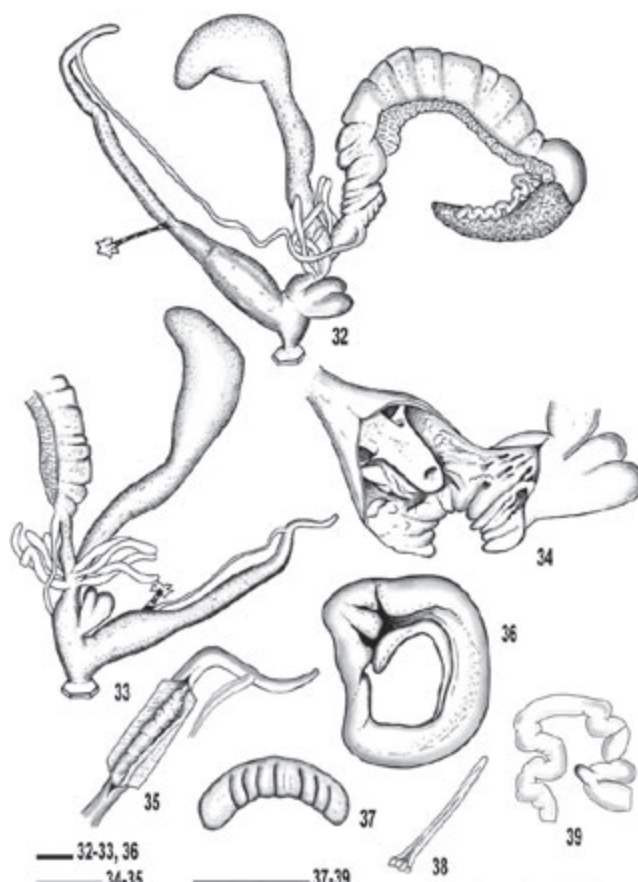
Despite its anatomical consistency, *Xerosecta sandaliotica*, shows an astonishing variability in its shell, which seems to be related to the habitat where the particular populations live. There is a coastal morph (Piscinas, Is Arenas and Gùtturu Flùmini) and a mountain morph (Monte Linas). The coastal morph (Figs 46–48, 50) has a markedly subglobose shell with a very high and swollen final whorl, with a waxy, creamy appearance which could represent an evolutionary adaptation both to protect itself from the extremely intensive solar radiation in the sandy environment and also as a camouflage in such lightly coloured soil. The adult specimens attain the biggest size among endemic Sardinian *Xerosecta* species. The mountain morph is smaller in size (Fig. 49) and without the waxy, light and creamy appearance, becoming dark brownish and the last whorl is somewhat less high. Ultimately, the mountain morph looks almost undistinguishable from many of the *Xerosecta dohrni* populations.

Status and conservation The persistence of the coastal morph of *Xerosecta sandaliotica* is strictly related to the conservation of the very unique and peculiar dune habitat which could be, in the future, threatened by the development of coastal tourism facilities. At the moment, neither the sand dunes nor the Monte Linas peak are threatened by human activity. Nonetheless, its limited distribution makes it Vulnerable as determined using Categories and Criteria of the IUCN Red List of Threatened Species (www.iucnredlist.org, Version 3.1).

***Xerosecta brachyflagellata* new species**
(Figs 32–39, 51–52)

Type series Holotype (Figs 32–39, 51) and 12 paratypes from Spiaggia Bianca (Golfo Aranci, province of Olbia-Tempio, Sardinia, Italy), 40°59'20"N, 09°35'15"E, 1 m asl, WDM leg., 12.xi.2007, deposited in the NTM, registration numbers: P.53338 (Holotype) and P.53339 (Paratypes). Paratypes: 6 specimens (3 shells and 3 alcohol-preserved, 3 dsp) from Spiaggia Bianca (Golfo Aranci) deposited in WDM collection; 5 specimens (3 shells and 2 alcohol preserved, 2 dsp) deposited in FM collection; 1 specimen deposited in DC collection.

Type locality Spiaggia Bianca (Golfo Aranci, province of Olbia-Tempio, Sardinia, Italy), 40°59'20"N, 09°35'15"E.



Figures 32–39 *Xerosecta brachyflagellata* n. sp. genitalia and anatomical parts of Holotype from Spiaggia Bianca (Golfo Aranci, Olbia-Tempio): 32 genitalia (gonad excluded); 34 details of distal genitalia; 35 inner structure of epiphallus; 36 mantle edge; 37 jaw; 38 dart; 39 distal portion of first hermaphrodite duct with talon; 33 distal genitalia of a Paratype.

Diagnosis *Xerosecta brachyflagellata* is easily distinguishable from all the other Sardinian species of *Xerosecta* by virtue of its extremely short flagellum that barely reaches 0.25 of the total length of the penis.

Shell (Figs 51–52) Dextral, conical and hairless. Protoconch pale brown to dark brown. Teleoconch brownish, with 4–8 brown to dark brown bands either fragmented into spots and segments, or continuous. Some bands very strong and fused together or barely visible, if not totally absent, rendering shell almost uniform in colour. Traces of smaller, ill-defined bands present on lower part of last whorl. External surface shows well-defined, irregularly spaced growth lines. Along last whorl growth lines clearly visible from suture as far as umbilicus. Spire conical to moderately conical with 4.75–5.25 convex and regularly increasing whorls separated by deep sutures. Protoconch comprises approximately 1–1.5 whorls, the last large and rounded, more or less descending near the aperture, and contributing 0.75 of total height of shell. Umbilicus open but narrow, about 1.10 maximum shell diameter in width. Aperture rounded, slightly elliptical, with a faint thickening along inner side of final whorl. Peristome is interrupted and thin. Columellar margin a little thicker.

Dimensions of shell Diameter 8.8 ± 0.7 mm (range 8.0–10.1 mm); height 7.1 ± 0.5 mm (range 6.4–7.7 mm) (n=20). Ratio D/H: 1.2.

Body Soft parts dark grey to brownish, foot creamy white. Mantle border (Fig. 36) grey to brownish with 5 lobes. Right lateral lobe small without incisions, whilst right dorsal lobe small and bean-like. Left dorsal lobe triangular. Walls of pallial cavity brownish with no stripes or spots and possessing a prominent pulmonary vein. Jaw odontognathous, with 6–8 cross, rounded ridges (Fig. 37). Right ommatophore retractor independent from both penis and vagina.

Anatomy of genitalia (Figs 32–39) General arrangement of genitalia semidiaulic monotrematic. Convolved first hermaphrodite duct arises from multilobed gonad and ends laterally in talon (Fig. 39). Albumen gland long and somewhat slim, connected to wide ovispermiduct consisting of prostatic and uterine portions.

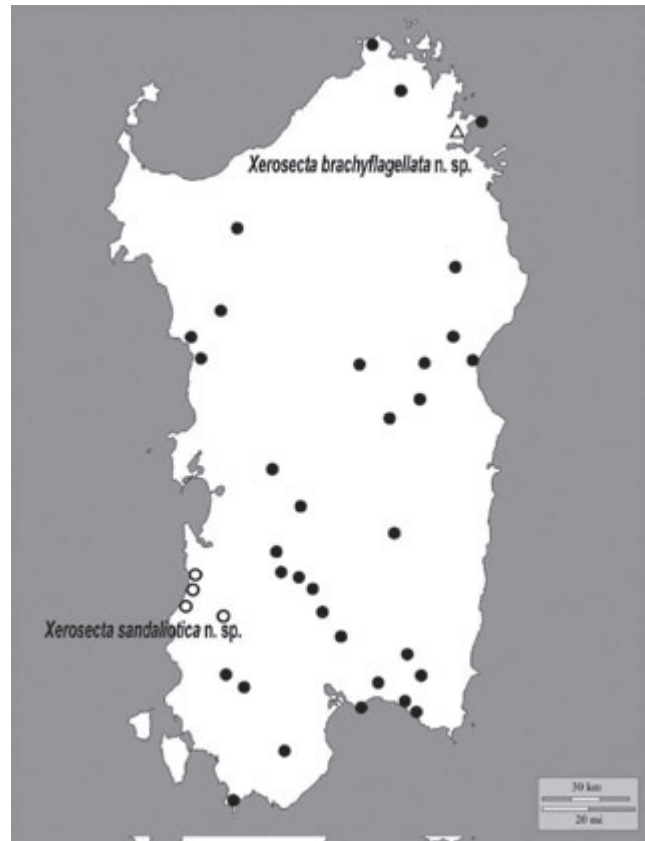
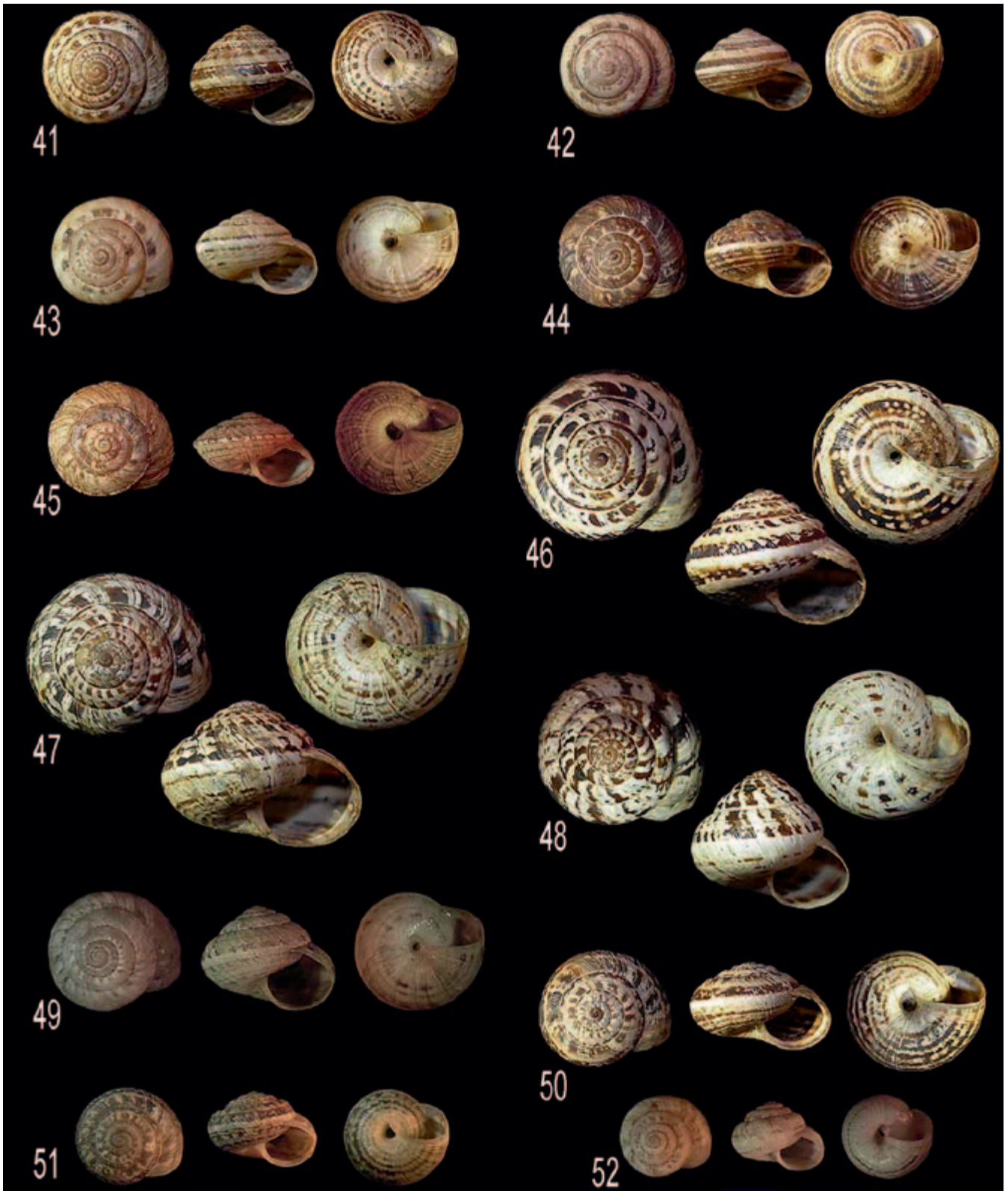


Figure 40 Distribution of *Xerosecta dohrni* (full dots), *Xerosecta sandaliotica* n. sp. (empty circles) and *Xerosecta brachyflagellata* n. sp. (empty triangle) in Sardinia.

Prostatic portion continues as thin vas deferens which ends in penial complex.

Female portion of ovispermiduct joined distally to free oviduct and turns into vagina at level of duct of bursa copulatrix. This duct usually wide, moderately long, and uniform in diameter; ends in a variable bursa copulatrix which is oval to roundish, coloured greenish or sometimes orange in fresh specimens. Four tufts of digitiform glands arise from proximal portion of vagina. These glands variable in number (8–12), and very rarely branched. Shape and length also variable, from short and wide, to long and slim. Proximal vagina (marked distally by entry of dart-sac complex) usually as long as free oviduct. Dart-sac complex arises from one side of vagina and is of the 0+2 type. This has a smaller, inner accessory sac and a bigger outer, dart-bearing stylophore. Outer stylophore with thin wall, while inner stylophore with thick, fibrous structure. Cavities of stylophores end side by side in common opening into vagina and bordered by 2



Figures 41–52 *Xerosecta* spp. from Sardinia. *Xerosecta dohrni* from: 41 Bosa Marina (Bosa, Oristano); 42 Ispinigoli (Dorgali, Nuoro); 43 Monte Gonare (Orani, Nuoro); 44 Mont' 'e Crèsia (Sinnai, Cagliari); 45 Rio San Giovanni Valley (Domusnovas, Carbonia-Iglesias). *Xerosecta sandaliotica* n. sp.: 46 Holotype and 47 Paratype from Piscinas (Arbus, Medio Campidano); 48 from Is Arenas (Arbus, Medio Campidano); 49 from Monte Linas (Gonnosfanàdiga, Medio Campidano); 50 from Gùtturu Flùmìni (Arbus, Medio Campidano). *Xerosecta brachyflagellata* n. sp.: 51, 52 Holotype and a Paratype from Spiaggia Bianca (Golfo Aranci, Olbia-Tempio).

strong pleats. Other pleats, variable in number and depth, run longitudinally on inner surface of vagina reaching genital atrium as far as aperture. No other inner structure present. Atrium funnel-like, never swollen, with thin walls.

Penial complex consists of flagellum, epiphallus (which extends from insertion of vas deferens to penial retractor), and penis ending at atrium. Penial flagellum extremely short and blunt, gradually narrowing towards tip, usually barely 0.25–0.20×total epiphallus-penis complex length. Epiphallus slender, its internal walls with just one longitudinal pleat which ends at penial retractor level. Penis, devoid of muscular or glandular sheath, attains approximately 0.3×epiphallus length, swollen, thick-walled, and housing penial papilla. The *Xerosecta* (s.s.) type penial papilla (see Manganelli & Favilli, 1995: 342) very variable in shape, from globose to elongate, sometimes folded, with subapical or apical opening emerging from inner corpus cavernosus. External penial connects with penial inner walls by 2 thin frenula.

Etymology Named after the key taxonomic feature, the very short penial flagellum.

Ecology *Xerosecta brachyflagellata* occurs on the lower, shaded branches and stems of coastal sclerophyll maquis mainly composed by *Pistacia lentiscus* L. The population lives close to the sea shore, and it's probably tolerant of salt spray since it is directly exposed to the salt air.

Distribution The species is known only from the SE part of Gallura region (Spiaggia Bianca) (Fig. 40). Further searches will probably extend the distributional range of this species since the same environmental and ecological conditions are present throughout a wide portion of SE coast of Gallura.

Remarks The shell's morphology does not permit separation of *Xerosecta brachyflagellata* from most populations of *X. dohrni*.

The specific diagnosis is instead unmistakable when considering the relative length of the penial flagellum which is the key character that separates *Xerosecta brachyflagellata* from both the others Sardinian *Xerosecta* species. In *X. dohrni* and *X. sandaliotica* the length is at least 1.3 times greater than the penis itself, whereas in *X. brachyflagellata* the flagellum attains barely one quarter

the length of the penis. The very short penial flagellum represents a remarkable character within the genus *Xerosecta* (s.s.), where instead it is a regular feature within the subgenus *Polloneriella* Alzona & Alzona Bisacchi 1940 (Schileyko, 2005: 1976–1978). The remaining genital features closely resemble *X. dohrni* and may suggest the two are sister species.

Status and conservation This species is not immediately threatened, though future development of tourism facilities could pose a serious threat to the survival of the only known population. Nonetheless, its limited distribution makes it Vulnerable as indicated in Categories and Criteria of the IUCN Red List of Threatened Species (www.iucnredlist.org, Version 3.1).

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